Infection prevention and control measures for Ebola and Marburg Virus disease: A series of rapid reviews

KQ1 Work Exclusion- Initial Summary

(Version 1.2, 21 April 2022)

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Funding: Funding for this protocol and the subsequent reviews was provided by the World Health Organization (Funding # 202818287). The working group (WG) from the WHO/HQ Country Readiness Strengthening Health Care Readiness Unit will be consulted to develop and refine the scope, and review and approve the protocol. The WG will not be involved in the conduct of the review including selection of studies and data analysis but will advise as needed on priority population(s), interventions, and outcomes in an iterative process during the review process based on the available evidence. The WG will also comment on the draft report and provide input on interpretations of findings. AT is funded by a Tier 2 Canada Research Chair in Knowledge Synthesis. SM is funded by a Tier 2 Canada Research Chair in Mathematical Modeling and Program Science.

Competing interests: DM was involved in the 2015 rapid review by Hersi et al. [1] There are no other competing interests to acknowledge.

Acknowledgements: We thank Kaitryn Campbell, MLIS, MSc (St. Joseph's Healthcare Hamilton/McMaster University) for peer review of the Embase search strategy.

Question

Should health workers who have had Ebola Virus Disease (EVD) exposure other than high-risk be excluded versus not excluded from work?

- No studies specifically addressing this question were identified. Therefore, additional searches were completed to address a revised question to provide information on occupational risks of EVD acquisition and transmission that might help in decision-making about work exclusion.
- **Revised PICO Question:**
  - What is the risk of EVD acquisition with different types of occupational exposures?
  - If acquired, what is the risk of transmitting the virus?

Methods Summary

This is one of a series of rapid reviews that will answer 12 key questions related to three themes on infection prevention and control measures for filoviruses: (i) transmission/exposure (n=3 questions), (ii) personal protective equipment (PPE) (n=5), and (iii) decontamination and disinfection (n=4). Data sources include Medline, Embase, bio/medRxiv pre-print servers, Global Medicus Index, Epistemonikos, China National Knowledge Infrastructure (CNKI) and Wangfang database. We will use an automation tool (CAL® tool) for titles/abstracts screening for relevant systematic reviews and primary comparative studies. Full-text screening, data extraction, risk of bias assessment, and GRADE (Grading of Recommendations Assessment, Development and Evaluation) for the certainty of evidence will be completed independently by two reviewers with any disagreements resolved by consensus, with arbitration by a third reviewer, if needed. Results from included studies will be synthesized narratively by theme and key question and pooled via random effects meta-analysis when appropriate.

Initial findings relating to work exclusion

We present study characteristics in Table 1 and a summary of findings in Table 2 and Table 3.

Initially, 203 studies were screened in the CAL tool software and 32 studies were included for full-text screening. Of these 32 studies, none met the eligibility criteria for the primary question (Appendix 2). However, 4 studies were deemed to provide information on occupational risks of EVD acquisition and transmission and were included to address the revised question. To capture additional information related to vaccination status of healthcare workers, an additional 203 studies were reviewed in the CAL tool and 34 of these studies were included. Following full-text screening, an additional 2 studies were deemed relevant. A list of excluded studies with reasons for exclusion can be found in Appendix 1.

Table 1. Characteristics of Included Studies

Citation [Author, Year]	Funding Source	Country	Dates of Outbreak	Study Type	Virus Species	Setting	# Total Health Workers	Study Objectives [as reported by study authors]
Doshi, 2020, [Cross-sectional][1]	Private research grant	Congo, DR	2014 outbreak	Serologic survey	Ebola	Individuals providing care to local populations in Boednde	611	"To conduct a serosurvey in November 2015 among HCWs providing care in Boende to improve our understanding of EBOV transmission dynamics"
Dunn, 2016, [Cross-sectional][2]	Not reported	Sierra Leone	2014 outbreak	Contact-tracing/identifying occupational exposures	Ebola	Health facility	64	"To determine the compliance with personal protective equipment (PPE) usage of HCWs during the follow-up of patients with CCHF; HCWs worked on the wards or handled contaminated materials from these patients in the laboratory"
Gsell, 2017, [Cohort][3]	Private, not-for-profit, research grants	Guinea	2016	Ring Vaccination study (Prospective)	Ebola	Health facility	1510 participants (307 HWs)	"To evaluate the vaccine safety in different populations and examine the transmission dynamics at the level of the rings"
Hoff, 2019, [Cross-sectional][4]	Private grant making foundation funding	Congo, DR	2014 outbreak	Seroprevalence survey	Ebola	Health facility	565	"To determine seroprevalence against multiple EBOV antigens among HCWs of Boende Health Zone, Democratic Republic of the Congo, the site of a 2014 EBOV outbreak"

Hoff, 2019, [Cross-sectional][5]	Not reported	Congo, DR	Unclear	Serologic survey/Interview	Ebola	Health facility	250	"To conduct a serosurvey among formal and informal HCWs in the Boende health zone in Tshuapa Districk, DRC"
Samai, 2018, [RCT][6]	Not reported	Sierra Leone	2014 outbreak	Randomized, unblinded Phase 2 trial	Ebola	ETU or hospital	8651	"To describe safety results from STRIVE, the largest cohort vaccinated with rVSVΔG-ZEBOV-GP."

Table 2. Summary of Findings: Exposure to high-risk activity[a] vs. no exposure to high-risk activity

Study details	*Activity Exposure vs Non-Exposure*	*Outcome details*	*Exposed with outcome (n/N, %)*	*Non-exposed with outcome (n/N, %)*	*Summary Effect Measure*	*Quality Assessment[b]*	*GRADE*	*Notes*
Incidence of EVD								
Doshi, 2020, [Cross-sectional][1]	Washed a cadaver	Seroreactivity (GP > 2.5) to anti-EBOV glycoprotein IgG	NR	NR	1.28 (95% CI 0.13–12.76)	Moderate Risk of Bias	⊕◯◯◯ Very low	None
Dunn, 2016, [Cross-sectional][2]	Performed\assisted in cesarean [No comparator]	PCR-confirmed EVD	0/3	N/A	N/A	Moderate Risk of Bias	⊕◯◯◯ Very low	PPE used: Gown; short gloves (three pairs); mask; goggles; shoe covers
	Placed urinary catheter [No comparator]	PCR-confirmed EVD	0/1	N/A	N/A		⊕◯◯◯ Very low	PPE used: Short gloves: gown
	Placed intravenous line [No comparator]	PCR-confirmed EVD	1/9 (11%)	N/A	N/A		⊕◯◯◯ Very low	PPE used: Short gloves
	Blood draw [No comparator]	PCR-confirmed EVD	0/4	N/A	N/A		⊕◯◯◯ Very low	PPE used: Gown; apron; short gloves (2 pairs); mask
	Discontinued intravenous line [No comparator]	PCR-confirmed EVD	0/1	N/A	N/A		⊕◯◯◯ Very low	PPE used: Short gloves
Gsell, 2017, [Cohort][3]	High-risk contact [No comparator]	Secondary cases of EVD	0/239[c]	N/A	N/A	Low Risk of Bias	⊕◯◯◯ Very low	All HCWs received the

Study details	*Activity Exposure vs Non-Exposure*	*Outcome details*	*Exposed with outcome (n/N, %)*	*Non-exposed with outcome (n/N, %)*	*Summary Effect Measure*	*Quality Assessment*[b]	*GRADE*	*Notes*
								rVSV-ZEBOV vaccine. The median delay from confirmation of index case to vaccination of individuals in the ring ranged from 2-10 days over the outbreak.
Samai, 2018, [RCT][6]	High perceived risk of Ebola infection [No comparator]	Laboratory-confirmed EVD	0 /2995	N/A	N/A	Moderate Risk of Bias	⊕◯◯◯ Very low	Unvaccinated HWs
	High perceived risk of Ebola infection [No comparator]	Laboratory-confirmed EVD	0/2811	N/A	N/A		⊕◯◯◯ Very low	HWs vaccinated with VSVΔG-ZEBOV-GP
	High perceived risk of Ebola infection [No comparator]	Laboratory-confirmed EVD	0/927	N/A	N/A		⊕◯◯◯ Very low	Crossover vaccinated (deferred)

a. Activity risk classifications were based on the list provided by the WHO (see Appendix 2).
b. Quality assessment of studies was completed using the ROBINS-I scale for observational studies. Scores from 7-9 were considered to be high quality (low risk of bias), scores of 4-6 of moderate quality (moderate risk of bias) and scores of 0-3 of low quality (high risk of bias). RCTs were assessed using the Cochrane ROB-2 tool.
c. Population consisted of 632 vaccinated individuals, 91 of these were frontline workers.

Table 3. Summary of Findings: Exposure to low or medium-risk activity[a] vs. no exposure to low or medium-risk activity

Study details	*Activity Exposure vs Non-Exposure*	*Outcome details*	*Exposed with outcome (n/N)*	*Non-exposed with outcome (n/N)*	*Summary Effect Measure*	*Quality Assessment[b]*	*GRADE*	*Notes*
Incidence of EVD								
Doshi, 2020, [Cross-sectional][1]	Been in the patient's room vs. Not exposed	Seroreactivity (GP > 2.5) to anti-EBOV glycoprotein IgG	NR	NR	0.79 (95% CI 0.22–2.83)	Moderate Risk of Bias	⊕◯◯◯ Very low	None
	Performed examinations (clinical or laboratory) vs. Not exposed	Seroreactivity (GP > 2.5) to anti-EBOV glycoprotein IgG	NR	NR	0.86 (95% CI 0.17–4.44)		⊕◯◯◯ Very low	
	Given food to a patient vs. Not exposed	Seroreactivity (GP > 2.5) to anti-EBOV glycoprotein IgG	NR	NR	1.13 (95% CI 0.32–3.99)		⊕◯◯◯ Very low	
	Conversed with a patient vs. Not exposed	Seroreactivity (GP > 2.5) to anti-EBOV glycoprotein IgG	NR	NR	3.80 (95% CI 0.73–19.83)		⊕◯◯◯ Very low	
	Washed the patient's clothes vs. Not exposed	Seroreactivity (GP > 2.5) to anti-EBOV glycoprotein IgG	NR	NR	0.99 (95% CI 0.10–10.41)		⊕◯◯◯ Very low	
	Had contact with patient's bodily fluids	Seroreactivity (GP > 2.5) to	NR	NR	2.39 (95% CI 0.79–7.30)		⊕◯◯◯ Very low	

	vs. Not exposed	anti-EBOV glycoprotein IgG						
	Cleaned patient's room vs. Not exposed	Seroreactivity (GP > 2.5) to anti-EBOV glycoprotein IgG	NR	NR	1.40 (95% CI 0.34–5.83)		⊕◯◯◯ Very low	
Dunn, 2016, [Cross-sectional][2]	Shared ward\latrine [No comparator]	PCR-confirmed EVD	3/15 (20%)	N/A	N/A	Moderate Risk of Bias	⊕◯◯◯ Very low	PPE used: None
	Took vital signs [No comparator]	PCR-confirmed EVD	0/16	N/A	N/A		⊕◯◯◯ Very low	PPE used: Short gloves
	Cleaned linens [No comparator]	PCR-confirmed EVD	1/2 (50%)	N/A	N/A		⊕◯◯◯ Very low	PPE used: Short gloves
	Cleaned body fluids [No comparator]	PCR-confirmed EVD	1/4 (25%)	N/A	N/A		⊕◯◯◯ Very low	PPE used: Short gloves
	Cleaned body fluids [No comparator]	PCR-confirmed EVD	1/1 (100%)	N/A	N/A		⊕◯◯◯ Very low	PPE used: None
	Cleaned surfaces: floor, walls, bed [No comparator]	PCR-confirmed EVD	0/3	N/A	N/A		⊕◯◯◯ Very low	PPE used: Gown; apron; short gloves (2 pairs); mask
	Cleaned surgical instruments [No comparator]	PCR-confirmed EVD	0/1	N/A	N/A		⊕◯◯◯ Very low	PPE used: Short gloves

	Moved patient [No comparator]	PCR-confirmed EVD	1/4 (25%)	N/A	N/A			PPE used: Short gloves
	Gave intravenous medications [No comparator]	PCR-confirmed EVD	0/15	N/A	N/A		⊕◯◯◯ Very low	PPE used: Short gloves: gown
	Gave intramuscular medications [No comparator]	PCR-confirmed EVD	0/1	N/A	N/A		⊕◯◯◯ Very low	PPE used: Short gloves
	Changed surgical site dressing [No comparator]	PCR-confirmed EVD	0/3	N/A	N/A		⊕◯◯◯ Very low	PPE used: Short gloves: gown
	General touching patient [No comparator]	PCR-confirmed EVD	0/5	N/A	N/A		⊕◯◯◯ Very low	PPE used: Short gloves
	General touching patient [No comparator]	PCR-confirmed EVD	2/4 (50%)	N/A	N/A		⊕◯◯◯ Very low	PPE used: None
Gsell, 2017, [Cohort][3]	Non-high-risk contact [No comparator]	Secondary cases of EVD	0/237[c]	N/A	N/A	Low Risk of Bias	⊕◯◯◯ Very low	All HCWs received the rVSV-ZEBOV vaccine. The median delay from confirmation

								of index case to vaccination of individuals in the ring ranged from 2-10 days over the outbreak.
Hoff, 2019, [Cross-sectional][4]	Direct contact with patients [No comparator]	Glycoprotein reactivity as >2.5 units/mL	57/279 (20%)	N/A	N/A	Moderate Risk of Bias	⊕◯◯◯ Very low	None
	Indirect contact with patients [No comparator]	Glycoprotein reactivity as >2.5 units/mL	29/177 (16%)	N/A	N/A		⊕◯◯◯ Very low	None
Hoff, 2019, [Cross-sectional][5]	Direct contact with patients [No comparator]	Seropositivity to anti-EBOV glycoprotein Ig	38/113 (34%)	N/A	N/A	High Risk of Bias	⊕◯◯◯ Very low	None
	Indirect contact with patients [No comparator]	Seropositivity to anti-EBOV glycoprotein Ig	7/18 (39%)	N/A	N/A		⊕◯◯◯ Very low	None
	Limited contact with patients [No comparator]	Seropositivity to anti-EBOV glycoprotein Ig	3/7 (43%)	N/A	N/A		⊕◯◯◯ Very low	None
Samai, 2018, [RCT][6]	Average perceived risk of Ebola infection [No comparator]	Laboratory-confirmed EVD	0/773	N/A	N/A	Moderate Risk of Bias	⊕◯◯◯ Very low	Unvaccinated HWs

	Average perceived risk of Ebola infection [No comparator]	Laboratory-confirmed EVD	0/760	N/A	N/A		⊕◯◯◯ Very low	HWs vaccinated with VSVΔG-ZEBOV-GP
	Average perceived risk of Ebola infection [No comparator]	Laboratory-confirmed EVD	0/724	N/A	N/A		⊕◯◯◯ Very low	Crossover vaccinated (deferred)
	Low perceived risk of Ebola infection [No comparator]	Laboratory-confirmed EVD	0/705	N/A	N/A		⊕◯◯◯ Very low	Unvaccinated HWs
	Low perceived risk of Ebola infection [No comparator]	Laboratory-confirmed EVD	0/606	N/A	N/A		⊕◯◯◯ Very low	HWs vaccinated with VSVΔG-ZEBOV-GP
	Low perceived risk of Ebola infection [No comparator]	Laboratory-confirmed EVD	0/2170	N/A	N/A		⊕◯◯◯ Very low	Crossover vaccinated (deferred)

a. Activity risk classifications were based on the list provided by the WHO (see Appendix 2).
b. Quality assessment of studies was completed using the ROBINS-I scale for observational studies. Scores from 7-9 were considered to be high quality (low risk of bias), scores of 4-6 of moderate quality (moderate risk of bias) and scores of 0-3 of low quality (high risk of bias). RCTs were assessed using the Cochrane ROB-2 tool.
c. Population consisted of 632 vaccinated individuals, 91 of these were frontline workers.

Citations:

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Appendix 1. Excluded Studies List – By Reason for Exclusion:

Does not provide risk of infection for HCWs for activities of interest (see Appendix 2)

Borchert M, Mulangu S, Lefèvre P, et al. Use of Protective Gear and the Occurrence of Occupational Marburg Hemorrhagic Fever in Health Workers from Watsa Health Zone, Democratic Republic of the Congo. J Infect Dis. 2007;196(s2):S168-S175. doi:10.1086/520540

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Wong KK, Davey RT, Hewlett AL, et al. Use of Postexposure Prophylaxis After Occupational Exposure to Zaire ebolavirus. Clin Infect Dis. 2016;63(3):376-379. doi:10.1093/cid/ciw256

Not about EVD or Marburg

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Study does not provide details on the exposure

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Study does not provide risk of infection by exposure

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No data from health workers

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Appendix 2. Eligibility Criteria

Question (1): Should health workers who have had EVD or Marburg exposure other than high-risk be excluded versus not excluded from work?

Background: 1) What is the risk of EVD acquisition with different types of occupational exposures? 2) If acquired, what is the risk of transmitting the virus?

Setting	Health care facilities, ETU, *community*
Population	Staff working in health care facilities, ETU Sub-groups: **High risk patient care activity** Broken skin or mucous membrane contact with a patient with Ebola virus disease (alive or deceased) or their bodily fluids: • Bodily fluid in direct contact with mucous membrane (e.g. eyes, nose or mouth) • Penetrating sharps injury from used device or through contaminate • Performed finger prick • Put in IV • Delivered babies • Performed invasive procedure • Performed major surgery • Performed autopsy • Drew blood • Cleaned blood spill • Controlled bleeding • Performed minor surgery • Moved dead bodies • Cleaned or disinfected latrines **Intermediate risk patient care activities** (intact-skin-only contact with a patient with Ebola virus disease or their body fluids):d • Clinical assessment of an individual with suspected Ebola virus disease before diagnosis without appropriate personal protective equipment (PPEClose contact with a patient, body or body fluid, linen or clothes of an infected patient/person • Bathes or cleaned patients • Gave injection • Handled urinary catheter • Contact with contaminated surfaces • Recapped needle

	• Handled IV line (e.g., gave IV medications) • Handled waste • Handled linen or clothes or mattresses **Low risk patient care activities** (No direct contact with a patient with Ebola virus disease or their body fluids): • Living in the same house as a patient with Ebola virus disease but no direct contact with their bodily fluids) • Breach of personal protective equipment (PPE) without risk of contamination • Provided general patient care (took vital signs, examined patients, moved patients) • Fed patients or administered oral medications • Discarded sharps (appropriately) • Cleaned patient room or ward Living in same house as a patient with EVD but no direct contact with their body fluids • Moved/ transported patients
Background interventions (Standard of care)	Continue with normal duties (no work exclusion)
Intervention	Continue with normal duties (no work exclusion)
Comparator(s)	Exclude from work for 21 days
Outcome	Infection with Ebola or Marburg virus, *health-care associated transmission of Ebola* **Indirect evidence:** Lassa fever
Potential effect modifiers	Impact of vaccination status on post exposure actions *Community exposures during exclusion period, type of exposure, vaccination*

Appendix 3. GRADE Assessment (High Risk Exposures)

Number of studies	*Study Design*	*Risk of Bias*[a]	*Inconsistency*	*Indirectness*	*Imprecision*	*Other Considerations*	*Quality*
Incidence of EVD							
Washed a cadaver [No comparator]							
1[1]	[Cross-sectional]	Serious[b]	No serious[c]	Serious[d]	Serious[e]	None	⊕◯◯◯ Very low
Performed\assisted in cesarean [No comparator]							
1[2]	[Cross-sectional	Serious[f]	No serious[c]	Serious[d]	Very Serious[g]	None	⊕◯◯◯ Very low
Placed urinary catheter [No comparator]							
1[2]	[Cross-sectional]	Serious[f]	No serious[c]	Serious[d]	Very Serious[g]	None	⊕◯◯◯ Very low
Placed intravenous line [No comparator]							
1[2]	[Cross-sectional]	Serious[f]	No serious[c]	Serious[d]	Very Serious[g]	None	⊕◯◯◯ Very low
Blood draw [No comparator]							
1[2]	[Cross-sectional]	Serious[f]	No serious[c]	Serious[d]	Very Serious[g]	None	⊕◯◯◯ Very low
Discontinued intravenous line [No comparator]							
1[2]	[Cross-sectional]	Serious[f]	No serious[c]	Serious[d]	Very Serious[g]	None	⊕◯◯◯ Very low
High-risk contact [No comparator]							
1[3]	[Cohort]	Not Serious[h]	No serious[c]	Serious[d]	Very Serious[g]	None	⊕◯◯◯ Very low
High perceived risk of Ebola infection [No comparator]							
1[6]	[RCT]	Serious[i]	No serious[c]	Serious[d]	Very Serious[g]	None	⊕◯◯◯ Very low

d. Individual quality assessment of studies was completed using the ROBINS-I scale for observational studies. Scores from 7-9 were considered to be high quality (low risk of bias), scores of 4-6 of moderate quality (moderate risk of bias) and scores of 0-3 of low quality (high risk of bias).
e. 5/9 on NOS; downrated for lack of controls, no reporting on non-response rate.
f. No inconsistency as only one study evaluated.

g. Downrated by 1 for failure to provide information on PICO intervention of work exclusion for 21 days.
h. Downrated by 1 as CI crosses null + appreciable benefit or harm.
i. 6/9 on NOS; downrated for lack of non-exposed cohort, failure to adjust for key confounders.
j. Downrated by 2 as very few or no events, and no relative effects reported.
k. 7/9 on NOS; downrated for failure to adjust for confounders.
l. Some concerns of risk of bias assessed using Cochrane ROB-2.

Appendix 4. GRADE Assessment (Low or Medium Risk Exposures)

Number of studies	*Study Design*	*Risk of Bias*[a]	*Inconsistency*	*Indirectness*	*Imprecision*	*Other Considerations*	*Quality*
Incidence of EVD							
Been in the patient's room [No comparator]							
1[1]	[Cross-sectional]	Serious[b]	No serious[c]	Serious[d]	Serious[e]	None	⊕◯◯◯ Very low
Performed examinations (clinical or laboratory) [No comparator]							
1[1]	[Cross-sectional	Serious[b]	No serious[c]	Serious[d]	Serious[e]	None	⊕◯◯◯ Very low
Given food to a patient [No comparator]							
1[1]	[Cross-sectional]	Serious[b]	No serious[c]	Serious[d]	Serious[e]	None	⊕◯◯◯ Very low
Conversed with a patient [No comparator]							
1[1]	[Cross-sectional]	Serious[b]	No serious[c]	Serious[d]	Serious[e]	None	⊕◯◯◯ Very low
Washed the patient's clothes [No comparator]							
1[1]	[Cross-sectional]	Serious[b]	No serious[c]	Serious[d]	Serious[e]	None	⊕◯◯◯ Very low
Had contact with patient's bodily fluids [No comparator]							
1[1]	[Cross-sectional]	Serious[b]	No serious[c]	Serious[d]	Serious[e]	None	⊕◯◯◯ Very low
Shared ward/latrine [No comparator]							
1[2]	[Cross-sectional]	Serious[f]	No serious[c]	Serious[d]	Very Serious[g]	None	⊕◯◯◯ Very low
Took vital signs [No comparator]							
1[2]	[Cross-sectional]	Serious[f]	No serious[c]	Serious[d]	Very Serious[g]	None	⊕◯◯◯ Very low
Cleaned linens [No comparator]							
1[2]	[Cross-sectional]	Serious[f]	No serious[c]	Serious[d]	Very Serious[g]	None	⊕◯◯◯ Very low
Cleaned body fluids [No comparator]							

Number of studies	*Study Design*	*Risk of Bias*[a]	*Inconsistency*	*Indirectness*	*Imprecision*	*Other Considerations*	*Quality*
1[2]	[Cross-sectional]	Serious[f]	No serious[c]	Serious[d]	Very Serious[g]	None	⊕◯◯◯ Very low
Cleaned body fluids [No comparator]							
1[2]	[Cross-sectional]	Serious[f]	No serious[c]	Serious[d]	Very Serious[g]	None	⊕◯◯◯ Very low
Cleaned surfaces: floor, walls, bed [No comparator]							
1[2]	[Cross-sectional]	Serious[f]	No serious[c]	Serious[d]	Very Serious[g]	None	⊕◯◯◯ Very low
Cleaned surgical instruments [No comparator]							
1[2]	[Cross-sectional]	Serious[f]	No serious[c]	Serious[d]	Very Serious[g]	None	⊕◯◯◯ Very low
Moved patient [No comparator]							
1[2]	[Cross-sectional]	Serious[f]	No serious[c]	Serious[d]	Very Serious[g]	None	⊕◯◯◯ Very low
Gave intravenous medications [No comparator]							
1[2]	[Cross-sectional]	Serious[f]	No serious[c]	Serious[d]	Very Serious[g]	None	⊕◯◯◯ Very low
Gave intramuscular medications [No comparator]							
1[2]	[Cross-sectional]	Serious[f]	No serious[c]	Serious[d]	Very Serious[g]	None	⊕◯◯◯ Very low
Changed surgical site dressing [No comparator]							
1[2]	[Cross-sectional]	Serious[f]	No serious[c]	Serious[d]	Very Serious[g]	None	⊕◯◯◯ Very low
General touching patient [No comparator]							
1[2]	[Cross-sectional]	Serious[f]	No serious[c]	Serious[d]	Very Serious[g]	None	⊕◯◯◯ Very low
Non-high-risk contact [No comparator]							
1[3]	[Cohort]	Not Serious[h]	No serious[c]	Serious[d]	Very Serious[g]	None	⊕◯◯◯ Very low
Direct contact with patients [No comparator]							

Number of studies	*Study Design*	*Risk of Bias*[a]	*Inconsistency*	*Indirectness*	*Imprecision*	*Other Considerations*	*Quality*
2[45]	[Cross-sectional]	Serious[i]	No serious[j]	Serious[d]	Serious[k]	None	⊕◯◯◯ Very low
Indirect contact with patients [No comparator]							
2[45]	[Cross-sectional]	Serious[i]	No serious[j]	Serious[d]	Serious[k]	None	⊕◯◯◯ Very low
Limited contact with patients [No comparator]							
1[5]	[Cross-sectional]	Very Serious[l]	No serious[c]	Serious[d]	Serious[k]	None	⊕◯◯◯ Very low
Average perceived risk of Ebola infection [No comparator]							
1[6]	[RCT]	Serious[m]	No serious[c]	Serious[d]	Very Serious[g]	None	⊕◯◯◯ Very low
Low perceived risk of Ebola infection [No comparator]							
1[6]	[RCT]	Serious[m]	No serious[c]	Serious[d]	Very Serious[g]	None	⊕◯◯◯ Very low

a. Individual quality assessment of studies was completed using the ROBINS-I scale for observational studies. Scores from 7-9 were considered to be high quality (low risk of bias), scores of 4-6 of moderate quality (moderate risk of bias) and scores of 0-3 of low quality (high risk of bias).
b. 5/9 on NOS; downrated for lack of controls, no reporting on non-response rate.
c. No inconsistency as only one study evaluated.
d. Downrated by 1 for failure to provide information on PICO intervention of work exclusion for 21 days.
e. Downrated by 1 as CI crosses null + appreciable benefit or harm.
f. 6/9 on NOS; downrated for lack of non-exposed cohort, failure to adjust for key confounders.
g. Downrated by 2 as very few or no events and no relative effects reported.
h. 7/9 on NOS; downrated for failure to adjust for confounders.
i. Both studies rated "serious" to "very serious" risk of bias on NOS.
j. No inconsistency; rates are similar across both studies.
k. Downrated by 1 due to small sample size; unable to evaluate relative effects.
l. 3/9 on NOS; Downrated for lack of controls, failure to adjust for confounders and no reporting on non-response rate.
m. Some concerns of risk of bias assessed using Cochrane ROB-2.

Contextual data

Key question: Should health workers who have had EVD exposure other than high-risk be excluded versus not excluded from work?

We collected the contextual data in light of the following preliminary answers to the key question:

- *Key answer 1:* There is very limited data to support the practice of identifying health workers with low/intermediate risk of EVD infection from a checklist of EVD exposure based upon patient care activities. As such, one cannot choose between letting these health workers continue working or excluding them from work using the existing evidence.
- *Key answer 2:* As requested, we considered EVD vaccine as a potential effect modifier in answering the key question. It turned out that the RING vaccination approach can *eliminate* the risk of EVD acquisition among health workers (under controlled conditions in randomized controlled trials, for example), even with a reasonably long delay of vaccination after EVD exposure (e.g., 3 weeks). As such, the RING vaccination approach is suggested as the evidence-based intervention for this key question.

Summary

Contextual data pertaining to key answer 1 are displayed in the table below; key findings are summarized below. (N.B. contextual data pertaining to key answer 2 will be provided subsequently, on Thursday April 21, 2022).

Implementation:

Consider the practicality of implementing the risk assessment of list of patient care activities with many items without the supporting evidence. The review team found it was challenging matching the risk assessment data (e.g., odds ratio estimate of seropositivity) with the prescribed care activities.

Health workers had numerous risk factors for virus exposure in ETUs, other areas of the hospital, and in the community, making it difficult to ascertain where Ebola infection occurred.[1] As such, comprehensive assessment of EVD exposure may be challenging and the sensitivity of the prescribed care activities for the detection of Ebola infection is uncertain.

An important feature of the Kikwit outbreak was that health care facility workers with jobs that in most settings do not usually involve patient contact appear to have had broader job descriptions, including patient contact.[2]

Health workers with low/intermediate EVD exposure were active monitored and those with high-risk exposure quarantine, with considerations regarding whether all contacts accepted these measures.[3]

Resources/costs:

Health workers with EVD exposure signifies basic deficiencies in implementation of and adherence to core IPC practices. Building IPC capacity will generally be of great benefit to the safety of patients and health workers.[4]

Appropriate infection control precautions and personal protective equipment should be available.[5]

Impact on health equity:

As observed in previously reported outbreaks from other African countries, including the concurrent outbreak in West Africa sub region, females were the most affected. This may be explained by the role that the female gender plays in care giving and nursing in our society, thereby exposing them to infection.[6]

Social and legal implications:

Recent EVD outbreaks had a huge psychological impact on both the members of affected communities and those caring for infected individuals. This suggests the necessity for relief care providers to be mentally prepared to respond to such disasters and for them to be taken care of while in the field. “When we left for Monrovia we had made our wills; I made it three times and tore it up three times and the fourth one went through. As you approach Monrovia, you pray and you pray, and as the planes arrive, you wonder what to expect.”[7]

The WHO and International Labor Organization recommend that HWs with EVD and MVD resulting from work activities should have the right to compensation, as well as free rehabilitation and access to curative services.[8]

Acceptability:

Acceptability of the risk assessment using the list of patient care activities may be important since the risk assessment may rely on self-reporting. We however could not identify any contextual data relevant to the acceptability of elements of the risk assessment (see Table).

RefID	Year	Study methods	Findings relevant to the extraction of contextual data	Data type	Contextual data
[4]	2015	Retrospective descriptive study of HCW with confirmed/suspected Ebola	Over half of infected HCWs (153) were nurses; others included laboratory staff (19, 6.5 %), doctors (9, 3.1 %), cleaners and porters (9, 3.1 %), Community Health Officers (8, 2.7 %), and pharmacists (2, 0.7 %). HCW infections were mainly reported from the Western Area (24.9 %), Kailahun (18.4 %), Kenema (17.7 %), and Bombali (13.3 %) districts. Almost half of the infected HCWs (120, 47.4 %) believed that their exposure occurred in a hospital setting. Others believed that they were exposed in the home (48, 19 %), at health centres (45, 17.8 %), or at other types of health facilities (13, 5.1 %). Only 27 (10.7 %) of all HCW infections were associated with Ebola virus disease (EVD) isolation units. Over half (60 %, 150) of infected HCWs said they had been trained in infection prevention and control prior to their infection, whereas 34 % (85) reported that they had not been so trained.	Implementation	The interviewees perceived common factors contributing to HCW infection in their districts to be the following: “negligence” (defined as non-adherence to basic IPC rules) and “overconfidence” (defined as a feeling of knowing the rules despite the opposite being true) of HCWs, both often resulting in breaches in IPC protocol; inadequate supervision; delayed and inadequate IPC training; inadequate supplies of IPC materials; poor triage systems at their health facilities.
				Implementation	Concerning mode of exposure, 55 % of respondents said that exposure was through general medical and nursing care of infected persons. Other modes of infection were direct body contact with an EVD patient, contact with a contaminated surface, transport of an EVD patient, or during removal of personal protective equipment (PPE) (Table 3). The most common types of exposure were parenteral (e.g., needle stick injury) and direct contact of mucous membranes with infectious material (Table 3). Blood and body fluid containing visible blood were the two most common types of infectious materials involved, and most respondents identified their hands as the body part that had been contaminated (Table 3).
				Implementation	The level of awareness among infected HCWs about IPC and the availability of IPC facilities and policies in the health facilities where they worked at the time of their infection provide insight into the factors contributing to the occurrence of EVD infection among HCWs. A significant percentage of infected HCWs reported having been trained in IPC prior to their infection (Table 5). Of those who were trained, 69 % had received only basic IPC training and 31 % were trained as part of their general medical or nursing education. Furthermore, 60 % of the trained HCWs said they had been trained during the outbreak. Many respondents reported an IPC policy in place at their workplace at the time of their infection, and a large percentage reported available hygiene stations or facilities. A few respondents reported a functional triage system at their facility. However, several of the infected HCWs working in a hospital setting said that there were no IPC policies at their workplace (Table 5).
			Most HCW infections are associated with general health care and home settings but not with dedicated EVD settings.	Acceptability	This result may also help alleviate the significant stigmatisation of HCWs working in such EVD facilities in Sierra Leone, which includes family and community rejection, isolation, and violence
			A sizable percentage (34 %) of infected HCWs interviewed had not been trained in basic IPC at the time of their infection.	Resources/Costs	HCW acquisition of EVD signifies basic deficiencies in implementation of and adherence to core IPC practices. Building IPC capacity will generally be of great benefit to the safety of patients and HCWs.

[6]	2015	Field investigation. Study included all confirmed and probable cases	The most frequent exposure type was direct physical contact in 70% of all cases and 73% among health care workers. The total case-fatality was 40%; higher among healthcare workers (46%) compared with non-healthcare workers (22%).	Health equity	As observed in previously reported outbreaks from other African countries, including the concurrent outbreak in West Africa sub region, females were the most affected [3-5, 7, 12-15]. This may be explained by the role that the female gender plays in care giving and nursing in our society, thereby exposing them to infection. [1-5].
[5]	2014	CDC Mortality Morbidity Weekly Report of a rapid evaluation of Ebola outbreak	Five cases of Ebola among HCWs at an ETU and an adjacent hospital in Monrovia, Liberia, did not have an identifiable common source of exposure or chain of transmission. However, opportunities existed for transmission of Ebola virus to HCWs in this cluster, including HCW exposure to unrecognized, infected patients outside of the ETU, inadequate use of personal protective equipment during cleaning and disinfection of environmental surfaces in hospital A, and potential transmission from an ill HCW to another HCW in the ETU or hospital A. No evidence was found of any previously unrecognized mode of transmission.	Implementation	Health care workers in ETUs who have clinical, cleaning, or disinfection responsibilities in other settings might be exposed to infected persons or contaminated surfaces in those settings. Hospital emergency departments should be alert to quickly recognize and isolate persons with suspected Ebola. Appropriate infection control precautions and personal protective equipment should be available.
				Resources/Costs	Appropriate infection control precautions and personal protective equipment should be available.
[1]	2016	Analyzed data from the Sierra Leone National Viral Hemorrhagic Fever Database, contact tracing records, Kenema Government Hospital (KGH) staff and Ebola Treatment Unit (ETU) rosters, and burial logs.	600 cases of EVD originated in Kenema District, including 92 (15%) HWs, 66 (72%) of whom worked at KGH. Among KGH medical staff and international volunteers, 18 of 62 (29%) who worked in the ETU developed EVD, compared with 48 of 83 (58%) who worked elsewhere in the hospital. Thirteen percent of HWs with EVD reported contact with EVD patients, while 27% reported contact with other infected HWs. The number of HW EVD cases at KGH declined roughly 1 month after implementation of a new triage system at KGH and the opening of a second ETU within the district. The case fatality ratio for HWs and non-HWs with EVD was 69% and 74%, respectively.	Implementation	Most HWs with EVD in Kenema had numerous risk factors for virus exposure in ETUs, other areas of the hospital, and in the community, making it difficult to ascertain where Ebola infection occurred.
				Implementation	Most HWs with EVD in Kenema had numerous risk factors for virus exposure in ETUs, other areas of the hospital, and in the community, making it difficult to ascertain where Ebola infection occurred. Furthermore, informal discussions with many of the KGH HWs with EVD revealed no discrete infecting events, such as needle-sticks or fluid splashes to mucous membranes, suggesting that such events were not central to the high attack rates in this group.
[7]	2017	A literature review and field experiences	Occupational exposure to blood and other body fluids due to inadequate use of personal protective equipment and needle stick or sharp injuries are among factors that contribute to the occurrence of OEVD.	Resources/Costs	It is critical to strengthen the general health care system and improve occupational safety in medical settings of countries at risk.
				Social/Legal Implications	Recent EVD outbreaks had a huge psychological impact on both the members of affected communities and those caring for infected individuals. This suggests the necessity for relief care providers to be mentally prepared to respond to such disasters and for them to be taken care of while in the field. "… When we left for Monrovia we had made our wills; I made it three times and tore it up three times and the fourth one went through. As you approach Monrovia, you pray and you pray, and as the planes arrive, you wonder what to expect. …"
				Implementation	Occupational safety and health in the Sub-Saharan African countries is still a neglected concept, and percutaneous exposure to blood or other body fluids, as well as rates of occupational needle stick and sharp injuries among HCWs are high.

[9]	2018	Systematic review	Ninety-four articles related to 22 outbreaks were included. HW infections composed 2%–100% of cases in EVD and 5%–50% of cases in MVD outbreaks. Among exposed HWs, 0.6%–92% developed EVD, and 1%–10% developed MVD. HW infection rates were consistent through outbreaks. The most common exposure risk situations were inadequate personal protective equipment and exposure to patients with unrecognized EVD/MVD.	Social/Legal Implications	The WHO and ILO recommend that HWs with EVD and MVD resulting from work activities should have the right to compensation, as well as free rehabilitation and access to curative services
[10]	2017	Observational study of transmission chain	All 142 confirmed and probable EVD cases registered were fully resolved in the transmission chain. 72.5% of all the EVD cases in the district were exposed in the community, 26.1% exposed during funerals, and 1.4% exposed in the health facility setting. Health-care workers contributed little to the EVD outbreak. 71.1% of EVD transmission occurred among family members. Female EVD cases generated more secondary cases than their male counterparts did (P = 0.03).	Health equity	Female EVD cases generated more secondary cases than their male counterparts did (P = 0.03).
[11]	2016	Contact tracing and risk factors assessment	Eighty-two contacts were identified: 64 health care workers, 7 caregivers, 4 patients, 4 newborns, and 3 children of patients. Seven contacts became symptomatic and tested positive for EVD: 2 health care workers (1 nurse and 1 hospital cleaner), 2 caregivers, 2 newborns, and 1 patient. The infected nurse placed an intravenous catheter in the pediatric index patient with only short gloves PPE and the hospital cleaner cleaned the operating room of the maternity ward index patient wearing short gloves PPE. Delayed recognition of EVD and inadequate PPE likely led to exposures and secondary infections.	Implementation	Aggregate exposure data from both outbreaks demonstrate that high-risk exposures that increase the likelihood for contact with body fluids (eg, performing exams, taking vital signs, cleaning body fluid spills or other potentially contaminated surfaces, and performing invasive procedures) in the absence of recommended PPE were commonly reported by health care workers in these facilities.
[12]	2014	CDC Mortality Morbidity Weekly Report of EVD Cases Among Health Care Workers Not Working in Ebola Treatment Units	Ninety-seven cases of Ebola (12% of the estimated total) were identified among HCWs; 62 HCW cases (64%) were part of 10 distinct clusters in non-ETU health care facilities, primarily hospitals. Early recognition and diagnosis of Ebola in patients who were the likely source of introduction to the HCWs (i.e., source patients)* was missed in four clusters.	Implementation	Inconsistent recognition and triage of cases of Ebola, overcrowding, limitations in layout of physical spaces, lack of training in the use of and adequate supply of personal protective equipment (PPE), and limited supervision to ensure consistent adherence to infection control practices all were observed.
[13]	2020	Aerosurvey among HCW	We conducted a serosurvey among HCW in Boende, Tshuapa Province, Democratic Republic of Congo. Human anti-EBOV glycoprotein IgG titers were measured using a commercially available ELISA kit. We assessed associations between anti-EBOV IgG seroreactivity, defined as ≥2.5 units/mL, and risk factors using univariable and multivariable logistic regression. Results. Overall, 22.5% of HCWs were seroreactive for EBOV. In multivariable analyses, using any form of personal protective equipment when interacting with a confirmed, probable, or suspect EVD case was negatively associated with seroreactivity (adjusted odds ratio, 0.23; 95% confidence interval, .07–.73).	Implementation	While it is likely that some of the participants were exposed to EBOV while working during the outbreak, we cannot confirm when and where exposure may have occurred.
[2]	1999	Serologic Survey among Hospital and Health Center Workers	From May to July 1995, a serologic and interview survey was conducted to describe Ebola hemorrhagic fever (EHF) among personnel working in 5 hospitals and 26 health care centers in and around Kikwit, Democratic Republic of the Congo. Job-specific attack rates estimated for Kikwit General Hospital, the epicenter of the EHF epidemic, were 31% for physicians, 11% for technicians/room attendants, 10% for nurses, and 4% for other workers.	Implementation	An important feature of the Kikwit outbreak was that health care facility workers with jobs that in most settings do not usually involve patient contact appear to have had broader job descriptions, including patient contact. Whether this phenomenon predated the epidemic or whether it occurred in response to the epidemic is not clear; however, it does emphasize the need for prompt recognition and confirmation of EHF outbreaks and implementation of appropriate infection control measures detection and prevention of Ebola hemorrhagic fever by everyone in contact with patients.

[3]	2015	First secondary case of Ebola outside Africa: epidemiological characteristics and contact monitoring, Spain	On 6 October 2014, a case of Ebola virus disease (EVD) acquired outside Africa was detected in Madrid in a healthcare worker who had attended to a repatriated Spanish missionary and used proper personal protective equipment. The patient presented with fever <38.6 °C without other EVD-compatible symptoms in the days before diagnosis. No case of EVD was identified in the 232 contacts investigated. The experience has led to the modification of national protocols.	Implementation	The public health measures applied immediately to the contacts of the secondary case in Madrid included active monitoring of low-risk contacts and quarantine for high-risk contacts. All contacts accepted these measures. However, in the future it may be necessary to apply the quarantine to more people or to contacts who refuse to be quarantined. In our opinion, it is necessary to develop procedures and laws, which would establish and help apply the quarantine.

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Infection prevention and control measures for Ebola and Marburg Virus disease: A series of rapid reviews

KQ2 Body Handling- Initial Summary

(Version 2.1, 21 April 2022)

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Funding: Funding for this protocol and the subsequent reviews was provided by the World Health Organization (Funding # 202818287). The working group (WG) from the WHO/HQ Country Readiness Strengthening Health Care Readiness Unit will be consulted to develop and refine the scope, and review and approve the protocol. The WG will not be involved in the conduct of the review including selection of studies and data analysis but will advise as needed on priority population(s), interventions, and outcomes in an iterative process during the review process based on the available evidence. The WG will also comment on the draft report and provide input on interpretations of findings. AT is funded by a Tier 2 Canada Research Chair in Knowledge Synthesis. SM is funded by a Tier 2 Canada Research Chair in Mathematical Modeling and Program Science.

Competing interests: DM was involved in the 2015 rapid review by Hersi et al. [1] There are no other competing interests to acknowledge.

Acknowledgements: We thank Kaitryn Campbell, MLIS, MSc (St. Joseph's Healthcare Hamilton/McMaster University) for peer review of the Embase search strategy.

Question

Should bodies of patients deceased from Ebola or Marburg disease be disinfected versus not disinfected prior to handling/moving into a body bag?

- No studies specifically address this question. Therefore, additional searches were completed to address a revised question to provide information on the risk of EVD acquisition and transmission from handling dead bodies.
- **Revised Question:**
    - What is the risk of EVD acquisition/exposure from handling dead bodies compared to health workers providing care to patients (people who are alive)?

Methods Summary

This is one of a series of rapid reviews that will answer 12 key questions related to three themes on infection prevention and control measures for filoviruses: (i) transmission/exposure (n=3 questions), (ii) personal protective equipment (PPE) (n=5), and (iii) decontamination and disinfection (n=4). Data sources include Medline, Embase, bio/medRxiv pre-print servers, Global Medicus Index, Epistemonikos, China National Knowledge Infrastructure (CNKI) and Wangfang database. We will use an automation tool (CAL® tool) for titles/abstracts screening for relevant systematic reviews and primary comparative studies. Full-text screening, data extraction, risk of bias assessment, and GRADE (Grading of Recommendations Assessment, Development and Evaluation) for the certainty of evidence will be completed independently by two reviewers with any disagreements resolved by consensus, with arbitration by a third reviewer, if needed. Results from included studies will be synthesized narratively by theme and key question and pooled via random effects meta-analysis when appropriate.

Initial Findings Related to Body Handling

We present study characteristics in Table 1 and a summary of findings in Table 2 and Table 3.

Initially, 201 studies were screened in the CAL tool software and 38 studies were included for full-text screening. Of these 38 studies, none met the eligibility criteria for the primary question (Appendix 2). However, 3 studies were deemed to provide information on the risk of EVD acquisition/exposure from post-mortem contact and were included to address the revised question. To capture additional information related to vaccination status of healthcare workers, an additional 155 studies were reviewed in the CAL tool and 25 of these studies were included. Following full-text screening, an additional 5 studies were deemed relevant. A list of excluded studies with reasons for exclusion can be found in Appendix 1.

Table 1. Characteristics of Included Studies

Citation [Author, Year][citation #]	Funding Source	Country	Dates of Outbreak	Study Type	Virus Species	# Total Participants	Study Objectives [as reported by study authors]
Curran, 2016[1]	NR	Sierra Leone	2014	[Cross-sectional] Outbreak investigation	Ebola	78 cases	"The Sierra Leone Ministry of Health and Sanitation and CDC conducted a retrospective analysis of laboratory-confirmed Ebola cases in Moyamba during July 11–October 31, to investigate the increase in cases in September 2014, determine the source and risk factors, and recommend prevention and control measures"
Diallo, 2019[2]	Private, not-for-profit	Guinea	2016	[Cross-sectional] Retrospective cross-sectional	Ebola	1390	"The study aimed to identify risk factors for seropositivity and to estimate the prevalence of Ebola virus infection in unvaccinated contact persons"
Dietz, 2014[3]	Public	Sierra Leone	2014	[Cross-sectional] Surveillance; data linkage	Ebola	8056 cases	"Describe trends in laboratory-confirmed EVD, symptom presentation, and risk factors"
International Ebola Response Team, 2015[4]	Public/Private not-for-profit	Sierra Leone, Liberia and Guinea	2016	[Cross-sectional] Surveillance; data linkage	Ebola	19618 cases	"Analyses of data collected during the outbreak identifying drivers of transmission and highlighting areas where control could be improved"

Muoghalu, 2017[5]	None	Sierra Leone	2017	[Cross-sectional] Surveillance; data linkage	Ebola	142 cases	"Conduct an observational study to describe the transmission chain in the Koinadugo District and the impact of the control measures to contain the outbreak"
Senga, 2016[6]	Public/Private not-for-profit	Sierra Leone	2016	[Cross-sectional] Surveillance; data linkage	Ebola	706 cases	"Examined factors associated with Ebola virus exposure and mortality in HWs in Kenema District, Sierra Leone."
Tiffany, 2016[7]	Private, not-for-profit	Sierra Leone, Liberia and Guinea	2017	[Cross-sectional] Outbreak investigation	Ebola	45 unsafe burials and 310 contacts	"We performed epidemiological investigations in EVD affected communities to better understand disease transmission linked to unsafe burials of (suspect) EVD infected individuals, and risk factors for transmission linked to caring and burial practices"
Tiffany, 2017[8]	NR	Sierra Leone, Liberia and Guinea	2016	[Cross-sectional] Outbreak investigation	Ebola	45 unsafe burials and 310 contacts	"Quantify the impact of the Red Cross Safe and Dignified Burial Program on the EVD epidemic."

Table 2. Summary of Findings: Handling of deceased EVD/Marburg patients vs. Providing care to EVD/Marburg patients

Citation [Author, Year]	Handling of deceased patients (post-mortem contact) vs Providing care to patients	Outcome details	# Total Participants	# Exposed Cases (Post-Mortem contact) (n/N, %)	# Exposed Cases (Care provision) (n/N, %)	# Exposed Controls (Post-Mortem contact) (n/N, %)	# Exposed Controls (Care provision) (n/N, %)	Summary Effect Measure	Quality Assessment[a]	GRADE	Notes
	Incidence of EVD										
Curran, 2016, [Cross-sectional][1]	Contact with corpse vs. Contact with live patient	RT-PCR confirmed EVD	78 cases	23 exposed / 78 cases (29%)	26 exposed / 78 cases (33%)	N/A	N/A	N/A	High Risk of Bias	⊕◯◯◯ Very low	None
Diallo, 2019, [Cross-sectional][2]	Participation in Burial Rituals vs. No participation in burial rituals	Seropositivity for EVD[b]	1390 contacts (198 participated, 1192 didn't)	16 cases / 198 exposed (8%)	N/A	41 cases /1192 unexposed (3%)	N/A	OR = 2·47 (1·32–4·41; p=0·0031) Adjusted OR = 2·30 (1·21–4·17; p=0·0079)	Moderate Risk of Bias	⊕⊕◯◯ Low	Contacts were unvaccinated
	Provided care to individual with Ebola virus disease vs. Did not provide care to individual with Ebola virus disease	Seropositivity for EVD[b]	1390 contacts (820 provided care, 570 didn't)	N/A	41 cases /820 exposed (5%)	N/A	16 cases /570 unexposed (3%)	OR=1·82 (1·03–3·37; p=0·0454) Adjusted OR= 1·00 (0·51–2·02; p=0·99)		⊕◯◯◯ Very low	Contacts were unvaccinated
	Participation in Burial Rituals vs. No participation in burial rituals	Seropositivity for EVD[b]	1174 asymptomatic contacts (154 participated, 1020 didn't)	9 cases /154 exposed (6%)	N/A	30 cases /1020 unexposed (3%)	N/A	OR=2·05 (0·90–4·23; p=0·066) Adjusted OR=2·30 (1·01–		⊕⊕◯◯ Low	Contacts were unvaccinated

								4·80; p=0·0356)			
	Provided care to individual with Ebola virus disease vs. Did not provide care to individual with Ebola virus disease	Seropositivity for EVD[b]	1174 asymptomatic contacts (659 provided care, 515 didn't)	N/A	27 cases /659 exposed (4%)	N/A	12/515 unexposed (2%)	OR=1·79 (0·92–3·70; p=0·098) Adjusted OR=1·10 (0·52–2·42; p=0·82)		⊕◯◯◯ Very low	Contacts were unvaccinated
	Participation in Burial Rituals vs. No participation in burial rituals	Seropositivity for EVD[b]	216 paucisymptomatic contacts (44 participated, 172 did not)	7 cases/44 exposed (16%)	N/A	11 cases /172 unexposed (6%)	N/A	OR=2·77 (1·00–7·53; p=0·049) Adjusted OR=2·40 (0·81–6·74; p=0·099)		⊕⊕◯◯ Low	Contacts were unvaccinated
	Provided care to individual with Ebola virus disease vs. Did not provide care to individual with Ebola virus disease	Seropositivity for EVD[b]	216 paucisymptomatic contacts (161 provided care, 55 did not)	N/A	14 cases/161 exposed (9%)	N/A	4 cases/55 unexposed (7%)	[Unadjusted only] OR= 1·21 (0·41–4·43; p=0·74		⊕◯◯◯ Very low	Contacts were unvaccinated
Dietz, 2014, [Cross-sectional][3]	Touched Body at Funeral Vs. Contact With Suspected Case Patient or Any Sick Person	Seropositivity for EVD*	8056 cases	518 exposed/ 782 cases who attended funerals (66%)	2340 exposed / 4885 cases who provided exposure data (48%)	N/A	N/A	N/A	High Risk of Bias	⊕⊕◯◯ Low	None
International Ebola Response Team, 2015,	Touched corpse (Funeral) Vs. Direct physical contact (Non-funeral)	Confirmed and probable EVD cases	19618 cases	1071 exposed / 1657 cases with a type of exposure	2136 exposed / 2461 cases with a non funeral with	N/A	N/A	N/A	High Risk of Bias	⊕◯◯◯ Very low	None

[Cross-sectional][4]				reported at a funeral (65%)	exposure reported (87%)						
Muoghalu, 2017, [Cross-sectional][5]	Funeral Exposure Vs. Patient Care	Confirmed and probable EVD cases	142 cases	37 exposed / 142 cases (26%)	2 exposed / 142 cases (1%)	N/A	N/A	N/A	High Risk of Bias	⊕◯◯◯ Very low	The patient care cases were HCWs exposed in a public health unit who attended to patients at the onset of the EVD outbreak
Senga, 2016, [Cross-sectional][6]	Touched Body at Funeral Vs. Reported contact with case of Ebola virus disease	Confirmed EVD	92 HCW cases	1 exposed /3 cases who attended funeral (33%)	39 exposed / 92 cases (42%)	N/A	N/A	N/A	High Risk of Bias	⊕◯◯◯ Very low	
Tiffany, 2016, [Cross-sectional][7]	Contact after death only Vs. Contact before & after death	Laboratory-confirmed EVD	301 contacts with lab results (203 confirmed cases, 98 controls)	120 exposed cases /203 cases (59%)	83 exposed cases / 203 cases (41%)	76 exposed / 98 controls (78%)	22 exposed / 98 controls (22%)	OR=0.20 (95% CI, 0.12, 0.35)	Moderate Risk of Bias	⊕⊕◯◯ Low	
	Contact after death: Exposure to blood/body fluids Vs. Care during illness	Exposure to EVD from primary case	310 contacts	21 exposed / 310 contacts (7%)	142 exposed / 310 contacts (46%)	N/A	N/A	N/A		⊕⊕◯◯ Low	23% of contacts reported using protection
	Contact after death: Washed clothes/bedding Vs. Care during illness	Exposure to EVD from primary case	310 contacts	40 exposed / 310 contacts (13%)	142 exposed / 310 contacts (46%)	N/A	N/A	N/A		⊕⊕◯◯ Low	
	Contact after death: Washed body Vs. Care during illness	Exposure to EVD from primary case	310 contacts	112 exposed / 310	142 exposed / 310	N/A	N/A	N/A		⊕⊕◯◯ Low	

				contacts (36%)	contacts (46%)						
	Contact after death: Transported body Vs. Care during illness	Exposure to EVD from primary case	310 contacts	75 exposed / 310 contacts (24%)	142 exposed / 310 contacts (46%)	N/A	N/A	N/A		⊕⊕◯◯ Low	
	Contact after death: Burial/funeral rituals Vs. Care during illness	Exposure to EVD from primary case	310 contacts	86 exposed / 310 contacts (28%)	142 exposed / 310 contacts (46%)	N/A	N/A	N/A		⊕⊕◯◯ Low	
	Contact after death: Burial of body Vs. Care during illness	Exposure to EVD from primary case	310 contacts	110 exposed / 310 contacts (35%)	142 exposed / 310 contacts (46%)	N/A	N/A	N/A		⊕⊕◯◯ Low	
	Contact after death: Other Vs. Care during illness	Exposure to EVD from primary case	310 contacts	22 exposed / 310 contacts (7%)	142 exposed / 310 contacts (46%)	N/A	N/A	N/A		⊕◯◯◯ Very low	
Tiffany, 2017, [Cross-sectional][8]	Contact after death only Vs. Contact during acute illness	EVD cases	310 contacts	"Those having contact with the index case before death were 2.5 - 6 times more likely to be infected with EVD, compared to those with post mortem contact alone"					High Risk of Bias	⊕◯◯◯ Very low	Same study as Tiffany cohort et al. 2016, but additional analysis reported.

a. Quality assessment of studies was completed using the ROBINS-I scale for observational studies. Scores from 7-9 were considered to be high quality (low risk of bias), scores of 4-6 of moderate quality (moderate risk of bias) and scores of 0-3 of low quality (high risk of bias).
b. Antibody response against glycoprotein, nucleoprotein, and 40-kDa viral protein of Zaire Ebola virus

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Appendix 1. Excluded Studies List – By Reason for Exclusion:

Full-text unavailable

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Study does not evaluate the risk of infection/exposure from handling patients deceased from EVD

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Appendix 2. Eligibility Criteria

Question (2): Should bodies of patients deceased from Ebola or Marburg disease be disinfected versus not disinfected prior to handling/moving *into a body bag?*

Setting	Health care facility, ETU, community
Population	Health workers and Burial teams handling bodies of Ebola and Marburg patients
Background interventions	Varies by organization. WHO says remains should not be sprayed, washed or embalmed.
Intervention	no disinfection of dead bodies prior to handling/moving
Comparator(s)	1) disinfection of dead bodies by wiping prior to handling/moving, 2) spraying dead bodies with disinfectant prior to handling/moving
Outcome	Symptoms of chemical exposure from spraying dead bodies, exposure during handling dead bodies, infection with Ebola or Marburg

Potential effect modifiers	*Ventilation in the area where bodies are sprayed may affect the outcome, vaccination*

Appendix 3. GRADE Table

Number of studies *Study Citations*	***Study Design***	***Risk of Bias*** [a]	***Inconsistency***	***Indirectness***	***Imprecision***	***Other Considerations***	***Quality***
Incidence of EVD							
Contact with corpse vs. Contact with live patient							
1[1]	[Cross-sectional]	Very Serious[b]	No serious[c]	Serious[d]	Serious[e]	None	⊕◯◯◯ Very low
Participation in Burial Rituals vs. No participation in burial rituals							
1[2]	[Cross-sectional	Serious[f]	No serious[c]	Serious[g]	Not Serious[h]	None	⊕⊕◯◯ Low
Provided care to individual with Ebola virus disease vs. Did not provide care to individual with Ebola virus disease							
1[2]	[Cross-sectional]	Serious[f]	No serious[c]	Serious[g]	Serious[i]	None	⊕◯◯◯ Very low
Touched Body at Funeral vs. Contact With Suspected Case Patient or Any Sick Person							
1[3]	[Cross-sectional]	Very Serious[j]	No serious[c]	Not Serious[k]	Not Serious[l]	None	⊕⊕◯◯ Low
Touched corpse (Funeral) Vs. Direct physical contact (Non-funeral)							
1[4]	[Cross-sectional]	Very Serious[m]	No serious[c]	Serious[n]	Not Serious[l]	None	⊕◯◯◯ Very low
Funeral Exposure Vs. Patient Care							
1[5]	[Cross-sectional]	Very Serious[o]	No serious[c]	Serious[p]	Serious[q]	None	⊕◯◯◯ Very low
Touched Body at Funeral Vs. Reported contact with case of Ebola virus disease							
1[6]	[Cross-sectional]	Serious[r]	No serious[c]	Serious[d]	Very Serious[s]	None	⊕◯◯◯ Very low
Contact after death only Vs. Contact before & after death							
1[7]	[Cross-sectional]	Serious[t]	No serious[c]	Serious[g]	Not Serious[u]	None	⊕⊕◯◯ Low
Contact after death: Exposure to blood/body fluids Vs. Care during illness							

Number of studies *Study Citations*	***Study Design***	***Risk of Bias***[a]	***Inconsistency***	***Indirectness***	***Imprecision***	***Other Considerations***	***Quality***
1[7]	[Cross-sectional]	Serious[t]	No serious[c]	Not Serious[k]	Serious[q]	None	⊕⊕◯◯ Low
Contact after death: Washed clothes/bedding Vs. Care during illness							
1[7]	[Cross-sectional]	Serious[t]	No serious[c]	Not Serious[k]	Serious[q]	None	⊕⊕◯◯ Low
Contact after death: Washed body Vs. Care during illness							
1[7]	[Cross-sectional]	Serious[t]	No serious[c]	Not Serious[k]	Serious[q]	None	⊕⊕◯◯ Low
Contact after death: Transported body Vs. Care during illness							
1[7]	[Cross-sectional]	Serious[t]	No serious[c]	Not Serious[k]	Serious[q]	None	⊕⊕◯◯ Low
Contact after death: Burial/funeral rituals Vs. Care during illness							
1[7]	[Cross-sectional]	Serious[t]	No serious[c]	Not Serious[k]	Serious[q]	None	⊕⊕◯◯ Low
Contact after death: Burial of body Vs. Care during illness							
1[7]	[Cross-sectional]	Serious[t]	No serious[c]	Not Serious[k]	Serious[q]	None	⊕⊕◯◯ Low
Contact after death: Other Vs. Care during illness							
1[7]	[Cross-sectional]	Serious[t]	No serious[c]	Serious[v]	Serious[q]	None	⊕◯◯◯ Very low
Contact after death only Vs. Contact during acute illness							
1[8]	[Cross-sectional]	Very Serious[w]	No serious[x]	Serious[d]	Very Serious[y]	None	⊕◯◯◯ Very low

a. Individual quality assessment of studies was completed using the ROBINS-I scale for observational studies. Scores from 7-9 were considered to be high quality (low risk of bias), scores of 4-6 of moderate quality (moderate risk of bias) and scores of 0-3 of low quality (high risk of bias).
b. NOS 3/9; Downrated for lack of controls, failure to adjust for confounders, and ascertainment of exposure not blinded to case/control status.
c. No inconsistency as only one study evaluated.
d. Downrated by 1 as study addresses any contact with live patient, rather than care provision.
e. Downrated by 1 due to small sample size; unable to evaluate relative effects.
f. NOS 6/9; Downrated for not addressing potential for selection bias, failure to report confounders adjusted in analysis and no reporting of non-response rate.

g. Downrated by 1 for not providing risk of EVD acquisition for post-mortem contact vs. for care provision.
h. Not downrated; most adjusted estimates do not cross null or show appreciable benefit or harm
i. Downrated by for most adjusted estimates crossing null and showing both appreciable benefit or harm
j. NOS 2/9; Downrated for lack of controls, lack of adjustment for confounders, ascertainment of exposure not blinded to case/control status, and no reporting of non-response rate.
k. Not downrated.
l. Not downrated; unable to evaluate relative effects.
m. NOS 2/9; Downrated due to no independent validation of cases, lack of controls, lack of adjustment for confounders, and ascertainment of exposure not blinded to case/control status.
n. Downrated by 1 as study addresses any direct contact with live patient, rather than care provision.
o. NOS 1/9; Downrated due to no independent validation of cases, lack of controls, lack of adjustment for confounders, ascertainment of exposure not blinded to case/control status and lack of reporting of non-response rate by EVD-status.
p. Downrated by 1 due to funeral exposure, not handling of deceased patients.
q. Downrated by 1 due to small sample size. Unable to evaluate relative effects.
r. NOS 2/10; Downrated for lack of controls, lack of adjustment for confounders, ascertainment of exposure not blinded to case/control status and lack of reporting of non-response rate.
s. Downrated by 2 due to small sample size and low number of events.
t. NOS 5/9; Downrated due to lack of adjustment for confounders, ascertainment of exposure not blinded to case/control status and lack of reporting of non-response rate by EVD-status.
u. Not downrated; estimates do not cross null or show appreciable benefit or harm
v. Downrated by 1 due to lack of clarity surround what "other" activities consisted of.
w. NOS 3/10; Downrated for failure to report case definition or sampling frame, details of ascertainment of exposure, and non-response rate.
x. Downrated by 1 for not providing details on type of contact after death.
y. Downrated by 2 for failure to provide measure of association or confidence intervals.

Contextual data

Key question 2: Should bodies of patients deceased from Ebola or Marburg disease be disinfected versus not disinfected prior to handling/moving into a body bag?

- We did not find any studies addressing this question.

Revised Question: What is the risk of EVD acquisition/exposure from handling dead bodies compared to health workers providing care to patients (people who are alive)?

- We found limited data relevant to this question.

We collected the contextual data on the broad question of handling dead bodies because there is no simple answer to key question 2.

Summary

Contextual data pertaining to key answer 2 are displayed in the table below; key findings are summarized below.

What is already known?

- Reduce transmission from exposure to dead bodies (e.g., contact with corpses, touching of bodies at funerals) through safe burial practices have been successful. [1]
- Safe funeral practices and fast hospitalization contributed to the containment of Ebola epidemics. [2]
- Some social/cultural issues, community perceptions and experiences related to burial practices are conducive to Ebola transmission. [3]

What this rapid review found?

- No data to support disinfection before moving the body to a body bag.
- Very limited data and virtually no operational details regarding safe handling of dead bodies with respect to Ebola and Marburg transmission.
- High degree of variation in transmission sources and high transmission risk around the time of death, before and after. [2]
- Reduced funeral attendance and faster hospitalization independently influenced local transmission intensity. [2]
- Health workers were half as likely to have touched a body at a funeral compared with non-health workers. [4]
- The higher prevalence of Ebola infection in contact persons who participated in burial rituals emphasizes the importance of safe and dignified burials during Ebola outbreaks and the need to systematically interview contact persons regarding participation in burial rituals. [5]
- Transmissions within community decreased to substantially low rates once isolation into community care centers was implemented. Transmission during funerals contributed a little after the safe dignified burials were put in place. [6]
- Public health messages promoted by community and religious leaders may have influenced safe burial behaviors during the Ebola outbreak in Sierra Leone. [7]
- Nearly all respondents (3049; 86%) intended to avoid touching or washing the corpse of a family member, regardless of exposure to religious leaders' messages (adjusted odds ratio: 0.89; 95% CI: 0.53–1.48). [7]

- Barriers include fears about how bodies are handled, lack of ability to view or participate in the burial at the cemetery, and the potential for quarantine and stigma when a family member requests collection of a body or following a burial. Facilitating factors for community acceptance may include community participation in digging the grave, as well as the possibility of participating on local burial teams, following appropriate training. [8]
- Safe burial using plastic bags, lack of burial clothes, and the absence of women in the burial team were described as showing a lack of honor for the deceased. Burials were described as being more compliant to control measures when practices such as community prayer were permitted. [9]
- Unsafe dead body management, including direct contact with biological liquids by multiple people close to the deceased. Safer approaches include informing the head of the health area, using chlorinated water during funeral baths, wearing household gloves when touching the dead body, and reducing the number of people in contact with the body. When community leaders, religious leaders, community members, and community health workers' supervisors were asked which unsafe practice was the most difficult to give up, dead body management and greetings with hands were the most frequently mentioned. [3]

Suggested implications of the available evidence

- Disinfection of dead bodies may be justifiable given the transmission risk associated with handling the bodies.
- The context of using disinfection of dead bodies as an intervention for reducing the transmission risk of Ebola and Marburg infection is complex. Understanding this context requires more data through qualitative and quantitative research methods, especially how to position this intervention within the continuum of IPC control in hospitals, operation of burial teams and safe burial practices.

Table: Contextual data

Ref.	Year	Study methods	Findings relevant to the extraction of contextual data	Data type	Contextual data
[1]	2015	Analyzed data related to epidemiology and risk factors of EVD cases from Sierra Leone	Among persons with confirmed cases, 47.9% reported having had contact with someone with suspected EVD or any sick person, and 25.5% reported having attended a funeral, of whom 66.2% reported touching the body. Almost half of patients with EVD in Sierra Leone reported physical contact with a person ill with EVD or a dead body.	Context	In past Ebola virus outbreaks, strict measures to identify and isolate cases quickly, trace their contacts, and reduce transmission from exposure to symptomatic persons and to dead bodies through safe burial practices have been successful. The exposures reported in this outbreak—contact with suspected cases by healthcare workers and family members, including contact with corpses and touching of bodies at funerals—are consistent with those reported in other outbreaks.
				Context	Approximately half of the cases in the VHF data had no known exposure recorded. This may reflect the stigma associated with an EVD diagnosis
				Context	Without the availability of vaccines or definitive treatment, application of standard public health control measures is essential to slow and stop the epidemic.These include comprehensive contact tracing, followed by daily monitoring of contacts for symptoms, with prompt transport to a treatment center where suspected cases can be cared for safely, and safe burials, all performed thoroughly and effectively.
[2]	2016	Observational study of Ebola transmission using data from confirmed and probable EVD cases in 3 countries in West Africa	The principal limitation of our analysis is limited data quality (especially dates, and possible misclassifications). The proportion of cases reporting a funeral exposure decreased over time. We found a positive correlation ($r = 0.35$, $p<0.001$) between this proportion in a given district for a given month and the within-district transmission intensity, quantified by the estimated reproduction number (R). We also found a negative correlation ($r =-0.37$, $p<0.001$) between R and the district proportion of hospitalized cases admitted within 4 days of symptom onset. **These two proportions were not correlated, suggesting that reduced funeral attendance and faster hospitalization independently influenced local transmission intensity.**	Context	Safe funeral practices and fast hospitalisation contributed to the containment of this Ebola epidemic. 25% of cases who reported any exposure in the current outbreak reported exposures at funerals. Most cases (89%) reporting a funeral exposure also reported one or more non-funeral exposures. For funeral exposures, cases were asked whether they had touched the corpse. Of those giving a response, 65% reported having touched the corpse, with this proportion being greatest for Guinea (71%) and least for Liberia (61%).
			We were able to identify 14% of potential source contacts as cases in the case line-list. Linking cases to the contacts who potentially infected them provided information on the transmission network. **This revealed a high degree of heterogeneity in inferred transmissions,** with only 20% of cases accounting for at least 73% of new infections, a phenomenon often called super-spreading.	Context	We find high to extreme variability in the offspring distribution. The estimated coefficient of variation for the offspring distribution ranges from 1.6 to 5.6. This implies that 5% of cases accounted for at least 30% of all new infections and that 20% of cases accounted for at least 73% of new infections, a phenomenon termed super-spreading [26]. Super-spreading was found to affect both non-funeral and funeral transmissions equally.
			Multivariable regression models allowed us to identify predictors of being named as a potential source contact. **These were similar for funeral and non-funeral contacts: severe symptoms, death, non-hospitalization, older age, and travelling prior to symptom onset. Non-funeral exposures were strongly peaked around the death of the contact.**	Context	Transmission events from non-funeral exposures were estimated to be strongly peaked on the day of and the day after the death of the contact. In all, 44% of non-funeral exposures to potential source contacts who died were estimated to occur on or after the date of death of the

					contact. Furthermore, individuals who died were more likely to be named as non-funeral contacts.
			There was evidence that hospitalization reduced but did not eliminate onward exposures. We found that Ebola treatment units were better than other health care facilities at preventing exposure from hospitalized and deceased individuals.	Context	Similar predictors were found for individuals being named as funeral contacts: more severely affected cases (fever versus no fever, OR = 1.81 [95% CI: 1.08, 3.18]; respiratory versus no respiratory symptoms, OR = 1.65 [95% CI: 1.09, 2.54]), adults (≥16 versus <16 years old, OR = 2.44 [95% CI: 1.47, 4.36]), cases not hospitalized (versus hospitalized in an ETU, OR = 5.56 [95% CI: 2.94, 11.11]), those who reported travelling before they became ill (versus not travelling, OR = 2.47 [95% CI: 1.50, 3.90]), confirmed cases (versus suspected cases, OR = 1.98 [95% CI: 1.28, 3.11]), probable cases (versus suspected cases, OR = 2.03 [95% CI: 1.21, 3.42]), and those who were reported as Ebola cases after death (versus before death, OR = 1.64 [95% CI: 1.12, 2.40]).
				Health equity	Sex did not appear as an important predictor of exposure risk in any of the analyses that we performed.
				Context	Our analysis confirms that exposure to Ebola cases at funerals is an important amplifier of Ebola transmission, in line with a study focused in Sierra Leone
[4]	2015	Analyzed data from Sierra Leone National VHF Database and related sources	Although not statistically significant, HWs were half as likely to have touched a body at a funeral compared with non-HWs.	Context	Although not statistically significant, HWs were half as likely to have touched a body at a funeral compared with non-HWs.
[5]	2019	Observational study of prevalence of infection among asymptomatic and paucisymptomatic contact persons exposed to Ebola virus in Guinea	Seropositivity increased with participation in burial rituals (adjusted odds ratio [aOR] 2·30, 95% CI 1·21–4·17; p=0·0079) and exposure to blood or vomit (aOR 2·15, 1·23–3·91; p=0·0090). This study provides a new assessment of the prevalence of Ebola virus infection among contact persons according to exposure, provides evidence for the occurrence of paucisymptomatic cases, and reinforces the importance of closely monitoring at-risk contact persons.	Implementation	The higher prevalence of Ebola virus infection in contact persons who participated in burial rituals emphasizes the importance of safe and dignified burials during Ebola outbreaks and the need to systematically interview contact persons regarding participation in burial rituals.
				Implementation	Ebola virus infection occurred in 3–17% of the contact persons, **depending on the presence of symptoms among contact persons and exposure to burial rituals**.
[6]	2017	Study of transmission chain using data from Sierra Leone	All 142 confirmed and probable EVD cases registered were fully resolved in the transmission chain. 72.5% of all the EVD cases in the district were exposed in the community, 26.1% exposed during funerals, and 1.4% exposed in the health facility setting. Health-care workers contributed little to the EVD outbreak. 71.1% of EVD transmission occurred among family members.	Health equity	Female EVD cases generated more secondary cases than their male counterparts did (P = 0.03).

				Context	The findings of the study show that most transmissions took place in the community and between family members. **However, these transmissions within community decreased to substantially low rates once isolation into the CCC was implemented. Transmission during funerals contributed a little after the safe dignified burials were put in place.** Although transmission due to exposure at the health facility had a minor role to the spread of the outbreak in the district, the full implementation of IPC measures at the health facilities further reduced the chances of transmission.
[7]	2021	Study the potential impact of engaging religious leaders in promoting safe burial practices	Of the respondents, 3148 (89%) had been exposed to faith-based messages from religious leaders on safe Ebola burials and 369 (10%) were unexposed. Exposure to religious leaders' messages was associated with a nearly twofold increase in the intention to accept safe alternatives to traditional burials and the intention to wait ≥ 2 days for burial teams (adjusted odds ratio, aOR: 1.69; 95% confidence interval, CI: 1.23–2.31 and aOR: 1.84; 95% CI: 1.38–2.44, respectively). Exposure to messages from religious leaders was also associated with avoidance of traditional burials and of contact with suspected Ebola patients (aOR: 1.46; 95% CI: 1.14–1.89 and aOR: 1.65; 95% CI: 1.27–2.13, respectively).	Implementation	Public health messages promoted by religious leaders may have influenced safe burial behaviours during the Ebola outbreak in Sierra Leone. Engagement of religious leaders in risk communication should be prioritized during health emergencies in similar settings.
				Implementation	Nearly all respondents (3049; 86%) intended to avoid touching or washing the corpse of a family member, regardless of exposure to religious leaders' messages (aOR: 0.89; 95% CI: 0.53–1.48).
[8]	2017	Facilitators and Barriers to Community Acceptance of Safe, Dignified Medical Burials in the Context of an Ebola Epidemic, Sierra Leone	In addition to concerns about breaking cultural traditions, barriers to safe burial acceptance included concerns by family members about being able to view the burial, perceptions that bodies were improperly handled, and fear that stigma may occur if a family member receives a safe, dignified medical burial. Participants suggested that providing opportunities for community members to participate in safe and dignified burials would improve community acceptance.	Implementation	Barriers include fears about how bodies are handled, lack of ability to view or participate in the burial at the cemetery, and the potential for quarantine and stigma when a family member requests collection of a body or following a burial. Facilitating factors for community acceptance may include community participation in digging the grave, as well as the possibility of participating on local burial teams (following appropriate training).
[10]	2021	Socio-cultural and anthropological implications of safe and dignified burial in DR Congo	Death, burial, funeral rites, and mourning beliefs and traditions can have a direct impact on Ebola transmission and influence trust between communities and responders.	Implementation	In the context of EVD in North Kivu, two-way dialogue and community consultations ensured community members understand the need for Safe Dignified Burial (SDB) and to raise awareness about the use of locally appropriate SDB. Rumors about the care of the deceased and the intentions of the burial teams were also reduced thanks to a well-managed and open process.

[9]	2018	Mixed-methods study in Sierra Leone about household transmission dynamics and community compliance with Ebola control measures	Burials in plastic bags, without female attendants or prayer, were perceived as dishonourable. Further reasons for low compliance were low EMC survival rates, family perceptions of a moral duty to provide care to relatives, poor communication with the EMC, and loss of livelihoods due to quarantine. Compliance with response measures increased only after the second generation, coinciding with the implementation of restrictive bylaws, return of the first survivor, reduced contact with dead bodies, and admission of patients to the EMC.	Implementation	Return of a survivor to the village and more effective implementation of control strategies coincided with increased compliance to control measures, with few subsequent cases.
				Context	Following death, the index case was buried in an unsafe manner by community members, many of whom had unprotected contact with the body. It is believed that this may have started the chain of person-to-person transmission in the village. Transmission lasted for 16 weeks, with 30 cases arising over five transmission generations: 11 cases in the 1st generation, seven in the 2nd, five in the 3rd, four in the 4th, and two in the 5th.
				Acceptability	"Initially, it [burial team] was not good but when we saw that the deaths increased, we knew it was for our own safety."
				Acceptability	"Without the burial team, the disease would have spread because touching dead bodies is bad."
				Health equity	"Men burying women is not good; women should be part of the burial team."
				Implementation	Safe burial using plastic bags, lack of burial clothes, and the absence of women in the burial team were described as showing a lack of honor for the deceased. Burials were described as being more compliant to control measures when practices such as community prayer were permitted. In addition, the burial team started to dress in PPE after arrival in the village as now recommended by WHO Guidelines [27]. Additional measures that can be implemented without compromising safe burial, such as including female members in the burial team, and safe alternatives to plastic burial bags, would further enhance community acceptance compliance, and should be included in EVD control guidelines.
[11]	2017	A survey/interview of community perceptions and experiences during periods of low but ongoing transmission of EVD in Sierra Leone	Participants perceived that as healthcare practices and facilities improved, so did community trust. Resource management remained a noted concern. Perceptions of survivors ranged from sympathy and empathy to fear and stigmatization. Barriers included persistent denial of ongoing Ebola transmission, secret burials and movement across porous borders. Facilitators included personal protective actions, consistent messaging and the inclusion of women and survivors in the response.	Context	Understanding community experiences during the devastating Ebola epidemic provides practical lessons for engaging similar communities in risk communication and social mobilization during future outbreaks and public health emergencies.
				Context	There should be targeted social mobilization and risk communication efforts particularly around safe burial practices and personal protective actions such as hand washing. There should be targeted communication with survivors

[3]	2017	Use of a community-led prevention strategy to enhance behavioral changes towards EVD prevention: a qualitative case study in Western Côte d'Ivoire	The community-led strategy was socially accepted in the villages. The people interviewed demonstrated accurate understanding of information about prevention practices. Some practices were easily adopted, while others remained difficult to implement (e.g., ensuring safe and dignified dead body management).	Implementation	The strategy was implemented in Western districts bordering Liberia, Guinea, and Mali. This study aims to analyze the community-led strategy, to document lessons learned from the experience, and to capitalize on the achievements. This research demonstrates that sensitization efforts led by well-integrated and respected community leaders can be conducive of behavior change.
				Implementation	Unsafe dead body management, including direct contact with biological liquids by multiple people close to the deceased. Alternative approaches include informing the head of the health area, using chlorinated water during funeral baths, wearing household gloves when touching the dead body, and reducing the number of people in contact with the body.
				Acceptability	When community leaders, religious leaders, community members, and community health workers' supervisors were asked which unsafe practice was the most difficult to give up, dead body management and greetings with hands were the most frequently mentioned.

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Infection prevention and control measures for Ebola and Marburg Virus disease: A series of rapid reviews

KQ3 IPC Ring Approach- Initial Summary

(Version 3, 16 May 2022)

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Funding: Funding for this protocol and the subsequent reviews was provided by the World Health Organization (Funding # 202818287). The working group (WG) from the WHO/HQ Country Readiness Strengthening Health Care Readiness Unit will be consulted to develop and refine the scope, and review and approve the protocol. The WG will not be involved in the conduct of the review including selection of studies and data analysis but will advise as needed on priority population(s), interventions, and outcomes in an iterative process during the review process based on the available evidence. The WG will also comment on the draft report and provide input on interpretations of findings. AT is funded by a Tier 2 Canada Research Chair in Knowledge Synthesis. SM is funded by a Tier 2 Canada Research Chair in Mathematical Modeling and Program Science.

Competing interests: DM was involved in the 2015 rapid review by Hersi et al. [1] There are no other competing interests to acknowledge.

Acknowledgements: We thank Kaitryn Campbell, MLIS, MSc (St. Joseph's Healthcare Hamilton/McMaster University) for peer review of the Embase search strategy.

Question

Question (3): Should the IPC ring approach* be used versus not used to prevent and control transmission of Ebola Virus Disease (EVD) or Marburg virus disease in health care facility and community settings? (How effective is IPC ring at preventing Ebola or Marburg transmission in health care and community settings?)

*The ICP ring approach rapidly mobilizes teams to assist affected health facilities and the community in implementing ICP measures to reduce Ebola transmission in a predetermined risk area whenever a case is identified.

Methods Summary

This is one of a series of rapid reviews answering 12 key questions related to three themes on infection prevention and control measures for filoviruses: (i) transmission/exposure (n=3 questions), (ii) personal protective equipment (PPE) (n=5), and (iii) decontamination and disinfection (n=4). Data sources include Medline, Embase, bio/medRxiv pre-print servers, Global Medicus Index, Epistemonikos, China National Knowledge Infrastructure (CNKI) and Wangfang database. We used an automation tool (CAL® tool) for titles/abstracts screening for relevant systematic reviews and primary comparative studies. Full-text screening, data extraction, risk of bias assessment, and GRADE (Grading of Recommendations Assessment, Development and Evaluation) for the certainty of evidence were completed independently by two reviewers with any disagreements resolved by consensus, with arbitration by a third reviewer, when needed.

Initial findings relating to work exclusion

We present study characteristics in Table 1 and a summary of findings in Table 2.

Initially, 141 studies were screened in the CAL tool software and 16 studies were included for full-text screening. Of these 16 studies, none met the eligibility criteria (Appendix 2). However, one non-comparative study was included to provide rates of EVD infection associated with the initiation of the approach. A list of excluded studies with reasons for exclusion can be found in Appendix 1.

Table 1. Characteristics of Included Study

Citation [Author, Year]	Funding Source	Country	Dates of Outbreak	Study Type	Virus Species	Setting	# Total Health Workers	# Health Care Facilities	Description of IPC Ring Approach	Study Objectives [as reported by study authors]
Nyenswah, 2015, [Cohort][1]	Not Reported	Liberia	2015 outbreak	Outbreak Investigation	Ebola	Health facility	166 exposed in St. Paul Bridge Cluster	59 HCFs across 4 IPC rings	Strategy: Identifying HCW exposure to an Ebola patient, neighboring HCFs around the HCF that treated a patient, or HCFs near the residence of a patient with confirmed Ebola. Components: Rapid IPC needs assessments focused on triage procedures and personal protective equipment use. Following assessment, PPE distribution, general IPC training and specialized triage training.	In mid-January to mid-February 2015, there were 22 confirmed patients with Ebola virus disease in Liberia. This report describes possible health care worker exposures to the cluster's eight patients who sought and received care from at least one of 10 non-Ebola health care facilities and the implementation of the IPC Ring approach.

Abbreviations: HCF, health care facility; HCW, health care worker

Table 2. Summary of Findings: Implementation of IPC Ring Approach

Study details	*Intervention and Comparator*	*Outcome details*	*Intervention with outcome (n/N, %)*	*Comparator with outcome (n/N, %)*	*Summary Effect Measure*	*Quality Assessment*[a]	*GRADE*	*Notes*
Incidence of EVD								
Nyenswah, 2015, [Cohort][1]	IPC Ring Approach [No Comparator]	Confirmed EVD	1/166	NA	NA	Moderate Risk of Bias	⊕◯◯◯ Very low	None

a. Quality assessment of studies was completed using the Newcastle Ottawa Scale (NOS) for observational studies. Scores from 7-9 were considered to be high quality (low risk of bias), scores of 4-6 of moderate quality (moderate risk of bias) and scores of 0-3 of low quality (high risk of bias).

Citations:

1. Nyenswah T, Massaquoi M, Gbanya MZ, et al. Initiation of a Ring Approach to Infection Prevention and Control at Non-Ebola Health Care Facilities — Liberia, January–February 2015. 2015;64(18):4.

Appendix 1. Excluded Studies List – By Reason for Exclusion:

Study does not evaluate the IPC ring approach for controlling the transmission of EVD/Marburg disease

Bangura I, Conteh C. The Impact of Quality Improvement Methodology to Improve Infection Control Practices. Antimicrobial Resistance & Infection Control. 2019;8(1):P405.

Bemah P, Baller A, Cooper C, et al. Strengthening healthcare workforce capacity during and post Ebola outbreaks in Liberia: an innovative and effective approach to epidemic preparedness and response. Pan Afr Med J. 2019;33. doi:10.11604/pamj.supp.2019.33.2.17619

Biedron C, Lyman M, Stuckey MJ, et al. Evaluation of Infection Prevention and Control Readiness at Frontline Health Care Facilities in High-Risk Districts Bordering Ebola Virus Disease–Affected Areas in the Democratic Republic of the Congo — Uganda, 2018. MMWR Morb Mortal Wkly Rep. 2019;68(39):851-854. doi:10.15585/mmwr.mm6839a4

Cooper C. Using Data to Enhance Implementation in a Low Resource Setting - Liberia Experience. Antimicrobial Resistance & Infection Control. 2017;6(Supp 3):175.

Forrester JD, Hunter JC, Pillai SK, et al. Cluster of Ebola Cases Among Liberian and U.S. Health Care Workers in an Ebola Treatment Unit and Adjacent Hospital — Liberia, 2014. 2014;63(41):5.

Keïta M, Camara AY, Traoré F, et al. Impact of infection prevention and control training on health facilities during the Ebola virus disease outbreak in Guinea. BMC Public Health. 2018;18(1):547. doi:10.1186/s12889-018-5444-3

Matanock A, Arwady MA, Ayscue P, et al. Ebola Virus Disease Cases Among Health Care Workers Not Working in Ebola Treatment Units — Liberia, June–August, 2014. 2014;63(46):5.

Mehtar S. The impact of education on reducing Ebola virus disease transmission in healthcare facilities. International Journal of Infectious Diseases. 2016;45:66-67. doi:10.1016/j.ijid.2016.02.193

Oji MO, Haile M, Baller A, et al. Implementing infection prevention and control capacity building strategies within the context of Ebola outbreak in a "Hard-to-Reach" area of Liberia. Pan Afr Med J. 2018;31. doi:10.11604/pamj.2018.31.107.15517

Tremblay N, Musa E, Cooper C. Infection prevention and control in health facilities in post-Ebola Liberia: don't forget the private sector! Public Health Action.:6.

Study is not about health workers

Fallah M, Dahn B, Nyenswah TG, et al. Interrupting Ebola Transmission in Liberia Through Community-Based Initiatives. Ann Intern Med. 2016;164(5):367. doi:10.7326/M15-1464

Nyenswah T, Fahnbulleh M, Massaquoi M, et al. Ebola Epidemic — Liberia, March–October 2014. 2014;63(46):5.

Nyenswah T, Fallah M, Sieh S, et al. Controlling the Last Known Cluster of Ebola Virus Disease — Liberia, January–February 2015. 2015;64(18):5.

Logan G, Vora NM, Nyensuah TG, et al. Establishment of a Community Care Center for Isolation and Management of Ebola Patients — Bomi County, Liberia, October 2014. 2014;63(44):3.

Appendix 2. Eligibility Criteria

Question (3): Should the IPC ring approach* be used versus not used to prevent and control transmission of Ebola Virus Disease (EVD) or Marburg virus disease in health care facility and community settings? (How effective is IPC ring at preventing Ebola or Marburg transmission in health care and community settings?)

Setting	Health care facility, community
Population	Staff, communities, organizations responsible for management of Ebola or Marburg cases
Background interventions (Standard of care)	New approach: Use the IPC ring approach when a new case of EVD is identified. The IPC ring approach rapidly mobilizes teams to assist affected health facilities and the community in implementing IPC measures to reduce Ebola transmission in a predetermined risk area whenever a case is identified.
Intervention	Implement the ring approach, which includes identification of nearby health centres, household and public places visited by the positive case for case finding, environmental cleaning/decontamination, IPC assessment, education, PPE supplies.
Comparator(s)	Single intervention, Single health facility prioritization
Outcome	Transmission of Ebola or Marburg, *score of IPC standard in the HCF*
Potential effect modifiers	**Effect modifier** – conflict zone

*The IPC ring approach rapidly mobilizes teams to assist affected health facilities and the community in implementing IPC measures to reduce Ebola transmission in a predetermined risk area whenever a case is identified.

Appendix 3. GRADE Assessment

Number of studies	*Study Design*	*Risk of Bias*[a]	*Inconsistency*	*Indirectness*	*Imprecision*	*Other Considerations*	*Quality*
Incidence of EVD							
IPC Ring Approach Intervention							
1[1]	[Cohort]	Very serious[b]	No serious[c]	No serious[d]	Serious[e]	None	⊕◯◯◯ Very low

a. Individual quality assessment of studies was completed using the Newcastle Ottawa scale (NOS) for observational studies. Scores from 7-9 were considered to be high quality (low risk of bias), scores of 4-6 of moderate quality (moderate risk of bias) and scores of 0-3 of low quality (high risk of bias).
b. 3/9 on NOS; downrated for lack of comparator group, no demonstration that the outcome of interest was not present at the start of study and a lack of reporting of outcome follow-up for study participants.
c. No inconsistency as only one study evaluated.
d. No serious indirectness as intervention evaluated was the IPC Ring Approach.
e. Downrated by 1 due to the small sample size and low event rate.

Contextual data for IPC Ring approach

KQ3 - Should the IPC ring approach be used versus not used to prevent and control transmission of Ebola Virus Disease (EVD) in health care facility and community settings?

Objectives: To reduce Ebola/Marburg transmission in a predetermined risk area whenever a case is identified.

- The IPC Ring approach is based upon the premise that early cluster detection can trigger a rapid, localized response in the high-risk radius around one or several health facilities to reduce transmission sufficiently to extinguish an outbreak or reduce its spread. This premise is the operating principle in case-area targeted interventions against cholera epidemics.[1]
- Although IPC Ring shows promise for outbreak control in Liberia, Guinea, Sierra Leone and the Democratic Republic of Congo, it is critically dependent on IPC training, contact tracing and triage capacities (table). [2] [3] [4] [5] [6]
- IPC Ring is an IPC approach that requires effectiveness evaluation. It was developed rapidly and collaboratively in response to an urgent public health need; as such, data were not collected and aggregated systematically across all facilities, potentially limiting the generalizability of these results (table).[3]

Stakeholders: Patients, health workers, health facilities, communities, health systems, governments of affected countries and countries providing humanitarian support, international health and humanitarian organizations.[6, 7]

Settings: Health facilities and communities in areas with low Ebola/Marburg community transmission, especially in settings of very limited resources and capabilities to deal with the disease burden.[3]

- In these settings, the effectiveness of new Ebola treatment centers can be maximized with concurrent acceleration of case ascertainment.[8]

Epidemic phase: Early or late phase of an endemic.[3]

Populations: patients and health workers

Health-system strategies related to IPC Ring intervention:

Establish governance structure for the IPC Ring intervention, such as IPC Task Force.[3]

Conduct surveillance of potential cases in the community and conduct contact tracing.[9]

Public communication to improve knowledge of signs and symptoms of Ebola/Marburg diseases in the community and notice of triage procedures at health facilities targeted by the IPC Ring intervention.[9, 10]

Conduct rapid IPC needs assessments at target health facilities (HFs) using validated assessment tools, focusing on *triage procedures, isolation structures, PPE use, gaps in PPE supply chain, general IPC training and specialized triage training*.[3]

- Coordination and collaboration among the national Incident Management System, county health teams, CDC, WHO, African Union and nongovernmental organization partners was key to identifying gaps in IPC needs and preventing duplication of efforts.[3]

Ring Intervention

The IPC Task Force formalizes components of the Ring IPC approach, including identification of target HFs, ***a focus on triage, organizing external staff members to support triage*****,** and coordination and definition of roles among partners.[3]

- The initial ring was coordinated by the IPC Task Force under Ministry of Health and Social Work (MOHSW) leadership. In subsequent rings, the national Incident Management System and county health departments joined efforts with CDC, WHO, African Union, and multiple nongovernmental organization partners participating in initial discussions, planning, and rapid IPC assessments.[3]

The Task Force identifies target HFs for the Ring IPC intervention, e.g. based upon known health worker exposure to an Ebola patient, neighboring HFs that ring around the HF that treated a case, or HFs in close proximity to the residence of a patient with confirmed Ebola.[3]

- Operating procedures for the implementation of the IPC Ring intervention are not available, e.g., the potentially relevant studies did not discuss implementation details (table).

Initiate Ring IPC intervention

Rings around target HFs should be initiated within 4 days after recognition that a facility had provided care to a case.[3] The isolation of 75% of individuals infected with Ebola virus in critical condition within 4 days from symptom onset has a high chance of eliminating the disease.[11]

Ensure PPE supplies for HWs and patients seeking help at target HFs.[9]

Conduct IPC training, triage training and training on PPE use for HWs at target HFs.[3]

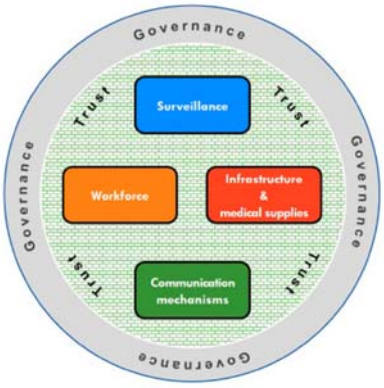
Providing ***rapid, intensive and short-term*** (21-days) support to healthcare facilities and communities in areas of active Ebola transmission - had a good impact in Guinea and Liberia. Throughout the EVD outbreak in Guinea, individual healthcare workers (usually 1 or 2 per healthcare facility) were selected to take part in an intensive five-day IPC training with a focus on EVD, organized by the Ministry of Health and partners (WHO, CDC and others). The participants were strongly encouraged to organize cascade training, i.e. training to other medical staff within their respective healthcare structures, following guidelines developed by the Ministry of Health. [12]

The first ring was initiated 4 days after recognition that a facility had provided care to an Ebola patient; subsequent rings were initiated within 2 days after recognition of other Ebola patients. In total, 59 target HFs were identified, 52 in Montserrado County (out of a total of 294 HFs) and seven (out of a total of 32) in Margibi County. There was an average of 15 HFs per ring (range = 3–31).[3]

Overall, Ring IPC efforts appeared to be associated with an increase in the identification and isolation of suspected or probable Ebola patients. Nevertheless, triage was not always completely successful (table).[3]

Issues to consider when implementing the IPC Ring intervention

The figure below displays a conceptual framework potentially relevant to the implementation of IPC Ring intervention. It includes six core constructs: (1) Surveillance, (2) Infrastructure and medical supplies, (3) Workforce, (4) Communication mechanisms, (5) Governance, and (6) Trust (table).[9]



Surveillance

Gaps in event-based Ebola surveillance systems in Ghana led to inadequate early case detection and response preparedness to prevent Ebola virus outbreaks and spread. An absence of Ebola surveillance systems was noted during a 2014 assessment of emergency preparedness in South Eastern Liberia. This led to a series of surveillance training workshops and creation of an Ebola incident management system, which enhanced preparedness and reduced Ebola case burden in the region, compared to other areas of the country (table).

The collaboration between the contact tracing team, active case finding teams and case investigation teams resulted in the detection of previously unidentified Ebola virus disease contacts and the locations of missing contacts in a 2015 cluster outbreak in Monrovia, Liberia (table).

Community health monitors in active (and early) case finding, contact tracing and the quarantine of high-risk individuals led to the eventual 2014–15 control of Ebola transmission in Liberia (table).

Community-appointed Village Health Teams in supporting outbreak response activities resulted in the quick containment of Ebola and Marburg virus epidemics in Uganda. This strategy of strong community mobilization also increased acceptability of the community to bring patients to isolation facilities (table).

Workforce

Three articles reinforced the need for a strong health workforce appropriately distributed at the sub-national level, rather than just a target aggregate number of health workers nationally. Continuity of health worker training, particularly around infection, prevention and control, was stressed as a critical aspect of emerging infectious disease prevention (table).

Infrastructure and medical supplies

Existing studies stress the presence of operationally ready isolation centers that are able to treat patients in as safe an environment as necessary. Studies also reinforced the need to ensure accessibility of health care facilities, both geographically and financially (table).

A study described the important role of a Government-NGO partnership in strengthening existing health facility infrastructure for the scale up of services for Ebola patients at the height of the 2014 outbreak in Sierra Leone, which included bolstering PPE supply chains. A lack of basic supplies of gloves, gowns and intravenous fluid were noted in another study as limiting the abilities of front-line health workers. The authors commented that the systems required for high-quality care during a crisis are the same as those required for effective routine health care and chronic disease management. The impact of weak existing

medicines supply chain systems was revealed in a qualitative study of community health workers in Liberia, where the Ebola outbreak response interrupted the district supply of essential medicines for community case management of diarrhea and pneumonia (table).

Communication mechanisms

A scoping review found 23 articles illustrating communication mechanisms underpinning effective emerging infectious disease prevention and response. Ten of these reinforced the necessity of a risk-communication strategy to guide a timely, coordinated and standardized approach to information sharing during outbreak management. The importance of partnership between national health organizations and media agencies to ensure dissemination of clinically accurate messages supportive of prevention and control efforts during public health emergencies was confirmed in a further eight articles (table).

The valuable role of community members as key players in risk communication activities was widely acknowledged (table).

Established and documented protocols, guidelines and procedures were widely affirmed by the literature as an integral element of the communications mechanisms associated with emerging infectious disease preparedness. For secondary and tertiary health facilities, these included a health worker protocol for infectious disease management, security protocols for both facility infrastructure and personnel, and procedures for patient isolation (table).

Governance

Governance here refers to a relational view emphasizing the making, changing, monitoring and enforcing of the rules that govern the demand and supply of health services. Leadership and coordination across global, regional, national and sub-national levels were presented as critical enablers of an effective, cohesive response to emerging infectious disease threats (table).

The capacity of governments to engage and collaborate with non-state actors and civil society was another facet of good governance identified as supporting health system preparedness for emerging infectious disease. Central to such effective engagement and partnerships is the ability to mobilize additional resources in the event of an outbreak – including emergency teams of clinicians and logistics personnel, community resources, and national and international non-government organizations (table).

Trust

The concept of trust – from the community level through to global governance – emerged as a fundamental element of health system preparedness for an EID outbreak, extending across each of the five identified core constructs. The notion of trust has been defined as encompassing both interpersonal trust between, for example, patient and provider as well as institutional trust between individuals/ communities and the health system or government (table).

Table: Contextual data for the implementation considerations of the IPC Ring intervention

Author	Year	Study methods	Findings relevant to the extraction of contextual data	Data type	Contextual data
Palagyi [9]	2019	Narrative synthesis, 49 included studies	The article reinforces the interconnectedness of the traditional health system building blocks to emerging infectious disease (EID) detection, prevention and response, and highlights the critical role of system 'software' (i.e. governance and trust) in enabling LMIC health systems to achieve and maintain EID preparedness.	Conceptual framework	The resulting conceptual framework recognised six core constructs: four focused on material resources and structures (i.e. system 'hardware'), including (i) Surveillance, (ii) Infrastructure and medical supplies, (iii) Workforce, and (iv) Communication mechanisms; and two focused on human and institutional relationships, values and norms (i.e. system 'software'), including (i) Governance, and (ii) Trust.
			Surveillance is the building block in EID detection, prevention and response: the early detection and monitoring of infectious diseases is an overarching enabler of EID preparedness.	Conceptual framework	Use indicator-based and event-based systems for surveillance. Indicator-based surveillance refers to the routine reporting of cases of disease, usually from health care providers to public health officials; event-based surveillance is the organised and rapid capture of information about events that are a potential risk to public health, through both formal and informal channels. Gaps in event-based Ebola surveillance systems in Ghana led to inadequate early case detection and response preparedness to prevent Ebola virus outbreaks and spread. An absence of Ebola surveillance systems was noted during a 2014 assessment of emergency preparedness in south-eastern Liberia. This led to a series of surveillance training workshops and creation of an Ebola incident management system which enhanced preparedness and reduced Ebola case burden in the region, compared to other areas of the country.
			Surveillance: The ability to rapidly implement effective patient screening processes for EIDs, and maintain such processes alongside systems for identification of known existing infectious diseases, was emphasized as a vital lesson learned from the West African Ebola outbreak.	Conceptual framework	For example, an integrated community-based management system of illness cases in children was no longer functioned effectively during the 2014 Ebola crisis in Liberia, and a reduction in immunization coverage and an increase in cases of severe malaria among children were observed during the 2014 Ebola outbreak in Guinea.
			Surveillance: Established contact tracing and monitoring procedures were another essential element of effective EID surveillance. These included contact identification and listing, classification of risk status, daily monitoring for symptoms and the effective management of symptomatic contacts.	Conceptual framework	For example, the collaboration between the contact tracing team, active case finding teams and case investigation teams resulted in the detection of previously unidentified Ebola virus disease (EVD) contacts and the locations of missing contacts in a 2015 cluster outbreak in Monrovia, Liberia.
			Surveillance: A functional data management system (and procedures for data sharing) is important.	Conceptual framework	Community health monitors in active (and early) case finding, contact tracing and the quarantine of high-risk individuals led to the eventual 2014–15 control of Ebola transmission in Liberia.
				Conceptual framework	Community-appointed Village Health Teams in supporting outbreak response activities resulted in the quick containment of Ebola and Marburg virus epidemics in Uganda. This strategy of strong community mobilization also increased acceptability of the community to bring patients to isolation facilities.
			Surveillance: Contact tracers need to practice 'subtlety and diplomacy' during often extended periods of personal interactions in situations of high stress and fear.	Conceptual framework	
			Surveillance: The inclusion of both zoonotic and animal surveillance was important to optimize local, national, and global EID surveillance and monitoring systems, as illustrated by the examples of Ebola, West Nile virus, Nipah virus, severe acute respiratory syndrome and Zika virus. These EID are notable emerging zoonotic infectious diseases of humans that have been caused by pathogens arising from animal reservoirs.	Conceptual framework	The authors state the importance of a 'One Health' approach to controlling zoonotic pathogens, involving sustainable and equitable collaborations between the animal, human, ecosystem, and environmental health sectors at the local, national, and international levels. Jacobsen et al. (2016) commented on the necessity for proactive zoonotic and animal surveillance activities in their review of lessons learned from the Ebola outbreak. They signaled the need for effective human − animal health collaboration and coordination, including simultaneous monitoring and linkage of human and animal disease surveillance systems, to promote early detection of potential pandemic

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					pathogens, and rapid response to protect health in both populations.
			Workforce: The availability of frontline healthcare workers (including doctors, nurses and midwives) in sufficient numbers and with appropriate training was identified in 13 articles as a key characteristic of an EID-prepared health system.	Conceptual framework	Three of these articles (Gostin & Friedman, 2015; Kruk et al., 2015 and Regmi, Gilbert, & Thunhurst, 2015) reinforced the need for a strong health workforce appropriately distributed at the sub-national level, rather than just a target aggregate number of health workers nationally. Continuity of health worker training, particularly around infection, prevention and control, was stressed as a critical aspect of EID prevention by both Thiam et al. (2015) and Nyarko, Goldfrank, Ogedegbe, Soghoian, and de-Graft Aikins (2015). Regmi et al. (2015) advocated for appropriate disease-specific health worker training programmes, tailored to the local circumstance, with inclusion of veterinary public health awareness, and training for health managers in outbreak and emergency response systems.
			Workforce: Other studies noted the requirement for sufficiently skilled epidemiologists able to define and validate signal events, integrate data from a variety of information sources and translate these into a public health response (Balajee et al., 2016; Siedner, Gostin, Cranmer, & Kraemer, 2015).	Conceptual framework	Balajee et al. (2016) support the concept of 'field epidemiology training' where, under the mentorship of more experienced epidemiologists, public health workers use real-life local events to develop the necessary skills to gather and assess critical disease data and use this to inform action. Trained laboratory officers with capacity to collect, prepare, analyse and store specimens were also identified as a critical addition to the frontline health workforce (Adokiya & Awoonor-Williams, 2016; Balajee et al., 2016; Bhatnagar, Grover, Kotwal, & Chauhan, 2016).
			Workforce: Eight articles addressed the need for trained community health workers (CHWs) to enhance the routine provision of essential primary health care services in addition to outbreak response activities.	Conceptual framework	Siekmans et al. (2017) described the successful involvement of CHWs in communicating awareness and prevention messages through village-based activities during the Ebola crisis in Liberia. Thiam et al. (2015) presented views of local stakeholders in Guinea, who underlined the essential role of both CHWs and members of community-based organizations in bridging the gap between communities and international agencies in Ebola response activities. The importance of this bridging role was reinforced by Scott, Crawford-Browne, and Sanders (2016) who, using evidence from the West Africa Ebola outbreak, highlighted the difficulties in engaging communities in prevention and response activities without a network of health workers who were both accountable to, and embedded within, those communities. Two articles (Alexander et al., 2015; McPake et al., 2015) advocated for the training of traditional healers in infection control and the delivery of public health messages as an important mechanism for sharing accurate and constructive information with communities regarding outbreak prevention and control. This needs to be balanced against the risks of providing traditional healers legitimacy within the health care system, if there is no system to ensure acceptable practice and minimal standards of care (Krah, de Kruijf, & Ragno, 2018).

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			Workforce: Aspects of financing and incentivizing the health workforce for effective EID preparedness were discussed by McPake et al. (2015). The authors list financial (along with logistical and managerial) investment in the health workforce as integral to building trust between communities and health providers.	Conceptual framework	Attracting and retaining a well-educated workforce to rural and remote locations poses a major challenge (Grobler, Marais, & Mabunda, 2015; Wilson et al., 2009). Nyarko et al. (2015) cite a lack of indemnities such as health insurance, workers' compensation and other services for health care workers in Ghana as a barrier to their commitment and continued quality care in the event of an Ebola virus outbreak. Non- and delayed payment of financial incentives implemented to attract, retain and motivate health workers in rural postings instead served as a source of demotivation and attrition during the 2014–15 Ebola outbreak in Sierra Leone.
			Infrastructure and medical supplies: Adequate numbers of health facilities and inpatient beds for population size, and their distribution relative to the geographic location of communities, were highlighted as factors integral to a health system's outbreak response capacity (Boozary et al., 2014; Cancedda et al., 2016; Espinal, Aldighieri, St John, Becerra-Posada, & Etienne, 2016; McPake et al., 2015; Regmi et al., 2015).	Conceptual framework	Likewise, the presence of operationally ready isolation centres, able to treat patients in a safe environment as necessary. Studies also reinforced the need to ensure accessibility of health care facilities, both geographically (Buseh, Stevens, Bromberg, & Kelber, 2015; Siekmans et al., 2017) and financially (Kaufman, 2008).
			Infrastructure and medical supplies: The importance of available and well-maintained medical equipment was commonly emphasised (19/49 articles), with particular attention to the lack of personal protective equipment (PPE) in West Africa health facilities during the Ebola crisis.	Conceptual framework	Cancedda et al. (2016) described the important role of a Government-NGO partnership in strengthening existing health facility infrastructure for the scale up of services for Ebola patients at the height of the 2014 outbreak in Sierra Leone, which included bolstering PPE supply chains. A lack of basic supplies of gloves, gowns and intravenous fluid were noted by Boozary et al. (2014) as limiting the abilities of front-line health workers; a product of inadequate supply and distribution systems. The authors commented that the systems required for high-quality care during a crisis are the same as those required for effective routine health care and chronic disease management. The impact of weak existing medicines supply chain systems was revealed in a qualitative study of community health workers in Liberia, where the Ebola outbreak response interrupted the district supply of essential medicines for community case management of diarrhoea and pneumonia (Siekmans et al., 2017).
			Infrastructure and medical supplies: The essential elements of a public health laboratory system underpinning early EID outbreak detection and response were described in 13 articles. These included: readiness of trained personnel and accessories for appropriate specimen collection (Bhatnagar et al., 2016; Cash & Narasimhan, 2000); availability of sample collection and transport kits at select sites in the laboratory network (Balajee et al., 2016); safe and rapid transport mechanisms to both national (Lapao et al., 2015) and international (Espinal et al., 2016; Forrester et al., 2014; Thiam et al., 2015) reference laboratories; and timely characterization of pathogens with mechanisms for the efficient feedback of results to national focal points to enable rapid and appropriate responses (Balajee et al., 2016).	Conceptual framework	Jacobsen et al. (2016) listed the need for point-of-care diagnostic assays among lessons learned from the West Africa Ebola outbreak of 2014–15.
			Communication mechanisms: The authors found 23 articles illustrating communication mechanisms underpinning effective EID prevention and response. Ten of these reinforced the necessity of a risk-communication strategy to guide a timely, coordinated and standardized approach to information sharing during outbreak management. The importance of partnership between national health organizations and media agencies to ensure dissemination of clinically accurate messages supportive of prevention and control efforts during public health emergencies was confirmed in a further eight articles.	Conceptual framework	Ozawa, Paina, and Qiu (2016) discussed how negative messages about vaccines from the media in Ebola-affected countries could undermine efforts to rebuild community trust in the health system following system-wide shocks.

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			Communication mechanisms: The valuable role of community members as key players in risk communication activities was widely acknowledged.	Conceptual framework	Nyarko et al. (2015) described the significance of bi-directional communication in devising educational messages for Ebola preparedness, i.e. engaging communities to understand fears, challenges and opinions on how issues should be addressed, through a co-production process involving community leaders and members, frontline healthcare workers and community- based organisations. Buseh et al. (2015) labelled this approach an 'empowerment model', in which community leaders are enabled to contribute positively to programs that embrace and represent the values of their community members, with the aims of reducing fear and stigma, and to encourage care-seeking.
			Communication mechanisms: Established and documented protocols, guidelines and procedures were widely affirmed by the literature as an integral element of the communications mechanisms associated with EID preparedness. For secondary and tertiary health facilities, these included a health worker protocol for infectious disease management (Bhatnagar et al., 2016; Boozary et al., 2014; Cancedda et al., 2016; Mulinge & Soyemi, 2016; Regmi et al., 2015; Siekmans et al., 2017), security protocols for both facility infrastructure and personnel (Cancedda et al., 2016; Lapao et al., 2015), and procedures for patient isolation (Bhatnagar et al., 2016; McPake et al., 2015; Regmi et al., 2015).	Conceptual framework	Four articles also addressed the need for standardized procedures to guide social mobilization for EID prevention and response, and community-centered infection prevention and control protocols championed by local leaders and community HWs (Cancedda et al., 2016; Espinal et al., 2016; McPake et al., 2015; Stoto et al., 2013). Bhatnagar et al. (2016) drew learnings from the 2014 West Africa Ebola outbreak to reinforce the need for a laboratory biosafety protocol, together with adherence to this by laboratory personnel. A simple, accessible directory containing the contact details of reference laboratories and contact information of key national (and subnational) laboratory personnel was also recommended as necessary for improving capacity for outbreak response (Balajee et al., 2016).
			Governance: Governance here refers to a relational view emphasizing the making, changing, monitoring and enforcing of the rules that govern the demand and supply of health services (Abimbola, Negin, Martiniuk, & Jan, 2017a). In the reviewed publications, leadership and coordination across global, regional, national and sub-national levels were presented as critical enablers of an effective, cohesive response to EID threats.	Conceptual framework	Gostin and Friedman (2015) discussed the vital role of an empowered global health leader (i.e. the WHO) in steering the overall direction, and coordinating the many participants, of an epidemic response. Scott et al. (2016) and Cancedda et al. (2016) highlighted the need for shared regional and national governance in mitigating the transboundary threat posed by many EIDs: Scott citing weak national governance in Sierra Leone and Guinea as lessening the ability of already compromised national health systems to manage the spread of Ebola virus associated with the movement of communities across country borders. The requirement for sub-national (local) governance structures that promote district-level coordination and management of EID detection and response featured in five articles (Kruk et al., 2015; Lapao et al., 2015; McPake et al., 2015; Stoto et al., 2013; Thiam et al., 2015). Thiam et al. (2015) provided the example of Regional and Prefecture Response Committees in the coordinated response to the 2014 Ebola outbreak in Guinea. They found that the effectiveness of these structures were weakened by a lack of community consultation in the appointment of Committee coordinators. Other studies also highlight the centrality of community advisory bodies, formed by national and local governments, in responding to an EID outbreak (e.g. Siedner et al., 2015; Siekmans et al., 2017). Ideally, such groups would represent a broad spectrum of community interests and comprise religious leaders, community leaders, representatives from NGOs, and other stakeholders.

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			Governance: The capacity of governments to engage and partner with non-state actors and civil society was another facet of good governance identified as supporting health system preparedness for EID. Central to such effective engagement and partnerships is the ability to rapidly mobilize additional resources in the event of an EID outbreak – including emergency teams of clinicians and logistics personnel (Kaufman, 2008; Siedner et al., 2015), community resources (Cancedda et al., 2016; Mbonye et al., 2014), and national and international non-government organizations (Gostin & Friedman, 2015).	Conceptual framework	Buseh et al. (2015) emphasized the need for public-private partnerships, both regionally and internationally, to strengthen the capacity of affected countries to handle infectious disease outbreaks while maintaining the provision of basic health care. McPake et al. (2015) described how stable governance arrangements facilitated effective coordination of international agencies in the containment and control of the 2000–2001 Ebola outbreak in Uganda, drawing contrast with the aid co-ordination problems undermining Ebola control efforts in Sierra Leone in 2014–15. The rapid control of the 2014–15 Ebola outbreak in Liberia was also attributed to effective engagement and collaboration between government and international partners by Nyenswah et al. (2016).
			Trust: The concept of trust – from the community level through to global governance – emerged as a fundamental element of health system preparedness for an EID outbreak, extending across each of the five identified core constructs. The notion of trust has been defined as encompassing both interpersonal trust between, for example, patient and provider as well as institutional trust between individuals/ communities and the health system or government (Topp & Chipukuma, 2016).	Conceptual framework	Kruk et al. (2015) incorporated trust as one of several preconditions for health system resilience – 'Health systems that earn the trust and support of the population and local political leaders by reliably providing high-quality services before crisis have a powerful resilience advantage' – reinforcing the need for inclusive and robust community engagement with the health system. Both Thiam et al. (2015) and Alexander et al. (2015) highlighted the role of community distrust of frontline health services in generating resistance to seeking health care and implementing infection control measures during the Ebola crisis. Through interviews with community leaders and community-based organisations, Thiam et al. (2015) found that the use of personal protective equipment by authorities during village-level infection control activities engendered fear in the community, and heightened mistrust of Western medicine and practices. Such negative reaction was primarily a result of the absence of both initial community consultation and appropriate community-led education on infection prevention and control. Alexander et al. (2015) discussed how a fear of Western medical practices led to individuals depending on traditional healers or family members for care during the Ugandan outbreak (Chan, 2014), with many patients fleeing hospitals after linking the hospital environment to likelihood of death. Dhillon and Kelly (2015) presented a case study demonstrating how mistrust of formal power structures led to community members hiding the sick from Ebola response teams. They recommended that trust be built through close, long-term engagement with community members and local leaders, and the incorporation of community preferences into infection prevention and control measures. Jacobsen et al. (2016) further identifies the centrality of community in the success of global zoonotic surveillance activities, suggesting that active community involvement builds trust, increases participation in zoonotic monitoring and improves existing surveillance systems.
			Trust: Health workers' trust in their local health leadership and government was identified by Nyarko et al. (2015) as essential to the effective control of infectious disease transmission. Based on a roundtable discussion involving frontline clinicians, they identified 'inadequate staff, space, stuff and systems' as the foundation of increased health worker fear and insecurity in the management of patients with suspected EVD, eroding both confidence and commitment to providing care.	Conceptual framework	There were reports of nursing staff claiming they would leave their jobs out of fear 'if Ebola comes'. The legitimacy of these claims was evidenced during the year 2000 Ebola epidemic in Uganda, where an account of nurses abandoning their posts at Kampala hospital following the suspicious death of a male patient was widely reported in the media (Kinsman, 2012). The distrust of healthcare workers in their leadership's ability and commitment to mobilize resources in the event of an EID outbreak was also noted by Nyarko in the Ghanaian context, arising from feelings of ineptness in dealing with EVD-like symptoms and inadequate availability of personal protective equipment.

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			Trust: Martineau (2016) applied evidence from the 2014–2016 West African Ebola outbreak to reinforce the importance of understanding, and engaging with, social and cultural dynamics in preparing health systems for future crises. Such relationships span those with and between national governments, non-formal health crisis response actors, non-health actors, non-government organizations, and influential local leaders (in addition to communities, health care providers and local leadership described previously).	Conceptual framework	Martinez et al. suggested that initiatives to strengthen a health system 'must embed explicit localized efforts to build mutual trust, respect and dignity between health actors and the communities they serve…' (Martineau, 2016, p. 308).
Nyenswah [4]	2015	This report describes possible health care worker exposures to the cluster's eight patients who sought care from an HCF and implementation of the Ring IPC approach.	Members of the IPC Task Force met to formalize components of the Ring IPC approach, including **identification of target HCFs, a focus on triage, involvement of external staff members to support triage, and coordination and definition of roles among partners**.	Implementation	The purpose of Ring IPC was to provide intensive IPC support (3,4) to HCFs in areas of active Ebola transmission, thus forming a strategically placed protective ring of intensified IPC attention around persons with known Ebola to help break the chain of transmission. This strategy entailed selecting target HCFs for Ring IPC intervention based on known health care worker exposure to an Ebola patient, neighboring HCFs around the HCF that treated a patient, or HCFs in close proximity to the residence of a patient with confirmed Ebola.
			Rapid IPC needs assessment found **inadequate or absent triage and isolation structures, gaps in the personal protective equipment supply chain, and a need for general IPC training in addition to specialized triage training.**	Implementation	Rapid IPC needs assessments were conducted at these HCFs using approved assessment tools (5). **These assessments focused on triage procedures and personal protective equipment use.**
			Training and Equipment: Identified challenges were addressed by the national IPC Task Force developing training that targeted key personnel. **Triage training**, based on existing MOHSW-approved IPC training materials, was developed and provided to 47 African Union clinicians. **Nongovernmental organization partners assessed and constructed triage structures when needed.**	Implementation	These clinicians were deployed to 36 target HCFs in Monteserrado County to provide onsite daily triage mentoring and support for the duration of the high-risk exposure monitoring period, or for at least 2 weeks. Three nurses, previously employed by an Ebola treatment unit, provided similar triage support for one hospital. In addition, three 1-day triage training sessions were provided for more than 125 staff members working in three target HCFs. In Margibi County, a 1-day triage training session was conducted for 11 staff members working in five target HCFs. African Union staff and nurses or other county health staff members provided ongoing triage mentoring and IPC support to seven target HCFs. This intensive IPC approach served to alert health care workers to recent Ebola virus transmission in their communities, identify additional contacts at HCFs where Ebola virus exposure had occurred, and provide a secondary source (in addition to contact tracing) of information on the health status of exposed health care workers.
			PPE supply in response to PPE shortages at HCFs	Implementation	In response to heightened awareness of clinic needs, partners provided personal protective equipment and other essential IPC supplies to target facilities. Ring IPC partners in Montserrado County and the national IPC Task Force initiated an emergency release of a 1-month supply of personal protective equipment to priority clinics.
			Initiation of Rings: During January 23–February 9, in response to the ongoing St. Paul Bridge cluster, four IPC rings were initiated in Liberia, three in Montserrado County and one in Margibi County (Figure). The first ring was initiated 4 days after recognition that a facility had provided care to an Ebola patient; subsequent rings were initiated within 2 days after recognition of other Ebola patients. In total, 59 target HCFs were identified, 52 in Montserrado County (out of a total of 294 HCFs) and seven (out of a total of 32) in Margibi County. There was an average of 15 HCFs per ring (range = 3–31).	Implementation	Overall, Ring IPC efforts appeared to be associated with an increase in the identification and isolation of suspected or probable Ebola patients. For example, three probable Ebola patients were identified through triage during training conducted at one target HCF in Montserrado County. Only one of the 166 exposed health care workers in the St. Paul Bridge cluster became infected with Ebola. This low prevalence of secondary infection among health care workers suggests that basic infection prevention principles were being observed by health care workers during this period. Nevertheless, **triage was not always completely successful;** the one health care worker who became infected with Ebola after Ring IPC activities were initiated

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					actually sought care at his place of employment, an identified target HCF, and was permitted to enter without first being properly triaged as a probable or suspect Ebola patient.
			Although a comprehensive strategy remains critical to raising the level of IPC capacity nationwide, an appropriately **targeted Ring IPC approach** might be an effective supplemental strategy to focus IPC support in response to clusters of disease.		Included among the Ebola response efforts in Liberia was the creation in early September 2014 of a national IPC Task Force to support the MOHSW. The **IPC Task Force** served as a coordinating body to facilitate IPC planning and implementation of activities in both health care and non–health care facilities, as well as providing IPC guidance and technical assistance through policy development and standardization of IPC training and implementation tools consistent with MOHSW priorities. The national IPC strategy had focused on providing a comprehensive package of IPC training and support, through trained IPC specialists, at major health facilities throughout the country because of widespread Ebola transmission occurring at the time. This strategy includes promoting essential IPC practices among health care workers, such as hand washing and proper use of personal protective equipment.
			The **initial ring was coordinated by the IPC Task Force** under MOHSW leadership. In subsequent rings, **the national Incident Management System and county health departments joined efforts with CDC, WHO, African Union, and multiple nongovernmental organization partners participating in initial discussions, planning, and rapid IPC assessments.**	Implementation	The public health intervention described in this report was rapidly implemented and integrated into Liberia's national Ebola response as a result of coordinated, collaborative efforts by multiple partners. Coordination and collaboration among the national Incident Management System, county health teams, CDC, WHO, African Union and nongovernmental organization partners was key to identifying gaps in IPC needs and preventing duplication of efforts. In general, HCFs welcomed additional training, personal protective equipment provision, and triage mentoring and support. The placement of IPC staff members trained in triage at target HCFs following training was readily adopted by clinic staff.
			The implementation of Ring IPC in Liberia might offer a useful model for rapid response to Ebola virus transmission and health care worker exposure in other settings.		This approach, however, might be most appropriate **at the beginning or near the end of an outbreak, when specific chains of transmission can be identified and when HCFs can be identified and targeted based on their risk for encountering an Ebola patient when there is known active transmission in their geographical area.**
				Implementation	Urban settings present challenges to this approach, because persons might seek care at HCFs outside of their immediate community.
				Resources/Costs	Although limitations in both supplies (personal protective equipment and infrared thermometers) and human resources (appropriately trained personnel) might inhibit a timely response to initiating IPC activities, **the Ring IPC approach might be used to prioritize these limited resources.**
			The Ring IPC approach was developed rapidly and collaboratively in response to an urgent public health need; as such, data were not collected and aggregated systematically across all facilities, potentially limiting the generalizability of these results. Nonetheless, as a result of Ring IPC efforts, health care workers at HCFs in areas with recent active transmission are now better equipped and trained to rapidly triage, isolate, and refer suspected	Implementation	As Liberia looks ahead, a new culture of IPC can be incorporated into the health system; a Ring IPC approach might be useful in minimizing the transmission in non-Ebola HCFs should new cases of Ebola occur.

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			and probable Ebola patients to appropriate Ebola treatment unit facilities.		
Dahl [2]	2016	Summary report of CDC's Response to the 2014–2016 Ebola Epidemic — Guinea, Liberia, and Sierra Leone	The MoHS in Sierra Leone used CDC's concept of Ring Infection Prevention and Control (Ring IPC) (24), and CDC was integral to implementing the strategy;	Implementation	This strategy supported improved screening, isolation, referral for treatment, use of hand hygiene and personal protective equipment, waste management, and cleaning and decontamination practices for health care facilities and health care workers at highest risk for Ebola exposure and infection. CDC staff commonly coordinated Ring IPC activities in collaboration with WHO, the United Kingdom's Department for International Development, and nongovernment organizational partners.
Nyenswah [13]	2016	Summary report of Ebola and Its Control in Liberia, 2014–2015	By the end of 2014, >4,000 healthcare workers from 350 facilities had received training in basic IPC. A cadre of physicians were trained to serve as technical advisors in the counties. IPC focal points for major hospitals were selected and trained; surveillance and investigative capacity for Ebola in healthcare workers was developed; and personal protective equipment was delivered to major facilities nationwide (gloves and bleach were made as widely available as possible).	Implementation	Weak IPC rendered all 657 healthcare facilities in Liberia vulnerable. The value of surveillance among healthcare staff was highlighted by a single transmission chain in early 2015, in which 166 non-ETU healthcare workers at 10 facilities were exposed to the virus; remarkably, only 1 healthcare worker became infected (24). An innovative intervention in response to this cluster was the ring IPC strategy, which provided intensified IPC training and support to healthcare facilities around areas of active transmission (25).
Hageman [14]	2016	CDC summary report of Infection Prevention and Control for Ebola in Health Care Settings — West Africa and United States	A critical first step was to establish national IPC task forces to coordinate infection control efforts within Guinea, Sierra Leone, and Liberia.		To supplement efforts to strengthen IPC practices systemwide, a new strategy known as Ring IPC was introduced in which rapid, intensive, and short-term IPC support is delivered to health care facilities in areas of active Ebola transmission to help break the chain of transmission (7). Once high-risk facilities were identified, IPC assessments were conducted to guide technical assistance, medical supply distribution, and daily supportive supervision to ensure HCWs were trained to triage, isolate, and refer suspected and probable Ebola patients rapidly to ETUs.
			Early in the Ebola epidemic, Ebola transmission to HCWs occurred in health care facilities that were not Ebola treatment units (ETUs) (1–3). Health care facility assessments conducted by CDC and partners in 2014 documented substantial gaps in IPC. These gaps (i.e., a lack of IPC oversight, poor waste management procedures, a lack of triage and isolation protocols, frequent lack or misuse of personal protective equipment [PPE], and inadequate standard infection control precautions) increased the risk for Ebola transmission in non-ETU health care settings (4,5).	Acceptability	Ring IPC impacted several places. For example, in Liberia, three febrile HCWs were identified when screened for work; all were properly isolated and transferred to an ETU for testing (7). Sierra Leone integrated Ring IPC around clusters of Ebola patients in three districts. Guinea focused on minimizing transmission by rapidly investigating infected HCWs and remediating IPC lapses.
Cooper [5]	2016	Report of Infection prevention and control of the Ebola outbreak in Liberia, 2014–2015: key challenges and successes	In September 2014, at the height of the outbreak, the national IPC Task Force was established with a Ministry of Health (MoH) mandate to coordinate IPC response activities. A steering group of the Task Force, including representatives of the World Health Organization (WHO) and the United States Centers for Disease Control and Prevention (CDC), supported MoH leadership in implementing standardized messaging and IPC training for the health workforce. This structure, and the activities implemented under this structure, played a crucial role in the implementation of IPC practices and successful containment of the outbreak.	Implementation	Montserrado County was divided into four geographic sectors, each with its own team. Each team focused primarily on healthcare facility readiness, with an emphasis on triage. Although the national IPC Task Force continued to set priorities and establish minimum standards, the implementation and monitoring of these standards in Montserrado was delegated to sector teams. These intensified efforts, implemented in a "ring approach", helped Liberia approach its goal of "getting to zero" after identification of the cluster of 22 EVD infections near St Paul Bridge in Monrovia in February 2015 [13].

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Keïta [12]	2018	This research aimed to evaluate the impact of IPC training and the quality of IPC performance in health care facilities of one municipality of Conakry, Guinea.	Twenty-five percent of health centres had one IPC-trained worker, 53% had at least two IPC-trained workers, and 22% of health centres had no IPC-trained workers. An IPC score above median was positively associated with the number of trained staff; health centres with two or more IPC-trained workers were eight times as likely to have an IPC score above median, while those with one IPC-trained worker were four times as likely, compared to centres with no trained workers. Health centres that implemented IPC cascade training to untrained medical staff were five times as likely to have an IPC score above median.	Implementation	The authors suggest that the 'Ring IPC strategy' - which consists of providing rapid, intensive and short-term (21-days) support to healthcare facilities and communities in areas of active Ebola transmission - had a good impact in Guinea and Liberia. Throughout the EVD outbreak in Guinea, individual healthcare workers (usually 1 or 2 per healthcare facility) were selected to take part in an intensive five-day IPC training with a focus on EVD, organised by the Ministry of Health and partners (WHO, CDC and others). The participants were strongly encouraged **to organise cascade training**, i.e. training to other medical staff within their respective healthcare structures, following guidelines developed by the Ministry of Health and as previously described [10].
Mobula [6]	2020	Lessons Learned from the Ebola Virus Disease Outbreak in the Democratic Republic of the Congo	The tenth outbreak of Ebola virus disease (EVD) in North Kivu, the Democratic Republic of the Congo (DRC), was declared 8 days after the end of the ninth EVD outbreak, in the Equateur Province on August 1, 2018. With a total of 3,461 confirmed and probable cases, the North Kivu outbreak was the second largest outbreak after that in West Africa in 2014–2016, and the largest observed in the DRC. This outbreak was difficult to control because of multiple challenges, including armed conflict, population displacement, movement of contacts, community mistrust, and high population density. It took more than 21 months to control the outbreak, with critical innovations and systems put into place.	Implementation	Implemented ring IPC with supervision (IPC focal point at health facilities) and frequent evaluations (use of IPC score card). A standardized package for IPC/water, sanitation, and hygiene was established to ensure a coordinated IPC strategy. Supervision (establishing an IPC focal point at health facilities) and frequent evaluations (use of an IPC score card) were put into place. Evaluations helped in developing plans to fill gaps andmonitor response progress. Traditional healers and pharmacists were involved in IPC training, albeit late, as they played an important role in the spread of Ebola. Triage systems set up in health facilities helped to ensure health service continuity, allowing access to health services for regular health care.
Nyenswah [4]	2015	CDC report on controlling the Last Known Cluster of Ebola Virus Disease — Liberia, January–February 2015	The last cluster of Ebola in Liberia included 22 cases, with three generations of transmission. Through enhanced control efforts, patients in successive generations were admitted to Ebola treatment units more quickly, mortality decreased, and community transmission was interrupted.		The last chain of transmission was controlled because of successful implementation of known strategies to control Ebola, including early detection of new cases; identification, monitoring, and support of contacts in acceptable settings; effective triage within the health care system; and rapid isolation of symptomatic contacts.
			In contrast to earlier in the Ebola epidemic, sector-based intensified contact tracing and in-depth case investigation, widespread infection prevention and control efforts (3), and coordination of case investigation and contact tracing activities between Montserrado and other counties (6) were key to stopping this final chain of Ebola transmission.	Implementation	The authors suggest that decentralization of sector management presented initial communication and coordination challenges, the enhanced sector-based efforts resulted in more complete contact tracing, more prompt isolation of symptomatic patients in the second and third generations of transmission, increased survival, and reduced transmission in the community.
Lewnard [8]	2014	Dynamics and control of Ebola virus transmission in Montserrado, Liberia: a mathematical modelling analysis	Our findings show that the effectiveness of new EVD treatment centers can be maximized with concurrent acceleration of case ascertainment.	Implementation	Accelerated case ascertainment is needed to maximize effectiveness of expanding the capacity of EVD treatment centers.
Yamin [11]	2015	Stochastic transmission mode	The isolation of 75% of infected individuals in critical condition within 4 days from symptom onset has a high chance of eliminating the disease.	Implementation	The results underscore the importance of isolating the most severely ill patients with Ebola within the first few days of their symptomatic phase.

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Infection prevention and control measures for Ebola and Marburg Virus disease: A series of rapid reviews

KQ4 and KQ7 Personal Protective Equipment- Initial Summary

(Version 1, 16 May 2022)

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Funding: Funding for this protocol and the subsequent reviews was provided by the World Health Organization (Funding # 202818287). The working group (WG) from the WHO/HQ Country Readiness Strengthening Health Care Readiness Unit will be consulted to develop and refine the scope, and review and approve the protocol. The WG will not be involved in the conduct of the review including selection of studies and data analysis but will advise as needed on priority population(s), interventions, and outcomes in an iterative process during the review process based on the available evidence. The WG will also comment on the draft report and provide input on interpretations of findings. AT is funded by a Tier 2 Canada Research Chair in Knowledge Synthesis. SM is funded by a Tier 2 Canada Research Chair in Mathematical Modeling and Program Science.

Competing interests: DM was involved in the 2015 rapid review by Hersi et al. [1] There are no other competing interests to acknowledge.

Acknowledgements: We thank Kaitryn Campbell, MLIS, MSc (St. Joseph's Healthcare Hamilton/McMaster University) for peer review of the Embase search strategy.

Questions

Question (4): Should health workers conducting EVD or Marburg virus disease related screening and triage activities wear a face shield alone versus in combination with a medical (non-structured) mask?
Question (7)- (a): Should health workers conducting Ebola or Marburg virus disease related screening activities wear a gown versus wear a coverall?
Question (7)- (b): Should health workers conducting Ebola or Marburg virus disease related triage activities wear a gown versus wear a coverall?

Methods Summary

This is one of a series of rapid reviews answering 12 key questions related to three themes on infection prevention and control measures for filoviruses: (i) transmission/exposure (n=3 questions), (ii) personal protective equipment (PPE) (n=5), and (iii) decontamination and disinfection (n=4). Data sources include Medline, Embase, bio/medRxiv pre-print servers, Global Medicus Index, Epistemonikos, China National Knowledge Infrastructure (CNKI) and Wangfang database. We used an automation tool (CAL® tool) for titles/abstracts screening for relevant systematic reviews and primary comparative studies. Full-text screening, data extraction, risk of bias assessment, and GRADE (Grading of Recommendations Assessment, Development and Evaluation) for the certainty of evidence were completed independently by two reviewers with any disagreements resolved by consensus, with arbitration by a third reviewer, when needed.

Findings

Initial searches and screening for key questions 4 and 7a/b were performed together due to the similarity of the questions under the theme of personal protective equipment use for healthcare workers during screening and triage activities. A total of 393 studies were screened in the CAL tool software and 86 studies were included for full-text screening. Two systematic reviews were identified to be of potential interest.[1,2] The included studies in these reviews were reviewed to determine if they addressed key questions 4 and 7a/b. While the reviews provided some contextual information, none of the 86 reviewed studies or the studies included in the two systematic reviews met the eligibility criteria for either key question (Appendix 2). A list of excluded studies with reasons for exclusion can be found in Appendix 1.

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Appendix 1. Excluded Studies List – By Reason for Exclusion:

Duplicate Reference (Different versions of same systematic review)

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Study does not evaluate health workers

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Unclear reporting of PPE worn during infection

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Appendix 2. Eligibility Criteria

Question (4): Should health workers conducting EVD or Marburg virus disease related screening and triage activities wear a face shield alone versus in combination with a medical (non-structured) mask?

Population	Staff performing screening and triage activities in health care facility or ETU
Background interventions (Standard of care)	WHO current guidance: *"Staff in the triage area should wear a scrub suit, a gown, examination gloves and a face shield. The area should be large enough to keep the patient at a 1-metre distance..."*
Intervention	wearing a medical mask in combination with the face shield
Comparator(s)	Not wearing a medical mask with the face shield
Outcome	Infection with Ebola or Marburg, *PPE breaches, compliance and/or breaches (touching face) related to heat/humidity and comfort, human factors, health worker confidence* Indirect evidence: Lassa fever
Potential effect modifiers	*Vaccination status, Design of face shield used may affect the face protection, heat/humidity and comfort*

Question (7)- (a): Should health workers conducting Ebola or Marburg virus disease related screening activities wear a gown versus wear a coverall?

Setting	Health care facilities, ETU *Contexts to consider: ETU use vs. healthcare facility; outbreak vs readiness vs. high alert scenario.
Population	Staff performing screening activities in health care facility or ETU
Background interventions (Standard of care)	Staff in the screening area should wear a scrub suit, a gown, examination gloves and a face shield.
Intervention	wearing a gown
Comparator(s)	wearing coverall
Outcome	Infection with Ebola or Marburg, PPE breaches, compliance related to heat and comfort, *human factors, health worker confidence* Indirect evidence: Lassa fever
Potential effect modifiers	*Vaccination, Receiving training for proper doffing,* *Staff job duties/activities in triage (pass/receive things, escort them to a new location, etc.)* *volume of patients, physical distance from patients, and hours of work (long vs. short shift)*

Question (7)- (b): Should health workers conducting Ebola or Marburg virus disease related triage activities wear a gown versus wear a coverall?

Setting	Health care facilities, ETU *Contexts to consider: ETU use vs. healthcare facility; outbreak vs readiness vs. high alert scenario.
Population	Staff performing triage activities in health care facility or ETU
Background interventions (Standard of care)	Staff in the triage area should wear a scrub suit, a gown, examination gloves and a face shield.
Intervention	wearing a gown
Comparator(s)	wearing coverall
Outcome	Infection with Ebola or Marburg, PPE breaches, compliance related to heat and comfort, *human factors, health worker confidence* Indirect evidence: Lassa fever
Potential effect modifiers	*Vaccination, Receiving training for proper doffing,* *Staff job duties/activities in triage (pass/receive things, escort them to a new location, etc.)* *volume of patients, physical distance from patients, and hours of work (long vs. short shift)*

Contextual data

KQ4. Should health workers conducting EVD related screening and triage activities wear a face shield alone versus in combination with a medical (non-structured) mask? (Contexts to consider: ETU use vs. healthcare facility; outbreak vs readiness vs. high alert scenario).

KQ7. Should health workers conducting Ebola or Marburg virus related screening and triage activities wear a gown versus wear a coverall? (Contexts to be considered: ETU use vs. healthcare facility)

We conducted our rapid reviews for KQs 4 and 7, especially conducting literature searches to update the Hersi et al. 2015 rapid review and the Verbeek et al. 2020 systematic review. [1] [2]With respect to the extraction of contextual data, the key findings are as follows:.

- Basic PPE ensemble did not seem to work as well as more protected PPE ensemble.[3]
- Gowns led to less contamination than aprons.[2]
- Two pairs of gloves led to less contamination than only one pair of gloves.[2]
- PPEs with more protective gear protected against contamination in simulation studies slightly better but felt more uncomfortable to health workers.[2]
- The peak of contagiousness is around the time of death but patients presenting to HFs and undergoing screening/triage often do so after the onset of symptoms, or they are contagious at the time of screening and triage.[4]

To protect HWs, the limited data (of very low quality) suggest that one would need to err on the side of extra protection, not less. Therefore, if the choice were between gown and coverall, one would go with coverall. If the choice were between face cover versus face cover and mask, one would also go with the latter. However, the tradeoff between more protection and usability (e.g., to be able to work comfortably for longer hours with less protective PPEs) is unclear.

Simulation studies are needed to clarify these choices - they are simple to do at a usability lab, require few participants (e.g., 40), [5] and have low costs. The WHO may consider commissioning a simulation study with an experimental design to test the choices of PPEs in both KQ4 and KQ7 at the same time. For example, the methods section of Drew et al. 2019 provides an example for the planning of such commissioned work, and simulation platforms exist for training and evaluating how HWs use PPE.[6, 7]

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Infection prevention and control measures for Ebola and Marburg Virus disease: A series of rapid reviews

KQ5 Head/Neck Covers- Initial Summary

(Version 2, 27 June 2022)

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Funding: Funding for this protocol and the subsequent reviews was provided by the World Health Organization (Funding # 202818287). The working group (WG) from the WHO/HQ Country Readiness Strengthening Health Care Readiness Unit will be consulted to develop and refine the scope, and review and approve the protocol. The WG will not be involved in the conduct of the review including selection of studies and data analysis but will advise as needed on priority population(s), interventions, and outcomes in an iterative process during the review process based on the available evidence. The WG will also comment on the draft report and provide input on interpretations of findings. AT is funded by a Tier 2 Canada Research Chair in Knowledge Synthesis. SM is funded by a Tier 2 Canada Research Chair in Mathematical Modeling and Program Science.

Competing interests: DM was involved in the 2015 rapid review by Hersi et al. [1] There are no other competing interests to acknowledge.

Acknowledgements: We thank Kaitryn Campbell, MLIS, MSc (St. Joseph's Healthcare Hamilton/McMaster University) for peer review of the Embase search strategy.

Key Question

KQ5: Should Health workers in direct contact and/or indirect contact to patients with Ebola Virus Disease (EVD) or Marburg virus disease cover head and neck skin and mucous membranes or just cover mucous membranes?

Methods Summary

This is one of a series of rapid reviews answering 12 key questions related to three themes on infection prevention and control measures for filoviruses: (i) transmission/exposure (n=3 questions), (ii) personal protective equipment (PPE) (n=5), and (iii) decontamination and disinfection (n=4). Data sources include Medline, Embase, bio/medRxiv pre-print servers, Global Medicus Index, Epistemonikos, China National Knowledge Infrastructure (CNKI) and Wangfang database. We used an automation tool (CAL® tool) for titles/abstracts screening for relevant systematic reviews and primary comparative studies. Full-text screening, data extraction, risk of bias assessment, and GRADE (Grading of Recommendations Assessment, Development and Evaluation) for the certainty of evidence were completed independently by two reviewers with any disagreements resolved by consensus, with arbitration by a third reviewer, when needed.

Initial findings

We present study characteristics in Table 1 and a summary of findings in Tables 2-4.

Initially, 137 studies were screened in the CAL tool software and 42 studies were included for full-text screening. Four studies met the eligibility criteria and were included (Appendix 2). A list of excluded studies with reasons for exclusion can be found in Appendix 1.

No studies provided direct information on the transmission or incidence of EVD or Marburg virus disease related to the use of personal protective equipment (PPE) for head and neck skin protection. We included two simulation studies that addressed outcomes related to heat stress for health care workers (HCW) donning extra head/neck covering PPE (hoods). Additionally, we included two crossover randomized controlled trials that simulated contamination events for HCWs while doffing PPE ensembles with and without neck covering.

Overall, for heat tolerance outcomes, we found very low certainty evidence that PPE ensembles with additional head/neck covering increased both physiological and subjective measures of heat exhaustion, compared to PPE with no cover of the head and neck. We found low to very low certainty of evidence that PPE ensembles with head/neck covering resulted in less contamination than PPE with no cover for the head and neck. We found low to very low certainty evidence that PPE ensembles that covered the head/neck resulted in more human errors during donning/doffing of equipment, compared to ensembles without head/neck cover.

Table 1. Characteristics of Included Studies

Citation [Author, Year]	Study Design	Funding Source	Virus Species	Setting	# Total Health Workers	# Health Care Facilities	Description of Health Worker Care/contact with patients	Study Objectives [as reported by study authors]
Coca, 2017[1]	Non-randomized simulation study	Not reported	N/A	Simulated ambient conditions for West African countries[a]	6 healthy individuals to simulate HCWs	N/A; one environmental chamber	Exercise intensity was set to the average for nursing care[b]	Evaluate the human physiological and subjective responses to continuous light exercise within environmental conditions similar to those in West Africa while wearing 3 different, commonly used PPE ensembles.
Coca, 2015[2]	Non-randomized simulation study	Not reported	N/A	Simulated ambient conditions for warmest months in West African countries[c]	N/A; sweating thermal manikins	N/A; one environmental chamber	Metabolic work rate (work intensity) was set to the average for nursing care[d]	The focus of the present study was to provide a baseline heat stress analysis of some of the PPE

								ensemble options used in West Africa in the fight against the spread of Ebola.
Suen, 2018[3]	Crossover randomized controlled trial	Public university funded	Fluorescent solution[e] on the PPE surface to simulate Ebola virus	Air-conditioned room with an average temperature of 23 °C ± 2 °C and a relative humidity of 60% ± 3%	59 HCWs (all evaluated in each of PPE ensembles)	N/A; one air-conditioned room	Fluorescent solution sprayed on PPE at the length of a stethoscope to simulate usual working distance between a patient and an HCW[f]; contamination events monitored during doffing	Compare the efficacy of three PPE ensembles for routine patient care and performing aerosol-generating procedures to prevent EVD transmission by measuring the degree of contamination of HCWs and the environment.
Zamora, 2006[4]	Crossover randomized controlled trial	Physicians' Services Incorporated Foundation and the Clinical Teachers' Association	Fluorescent solution[g] on the PPE surface to simulate HID	Not reported	50 HCWs	N/A	Participants' front face shield, torso, hands, forearms and elbows were contaminated with	Examine the difference in self-contamination rates and the level of contact and droplet

		of Queen's University					fluorescent solution/ paste	protection-associated with E-RCP and the PAPR system.

Abbreviations: HCW, health care workers, HID, highly infectious diseases, NR, not reported, PPE, personal protective equipment

a. For each testing protocol, three periods with different conditions were simulated: 15-minute pre-exercise stabilization period (22°C, 50% relative humidity) and a 60-minute exercise period (32°C, 92% relative humidity), followed by a 30-minute recovery period in ambient conditions (22°C, 50% relative humidity).
b. The exercise protocol consisted of 60 minutes of continuous walking, within an environmental chamber, on a treadmill at an intensity of three METs (2.5 mph, 0% grade). This exercise intensity was chosen to represent the working intensity seen in hospital nurses during patient care, such as walking, standing, and carrying light objects.
c. Two conditions were simulated. Condition A consisted of 32°C, 92% relative humidity, Condition B consisted of 26°C, 80% relative humidity
d. Average work intensity for nursing corresponded to patient care that includes standing and walking slowly [2.5 mph] and carrying light objects [<11.3 kg]) of 3 METs (metabolic equivalent, or the measure of the intensity of aerobic exercise) over 80 min of continuous activity
e. UV GERM Hygiene Spray, Glow Tec Ltd., London, England
f. Three strokes of fluorescent solution were sprayed onto the face shield, two upper limb/ gloves and anterior surfaces of the gown at a distance of 60 cm from the participants (total 12 strokes per case). There was an average of 1.99 g fluorescent solution/per stroke.
g. Fluorescein solution (1 mL of a 25% solution in 100 mL of sterile water). A Devilbiss atomizer (model DV15-RD, Sunrise Medical Products, Carlsbad, Calif.) was used to apply 5 mL of solution to each participant's front face shield and torso. "Invisible" Detection Paste (15 mL; Sirchie, Youngsville, NC) was applied from the forearms to the elbow and to the palmar aspects of participants' hands

Table 2. Summary of Findings: Heat Tolerance

Study details	*Intervention (cover head/neck and mucus membranes)*	*Comparator (cover mucous membranes only)*	*Mean (± SD) in intervention group*	*Mean (± SD) in comparator group*	*Pairwise comparison*	*Quality Assessment*[a]	*GRADE*	*Notes*
Time (min) to reach critical core temperature of 39°C under condition A[b]								
Coca, 2015[2]	E4[c]	E2[d]	62±6 min	78±7 min	P = 0.04	Moderate risk of bias	⊕◯◯◯ Very low	None
	E3[e]	E2[d]	65±3 min	78±7 min	P = 0.04			
	E4[c]	E1[f]	62±6 min	+80 min	P <0.05			
	E3[e]	E1[f]	65±3 min	+80 min	P <0.05			
Body surface skin temperature (°C) time to reach critical core temperature of 39°C under condition A[b]								
Coca, 2015[2]	E4[c]	E2[d]	38.4 ± 0.8	37.7 ± 0.2	NS	Moderate risk of bias	⊕◯◯◯ Very low	None
	E3[e]	E2[d]	38.3 ± 0.2	37.7 ± 0.2	NS			
	E4[c]	E1[f]	38.4 ± 0.8	37.3 ± 0.3	P <0.05			
	E3[e]	E1[f]	38.3 ± 0.2	37.3 ± 0.3	P <0.05			
Heat sensation[g] at time to reach critical core temperature of 39°C under condition A[b]								
Coca, 2015[2]	E4[c]	E2[d]	3.8 ± 0.1	3.5 ± 0.2	NS	Moderate risk of bias	⊕◯◯◯ Very low	None
	E3[e]	E2[d]	3.7 ± 0.1	3.5 ± 0.2	NS			
	E4[c]	E1[f]	3.8 ± 0.1	3.6 ± 0.2	NS			
	E3[e]	E1[f]	3.7 ± 0.1	3.6 ± 0.2	NS			
Discomfort[h] at time to reach critical core temperature of 39°C under condition A[b]								
Coca, 2015[2]	E4[c]	E2[d]	− 3.4 ± 0.1	− 3.2 ± 0.1	NS	Moderate risk of bias	⊕◯◯◯ Very low	None
	E3[e]	E2[d]	− 3.4 ± 0.1	− 3.2 ± 0.1	NS			
	E4[c]	E1[f]	− 3.4 ± 0.1	− 3.2 ± 0.1	NS			
	E3[e]	E1[f]	− 3.4 ± 0.1	− 3.2 ± 0.1	NS			
Core temperature (°C) after 80 minutes of activity under condition B[i]								
Coca, 2015[2]	E4[c]	E2[d]	38.9 ± 0.2	38.33 ± 0.1	P <0.05	Moderate risk of bias	⊕◯◯◯ Very low	None
	E3[e]	E2[d]	38.7 ± 0.1	38.33 ± 0.1	P <0.05			
	E4[c]	E1[f]	38.9 ± 0.2	38.05 ± 0.1	P <0.05			
	E3[e]	E1[f]	38.7 ± 0.1	38.05 ± 0.1	P <0.05			
Body surface skin temperature (°C) after 80 minutes of activity under condition B[i]								

Study details	*Intervention (cover head/neck and mucus membranes)*	*Comparator (cover mucous membranes only)*	*Mean (± SD) in intervention group*	*Mean (± SD) in comparator group*	*Pairwise comparison*	*Quality Assessment*[a]	*GRADE*	*Notes*
Coca, 2015[2]	E4[c]	E2[d]	37.6 ± 0.4	36.4 ± 0.4	P <0.05	Moderate risk of bias	⊕◯◯◯ Very low	None
	E3[e]	E2[d]	36.9 ± 0.2	36.4 ± 0.4	NS			
	E4[c]	E1[f]	37.6 ± 0.4	35.8 ± 0.6	P <0.05			
	E3[e]	E1[f]	36.9 ± 0.2	35.8 ± 0.6	NS			
Heat sensation[g] after 80 minutes of activity under condition B[i]								
Coca, 2015[2]	E4[c]	E2[d]	3.2 ± 0.6	2.5 ± 0.6	NS	Moderate risk of bias	⊕◯◯◯ Very low	None
	E3[e]	E2[d]	2.5 ± 0.4	2.5 ± 0.6	NS			
	E4[c]	E1[f]	3.2 ± 0.6	2.4 ± 0.5	P <0.05			
	E3[e]	E1[f]	2.5 ± 0.4	2.4 ± 0.5	NS			
Discomfort[h] after 80 minutes of activity under condition B[i]								
Coca, 2015[2]	E4[c]	E2[d]	− 3.2 ± 0.2	− 2.6 ± 0.4	P <0.05	Moderate risk of bias	⊕◯◯◯ Very low	None
	E3[e]	E2[d]	− 3 ± 0.2	− 2.6 ± 0.4	NS			
	E4[c]	E1[f]	− 3.2 ± 0.2	− 2.3 ± 0.3	P <0.05			
	E3[e]	E1[f]	− 3 ± 0.2	− 2.3 ± 0.3	NS			
Core Temperature (°C) at end of exercise								
Coca, 2017[1]	E3[j]	E1[k]	38.91 ± 0.29	38.18 ± 0.46	P <0.05	High risk of bias	⊕◯◯◯ Very low	None
	E2[l]	E1[k]	38.78 ± 0.36	38.18 ± 0.46	P <0.05			
Skin Temperature (°C) at end of exercise								
Coca, 2017[1]	E3[j]	E1[k]	37.94 ± 0.15	36.12 ± 0.65	NS	High risk of bias	⊕◯◯◯ Very low	None
	E2[l]	E1[k]	37.21 ± 0.21	36.12 ± 0.65	NS			
Heart Rate (beats per minute) at end of exercise								
Coca, 2017[1]	E3[j]	E1[k]	163 ± 17.52	135.57 ± 15.05	P <0.05	High risk of bias	⊕◯◯◯ Very low	None
	E2[l]	E1[k]	156 ± 16.71	135.57 ± 15.05	P <0.05			
Average sweat weight loss (kg) per hour								
Coca, 2017[1]	E3[j]	E1[k]	1.48 ± 0.47 kg	0.94 ± 0.40 kg	P = 0.000	High risk of bias	⊕◯◯◯	None

Study details	*Intervention (cover head/neck and mucus membranes)*	*Comparator (cover mucous membranes only)*	*Mean (± SD) in intervention group*	*Mean (± SD) in comparator group*	*Pairwise comparison*	*Quality Assessment[a]*	*GRADE*	*Notes*
	E2[l]	E1[k]	1.26 ± 0.53 kg	0.94 ± 0.40 kg	P = 0.032		Very low	
Heat Sensation[g] at end of exercise								
Coca, 2017[1]	E3[j]	E1[k]	3.86 ± 0.38	3.29 ± 0.49	P <0.05	High risk of bias	⊕◯◯◯ Very low	None
	E2[l]	E1[k]	3.86 ± 0.38	3.29 ± 0.49	P <0.05			
Thermal Comfort[m] at end of exercise								
Coca, 2017[1]	E3[j]	E1[k]	2.71 ± 2.56	2.71 ± 0.76	NS	High risk of bias	⊕◯◯◯ Very low	None
	E2[l]	E1[k]	3.57 ± 0.79	2.71 ± 0.76	P <0.05			
Rated perceived exertion[n] at end of exercise								
Coca, 2017[1]	E3[j]	E1[k]	15.29 ± 2.50	11.86 ± 2.12	P <0.05	High risk of bias	⊕◯◯◯ Very low	None
	E2[l]	E1[k]	14.43 ± 3.10	11.86 ± 2.12	P <0.05			
Breathing comfort[o] at end of exercise								
Coca, 2017[1]	E3[j]	E1[k]	5.14 ± 0.69	3.57 ± 1.27	P <0.05	High risk of bias	⊕◯◯◯ Very low	None
	E2[l]	E1[k]	5.29 ± 1.11	3.57 ± 1.27	P <0.05			
Wetness[p] at end of exercise								
Coca, 2017[1]	E3[j]	E1[k]	2.86 ± 0.38	2.86 ± 0.38	NS	High risk of bias	⊕◯◯◯ Very low	None
	E2[l]	E1[k]	2.86 ± 0.38	2.86 ± 0.38	NS			

Abbreviations: NS, non-significant (P>0.05); SD, standard deviation

a. Quality assessment of studies was completed using the ROBINS-I scale for observational/non-randomized studies. For the mannequin simulation study (Coca et al. 2015), quality assessment was performed under assumption that mannequin could be treated as a volunteer and humanized.
b. Condition A consisted of 32°C, 92% relative humidity
c. Ensemble 4 (E4): medical scrubs, socks, and rubber boots, impermeable coverall, Tyvek hood with an integrated splash-resistant surgical mask; rubber surgical apron, splash-resistant goggles, surgical nitrile inner gloves, heavy-duty nitrile outer gloves, N95 mask, a fluid-resistant surgical cap. The Tyvek hood provided the head and neck cover.
d. Ensemble 2 (E2): medical scrubs, socks, rubber boots with a mid-calf-length, disposable, fluid-resistant surgical gown, a polyethylene surgical apron, a face shield, disposable nitrile examination inner gloves, N95 mask, a fluid-resistant surgical cap. The cap provided some head covering, but the majority of head and neck skin remained exposed.

e. Ensemble 3 (E3): medical scrubs, socks, rubber boots with a Tyvek coverall, Tyvek hood with an integrated splash-resistant surgical mask; a rubber surgical apron, splash-resistant goggles, surgical nitrile inner gloves; heavy-duty nitrile outer gloves, a duckbill N95 filtering face piece respirator, and a fluid-resistant surgical cap. The Tyvek hood provided the head and neck cover.
f. Ensemble 1 (E1): medical scrubs, socks, rubber boots with a mid-calf-length, disposable, fluid-resistant surgical gown, a fluid-resistant 3-ply surgical mask, a disposable polyester lens face shield, disposable nitrile examination gloves. Head and neck skin was exposed.
g. Heat sensation (rated from −4 [very cold] to 4 [very hot]
h. Thermal comfort rated from −4 [very uncomfortable] to 4 [very comfortable])
i. Condition B consisted of 26°C, 80% relative humidity
j. Ensemble 3 (E3): medical scrubs, socks and rubber boots, Tychem QC highly impermeable coverall (DuPont), Médecins Sans Frontières (MSF) custom-made Tyvek (DuPont) hood with integrated splash-resistant surgical mask, rubber surgical apron, splash-resistant goggles, surgical nitrile inner gloves, heavy-duty nitrile outer gloves, duckbill N95 filtering face piece respirator and fluid-resistant surgical cap
k. Ensemble 2 (E2): medical scrubs, socks and rubber boots, Microgard coverall, Tyvek hood with integrated splash-resistant surgical mask, rubber surgical apron, splash-resistant goggles, surgical nitrile inner gloves, heavy-duty nitrile outer gloves, duckbill N95 filtering face piece respirator, fluid-resistant surgical cap
l. Ensemble 1 (E1): medical scrubs; socks and rubber boots; a midcalf-length disposable, fluid-resistant surgical gown, Performance Surgical Gown 7696C; polyethylene surgical apron, face shield, disposable nitrile examination inner gloves, duckbill N95 surgical filtering face piece respirator, and fluid-resistant surgical cap
m. Subjective thermal comfort was measured on a scale of 1 to 4 (where 1 = not uncomfortable and 4 = very uncomfortable)
n. Rate of perceived exertion was measured by using the OMNI 6-20 exertional scale
o. Breathing comfort was measured by using a scale of 1 to 7 (where 1 = no discomfort and 7 = intolerable discomfort)
p. Subjective wetness was measured by using a scale of 1 to 5 (where 1 = dry and 5 = soaked)

Table 3. Summary of Findings: Contamination during doffing of PPE

Study details	*Intervention (cover head/neck and mucus membranes)*	*Comparator (cover mucous membranes only)*	*Outcome in intervention group*	*Outcome in control group*	*Statistical test*	*Quality Assessment*[a]	*GRADE*	*Notes*
Overall contamination during doffing of PPE: Small sized contaminated patches (< 1 cm²), median								
Suen, 2018[3]	PPE1[b] - Hospital Authority Standard Ebola PPE set	PPE3[c] - HA isolation gown for routine patient care and performing AGPs	5.00	7.00	ANOVA: PPE1 vs. PPE2 vs. PPE3 : p-value = 0.05	Low risk of bias	⊕⊕◯◯ Low	None
	PPE2[d] - DuPont™ Tyvek®, Model 1422A	PPE3[c] - HA isolation gown for routine patient care and performing AGPs	7.00	7.00		Low risk of bias	⊕⊕◯◯ Low	None
Hair and head contamination during doffing of PPE: Small sized contaminated patches (< 1 cm²), median								
Suen, 2018[3]	PPE1[b] - Hospital Authority Standard Ebola PPE set	PPE3[c] - HA isolation gown for routine patient care and performing AGPs	1.00	2.50	ANOVA: PPE1 vs. PPE2 vs. PPE3 : p-value = 0.68	Low risk of bias	⊕⊕◯◯ Low	None
	PPE2[d] - DuPont™ Tyvek®, Model 1422A	PPE3[c] - HA isolation gown for routine patient care and performing AGPs	2.00	2.50		Low risk of bias	⊕⊕◯◯ Low	None
Neck (anterior) contamination during doffing of PPE: Small sized contaminated patches (< 1 cm²), median								
Suen, 2018[3]	PPE1[b] - Hospital Authority Standard Ebola PPE set	PPE3[c] - HA isolation gown for routine patient	2.50	11.00	ANOVA: PPE1 vs. PPE2 vs.	Low risk of bias	⊕⊕◯◯ Low	None

Study details	*Intervention (cover head/neck and mucus membranes)*	*Comparator (cover mucous membranes only)*	*Outcome in intervention group*	*Outcome in control group*	*Statistical test*	*Quality Assessment*[a]	*GRADE*	*Notes*
		care and performing AGPs			PPE3 : p-value = 0.095			
	PPE2[d] - DuPont™ Tyvek®, Model 1422A	PPE3[c] - HA isolation gown for routine patient care and performing AGPs	5.00	11.00		Low risk of bias	⊕⊕◯◯ Low	None
Neck (posterior) contamination during doffing of PPE: Small sized contaminated patches (< 1 cm^2), median								
Suen, 2018[3]	PPE1[b] - Hospital Authority Standard Ebola PPE set	PPE3[c] - HA isolation gown for routine patient care and performing AGPs	2.00	18.50	ANOVA: PPE1 vs. PPE2 vs. PPE3 : p-value = 0.824	Low risk of bias	⊕⊕◯◯ Low	None
	PPE2[d] - DuPont™ Tyvek®, Model 1422A	PPE3[c] - HA isolation gown for routine patient care and performing AGPs	1.00	18.50		Low risk of bias	⊕⊕◯◯ Low	None
Overall contamination during doffing of PPE: Extra large sized contaminated patches (≥ 5cm^2), median								
Suen, 2018[3]	PPE1[b] - Hospital Authority Standard Ebola PPE set	PPE3[c] - HA isolation gown for routine patient care and performing AGPs	39.00	47.00	ANOVA: PPE1 vs. PPE2 vs. PPE3 : p-value = < 0.001*	Low risk of bias	⊕⊕◯◯ Low	None
	PPE2[d] - DuPont™ Tyvek®, Model 1422A	PPE3[c] - HA isolation gown for routine patient care and performing AGPs	43.00	47.00		Low risk of bias	⊕⊕◯◯ Low	None

Study details	*Intervention (cover head/neck and mucus membranes)*	*Comparator (cover mucous membranes only)*	*Outcome in intervention group*	*Outcome in control group*	*Statistical test*	*Quality Assessment*[a]	*GRADE*	*Notes*
Hair and head contamination during doffing of PPE: Extra large sized contaminated patches (≥ 5cm^2), median								
Suen, 2018[3]	PPE1[b] - Hospital Authority Standard Ebola PPE set	PPE3[c] - HA isolation gown for routine patient care and performing AGPs	0.00	0.00	ANOVA: PPE1 vs. PPE2 vs. PPE3 : p-value = N/A	Low risk of bias	⊕⊕◯◯ Low	None
	PPE2[d] - DuPont™ Tyvek®, Model 1422A	PPE3[c] - HA isolation gown for routine patient care and performing AGPs	17.00	0.00		Low risk of bias	⊕⊕◯◯ Low	None
Neck (anterior) contamination during doffing of PPE: Extra large sized contaminated patches (≥ 5cm^2), median								
Suen, 2018[3]	PPE1[b] - Hospital Authority Standard Ebola PPE set	PPE3[c] - HA isolation gown for routine patient care and performing AGPs	0.00	24.00	ANOVA: PPE1 vs. PPE2 vs. PPE3 : p-value = N/A	Low risk of bias	⊕⊕◯◯ Low	None
	PPE2[d] - DuPont™ Tyvek®, Model 1422A	PPE3[c] - HA isolation gown for routine patient care and performing AGPs	0.00	24.00		Low risk of bias	⊕⊕◯◯ Low	None
Neck (posterior) contamination during doffing of PPE: Extra large sized contaminated patches (≥ 5cm^2), median								
Suen, 2018[3]	PPE1[b] - Hospital Authority Standard Ebola PPE set	PPE3[c] - HA isolation gown for routine patient care and performing AGPs	0.00	0.00	ANOVA: PPE1 vs. PPE2 vs. PPE3 : p-value = N/A	Low risk of bias	⊕⊕◯◯ Low	None

Study details	*Intervention (cover head/neck and mucus membranes)*	*Comparator (cover mucous membranes only)*	*Outcome in intervention group*	*Outcome in control group*	*Statistical test*	*Quality Assessment*[a]	*GRADE*	*Notes*
	PPE2[d] - DuPont™ Tyvek®, Model 1422A	PPE3[c] - HA isolation gown for routine patient care and performing AGPs	0.00	0.00		Low risk of bias	⊕⊕◯◯ Low	None
Overall contamination during doffing of PPE, any size, n (%)								
Zamora, 2006[4]	PAPR[e]	E-RCP[f]	13 (26%)	48 (96%)	Mainland–Gart: p <0.001	Some concerns	⊕◯◯◯ Very low	None
Face contamination during doffing of PPE, any size, n (%)								
Zamora, 2006[4]	PAPR[e]	E-RCP[f]	0	2 (4%)	Mainland–Gart: p=1	Some concerns	⊕◯◯◯ Very low	None
Back of the head contamination during doffing of PPE, any size, n (%)								
Zamora, 2006[4]	PAPR[e]	E-RCP[f]	0	0	Mainland–Gart: undefined	Some concerns	⊕◯◯◯ Very low	None
Neck (anterior) contamination during doffing of PPE, any size, n (%)								
Zamora, 2006[4]	PAPR[e]	E-RCP[f]	3 (6%)	48 (96%)	Mainland–Gart: p<0.001	Some concerns	⊕◯◯◯ Very low	None
Neck (posterior) contamination during doffing of PPE, any size, n (%)								
Zamora, 2006[4]	PAPR[e]	E-RCP[f]	1 (2%)	9 (18%)	Mainland–Gart: p=0.012	Some concerns	⊕◯◯◯ Very low	None

a. Quality assessment of studies was completed using the Cochrane RoB 2 for randomized trials.

b. Hospital Authority Standard Ebola PPE set (PPE 1): a neck-to-ankle overall with an overlying water-resistant gown double and long nitrate gloves, boots, hood, disposable face shield and N95 respirator. Order of doffing: gloves, gown, boots, hood, N95.

c. HA isolation gown for routine patient care and performing AGPs (PPE3): pure cotton surgical scrub suit, appropriate size gowns and gloves and the known best-fitted respirator model (3 M 1860, 1860s and 1870). Order of doffing: gloves, gown, full face shield, cap, N95 respirator.

d. DuPont™ Tyvek®, Model 1422A (PPE2): head-to-ankle overall with a zipper on the front. The whole outfit includes double gloves, boots, disposable face shield and an N95 respirator. A plastic apron was used to cover up the front zipper before use. Order of doffing: apron, hood, coverall/outer gloves, face shield, N95 respirator, boots, inner gloves.

e. PAPR (powered air-purifying respirator): Tyvek hood, Bouffant hair cover, Economy impact goggle, Air-mate breathing tube, face-shield, HEPA filter unit, N95 mask - any of several modes (8210, 1860s, PFR95, 7210, 695), Gloves (Non-latex, latex, latex surgical), Tyvek coveralls with hood, Tyvek boot covers, Astound impervious surgical gown

f. E-RCP (Enhanced respiratory and contact precautions) contains a bouffant hair cover, economy impact goggle, face-shield, N95 mask - any of several modes (8210, 1860s, PFR95, 7210, 695), gloves (Non-latex, latex), astound impervious surgical gown

Table 4. Summary of Findings: Human factors: Deviation rate (%) during donning and doffing of personal protective equipment

Study details	*Intervention (cover head/neck and mucus membranes)*	*Comparator (cover mucous membranes only)*	*Outcome in intervention group*	*Outcome in control group*	*Quality Assessment*[a]	*GRADE*	*Notes*
Overall deviation rate (%) during donning of PPE							
Suen, 2018[3]	PPE1[b] - Hospital Authority Standard Ebola PPE set	PPE3[c] - HA isolation gown for routine patient care and performing AGPs	6.06	3.70	Low risk of bias	⊕⊕◯◯ Low	None
	PPE2[d] - DuPont™ Tyvek®, Model 1422A	PPE3[c] - HA isolation gown for routine patient care and performing AGPs	6.00	3.70			
Deviation rate (%) during donning of hood							
Suen, 2018[3]	PPE1[b] - Hospital Authority Standard Ebola PPE set	PPE3[c] - HA isolation gown for routine patient care and performing AGPs	20.00	N/A	Low risk of bias	⊕⊕◯◯ Low	None
	PPE2[d] - DuPont™ Tyvek®, Model 1422A	PPE3[c] - HA isolation gown for routine patient care and performing AGPs	3.33	N/A			
Deviation rate (%) during donning of faceshield							
Suen, 2018[3]	PPE1[b] - Hospital Authority Standard Ebola PPE set	PPE3[c] - HA isolation gown for routine patient care and performing AGPs	11.67	6.67	Low risk of bias	⊕⊕◯◯ Low	None
	PPE2[d] - DuPont™ Tyvek®, Model 1422A	PPE3[c] - HA isolation gown for routine patient care and performing AGPs	15.00	6.67			
Overall deviation rate (%) during doffing of PPE							

Study details	*Intervention (cover head/neck and mucus membranes)*	*Comparator (cover mucous membranes only)*	*Outcome in intervention group*	*Outcome in control group*	*Quality Assessment*[a]	*GRADE*	*Notes*
Suen, 2018[3]	PPE1[b] - Hospital Authority Standard Ebola PPE set	PPE3[c] - HA isolation gown for routine patient care and performing AGPs	2.95	3.52	Low risk of bias	⊕⊕◯◯ Low	None
	PPE2[d] - DuPont™ Tyvek®, Model 1422A	PPE3[c] - HA isolation gown for routine patient care and performing AGPs	9.48	3.52			
Deviation rate (%) during doffing of hood							
Suen, 2018[3]	PPE1[b] - Hospital Authority Standard Ebola PPE set	PPE3[c] - HA isolation gown for routine patient care and performing AGPs	5.00	N/A	Low risk of bias	⊕⊕◯◯ Low	None
	PPE2[d] - DuPont™ Tyvek®, Model 1422A	PPE3[c] - HA isolation gown for routine patient care and performing AGPs	8.33	N/A			
Deviation rate (%) during doffing of faceshield							
Suen, 2018[3]	PPE1[b] - Hospital Authority Standard Ebola PPE set	PPE3[c] - HA isolation gown for routine patient care and performing AGPs	6.67	10.00	Low risk of bias	⊕⊕◯◯ Low	None
	PPE2[d] - DuPont™ Tyvek®, Model 1422A	PPE3[c] - HA isolation gown for routine patient care and performing AGPs	11.67	10.00			
Total donning errors, n (%)							
Zamora, 2006[4]	PAPR[e]	E-RCP[f]	19 (38%)	2 (4%)	Some concerns	⊕◯◯◯ Very low	None
Total doffing errors, n (%)							

Study details	*Intervention (cover head/neck and mucus membranes)*	*Comparator (cover mucous membranes only)*	*Outcome in intervention group*	*Outcome in control group*	*Quality Assessment*[a]	*GRADE*	*Notes*
Zamora, 2006[4]	PAPR[e]	E-RCP[f]	6 (12%)	12 (24%)	Some concerns	⊕◯◯◯ Very low	None
Error in application of goggles during donning, n (%)							
Zamora, 2006[4]	PAPR[e]	E-RCP[f]	2 (4%)	0	Some concerns	⊕◯◯◯ Very low	None
Failure to zip up coveralls or put hood over head during donning, n (%)							
Zamora, 2006[4]	PAPR[e]	E-RCP[f]	1 (2%)	N/A	Some concerns	⊕◯◯◯ Very low	None
Error in application of bouffant hair-cover during donning, n (%)							
Zamora, 2006[4]	PAPR[e]	E-RCP[f]	N/A	1 (2%)	Some concerns	⊕◯◯◯ Very low	None
Error in removal of face shield during doffing, n (%)							
Zamora, 2006[4]	PAPR[e]	E-RCP[f]	N/A	1 (2%)	Some concerns	⊕◯◯◯ Very low	None
Error in removal of hair-cover during doffing, n (%)							
Zamora, 2006[4]	PAPR[e]	E-RCP[f]	N/A	2 (4%)	Some concerns	⊕◯◯◯ Very low	None

a. Quality assessment of studies was completed using the Cochrane RoB 2 for randomized trials.

b. Hospital Authority Standard Ebola PPE set (PPE 1): a neck-to-ankle overall with an overlying water-resistant gown double and long nitrate gloves, boots, hood, disposable face shield and N95 respirator. Order of doffing: gloves, gown, boots, hood, N95.

c. HA isolation gown for routine patient care and performing AGPs (PPE3): pure cotton surgical scrub suit, appropriate size gowns and gloves and the known best-fitted respirator model (3 M 1860, 1860s and 1870). Order of doffing: gloves, gown, full face shield, cap, N95 respirator.

d. DuPont™ Tyvek®, Model 1422A (PPE2): head-to-ankle overall with a zipper on the front. The whole outfit includes double gloves, boots, disposable face shield and an N95 respirator. A plastic apron was used to cover up the front zipper before use. Order of doffing: apron, hood, coverall/outer gloves, face shield, N95 respirator, boots, inner gloves.

e. PAPR (powered air-purifying respirator): Tyvek hood, Bouffant hair cover, Economy impact goggle, Air-mate breathing tube, face-shield, HEPA filter unit, N95 mask - any of several modes (8210, 1860s, PFR95, 7210, 695), Gloves (Non-latex, latex, latex surgical), Tyvek coveralls with hood, Tyvek boot covers, Astound impervious surgical gown

f. E-RCP (Enhanced respiratory and contact precautions) contains a bouffant hair cover, economy impact goggle, face-shield, N95 mask - any of several modes (8210, 1860s, PFR95, 7210, 695), gloves (Non-latex, latex), astound impervious surgical gown

Citations:

1. Coca A, Quinn T, Kim JH, et al. Physiological Evaluation of Personal Protective Ensembles Recommended for Use in West Africa. *Disaster Med Public Health Prep*. 2017;11(5):580-586. doi:10.1017/dmp.2017.13

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3. Suen LKP, Guo YP, Tong DWK, et al. Self-contamination during doffing of personal protective equipment by healthcare workers to prevent Ebola transmission. *Antimicrob Resist Infect Control*. 2018;7(1):157. doi:10.1186/s13756-018-0433-y

4. Zamora JE. Contamination: a comparison of 2 personal protective systems. *Can Med Assoc J*. 2006;175(3):249-254. doi:10.1503/cmaj.060094

Appendix 1. Excluded Studies List – By Reason for Exclusion:

Abstract Only

Abela N, Bonnici ET, Parascandalo A, Borg M. Lessons learnt and challenges in adopting the ECDC and who Ebola guidelines at Mater Dei Hospital. *Antimicrob Resist Infect Control.* 2015;4(S1):P5, 2047-2994-4-S1-P5. doi:10.1186/2047-2994-4-S1-P5

Commentary

MacIntyre CR, Chughtai AA, Seale H, Richards GA, Davidson PM. Response to Martin-Moreno et al. (2014) Surgical mask or no mask for health workers not a defensible position for Ebola. *International Journal of Nursing Studies.* 2014;51(12):1694-1695. doi:10.1016/j.ijnurstu.2014.10.004

MacIntyre CR, Chughtai AA, Seale H, Richards GA, Davidson PM. Uncertainty, risk analysis and change for Ebola personal protective equipment guidelines. *International Journal of Nursing Studies.* 2015;52(5):899-903. doi:10.1016/j.ijnurstu.2014.12.001

Narrative review

Franklin SM. A Comparison of Personal Protective Standards: Caring for Patients With Ebola Virus. *Clinical Nurse Specialist.* 2016;30(2):E1-E8. doi:10.1097/NUR.0000000000000183

Honda H, Iwata K. Personal protective equipment and improving compliance among healthcare workers in high-risk settings: *Current Opinion in Infectious Diseases.* 2016;29(4):400-406. doi:10.1097/QCO.0000000000000280

No information on PPE

De Clerck H. Protecting the health care worker during outbreaks – The case of viral hemorrhagic fever outbreaks. *International Journal of Infectious Diseases.* 2016;45:67. doi:10.1016/j.ijid.2016.02.194

Fischer WA, Hynes NA, Perl TM. Protecting Health Care Workers From Ebola: Personal Protective Equipment Is Critical but Is Not Enough. *Ann Intern Med.* 2014;161(10):753. doi:10.7326/M14-1953

Martin-Moreno JM, Llinás G, Hernández JM. Is respiratory protection appropriate in the Ebola response? *The Lancet.* 2014;384(9946):856. doi:10.1016/S0140-6736(14)61343-X

Martin-Moreno JM, Llinás G, Martínez-Hernández J. Response to "MacIntyre et al., 2014: Respiratory protection for healthcare workers treating Ebola virus disease (EVD): are facemasks sufficient to meet occupational health and safety obligations?" *International Journal of Nursing Studies.* 2014;51(12):1693. doi:10.1016/j.ijnurstu.2014.10.005

Savini H, Janvier F, Karkowski L, et al. Occupational Exposures to Ebola Virus in Ebola Treatment Center, Conakry, Guinea. *Emerg Infect Dis.* 2017;23(8):1380-1383. doi:10.3201/eid2308.161804

No relevant comparisons

Den Boon S, Vallenas C, Ferri M, Norris SL. Incorporating health workers' perspectives into a WHO guideline on personal protective equipment developed during an Ebola virus disease outbreak. *F1000Res.* 2018;7:45. doi:10.12688/f1000research.12922.2

Doshi RH, Hoff NA, Bratcher A, et al. Risk Factors for Ebola Exposure in Health Care Workers in Boende, Tshuapa Province, Democratic Republic of the Congo. *The Journal of Infectious Diseases.* Published online 2020:jiaa747. doi:10.1093/infdis/jiaa747

Doshi RH, Hoff NA, Mukadi P, et al. Seroprevalence of ebola virus among health care workers in the Tshuapa district democratic republic of congo. *Am J Tropic Med Hygiene.* Published online 2016.

Dunn AC, Walker TA, Redd J, et al. Nosocomial transmission of Ebola virus disease on pediatric and maternity wards: Bombali and Tonkolili, Sierra Leone, 2014. *American Journal of Infection Control.* 2016;44(3):269-272. doi:10.1016/j.ajic.2015.09.016

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Appendix 2. Eligibility Criteria

Question (5): Should Health workers in direct contact and/or indirect contact to patients with Ebola Virus Disease (EVD) or Marburg virus disease cover head and neck skin and mucous membranes or just cover mucous membranes?

Setting	Health care facilities, ETU, *community (e.g. burial teams)* *Contexts to consider: ETU use vs. healthcare facility; outbreak vs readiness vs. high alert scenario.
Population	Staff in HCF, ETU, community (e.g. burial teams)
Background interventions (Standard of care) 	The mucous membranes of eyes, mouth and nose are covered by PPE. Use of a head cover that covers head and neck.
Intervention	Use a cover for the head and neck.
Comparator(s)	Not use a cover for head and neck. *Direct contact, indirect contact*
Outcome	Infection with Ebola or Marburg, PPE breaches, compliance related to heat and comfort, *dehydration, heat tolerance, human factors, health worker confidence* **Indirect evidence:** Lassa fever
Potential effect modifiers	*Frequency and type of exposure, vaccination*

Appendix 3. GRADE Assessment: Heat Tolerance

Certainty assessment							№ of patients		Effect		Certainty	Importance
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	A cover for the head and neck	No cover for the head and neck	Relative (95% CI)	Absolute (95% CI)		
Time (min) to reach critical core temperature of 39°C under condition A												
1	observational studies	not serious[a]	not serious	very serious[b]	serious[c]	none	3	3	-	MD **16 min fewer** (30.78 fewer to 1.22 fewer)	⨁◯◯◯ Very low	
									-	MD **13 min fewer** (25.2 fewer to 0.79 fewer)		
									-	MD **18 min fewer** (27.7 fewer to 8.2 fewer)		
									-	MD **15 min fewer** (20.06 fewer to 9.9 fewer)		
Body surface skin temperature (°C) at time to reach critical core temperature of 39°C under condition A												
1	observational studies	not serious[a]	not serious	very serious[b]	serious[c]	none	3	3	-	MD **0.7 C higher** (0.62 lower to 2.02 higher)	⨁◯◯◯ Very low	
									-	MD **0.6 C higher** (0.14 higher to 1.05 higher)		
									-	MD **1.1 C higher** (0.26 lower to 2.46 higher)		
									-	MD **1 C higher** (0.42 higher to 1.57 higher)		
Heat sensation at time to reach critical core temperature of 39°C under condition A												
1	observational studies	not serious[a]	not serious	very serious[b]	serious[c]	none	3	3	-	MD **0.3 higher** (0.05 lower to 0.65 higher)	⨁◯◯◯ Very low	

Certainty assessment							№ of patients		Effect		Certainty	Importance
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	A cover for the head and neck	No cover for the head and neck	Relative (95% CI)	Absolute (95% CI)		
									-	MD **0.2 higher** (0.15 lower to 0.55 higher)		
									-	MD **0.2 higher** (0.15 lower to 0.55 higher)		
									-	MD **0.1 higher** (0.25 lower to 0.45 higher)		
Discomfort at time to reach critical core temperature of 39°C under condition A												
1	observational studies	not serious[a]	not serious	very serious[b]	serious[c]	none	3	3	-	MD **0.2 lower** (0.42 lower to 0.02 higher)	⨁◯◯◯ Very low	
									-	MD **0.2 lower** (0.42 lower to 0.02 higher)		
									-	MD **0.2 lower** (0.42 lower to 0.02 higher)		
									-	MD **0.2 lower** (0.42 lower to 0.02 higher)		
Core temperature (°C) after 80 minutes of activity under condition B												
1	observational studies	not serious[a]	not serious	very serious[b]	serious[c]	none	3	3	-	MD **0.57 C higher** (0.21 higher to 0.92 higher)	⨁◯◯◯ Very low	
									-	MD **0.37 C higher** (0.14 higher to 0.59 higher)		
									-	MD **0.85 C higher** (0.49 higher to 1.2 higher)		
									-	MD **0.65 C higher** (0.42 higher to 0.87 higher)		
Body surface skin temperature (°C) after 80 minutes of activity under condition B												

Certainty assessment							№ of patients		Effect		Certainty	Importance
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	A cover for the head and neck	No cover for the head and neck	Relative (95% CI)	Absolute (95% CI)		
1	observational studies	not serious[a]	not serious	very serious[b]	serious[c]	none	3	3	-	MD **1.2 C higher** (0.29 higher to 2.1 higher)	⨁◯◯◯ Very low	
									-	MD **0.5 C higher** (0.21 lower to 1.21 higher)		
									-	MD **1.8 C higher** (0.64 higher to 2.95 higher)		
									-	MD **1.1 C higher** (0.08 higher to 2.11 higher)		
Heat sensation after 80 minutes of activity under condition B												
1	observational studies	not serious[a]	not serious	very serious[b]	serious[c]	none	3	3	-	MD **0.7 higher** (0.66 lower to 2.06 higher)	⨁◯◯◯ Very low	
									-	MD **0 higher** (1.15 lower to 1.15 higher)		
									-	MD **0.8 higher** (0.45 lower to 2.05 higher)		
									-	MD **0.1 higher** (0.92 lower to 1.12 higher)		
Discomfort after 80 minutes of activity under condition B												
1	observational studies	not serious[a]	not serious	very serious[b]	serious[c]	none	3	3	-	MD **0.6 lower** (1.31 lower to 0.11 higher)	⨁◯◯◯ Very low	
									-	MD **0.4 lower** (1.11 lower to 0.31 higher)		
									-	MD **0.9 lower** (1.47 lower to 0.32 lower)		

Certainty assessment							№ of patients		Effect		Certainty	Importance
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	A cover for the head and neck	No cover for the head and neck	Relative (95% CI)	Absolute (95% CI)		
									-	MD **0.7 lower** (1.27 lower to 0.12 lower)		
Core Temperature (°C) at end of exercise												
1	observational studies	serious[d]	not serious	very serious[b]	serious[c]	none	3	3	-	MD **0.73 C higher** (0.14 lower to 1.6 higher)	⨁◯◯◯ Very low	
									-	MD **0.6 C higher** (0.33 lower to 1.53 higher)		
Skin Temperature (°C) at end of exercise												
1	observational studies	serious[d]	not serious	very serious[b]	serious[c]	none	3	3	-	MD **1.8 C higher** (0.75 higher to 2.88 higher)	⨁◯◯◯ Very low	
									-	MD **1.09 C higher** (0 higher to 2.18 higher)		
Heart Rate (beats per minute) at end of exercise												
1	observational studies	serious[d]	not serious	very serious[b]	serious[c]	none	3	3	-	MD **27.43 BPM higher** (9.59 lower to 64.45 higher)	⨁◯◯◯ Very low	
									-	MD **20.43 BPM higher** (15.61 lower to 56.47 higher)		
Average sweat weight loss (kg) per hour												
1	observational studies	serious[d]	not serious	very serious[b]	serious[c]	none	3	3	-	MD **0.54 kg higher** (0.44 lower to 1.52 higher)	⨁◯◯◯ Very low	
									-	MD **0.32 kg higher** (0.74 lower to 1.38 higher)		
Heat Sensation at end of exercise												

Certainty assessment							№ of patients		Effect		Certainty	Importance
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	A cover for the head and neck	No cover for the head and neck	Relative (95% CI)	Absolute (95% CI)		
1	observational studies	serious[d]	not serious	very serious[b]	serious[c]	none	3	3	-	MD **0.57 higher** (0.42 lower to 1.56 higher)	⨁◯◯◯ Very low	
									-	MD **0.57 higher** (0.42 lower to 1.56 higher)		
Thermal Comfort at end of exercise												
1	observational studies	serious[d]	not serious	very serious[b]	serious[c]	none	3	3	-	MD **0** (4.28 lower to 4.28 higher)	⨁◯◯◯ Very low	
									-	MD **0.86 higher** (0.89 lower to 2.61 higher)		
Rated perceived exertion at end of exercise												
1	observational studies	serious[d]	not serious	very serious[b]	serious[c]	none	3	3	-	MD **3.43 higher** (1.82 lower to 8.68 higher)	⨁◯◯◯ Very low	
									-	MD **2.57 higher** (3.45 lower to 8.59 higher)		
Breathing comfort at end of exercise												
1	observational studies	serious[d]	not serious	very serious[b]	serious[c]	none	3	3	-	MD **1.57 higher** (0.74 lower to 3.88 higher)	⨁◯◯◯ Very low	
									-	MD **1.72 higher** (0.98 lower to 4.42 higher)		
Wetness at end of exercise												
1	observational studies	serious[d]	not serious	very serious[b]	serious[c]	none	3	3	-	MD **0** (0.86 lower to 0.86 higher)	⨁◯◯◯ Very low	
									-	MD **0** (0.86 lower to 0.86 higher)		

CI: confidence interval; **MD:** mean difference

Explanations

a. Coca et al., 2015 was judged to be at moderate risk of bias. The mannequins were treated in the quality assessment, as if the mannequin were a volunteer. There was a lack of information reported for several ROBINS-I domains, including outcome measurement. There was no outcome assessor blinding, though outcomes were less vulnerable to bias, due to simulated nature of the study.
b. Downrated due to simulation study and non-human participants, as well as other differences in evaluated PPE equipment other than just head/neck cover vs. no cover.
c. Few participants and optimal information size (OIS) threshold not met.
d. We rated Coca et al., 2017, at a high risk of bias because of no demonstration of data availability for all the study participants and lack of blinding of the outcome assessor. Outcomes like thermal comfort, heat sensation, rating of perceived exertion, breathing comfort, and wetness were subjective measures which could potentially be more vulnerable to bias.

Appendix 4. GRADE Assessment: Contamination during doffing of PPE

Certainty assessment							№ of patients		Effect		Certainty	Importance
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	A cover for the head and neck	No cover for the head and neck	Relative (95% CI)	Absolute (95% CI)		
Overall contamination during doffing of PPE: Small sized contaminated patches (< 1 cm2), median												
1	randomised trials	not serious	not serious	serious[b]	serious[a]	none	59	59	not estimable	not estimable	⨁⨁◯◯ Low	
Hair and head contamination during doffing of PPE: Small sized contaminated patches (< 1 cm2), median												
1	randomised trials	not serious	not serious	serious[b]	serious[a]	none	59	59	not estimable	not estimable	⨁⨁◯◯ Low	
Neck (anterior) contamination during doffing of PPE: Small sized contaminated patches (< 1 cm2), median												
1	randomised trials	not serious	not serious	serious[b]	serious[a]	none	59	59	not estimable	not estimable	⨁⨁◯◯ Low	
Neck (posterior) contamination during doffing of PPE: Small sized contaminated patches (< 1 cm2), median												
1	randomised trials	not serious	not serious	serious[b]	serious[a]	none	59	59	not estimable	not estimable	⨁⨁◯◯ Low	
Overall contamination during doffing of PPE: Extra large sized contaminated patches (≥ 5cm2), median												
1	randomised trials	not serious	not serious	serious[b]	serious[a]	none	59	59	not estimable	not estimable	⨁⨁◯◯ Low	
Hair and head contamination during doffing of PPE: Extra large sized contaminated patches (≥ 5cm2), median												
1	randomised trials	not serious	not serious	serious[b]	serious[a]	none	59	59	not estimable	not estimable	⨁⨁◯◯ Low	
Neck (anterior) contamination during doffing of PPE: Extra large sized contaminated patches (≥ 5cm2), median												
1	randomised trials	not serious	not serious	serious[b]	serious[a]	none	59	59	not estimable	not estimable	⨁⨁◯◯ Low	
Neck (posterior) contamination during doffing of PPE: Extra large sized contaminated patches (≥ 5cm2), median												
1	randomised trials	not serious	not serious	serious[b]	serious[a]	none	59	59	not estimable	not estimable	⨁⨁◯◯ Low	
Overall contamination during doffing of PPE, any size, n (%)												

Certainty assessment							№ of patients		Effect		Certainty	Importance
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	A cover for the head and neck	No cover for the head and neck	Relative (95% CI)	Absolute (95% CI)		
1	randomised trials	serious[c]	not serious	serious[d]	serious[a]	none	13/50 (26.0%)	48/50 (96.0%)	**RR 0.27** (0.17 to 0.43)	**701 fewer per 1,000** (from 797 fewer to 547 fewer)	⨁◯◯◯ Very low	
Face contamination during doffing of PPE, any size, n (%)												
1	randomised trials	serious[c]	not serious	serious[d]	serious[a]	none	0/50 (0.0%)	2/50 (4.0%)	**RR 0.2000** (0.0098 to 4.0636)	**32 fewer per 1,000** (from 40 fewer to 123 more)	⨁◯◯◯ Very low	
Back of the head contamination during doffing of PPE, any size, n (%)												
1	randomised trials	serious[c]	not serious	serious[d]	serious[a]	none	0/50 (0.0%)	0/50 (0.0%)	not estimable	not estimable	⨁◯◯◯ Very low	
Neck (anterior) contamination during doffing of PPE, any size, n (%)												
1	randomised trials	serious[c]	not serious	serious[d]	serious[a]	none	3/50 (6.0%)	48/50 (96.0%)	**RR 0.1200** (0.0378 to 0.3533)	**845 fewer per 1,000** (from 924 fewer to 621 fewer)	⨁◯◯◯ Very low	
Neck (posterior) contamination during doffing of PPE, any size, n (%)												
1	randomised trials	serious[c]	not serious	serious[d]	serious[a]	none	1/50 (2.0%)	9/50 (18.0%)	**RR 0.1300** (0.0169 to 0.9804)	**157 fewer per 1,000** (from 177 fewer to 4 fewer)	⨁◯◯◯ Very low	

CI: confidence interval; **RR:** risk ratio

Explanations

a. Few participants and optimal information size (OIS) threshold not met.
b. Downrated due to simulation study: Fluorescent contamination as a surrogate outcome for EVD/Marburg Virus Disease, other differences in evaluated PPE equipment other than just head/neck cover vs. no cover.
c. Downrated due to concerns with risk of bias. Unclear risk of bias for several domains, including allocation bias, blinding of participants, and unclear if all outcomes were reported.
d. Downrated due to simulation study: Fluorescent contamination as a surrogate outcome, other differences in evaluated PPE equipment other than just head/neck cover vs. no cover.

Appendix 5. GRADE Assessment: Deviation rate (%) during donning and doffing of personal protective equipment

Certainty assessment							№ of patients		Effect		Certainty	Importance
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	A cover for the head and neck	No cover for the head and neck	Relative (95% CI)	Absolute (95% CI)		
Overall deviation rate (%) during donning of PPE												
1	randomised trials	not serious	not serious	serious[a]	serious[b]	none	59	59	-	-	⨁⨁◯◯ Low	
Deviation rate (%) during donning of hood												
1	randomised trials	not serious	not serious	serious[a]	serious[b]	none	59	59	-	-	⨁⨁◯◯ Low	
Deviation rate (%) during donning of faceshield												
1	randomised trials	not serious	not serious	serious[a]	serious[b]	none	59	59	-	-	⨁⨁◯◯ Low	
Overall deviation rate (%) during donning of PPE												
1	randomised trials	not serious	not serious	serious[a]	serious[b]	none	59	59	-	-	⨁⨁◯◯ Low	
Deviation rate (%) during doffing of hood												
1	randomised trials	not serious	not serious	serious[a]	serious[b]	none	59	59	-	-	⨁⨁◯◯ Low	
Deviation rate (%) during donning of faceshield												
1	randomised trials	not serious	not serious	serious[a]	serious[b]	none	59	59	-	-	⨁⨁◯◯ Low	
Total donning errors, n (%)												
1	randomised trials	serious[c]	not serious	serious[d]	serious[b]	none	19/50 (38.0%)	2/50 (4.0%)	**RR 9.50** (2.33 to 38.70)	**340 more per 1,000** (from 53 more to 1,000 more)	⨁◯◯◯ Very low	
Total doffing errors, n (%)												
1	randomised trials	serious[c]	not serious	serious[d]	serious[b]	none	6/50 (12.0%)	12/50 (24.0%)	**RR 0.42** (0.17 to 1.03)	**139 fewer per 1,000** (from 199 fewer to 7 more)	⨁◯◯◯ Very low	
Error in application of goggles during donning, n (%)												
1	randomised trials	serious[c]	not serious	serious[d]	serious[b]	none	2/50 (4.0%)	0/50 (0.0%)	**RR 5.00** (0.25 to 101.60)	**0 fewer per 1,000** (from 0 fewer to 0 fewer)	⨁◯◯◯ Very low	

Certainty assessment							№ of patients		Effect		Certainty	Importance
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	A cover for the head and neck	No cover for the head and neck	Relative (95% CI)	Absolute (95% CI)		
Failure to zip up coveralls or put hood over head during donning, n (%)												
1	randomised trials	serious[c]	not serious	serious[d]	serious[b]	none	1/50 (2.0%)	N/A	not estimable	not estimable	⨁◯◯◯ Very low	
Error in application of bouffant hair-cover during donning, n (%)												
1	randomised trials	serious[c]	not serious	serious[d]	serious[b]	none	N/A	1/50 (2.0%)	not estimable	not estimable	⨁◯◯◯ Very low	
Error in removal of face shield during doffing, n (%)												
1	randomised trials	serious[c]	not serious	serious[d]	serious[b]	none	N/A	1/50 (2.0%)	not estimable	not estimable	⨁◯◯◯ Very low	
Error in removal of hair-cover during doffing, n (%)												
1	randomised trials	serious[c]	not serious	serious[d]	serious[b]	none	N/A	2/50 (4.0%)	not estimable	not estimable	⨁◯◯◯ Very low	

CI: confidence interval; **RR:** risk ratio

Explanations

a. Downrated due to simulation study: Fluorescent contamination as a surrogate outcome for EVD/Marburg Virus Disease, other differences in evaluated PPE equipment other than just head/neck cover vs. no cover.
b. Few participants and optimal information size (OIS) threshold not met.
c. Downrated due to concerns with risk of bias. Unclear risk of bias for several domains, including allocation bias, blinding of participants, and unclear if all outcomes were reported.
d. Downrated due to simulation study: Fluorescent contamination as a surrogate outcome, other differences in evaluated PPE equipment other than just head/neck cover vs. no cover.

Contextual data

KQ5. Should health workers in direct contact and/or indirect contact to patients with Ebola or Marburg virus disease *cover head and neck skin* and mucous membranes or just cover mucous membranes?

We conducted a rapid review for KQ 5, especially updating the Hersi et al. 2015 rapid review and the Verbeek et al. 2020 systematic review with respect to cover head and neck skin. [1] [2] There is very limited data to support the choice of "*covering head and neck skin"*. The data gap related to this key question identified in the WHO recommendations in 2014 remains an issue today. [3]

Table 1 summarizes PPE recommendations related to cover head and neck skin by the WHO, US CDC and European CDC. The WHO recommends a head cover that covers the head and neck skin for HWs providing clinical care for patients with filovirus disease; the head cover is suggested to be separate from the gown or coverall, so that these may be removed separately. [3]

The US CDC recommends that either a Powered Air Purifying Respirator (PAPR) or disposable, NIOSH-certified N95 respirator should be worn in case a potentially aerosol-generating procedure needs to be performed emergently. If N95 respirators are used instead of PAPRs, use it in combination with a single-use (disposable) surgical hood extending to shoulders and a single-use (disposable) full-face shield. [4]

The European CDC recommends that a separate splash-proof hood with an integrated surgical mask offer advantages in the splash protection for the face area. If a separate hood is used, the integrated hood of the coverall needs to be folded into the inside of the coverall first. Separated hood without straps are also available, making the donning and doffing process easier. [5]

The Occupational Safety and Health Administration (OSHA) in the US recommends head/neck cover for individuals providing medical and supportive care, conducting research and clinical laboratory work, maintenance work, cleaning and disinfecting environments and handling of death bodies in area suspected or known to have Ebola contamination (Table 2). [6] The recommended PPE is an impermeable head/neck cover (eg, surgical hood). PAPR powered air-purifying respirator is recommended in these working conditions when high(er)-risk exposure(s) is present.

With respect to the extraction of contextual data, the key findings are as follows (Table 2).

- Zamora et al. 2006 conducted a prospective, randomized, controlled crossover study to compare two PPE ensembles.[7] The PPE ensemble E-RCP (enhance respiratory and contact precautions) included a head covering (without covering the neck skin), goggles and a face shield (Figure 1). The PAPR system in use had outer and inner protective layers (Figure 1). According to the results, participants wearing E-RCP were more likely to experience skin and base-clothing contamination; their contamination episodes measuring ≥1 cm2 were more frequent, and they had larger total areas of contamination (all $p < 0.0001$; Figure 2). The anterior neck, forearms, wrists and hands were the likeliest zones for contamination (Figure 2). Participants donning powered air-purifying respirator (PAPR) committed more donning procedure violations ($p = 0.0034$). Donning and removing the PAPR system took longer than donning and removing E-RCP garments ($p < 0.0001$).
- Suen et al. 2018 conducted an experimental study using a group of 59 participants who randomly performed PPE donning and doffing.[8] The study consisted of PPE donning, applying fluorescent solution on the PPE surface, PPE doffing of participants, and estimation of the degree of contamination as indicated by the number of fluorescent stains on the working clothes and environment. They monitored protocol deviations during PPE donning and doffing. They tested three PPE ensembles: PPE1 consists of a neck-to-ankle outfit, N95 respirator, **hood,** disposable face shield,

surgical gown, boots and double gloves. PPE2 consists of a *head-to-ankle* coverall, N95 respirator, hood, disposable face shield, boots and double gloves. PPE3 consists of neck-to-ankle outfit, N95 respirator, **no hood**, disposable face shield, isolation gown, shoes and single latex gloves. Everything else being equal, PPE1 differed from PPE3 with respect to hood (PPE1) vs no hood (PPE3), double gloves (PPE1) vs single gloves (PPE3), and boots (PPE1) vs shoes (PPE3). During doffing of the PPE, PPE1 was less contaminated in regions purportedly protected by the hood, including hair, head and neck than PPE3 (Figure 1). The results seemed to support covering the head and neck skin.

- Coca et al. 2015 conducted a simulation study using a thermal manikin to assess the time to achievement of a critical core temperature of 39°C while wearing 4 different PPE ensembles similar to those recommended by the World Health Organization and Médecins Sans Frontières at 2 different ambient conditions: temperature/humidity of 32°C/92% relative to 26°C/80%).[9] The results suggest that encapsulation of the head and neck region resulted in higher model-predicted subjective impressions of heat sensation.
- Coca et al. 2017 conducted a simulation study with six healthy individuals in an environmental chamber (32°C, 92% relative humidity) while walking (3 Metabolic equivalent of tasks, 2.5 mph, 0% incline) on a treadmill for 60 minutes.[10] All subjects wore medical scrubs and PPE items. Ensemble E1 had a face shield, **no hood**, and fluid-resistant surgical gown; E2 additionally included goggles, coverall, and separate **hood**; and E3 also contained a highly impermeable coverall, separate **hood**, and surgical mask cover over the N95 respirator. They showed that heart rate and core temperature at the end of the exercise were significantly higher for E2 and E3 than for E1. Subjective perceptions of heat and exertion were significantly higher for E2 and E3 than for E1.
- Boon et al. 2014 conducted a survey of frontline physicians' and nurses' perspectives about PPE use during the 2014-2016 EVD outbreak in West Africa.[11] The aim was to incorporate these findings into the development process of a WHO rapid advice guideline. They surveyed 44 frontline physicians and nurses deployed to West Africa between March and September of 2014. They report that heat and dehydration were a major issue for 64% of the surveyees using a hood. In terms of preferences, a hood was perceived as pausing extremely low risk or low risk in term of safety by 93% (38/41) of surveyees, none or minor impairment in term of communication by 58% (18/42), no reduction or minor reduction in term of the ability to provide patient care by 60% (18/30), no issues or minor issues in term of personal wellbeing (heat or dehydration) by 13% (4/30), and comfortable or fairly comfortable by 53% (16/30).
- Grélot et al. 2016 assessed thermal strain of 25 HWs in the 2014 Ebola virus disease outbreak. [12] The PPE was used in accordance with the World Health Organization regulations. Its ensemble was comprised of waterproof garments from head to toe (DuPont Tychem), European standard EN 143–approved class 2 respirators (3M Company), 2-layered gloves, **surgical hoods** covering the head and neck, leg-covering waterproof boot covers, and waterproof aprons covering the torso to the level of the mid-calf. They report a mean (standard deviation) working ambient temperature of 29.6°C (2.0°C) and a mean relative humidity of 65.4% (10.3%), a mean time wearing PPE of 65.7 (13.5) minutes, and a mean core body temperature increase of 0.46°C (0.20°C). Four HCWs (16%, 4/25) reached or exceeded a mean core body temperature of ≥38.5°C. The results suggest that HWs wearing PPE for approximately 1 hour exhibited moderate but safe thermal strain.
- Sprecher et al. 2015 report on a meeting convened by Médecins Sans Frontières in 2014 to address concerns with PPE. [13] Meeting participants included representatives from the CDC Viral Special Pathogens Branch, the World Health Organization, the National Institutes of Health's Integrated Research Facilities at Frederick, Maryland and Rocky Mountain Laboratories at Hamilton, Montana the Galveston National Laboratory, the Public Health Agency of Canada's Special Pathogens Unit, the PPE divisions of DuPont, 3M, and Microgard, and the CDC National Institute for Occupational

Safety and Health. According to the meeting deliberation, *polyethylene fabric hoods* that fully covered the head and neck became favored over surgical head covering. The meeting attendants called for better evidence in the selection of PPE's.

Figure 1. Equipment list and pictures for the 2 protective-clothing systems compared in Zamora et al. 2006 (use without permission) [14]

System			
E-RCP	PAPR	Item	Manufacturer (location)
	√	Tyvek hood	3M (St. Paul, Minn.)
√	√	Bouffant hair cover	Prime Line Medical Products (Edmonton, Alta.)
√	√	Economy impact goggle	Spartan (Taiwan)
	√	Air-mate breathing tube	3M (Berkshire, United Kingdom)
√		Face shield	Splash Shield (Uniontown, Penn.)
	√	HEPA filter unit	3M (St. Paul, Minn.)
√	√	N95 mask — any of several models:	
		8210	3M (St. Paul)
		1860s	3M (St. Paul)
		PFR95	Kimberly-Clark (Roswell, Geo.)
		7210	Northern Safety (Frankfort, NY)
		695	Alpha Protech (North Salt Lake, Utah)
		Gloves	
√	√	Nonlatex	SensiCare (Caledonia, Mich.)
	√	Latex surgical	MicroTouch (Dothan, Ala.)
√	√	Latex	AMD (Lachine, Que.)
	√	Tyvek coveralls with hood	Lakeland Industries (Decatur, Ala.)
	√	Tyvek boot covers	Lakeland Industries (Decatur)
√	√	Astound impervious surgical gown	Cardinal Health (McGraw Park, Ill.)

Note: E-RCP = enhanced respiratory and contact precautions, PAPR = powered air-purifying respirator, HEPA = high-efficiency particulate air.

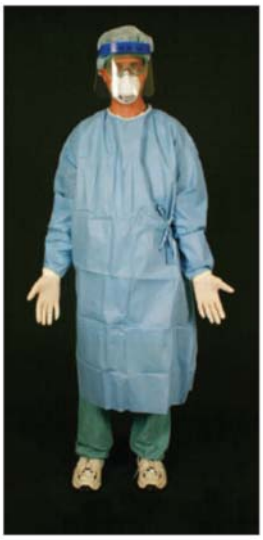

Fig. 1: Enhanced respiratory and contact precautions (E-RCP), familiar to most health care workers. The towel used for neck protection was omitted for illustrative purposes.

Fig. 2: The other system studied, named for its powered air-purifying respirator (PAPR), has 2 protective layers, shown above. The outer layer (left panel) consists of a hood, fluid-resistant surgical gown, shoe covers and 2 pairs of fitted surgical gloves. The inner (right) includes a hooded coverall and shoe covers, PAPR power unit, N95 mask, goggles, bouffant hair cover, and 1 pair of fitted surgical gloves. Contamination assessment for this layer was performed with the PAPR power unit and fitted surgical gloves removed. The towel worn to protect the neck has been omitted for illustrative purposes.

Figure 2. Contamination data for skin and the base layer of clothing worn under the PAPR and E-RCP personal protective systems (use without permission from Zamora et al. 2006) [14]

Location	Contamination, PAPR system			Contamination, E-RCP			*p*, Mainland-Gart test*		*p* value, WMW test‡
	Any *n* (%)	≥ 1 cm^2 *n* (%)	Area, cm^2 mean *n* (SD)	Any *n* (%)	≥ 1 cm^2 *n* (%)	Area, cm^2 mean *n* (SD)	Actual areas	Areas ≥ 1 cm^2†	
Face	0	0	NA	2 (4)	1 (2)	1.1 (0.6)	1	1*	Und.
Back of head	0	0	NA	0	0	NA	Und.	Und.	Und.
Anterior neck	3 (6)	2 (4)	1.5 (0.9)	48 (96)	48 (96)	76.5 (54.4)	< 0.001	< 0.001	< 0.001
Posterior neck	1 (2)	1 (2)	1.0	9 (18)	4 (8)	1.7 (1.9)	0.012	0.25	1
Forearms, hands or wrists	9 (18)	7 (14)	1.8 (1.8)	38 (76)	35 (70)	6.5 (7.6)	< 0.001	< 0.001	0.015
Anterior torso, anterior upper arms	0	0	NA	5 (10)	4 (8)	6.3 (6.2)	0.06*	0.13*	Und.
Back and posterior upper arms	0	0	NA	1 (2)	1 (2)	7.0	1*	1*	Und.
Anywhere below beltline	0	0	NA	1 (2)	0	0.5	1*	Und.	Und.
Total	13 (26)	10 (20)	1.7 (1.5)	48 (96)	48 (96)	82.8 (54.0)	< 0.001	< 0.001	< 0.001
Total excluding the neck	9 (18)	7 (14)	1.8 (1.8)	39 (78)	36 (72)	7.4 (8.2)	< 0.001	< 0.001	0.013

Note: E-RCP = enhanced respiratory and contact precautions, PAPR = powered air-purifying respirator, WMW = Wilcoxon-Mann-Whitney test, NA = not applicable, Und. = undefined.
*Except where McNemar's test was used, as indicated with asterisks. The Mainland-Gart test was used when contamination occurred during both periods. McNemar's test was substituted when only 1 period had any contamination. Neither test was applied when there was no contamination in either period.
†Repeat analysis, in which areas smaller than 1 cm^2 in area were counted as 0 cm.
‡The Wilcoxon-Mann-Whitney test was used to compare the area of contamination for subjects with some contamination. Since these contaminated subjects were different for each system, a test for paired data was not used.

Figure 3. Contamination during doffing of PPE (copy from Suen et al. 2018 without permission)[8]

	Small sized contaminated patches (< 1 cm ^{2}), median				Extra large sized contaminated patches (≥ 5 cm^2), median			
Location	PPE1	PPE2	PPE3	*p*-value	PPE1	PPE2	PPE3	*p*-value
Hair and head	1.00	2.00	2.50	0.68	0.00	17.00	0.00	N/A
Face	1.00	4.00	2.00	0.602	0.00	0.00	8.00	N/A
Neck (anterior)	2.50	5.00	11.00	0.095	0.00	0.00	24.00	N/A
Neck (posterior)	2.00	1.00	18.50	0.824	0.00	0.00	0.00	N/A
Arms (right)	3.50	1.00	4.00	0.414	0.00	0.00	28.00	N/A
Arms (left)	2.00	2.00	1.00	0.909	0.00	0.00	49.00	N/A
Hands or wrists	1.00	1.00	6.00	0.414	8.00	61.00	0.00	N/A
Working clothes (upper)	8.50	9.00	7.00	0.997	21.00	48.50	42.00	0.690
Working clothes (lower)	2.00	2.50	6.00	0.111	12.00	46.00	17.50	0.276
Clogs	3.00	5.00	13.50	< 0.001*	121.00	55.00	133.00	0.397
Environment (rubbish bin cover)	2.00	7.00	2.50	0.254	20.00	14.00	23.00	0.737
Environment (chair)	3.00	6.50	2.00	0.053	0.00	36.00	0.00	N/A
Faucet	2.00	2.00	1.50	0.659	0.00	16.00	14.00	N/A
Sink	12.50	14.00	10.00	0.072	75.50	66.50	44.00	0.649
Overall	5.00	7.00	7.00	0.05*	39.00	43.00	47.00	< 0.001*

*significant *p* values
N/A: There are fewer than two groups for the dependent variables, so no inferential statistics are computed using ANOVA
PPE1: Hospital Authority Standard Ebola PPE set
PPE2: DuPont™ Tyvek®, Model 1422A
PPE3: Hospital Authority isolation gown for routine patient care and performing aerosol-generating procedures

Table 1: Summary of PPE recommendations regarding head cover by WHO, US and European CDC

Source	Head cover
WHO [3]	
Recommendation 11	All health workers should wear a head cover that covers the head and neck while providing clinical care for patients with filovirus disease in order to prevent virus exposure. *Conditional recommendation. Low quality evidence for effectiveness of head cover in preventing transmission*
Recommendation 12	The head cover is suggested to be separate from the gown or coverall, so that these may be removed separately. *Conditional recommendation. Low quality evidence comparing different types of head covers*. **Rationale and remarks:** The purpose of head covers is to protect the head and neck skin and hair from virus contamination and the possibility of subsequent unrecognized transmission to the mucosae of the eyes, nose or mouth. Hair and hair extensions need to fit inside the head cover. Recommendation 11 is conditional since there is no evidence to support use of a head cover over a hood (covering the shoulders) or hair cap for preventing transmission of infection. The need for covering all skin surfaces including the back of the neck was discussed in detail during the GDG meeting. There was no consensus among the GDG: nine experts were of the opinion that all skin surfaces should be covered, three disagreed and one was absent during voting. Recommendation 12 is conditional since there was no comparative evidence of effectiveness in preventing transmission between a separate head cover and a head cover that is integrated in the coverall. When a separate head cover is not available, a coverall with hood can be worn if the hood is put on after eye, nose and mouth protection so that mucosal protection is maintained after taking off the hooded coverall.
Other recommendation	PAPR powered air-purifying respirator is recommended for aerosol generating procedures
US CDC [4]	**Respiratory Protection**: Either a Powered Air Purifying Respirator (PAPR) or disposable, NIOSH-certified N95 respirator should be worn in case a potentially aerosol-generating procedure needs to performed emergently. PAPRs with *a full-face covering and head-shroud* make accidental self-contamination during care more difficult (e.g., while adjusting eyeglasses); disposable N95 face piece respirators are less cumbersome and can be easier to doff safely. … PAPR: A hooded respirator with a full-face shield, helmet, or headpiece. Any reusable helmet or headpiece must be covered *with a single-use (disposable) hood that extends to the shoulders and fully covers the neck* and is compatible with the selected PAPR. If a hood is used over the PAPR, it must not interfere with the function of the PAPR. … N95 Respirator: Single-use (disposable) N95 respirator or higher in combination with *single-use (disposable) surgical hood extending to shoulders* and single-use (disposable) full-face shield. If N95 respirators are used instead of PAPRs, healthcare workers should be carefully observed to ensure that they do not inadvertently touch their faces under the face shield during patient care.

European CDC [5]	**Hair covers** Hair covers (surgical hoods) should be worn under the hood of the coveralls to prevent hair from hanging out, where it can be easily contaminated with bodily fluids from the patient. This also prevents the hair from sticking to the flaps and the tape. Ideally, different types of hair covers are available, so PPE users can adapt them to their personal requirements. **Separate hood** Using a separate splash-proof hood with an integrated surgical mask offers advantages in the splash protection for the face area. If a separate hood is used, the integrated hood of the coverall needs to be folded into the inside of the coverall first. Separated hood without straps are also available, making the donning and doffing process easier.

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Table 2. Summary of contextual data

Author	Year	Study methods	Method details, measures or findings relevant to the extraction of contextual data	Data type	Contextual data
Zamora [7]	2006	Prospective, randomized, controlled crossover study	The study compared two PPE ensembles. The PPE ensemble E-RCP (enhance respiratory and contact precautions) included a head covering (without covering the neck skin), goggles and a face shield (Figure 1). The PAPR system in use had outer and inner protective layers (Figure 1).	Usability	Participants wearing E-RCP were more likely to experience skin and base-clothing contamination; their contamination episodes measuring ≥1 cm2 were more frequent, and they had larger total areas of contamination (all $p < 0.0001$). The anterior neck, forearms, wrists and hands were the likeliest zones for contamination. Participants donning PAPR committed more donning procedure violations ($p = 0.0034$). Donning and removing the PAPR system took longer than donning and removing E-RCP garments ($p < 0.0001$).
Abela [15]	2015	Use WHO and ECDC guides to select PPE	During the preparedness for the admission of a potential EVD case, the infection control unit in the tertiary care hospital in Malta guided the selection process of different types of PPE supplies according the WHO and ECDC guidelines.	Acceptability	The best preferred option to be the use of PAPR rather than goggles and particulate respirator (N95), the former providing comfort and a sense of protection.
Coca [9]	2015	Simulation study using a thermal manikin	A sweating thermal manikin was used to ascertain the time to achievement of a critical core temperature of 39°C while wearing 4 different PPE ensembles similar to those recommended by the World Health Organization and Médecins Sans Frontières (Doctors Without Borders) at 2 different ambient conditions (32°C/92% relative humidity and 26°C/80% relative humidity) compared with a control ensemble.	Usability	Encapsulation of the head and neck region resulted in higher model-predicted subjective impressions of heat sensation. To maximize work capacity and to protect health care workers in the challenging ambient conditions of West Africa, consideration should be given to adjustment of work and rest schedules, improvement of PPE (e.g., using less impermeable and more breathable fabrics that provide the same protection), and the possible use of cooling devices worn simultaneously with PPE.
Coca	2015	Simulation study using a thermal manikin		Usability	PPE ensemble similar to the E4 PPE studied here are currently in use by Medicine Sans Frontiers health care personnel in Ebola-affected countries of West Africa. The results of the present study indicate that use of this ensemble results in significant heat stress after 1 hour of use (80 minutes) in a "near worst case" ambient environment scenario (32°C, 92% relative humidity) at a typical HW work rate. The results also suggests that the encapsulation of the head and neck by the cape/hood and goggles has a greater impact on subjective perceptions of heat, but this supposition would require human trials to verify.
Coca[10]	2017	Simulation study with healthy individuals	Six healthy individuals were tested in an environmental chamber (32°C, 92% relative humidity) while walking (3 Metabolic equivalent of tasks, 2.5 mph, 0% incline) on a treadmill for 60 minutes. All subjects wore medical scrubs and PPE items. E1 also had a face shield and fluid-resistant surgical gown; E2 additionally included goggles, coverall, and separate hood; and E3 also contained a highly impermeable coverall, separate hood, and surgical mask cover over the N95 respirator.	Usability	Results: Heart rate and core temperature at the end of the exercise were significantly higher for E2 and E3 than for E1. Subjective perceptions of heat and exertion were significantly higher for E2 and E3 than for E1. Conclusions: Heat stress and PPE training, as well as the implementation of a work-to-rest ratio that avoids dehydration and possible heat stress issues, are recommended.
Suen [8]	2018	An experimental study of one group using multiple comparisons	A total of 59 participants randomly performed PPE donning and doffing. The trial consisted of PPE donning, applying fluorescent solution on the PPE surface, PPE doffing of participants, and estimation of the degree of contamination as indicated by the number of fluorescent stains on the working clothes and environment. Protocol deviations during PPE donning and doffing were monitored. PPE1 consists of a neck-to-ankle outfit, N95 respirator, hood, disposable face shield, surgical gown, boots and double gloves. PPE2 consists of a head-to-ankle coverall, N95 respirator, hood, disposable face shield, boots and double gloves. PPE3 consists of neck-to-ankle outfit, N95 respirator, no hood, disposable face shield, isolation gown, shoes and single latex gloves.	Usability	Results: PPE2 and PPE3 presented higher contamination risks than PPE1. Environmental contaminations such as those originating from rubbish bin covers, chairs, faucets, and sinks were detected. Procedure deviations were observed during PPE donning and doffing, with PPE1 presenting the lowest overall deviation rate (%) among the three PPE ensembles ($p < 0.05$). **Everything else being equal, PPE1 differed from PPE3 with respect to hood (PPE1) vs no hood (PPE3), double gloves (PPE1) vs single gloves (PPE3), and boots (PPE1) vs shoes (PPE3). PPE1 was less contaminated in the hair, head and neck than PPE1 (Figure 1). The results seemed to support covering the head and neck skin.**
Brown [6]	2019	Guidelines development	Development of an Occupational Safety and Health Administration (OSHA) EBV PPE selection matrix during the response to the West Africa epidemic and resulting US cases	Implementation	OSHA recommends head/neck cover for individuals providing medical and supportive care, conducting research and clinical laboratory work, maintenance work, cleaning and disinfecting environments and handling of death bodies in area suspected or known to have Ebola contamination.

					The recommended PPE is an impermeable head/neck cover (eg, surgical hood). PAPR powered air-purifying respirator is recommended in these working conditions, especially when high(er)-risk exposure(s) is present.
Boon [11]	2014	Survey	To understand frontline physicians' and nurses' perspectives about personal protective equipment (PPE) use during the 2014-2016 EVD outbreak in West Africa and to incorporate these findings into the development process of a WHO rapid advice guideline. Survey 44 frontline physicians and nurses deployed to West Africa between March and September of 2014.	Implementation	Heat and dehydration were a major issue for 64% using a hood and for 76% of the participants using goggles. Both gowns and coveralls were associated with significant heat stress and dehydration. In terms of HW preferences, a hood was perceived as pausing extremely low risk or low risk in terms of safety by 93% (38/41 of surveyees), none or minor impairment in communication by 58% (18/42), no reduction or minor reduction in ability to provide patient care by 60% (18/30), no issues or minor issues in term of personal wellbeing (heat or dehydration) by 13% (4/30), and comfortable or fairly comfortable by 53% (16/30).
Grélot [12]	2016	Thermal strain monitor of 25 HWs in 2014 Ebola Virus Disease Outbreak	The PPE was used in accordance with the World Health Organization regulations [4]. It comprised waterproof garments from head to toe (DuPont Tychem), European standard EN 143–approved class 2 respirators (3M Company), 2-layered gloves, surgical hoods covering the head and neck, leg-covering waterproof boot covers, and waterproof aprons covering the torso to the level of the midcalf.	Implementation	The mean (standard deviation) working ambient temperature and relative humidity were 29.6°C (2.0°C) and 65.4% (10.3%), respectively; the mean time wearing PPE was 65.7 (13.5) minutes; and themean core body temperature increased by 0.46°C (0.20°C). Four HCWs (16%, 4/25) reached or exceeded a mean core body temperature of ≥38.5°C. HCWs wearing PPE for approximately 1 hour exhibited moderate but safe thermal strain.
Sprecher [13]	2015	Meeting report	The article is titled "Personal Protective Equipment for Filovirus Epidemics: A Call for Better Evidence". To try to address concerns with PPE, Médecins Sans Frontières convened a meeting on 3 April 2014, at the Galveston National Laboratory in Galveston, Texas. Representatives were present from the CDC Viral Special Pathogens Branch, the World Health Organization, the National Institutes of Health's Integrated Research Facilities at Frederick, Maryland and Rocky Mountain Laboratories at Hamilton, Montana the Galveston National Laboratory, the Public Health Agency of Canada's Special Pathogens Unit, the PPE divisions ofDuPont, 3M, and Microgard, and the CDC National Institute for Occupational Safety and Health. This meeting brought together, for the first time, experts in the virology of filoviruses, worker protection and protective equipment, epidemiologists, and outbreak response agencies. Their deliberations are summarized.	Implementation	In subsequent outbreaks coveralls were added, as wearers sought more complete coverage. The garments became more resistant, changing from the material used in surgical gowns to uncoated polyethylene fabric and then to coated polyethylene. Polyethylene fabric hoods that fully covered the head and neck became favored over surgical head covering. Surgical masks were abandoned in favor of masks that did not lie flat against the face.Most of these changes were made because of the presumption of increased security, but there was no empiric basis for the changes other than that granted by the EN 14126 certification [2] of the coated polyethylene material.
Roberts [16]	2014	Review by a single expert	The present review discusses the advantages and disadvantages of using a PAPR versus an N95 mask, and relates the experience of the Jewish General Hospital (Montreal, Quebec) of PAPR policy implementation.	Usability	The use of HEPA filters in PAPRs implies that they have a greater level of respiratory protection than N95 masks. They also have the advantage of providing head and neck protection, do not require fit testing because of a full hood, are approved for use with facial hair and allow for continuous bedside care of a patient. Their disadvantages include difficulties in communicating due to their bulk and noise, the inability to use a stethoscope and a requirement for electricity (batteries) to ensure proper airflow rates into the hood.

Infection prevention and control measures for Ebola and Marburg Virus disease: A series of rapid reviews

KQ6 Eye Protection and Head/Neck Covering- Initial Summary

(Version 1, 20 June 2022)

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Funding: Funding for this protocol and the subsequent reviews was provided by the World Health Organization (Funding # 202818287). The working group (WG) from the WHO/HQ Country Readiness Strengthening Health Care Readiness Unit will be consulted to develop and refine the scope, and review and approve the protocol. The WG will not be involved in the conduct of the review including selection of studies and data analysis but will advise as needed on priority population(s), interventions, and outcomes in an iterative process during the review process based on the available evidence. The WG will also comment on the draft report and provide input on interpretations of findings. AT is funded by a Tier 2 Canada Research Chair in Knowledge Synthesis. SM is funded by a Tier 2 Canada Research Chair in Mathematical Modeling and Program Science.

Competing interests: DM was involved in the 2015 rapid review by Hersi et al. [1] There are no other competing interests to acknowledge.

Acknowledgements: We thank Kaitryn Campbell, MLIS, MSc (St. Joseph's Healthcare Hamilton/McMaster University) for peer review of the Embase search strategy.

Key Question

KQ6: Should health workers providing direct care or indirect care to patients with Ebola or Virus Marburg disease and using eye protection (goggles /face shield) wear them under versus over the head and neck covering?

Methods Summary

This is one of a series of rapid reviews answering 12 key questions related to three themes on infection prevention and control measures for filoviruses: (i) transmission/exposure (n=3 questions), (ii) personal protective equipment (PPE) (n=5), and (iii) decontamination and disinfection (n=4). Data sources include Medline, Embase, bio/medRxiv pre-print servers, Global Medicus Index, Epistemonikos, China National Knowledge Infrastructure (CNKI) and Wangfang database. We used an automation tool (CAL® tool) for titles/abstracts screening for relevant systematic reviews and primary comparative studies. Full-text screening, data extraction, risk of bias assessment, and GRADE (Grading of Recommendations Assessment, Development and Evaluation) for the certainty of evidence were completed independently by two reviewers with any disagreements resolved by consensus, with arbitration by a third reviewer, when needed.

Initial findings

We present study characteristics in Table 1 and a summary of findings in Table 2 and 3.

Initially, 122 studies were screened in the CAL tool software and 33 studies were included for full-text screening. Two studies met the eligibility criteria and were included (Appendix 2). A list of excluded studies with reasons for exclusion can be found in Appendix 1.

No studies provided direct information on the transmission or incidence of Ebola virus disease (EVD) or Marburg virus disease related to the order in which eye protection and head/neck covering was worn. We included two crossover randomized controlled trials that simulated contamination events for health care workers (HCWs). Contamination was recorded during the donning/doffing of Ebola personal protective equipment (PPE) ensembles with differing equipment and orders in which the eye protection (face shields) and head/neck covering (hoods) was worn. Deviation rates from the donning/doffing protocols were also noted.

Table 1. Characteristics of Included Studies

Citation [Author, Year]	Study Design	Funding Source	Virus Species	Setting	# Total Health Workers	# Health Care Facilities	Description of Health Worker Care/contact with patients	Study Objectives [as reported by study authors]
Chughtai, 2018, [1]	Crossover randomized controlled trial (simulation study)	Public university funded	Fluorescent solution[a] on the PPE surface to simulate Ebola virus	Healthcare simulation room	10 participants (5 staff and 5 students from University of New South Wales)	N/A; one simulation room	Fluorescent lotion applied on external PPE to simulate contamination and sprayed (1 metre) to mimic droplet infection	The aim of this study was to quantify and describe the risk of self-contamination associated with doffing in different PPE protocols.
Suen, 2018, [2]	Crossover randomized controlled trial (simulation study)	Public university funded	Fluorescent solution[b] on the PPE surface to simulate Ebola virus	Air-conditioned room with an average temperature of 23 °C ± 2 °C and a relative humidity of 60% ± 3%	59 HCWs	N/A; one air-conditioned room	Fluorescent solution sprayed on PPE at the length of a stethoscope to simulate usual working distance between a patient and an HCW[c]; contamination events	Compare the efficacy of three PPE ensembles for routine patient care and performing aerosol-generating procedures to prevent EVD transmission by measuring the degree of

							monitored during doffing	contamination of HCWs and the environment.

Abbreviations: HCW, health care workers, PPE, personal protective equipment

a. GlitterBug. Glitterbug kits. Available from: https://glitterbug.net.au/products/
b. UV GERM Hygiene Spray, Glow Tec Ltd., London, England
c. Three strokes of fluorescent solution were sprayed onto the face shield, two upper limb/ gloves and anterior surfaces of the gown at a distance of 60 cm from the participants (total 12 strokes per case). There was an average of 1.99 g fluorescent solution/per stroke.

Table 2. Summary of Findings: Contamination during doffing of PPE

Study details	***Intervention*** (Wearing (goggles /face shield) under the head/neck covering)	***Comparator(s)*** (Wearing eye protection (goggles/face shield) over the head /neck covering)	***Outcome in intervention group***	***Outcome in control group***	***Quality Assessment***[a]	***GRADE***	***Notes***
Number of participants (n/N, %) with small fluorescent patches after various personal protective equipment (PPE) protocols							
Chughtai, 2018, [1]	WHO, coverall and N95[b]	CDC, coverall and PAPR[c]	0/3	0/3	Some risk	⊕◯◯◯ Very low	The hood used in the WHO (coverall, N95) protocol is donned after the face shield. In all other doffing sequences, the face shield is donned after the hood and removed first.
		CDC, coverall and N95[d]		1/3 (33%)			
		ECDC, coverall and N95[e]		0/3			
		Health Canada, gown and N95[f]		1/3 (33%)			
		NC, coverall and N95[g]		0/3			
		NSW DoH CEC, gown and PAPR[h]		0/3			
		NSW DoH CEC, gown and N95[i]		0/3			
		MSF, coverall and N95[j]		0/3			
		WHO, gown and N95[k]		0/3			
Number of participants (n/N, %) with large fluorescent patches after various personal protective equipment (PPE) protocols							
Chughtai, 2018, [1]	WHO, coverall and N95[b]	CDC, coverall and PAPR[c]	1/3 (33%)	0/3	Some risk	⊕◯◯◯ Very low	The hood used in the WHO (coverall, N95) protocol is donned after the face shield. In all other doffing sequences, the face shield is
		CDC, coverall and N95[d]		0/3			
		ECDC, coverall and N95[e]		0/3			
		Health Canada, gown and N95[f]		0/3			
		NC, coverall and N95[g]		1/3 (33%)			

Study details	***Intervention*** (Wearing (goggles /face shield) under the head/neck covering)	***Comparator(s)*** (Wearing eye protection (goggles/face shield) over the head /neck covering)	***Outcome in intervention group***	***Outcome in control group***	***Quality Assessment[a]***	***GRADE***	***Notes***
		NSW DoH CEC, gown and PAPR[h]		0/3			donned after the hood and removed first.
		NSW DoH CEC, gown and N95[i]		0/3			
		MSF, coverall and N95[j]		0/3			
		WHO, gown and N95[k]		0/3			
Overall contamination during doffing of PPE: Small sized contaminated patches (< 1 cm^2), median							
Suen, 2018, [3]	PPE2[l] - DuPont™ Tyvek®, Model 1422A	PPE1[m] - Hospital Authority Standard Ebola PPE set	7.00	5.00	Low risk of bias	⊕⊕◯◯ Low	None
Hair and head contamination during doffing of PPE: Small sized contaminated patches (< 1 cm^2), median							
Suen, 2018, [3]	PPE2[l] - DuPont™ Tyvek®, Model 1422A	PPE1[m] - Hospital Authority Standard Ebola PPE set	2.00	1.00	Low risk of bias	⊕⊕◯◯ Low	None
Neck (anterior) contamination during doffing of PPE: Small sized contaminated patches (< 1 cm^2), median							
Suen, 2018, [3]	PPE2[l] - DuPont™ Tyvek®, Model 1422A	PPE1[m] - Hospital Authority Standard Ebola PPE set	5.00	2.50	Low risk of bias	⊕⊕◯◯ Low	None
Neck (posterior) contamination during doffing of PPE: Small sized contaminated patches (< 1 cm^2), median							
Suen, 2018,	PPE2[l] - DuPont™ Tyvek®,	PPE1[m] - Hospital Authority Standard Ebola PPE set	1.00	2.00	Low risk of bias	⊕⊕◯◯ Low	None

Study details	***Intervention*** (Wearing (goggles /face shield) under the head/neck covering)	***Comparator(s)*** (Wearing eye protection (goggles/face shield) over the head /neck covering)	***Outcome in intervention group***	***Outcome in control group***	***Quality Assessment[a]***	***GRADE***	***Notes***
[3]	Model 1422A						
Overall contamination during doffing of PPE: Extra large sized contaminated patches (≥ 5cm^2), median							
Suen, 2018, [3]	PPE2[l] - DuPont™ Tyvek®, Model 1422A	PPE1[m] - Hospital Authority Standard Ebola PPE set	43.00	39.00	Low risk of bias	⊕⊕◯◯ Low	None
Hair and head contamination during doffing of PPE: Extra large sized contaminated patches (≥ 5cm^2), median							
Suen, 2018, [3]	PPE2[l] - DuPont™ Tyvek®, Model 1422A	PPE1[m] - Hospital Authority Standard Ebola PPE set	17.00	0.00	Low risk of bias	⊕⊕◯◯ Low	None
Neck (anterior) contamination during doffing of PPE: Extra large sized contaminated patches (≥ 5cm^2), median							
Suen, 2018, [3]	PPE2[l] - DuPont™ Tyvek®, Model 1422A	PPE1[m] - Hospital Authority Standard Ebola PPE set	0.00	0.00	Low risk of bias	⊕⊕◯◯ Low	None
Neck (posterior) contamination during doffing of PPE: Extra large sized contaminated patches (≥ 5cm^2), median							
Suen, 2018, [3]	PPE2[l] - DuPont™ Tyvek®, Model 1422A	PPE1[m] - Hospital Authority Standard Ebola PPE set	0.00	0.00	Low risk of bias	⊕⊕◯◯ Low	None

a. Quality assessment of studies was completed using the Cochrane RoB 2 for randomized trials.

b. Word Health Organization (WHO) recommended protocol from 2014 rapid advice guideline (with coverall). This protocol is different than the others, as it recommends wearing the face shield before the hood and removing the hood before the face shield. Other notable differences in this personal protective equipment (PPE) donning/ doffing protocol tested include: using coveralls/face shields, trained observer only for doffing instructions.
c. Centers for Disease Control and Prevention (CDC), coverall and PAPR. Notable differences in this personal protective equipment (PPE) donning/ doffing protocol tested include: using coveralls/face shields, trained observer with partial assisted doffing.
d. Centers for Disease Control and Prevention (CDC), coverall and N95. Notable differences in this personal protective equipment (PPE) donning/ doffing protocol tested include: using coveralls/face shields, trained observer with partial assisted doffing.
e. European Centre for Disease Prevention and Control (ECDC), coverall and N95. Notable differences in this personal protective equipment (PPE) donning/ doffing protocol tested include: using coveralls/face shields, assisted doffing by active assistant.
f. Health Canada, gown and N95. Notable differences in this personal protective equipment (PPE) donning/ doffing protocol tested include: using gowns, face shields, removing gown/coverall before face shield, trained observer with partial assisted doffing.
g. North Carolina (NC), coverall and N95. Notable differences in this personal protective equipment (PPE) donning/ doffing protocol tested include: using coveralls/face shields, removing outer gloves before apron, removing gown/coverall before face shield, trained observer only for doffing instructions.
h. New South Wales (NSW), Clinical Excellence Commission (CEC), gown and PAPR. Notable differences in this personal protective equipment (PPE) donning/ doffing protocol tested include: using gowns/face shields, removing shoe covers after apron and before all other PPE, trained observer only for doffing instructions.
i. New South Wales (NSW), Clinical Excellence Commission (CEC), gown and N95. Notable differences in this personal protective equipment (PPE) donning/ doffing protocol tested include: using gowns/face shields, removing shoe covers after apron and before all other PPE, trained observer only for doffing instructions.
j. Médecins Sans Frontières (MSF), coverall and N95. Notable differences in this personal protective equipment (PPE) donning/ doffing protocol tested include: using coveralls/face shields/goggles, removing outer gloves before apron, trained observer only for doffing instructions.
k. Word Health Organization (WHO) recommended protocol from 2014 rapid advice guideline (with gown): Notable differences in this personal protective equipment (PPE) donning/ doffing protocol tested include: using gowns/face shields, trained observer only for doffing instructions.
l. DuPont™ Tyvek®, Model 1422A (PPE2): head-to-ankle overall with a zipper on the front. The whole outfit includes double gloves, boots, disposable face shield and an N95 respirator. A plastic apron was used to cover up the front zipper before use. Order of doffing: apron, hood, coverall/outer gloves, face shield, N95 respirator, boots, inner gloves.

m. Hospital Authority Standard Ebola PPE set (PPE 1): a neck-to-ankle overall with an overlying water-resistant gown double and long nitrate gloves, boots, hood, disposable face shield and N95 respirator. Order of doffing: gloves, gown, boots, hood, N95.

Table 3. Summary of Findings: Human factors: Deviation rate (%) during donning and doffing of personal protective equipment

Study details	***Intervention*** (Wearing (goggles /face shield) under the head/neck covering)	***Comparator*** (Wearing eye protection (goggles/face shield) over the head /neck covering)	***Outcome in intervention group***	***Outcome in control group***	***Quality Assessment[a]***	***GRADE***	***Notes***
Overall deviation rate (%) during donning of PPE							
Suen, 2018, [3]	PPE2[b] - DuPont™ Tyvek®, Model 1422A	PPE1[c] - Hospital Authority Standard Ebola PPE set	6.00	6.06	Low risk of bias	⊕⊕◯◯ Low	None
Deviation rate (%) during donning of hood							
Suen, 2018, [3]	PPE2[b] - DuPont™ Tyvek®, Model 1422A	PPE1[c] - Hospital Authority Standard Ebola PPE set	3.33	20.00	Low risk of bias	⊕⊕◯◯ Low	None
Deviation rate (%) during donning of faceshield							
Suen, 2018, [3]	PPE2[b] - DuPont™ Tyvek®, Model 1422A	PPE1[c] - Hospital Authority Standard Ebola PPE set	15.00	11.67	Low risk of bias	⊕⊕◯◯ Low	None
Overall deviation rate (%) during doffing of PPE							
Suen, 2018, [3]	PPE2[b] - DuPont™ Tyvek®, Model 1422A	PPE1[c] - Hospital Authority Standard Ebola PPE set	9.48	2.95	Low risk of bias	⊕⊕◯◯ Low	None
Deviation rate (%) during doffing of hood							
Suen, 2018, [3]	PPE2[b] - DuPont™ Tyvek®, Model 1422A	PPE1[c] - Hospital Authority Standard Ebola PPE set	8.33	5.00	Low risk of bias	⊕⊕◯◯ Low	None
Deviation rate (%) during doffing of faceshield							

Study details	***Intervention*** (Wearing (goggles /face shield) under the head/neck covering)	***Comparator*** (Wearing eye protection (goggles/face shield) over the head /neck covering)	***Outcome in intervention group***	***Outcome in control group***	***Quality Assessment[a]***	***GRADE***	***Notes***
Suen, 2018, [3]	PPE2[b] - DuPont™ Tyvek®, Model 1422A	PPE1[c] - Hospital Authority Standard Ebola PPE set	11.67	6.67	Low risk of bias	⊕⊕◯◯ Low	None

a. Quality assessment of studies was completed using the Cochrane RoB 2 for randomized trials.

b. DuPont™ Tyvek®, Model 1422A (PPE2): head-to-ankle overall with a zipper on the front. The whole outfit includes double gloves, boots, disposable face shield and an N95 respirator. A plastic apron was used to cover up the front zipper before use. Order of doffing: apron, hood, coverall/outer gloves, face shield, N95 respirator, boots, inner gloves

c. Hospital Authority Standard Ebola PPE set (PPE 1): a neck-to-ankle overall with an overlying water-resistant gown double and long nitrate gloves, boots, hood, disposable face shield and N95 respirator. Order of doffing: gloves, gown, boots, hood, N95

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2. Suen LKP, Guo YP, Tong DWK, et al. Self-contamination during doffing of personal protective equipment by healthcare workers to prevent Ebola transmission. *Antimicrob Resist Infect Control.* 2018;7(1):157. doi:10.1186/s13756-018-0433-y

Appendix 1. Excluded Studies List – By Reason for Exclusion:

Intervention not of interest

Andonian J, Kazi S, Therkorn J, et al. Effect of an Intervention Package and Teamwork Training to Prevent Healthcare Personnel Self-contamination During Personal Protective Equipment Doffing. *Clinical Infectious Diseases*. 2019;69(Supplement_3):S248-S255. doi:10.1093/cid/ciz618

Bell T, Smoot J, Patterson J, Smalligan R, Jordan R. Ebola virus disease: The use of fluorescents as markers of contamination for personal protective equipment. *IDCases*. 2015;2(1):27-30. doi:10.1016/j.idcr.2014.12.003

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Cummings KJ, Choi MJ, Esswein EJ, et al. Addressing Infection Prevention and Control in the First U.S. Community Hospital to Care for Patients With Ebola Virus Disease: Context for National Recommendations and Future Strategies. *Ann Intern Med*. 2016;165(1):41. doi:10.7326/M15-2944

Ho L, Ratnayake R, Brown H, et al. Precious. Lifesaving but not without problems; a mixed-methods study examining barriers and facilitators to infection prevention and control in health facilities during the ebola virus disease epidemic in Sierra Leone. Published online 2015.

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Lee M a, Huh K, Jeong J, et al. Adherence to Protocols by Healthcare Workers and Self-Contamination During Doffing of Personal Protective Equipment. *American Journal of Infection Control*. 2018;46(6):S11. doi:10.1016/j.ajic.2018.04.024

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No relevant comparisons

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Coca A, Quinn T, Kim JH, et al. Physiological Evaluation of Personal Protective Ensembles Recommended for Use in West Africa. *Disaster med public health prep*. 2017;11(5):580-586. doi:10.1017/dmp.2017.13

Dan-Nwafor CC, Ipadeola O, Smout E, et al. A cluster of nosocomial Lassa fever cases in a tertiary health facility in Nigeria: Description and lessons learned, 2018. *International Journal of Infectious Diseases*. 2019;83:88-94. doi:10.1016/j.ijid.2019.03.030

Fischer WA, Weber DJ, Wohl DA. Personal Protective Equipment: Protecting Health Care Providers in an Ebola Outbreak. *Clinical Therapeutics*. 2015;37(11):2402-2410. doi:10.1016/j.clinthera.2015.07.007

Hall S, Poller B, Bailey C, et al. Use of ultraviolet-fluorescence-based simulation in evaluation of personal protective equipment worn for first assessment and care of a patient with suspected high-consequence infectious disease. *Journal of Hospital Infection*. 2018;99(2):218-228. doi:10.1016/j.jhin.2018.01.002

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Ratnayake R, Ho LS, Ansumana R, et al. Improving Ebola infection prevention and control in primary healthcare facilities in Sierra Leone: a single-group pretest post-test, mixed-methods study. *BMJ Glob Health*. 2016;1(4):e000103. doi:10.1136/bmjgh-2016-000103

Ukwenya VO, Fuwape TA, Fadahunsi TI, Ilesanmi OS. Disparities in knowledge, attitude, and practices of infection prevention and control of lassa fever among health care workers at The Federal Medical Centre, Owo, Ondo State, Nigeria. *Pan Afr Med J*. 2021;38. doi:10.11604/pamj.2021.38.357.26208

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Appendix 2. Eligibility Criteria

Question (6): Should health workers providing direct care or indirect care to patients with Ebola or Virus Marburg disease and using eye protection (goggles /face shield) wear them under versus over the head and neck covering?

Setting	Health care facilities, ETU, community (e.g., burial teams)
Population	Health workers in health care facilities, ETU and community
Background interventions (Standard of care)	Wearing eye protection (goggles /face shield) and head & neck covering.
Intervention	Wearing (goggles /face shield) under the head/neck covering,
Comparator(s)	Wearing eye protection (goggles/face shield) over the head /neck covering
Outcome	Infection with Ebola or Marburg, PPE breaches (exposures), *comfort, visibility and communication, human factors* **Indirect evidence:** Lassa fever
Potential effect modifiers	PPE design Doffing procedure employed during doffing PPE supply (goggles versus face shields) *Spaying vs. not spraying, vaccination*

Appendix 3. GRADE Assessment: Contamination during doffing of PPE

Certainty assessment							№ of patients		Effect		Certainty	Importance
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Intervention (Wearing (goggles /face shield) under the head/neck covering)	Comparator (Wearing eye protection (goggles/face shield) over the head /neck covering)	Relative (95% CI)	Absolute (95% CI)		
Number of participants (n/N, %) with small fluorescent patches after various personal protective equipment (PPE) protocols												
1	randomised trials	serious[a]	not serious	serious[b]	serious[c]	none	3	3	-	-	⨁◯◯◯ Very low	
Number of participants (n/N, %) with large fluorescent patches after various personal protective equipment (PPE) protocols												
1	randomised trials	serious[a]	not serious	serious[b]	serious[c]	none	3	3	-	-	⨁◯◯◯ Very low	
Overall contamination during doffing of PPE: Small sized contaminated patches (< 1 cm2), median												
1	randomised trials	not serious	not serious	serious[d]	serious[c]	none	59	59	-	-	⨁⨁◯◯ Low	
Hair and head contamination during doffing of PPE: Small sized contaminated patches (< 1 cm2), median												
1	randomised trials	not serious	not serious	serious[d]	serious[c]	none	59	59	-	-	⨁⨁◯◯ Low	
Neck (anterior) contamination during doffing of PPE: Small sized contaminated patches (< 1 cm2), median												
1	randomised trials	not serious	not serious	serious[d]	serious[c]	none	59	59	-	-	⨁⨁◯◯ Low	
Neck (posterior) contamination during doffing of PPE: Small sized contaminated patches (< 1 cm2), median												
1	randomised trials	not serious	not serious	serious[d]	serious[c]	none	59	59	-	-	⨁⨁◯◯ Low	
Overall contamination during doffing of PPE: Extra large sized contaminated patches (≥ 5cm2), median												
1	randomised trials	not serious	not serious	serious[d]	serious[c]	none	59	59	-	-	⨁⨁◯◯ Low	
Hair and head contamination during doffing of PPE: Extra large sized contaminated patches (≥ 5cm2), median												
1	randomised trials	not serious	not serious	serious[d]	serious[c]	none	59	59	-	-	⨁⨁◯◯ Low	
Neck (anterior) contamination during doffing of PPE: Extra large sized contaminated patches (≥ 5cm2), median												
1	randomised trials	not serious	not serious	serious[d]	serious[c]	none	59	59	-	-	⨁⨁◯◯ Low	

Certainty assessment							№ of patients		Effect		Certainty	Importance
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Intervention (Wearing (goggles /face shield) under the head/neck covering)	Comparator (Wearing eye protection (goggles/face shield) over the head /neck covering)	Relative (95% CI)	Absolute (95% CI)		
Neck (posterior) contamination during doffing of PPE: Extra large sized contaminated patches (≥ 5cm2), median												
1	randomised trials	not serious	not serious	serious[d]	serious[c]	none	59	59	-	-	⨁⨁◯◯ Low	

CI: confidence interval

Explanations

a. Chughtai et al., 2018 was rated to have a high risk of bias as there is no information on randomization, allocation concealment and blinding of participants and outcome assessors. Additionally, the domains' effect of assignment to intervention (Domain 2) and Risk of bias in the measurement of the outcome (Domain 4) were rated to have a high risk of bias.
b. Downrated due to simulation study: Fluorescent contamination as a surrogate outcome for EVD/Marburg Virus Disease, other differences in evaluated PPE equipment beyond order of face cover and hood.
c. Few participants and optimal information size (OIS) threshold not met.
d. Downrated due to simulation study: Fluorescent contamination as a surrogate outcome for EVD/Marburg Virus Disease, other differences in evaluated PPE equipment beyond order of face cover and hood.

Appendix 4. GRADE Assessment: Deviation rate (%) during donning and doffing of personal protective equipment

Certainty assessment							№ of patients		Effect		Certainty	Importance
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Intervention (Wearing (goggles /face shield) under the head/neck covering)	Comparator (Wearing eye protection (goggles/face shield) over the head /neck covering)	Relative (95% CI)	Absolute (95% CI)		
Overall deviation rate (%) during donning of PPE												
1	randomised trials	not serious	not serious	serious[a]	serious[b]	none	59	59	-	-	⨁⨁◯◯ Low	
Deviation rate (%) during donning of hood												
1	randomised trials	not serious	not serious	serious[a]	serious[b]	none	59	59	-	-	⨁⨁◯◯ Low	
Deviation rate (%) during donning of faceshield												
1	randomised trials	not serious	not serious	serious[a]	serious[b]	none	59	59	-	-	⨁⨁◯◯ Low	
Overall deviation rate (%) during donning of PPE												
1	randomised trials	not serious	not serious	serious[a]	serious[b]	none	59	59	-	-	⨁⨁◯◯ Low	
Deviation rate (%) during doffing of hood												
1	randomised trials	not serious	not serious	serious[a]	serious[b]	none	59	59	-	-	⨁⨁◯◯ Low	
Deviation rate (%) during donning of faceshield												
1	randomised trials	not serious	not serious	serious[a]	serious[b]	none	59	59	-	-	⨁⨁◯◯ Low	

CI: confidence interval

Explanations

a. Downrated due to simulation study: Fluorescent contamination as a surrogate outcome for EVD/Marburg Virus Disease, other differences in evaluated PPE equipment beyond order of face cover and hood.
b. Few participants and optimal information size (OIS) threshold not met.

Contextual data

KQ6. Should health workers providing direct care or indirect care to patients with Ebola or Marburg disease and using eye protection (goggles/face shield) wear them under versus over the *head and neck covering*?

We conducted a rapid review for KQ6, especially updating the Hersi et al. 2015 rapid review and the Verbeek et al. 2020 systematic review with respect to protocols, procedures and order for donning and doffing of eye protection PPEs and head/neck protection PPEs. [1] [2] We found very limited data to support the choice of whether HWs should wear the PPE for eye protection under or over the PPE to protect head/neck skin.

Table 1 summarizes PPE recommendations related to the order on how to don and doff PPEs for eye and head/neck protection by the WHO, US CDC and European CDC. According to the European CDC, there are different ways of putting on and removing the PPEs but there is no gold standard on how to do this. The European CDC suggests it is more important to understand the rationale behind the chosen approach for donning and doffing. The most critical aspects in the process are how to avoid secondary disease transmission to HWs involved in patient care and avoid self-contamination while doffing. [3]

The WHO recommends that PPEs to protect mucosae should be taken off as late as possible during the PPE removal process, preferably at the end, to prevent inadvertent exposure of the mucous membranes (Table 1). If a hood is used, it should be put on after eye, nose and mouth protection PPEs so that mucosal protection is maintained after taking off the hood. As such, the WHO recommends wearing a PPE for eye protection under a PPE for head/neck skin protection. [4]

In the procedures for donning PPE with a N95 respirator option, the US CDC recommends putting on a hood before putting on a face shield, wearing a PPE for eye protection over a PPE for head/neck skin protection (Table 1). [5]

In the suggested steps for donning PPEs, the European CDC recommends putting on the hood (step 7) then putting on eye protection (step 10), wearing a PPE for eye protection over a PPE for head/neck skin protection (Table 1). [3]

With respect to the extraction of contextual data, the key findings are as follows (Table 2).

- Chughtai et al. 2018 conducted a simulation study in which they tested 10 different PPE donning and doffing protocols recommended by various health organizations for Ebola. Ten participants were recruited for this study and each was randomly assigned to use three different PPE protocols. After donning of PPE, fluorescent lotion and spray were applied on the external surface of the PPE to simulate contamination, and ultraviolet light was used to count fluorescent patches on the skin after doffing.
    - Two PPE protocols were tested in which the eye-protection PPEs were worn under the head/neck protection PPEs, with 1 protocol (WHO, coverall and N95) was observed with 4 large patches (Table 3). There were no small patches observed with these two protocols.
    - Eight PPE protocols were tested in which the eye-protection PPEs were worn over the head/neck protection (Table 3). One protocol (North Carolina, coverall and N95) was observed with 1 large patch on a front forehead and 1 large patch on a front right forearm. Two PPE protocols were observed with small patches, including the "CDC, coverall and N95" with 1 small patch on the back of a right hand and the "Health Canada, gown and N95" with 1 small patch on a front forehead and 1 large patch on a front right forearm.

- Suen et al. 2018 conducted an experimental study with one group using multiple comparisons. In total, 59 participants randomly performed PPE donning and doffing (Table 2). The trial consisted of PPE donning, applying fluorescent solution on the PPE surface, PPE doffing of participants, and estimation of the degree of contamination as indicated by the number of fluorescent stains on the working clothes and environment. PPE1 consisted of a neck-to-ankle outfit, N95 respirator, hood, disposable face shield, surgical gown, boots and double gloves. PPE2 consisted of a head-to-ankle coverall, N95 respirator, hood, disposable face shield, boots and double gloves. PPE3 consisted of neck-to-ankle outfit, N95 respirator, no hood, disposable face shield, isolation gown, shoes and single latex gloves. The results relevant to KQ 6 are displayed in Figure 1.
    - With PPE1, the face shield was worn over the head cover (Figure 1). One contamination with a small patch was observed on the face with PPE1.
    - With PPE2, the face shield was worn under the hood of the coverall (Figure 1). Four contaminations with small patches were observed on the face with PPE2.
    - Neither PPE1 nor PPE2 was observed with large patches on the face (Figure 1).
- Poller et al. 2018 conducted a simulation study and consensus panel to identify a unified PPE ensemble for clinical response to possible high consequence infectious diseases (HCID) in the United Kingdom (Table 2). A simulation-based exercise was developed to assess the safety of PPE ensembles in use in the UK during first assessment of a patient with a possible HCID. A mannequin was adapted to expose volunteer HCWs to synthetic bodily fluids (vomit, sweat, diarrhea and cough), each with a different colored fluorescent tracer, invisible other than under ultraviolet (UV) light. After exposure, HCWs were examined under UV lights to locate fluorescent contamination, and were screened again after PPE doffing to detect any personal contamination. The exercise was videoed, allowing retrospective analysis of contamination events and user errors.
    - The simulation testing identified significant HCW contamination events after doffing, related to protocol failure or complications in PPE doffing. The consensus PPE ensemble were also tested in the study; it attained no contamination events. In the ensemble, a disposable full-face visor was worn over the hood.

Real-world studies to generate evidence in support of the choice of whether HWs should wear the PPE for eye protection under or over the PPE to protect head/neck skin are challenging to conduct since these studies will need to test protocols involving multiple steps, generally under highly stressful conditions for study participants. Simulation studies offer alternative designs, particularly suitable for testing these protocols. For example, see the methods section of Drew et al. 2019 for the planning and Poller et al. 2018 for a simulation platform for such studies. [6, 7]

Table 1: Summary of PPE recommendations regarding protocols, procedures and order for donning and doffing of goggles, face shield and head cover by the WHO, US and European CDC

Source	Procedures and order for donning and doffing of goggles, face shield and head cover
WHO [4]	2014
Recommendation 1	All health workers should have the mucous membranes of their eyes, mouth and nose completely covered by PPE while providing clinical care for patients with filovirus disease in order to prevent virus exposure. *Strong recommendation. High quality evidence for protecting mucous membranes compared to no protection.*
Recommendation 2	All health workers should use either a face shield or goggles while providing clinical care for patients with filovirus disease in order to prevent virus exposure. *Strong recommendation. Very low quality evidence for the comparative effectiveness of face shields and goggles for the prevention of filovirus transmission to health workers.* **Rationale and remarks** Protection of the mucous membranes of the eyes, nose and mouth is an integral part of standard and contact precautions. Contamination of mucous membranes is probably the most important mode for filovirus transmission. Hence, PPE to protect mucosae is essential. *These devices should be taken off as late as possible during the PPE removal process, preferably at the end, to prevent inadvertent exposure of the mucous membranes.* There is currently no scientific evidence comparing the effectiveness of face shields and goggles, worn with an appropriate head cover (see recommendations 11 and 12), for the prevention of filovirus transmission to health workers. Their effectiveness was considered equal and either device could be used as determined by other factors, including the personal preference of the health worker and local availability of good quality items. Face shields and goggles, however, should not to be used together.
Recommendation 11	All health workers should wear a head cover that covers the head and neck while providing clinical care for patients with filovirus disease in order to prevent virus exposure. *Conditional recommendation. Low quality evidence for effectiveness of head cover in preventing transmission*
Recommendation 12	The head cover is suggested to be separate from the gown or coverall, so that these may be removed separately. *Conditional recommendation. Low quality evidence comparing different types of head covers.* **Rationale and remarks:** The purpose of head covers is to protect the head and neck skin and hair from virus contamination and the possibility of subsequent unrecognized transmission to the mucosae of the eyes, nose or mouth. Hair and hair extensions need to fit inside the head cover. Recommendation 11 is conditional since there is no evidence to support use of a head cover over a hood (covering the shoulders) or hair cap for preventing transmission of infection. The need for covering all skin surfaces including the back

	of the neck was discussed in detail during the GDG meeting. There was no consensus among the GDG: nine experts were of the opinion that all skin surfaces should be covered, three disagreed and one was absent during voting. Recommendation 12 is conditional since there was no comparative evidence of effectiveness in preventing transmission between a separate head cover and a head cover that is integrated in the coverall. When a separate head cover is not available, a coverall with hood can be worn if *the hood is put on after eye, nose and mouth protection so that mucosal protection is maintained after taking off the hooded coverall.*
US CDC [5]	**Section 9B. Donning PPE, N95 Respirator Option** **Donning PPE, N95 Respirator Option** – This donning procedure assumes the facility has elected to use N95 respirators. 1. Engage Trained Observer 2. Remove Personal Clothing and Items 3. Inspect PPE Before Donning 4. Put on Boot Covers 5. Put on Inner Gloves 6. Put on Gown or Coverall 7. Put on N95 Respirator: Put on N95 respirator. Complete a user seal check. 8. **Put on Surgical Hood:** *Over the N95 respirator, place a surgical hood that covers all of the hair and the ears, and extends past the neck to the shoulders. Ensure that hood completely covers the ears and neck.* 9. Put on Outer Apron (if used) 10. Put on Outer Gloves 11. **Put on Face Shield:** *Put on full-face shield over the N95 respirator and surgical hood to protect the eyes, as well as front and sides of the face.* 12. Verify
European CDC [3]	**Suggested steps for donning** 1 Putting on scrubs and hair cover 2 Perform hand hygiene 3 Putting on the coverall 4 Putting on foot protection 5 Perform hand protection 6 Wear respiratory protection and perform orientation fit test 7 Putting on the hood 8 Close the zipper 9 Close adhesive flaps 10 Put on eye protection 11-14 …

Figure 1. Contamination during doffing of PPE (copy from Suen et al. 2018 without permission)[8]

	Small sized contaminated patches (< 1 cm ^{2}), median				Extra large sized contaminated patches (≥ 5 cm^2), median			
Location	PPE1	PPE2	PPE3	*p*-value	PPE1	PPE2	PPE3	*p*-value
Hair and head	1.00	2.00	2.50	0.68	0.00	17.00	0.00	N/A
Face	1.00	4.00	2.00	0.602	0.00	0.00	8.00	N/A
Neck (anterior)	2.50	5.00	11.00	0.095	0.00	0.00	24.00	N/A
Neck (posterior)	2.00	1.00	18.50	0.824	0.00	0.00	0.00	N/A
Arms (right)	3.50	1.00	4.00	0.414	0.00	0.00	28.00	N/A
Arms (left)	2.00	2.00	1.00	0.909	0.00	0.00	49.00	N/A
Hands or wrists	1.00	1.00	6.00	0.414	8.00	61.00	0.00	N/A
Working clothes (upper)	8.50	9.00	7.00	0.997	21.00	48.50	42.00	0.690
Working clothes (lower)	2.00	2.50	6.00	0.111	12.00	46.00	17.50	0.276
Clogs	3.00	5.00	13.50	< 0.001*	121.00	55.00	133.00	0.397
Environment (rubbish bin cover)	2.00	7.00	2.50	0.254	20.00	14.00	23.00	0.737
Environment (chair)	3.00	6.50	2.00	0.053	0.00	36.00	0.00	N/A
Faucet	2.00	2.00	1.50	0.659	0.00	16.00	14.00	N/A
Sink	12.50	14.00	10.00	0.072	75.50	66.50	44.00	0.649
Overall	5.00	7.00	7.00	0.05*	39.00	43.00	47.00	< 0.001*

*significant *p* values
N/A: There are fewer than two groups for the dependent variables, so no inferential statistics are computed using ANOVA
PPE1: Hospital Authority Standard Ebola PPE set
PPE2: DuPont™ Tyvek®, Model 1422A
PPE3: Hospital Authority isolation gown for routine patient care and performing aerosol-generating procedures

PPE 1

PPE 2

PPE 2

Table 2. Summary of contextual data

Author	Year	Study methods	Method details, measures or findings relevant to the extraction of contextual data	Data type	Contextual data
Chughtai [9]	2018	Simulation study	We tested 10 different PPE donning and doffing protocols, recommended by various health organizations for Ebola. Ten participants were recruited for this study and randomly assigned to use 3 different PPE protocols. After donning of PPE, fluorescent lotion and spray were applied on the external surface of the PPE to simulate contamination, and ultraviolet light was used to count fluorescent patches on the skin after doffing.	Implementation	After testing 30 PPE sequences, large fluorescent patches were recorded after using "WHO coverall and 95" and "North Carolina coverall and N95" sequences, and small patches were recorded after using "CDC coverall and N95" and "Health Canada gown and N95" sequences. In the results, two PPE protocols were tested in which the eye-protection PPEs were worn under the head/neck protection, with 1 protocol (WHO, coverall and N95) was observed with 4 large patches (no small patches were observed). Eight PPE protocols were tested in which the eye-protection PPEs were worn over the head/neck protection, with 1 protocol (North Carolina, coverall and N95) was observed with 1 large patch on a front forehead and 1 large patch on a front right forearm. Two PPE protocols were observed with small patches, including the "CDC, coverall and N95" with 1 small patch on the back of a right hand and the "Health Canada, gown and N95" with 1 small patch on a front forehead and 1 large patch on a front right forearm (Table 2).
Suen [8]	2018	An experimental study of one group using multiple comparisons	A total of 59 participants randomly performed PPE donning and doffing. The trial consisted of PPE donning, applying fluorescent solution on the PPE surface, PPE doffing of participants, and estimation of the degree of contamination as indicated by the number of fluorescent stains on the working clothes and environment. Protocol deviations during PPE donning and doffing were monitored. PPE1 consists of a neck-to-ankle outfit, N95 respirator, hood, disposable face shield, surgical gown, boots and double gloves. PPE2 consists of a head-to-ankle coverall, N95 respirator, hood, disposable face shield, boots and double gloves. PPE3 consists of neck-to-ankle outfit, N95 respirator, no hood, disposable face shield, isolation gown, shoes and single latex gloves.	Usability	The results relevant to KQ 6 are displayed in Figure 1. With PPE1, the face shield was worn over the head cover. One contamination with a small patch was observed on the face with PPE1. With PPE2, the face shield was worn under the hood of the coverall. Four contaminations with small patches were observed on the face with PPE2. Neither PPE1 nor PPE2 was observed with large patches on the face.
Poller [10]	2018	Simulation study and consensus panel to identify a unified PPE ensemble for clinical response to possible high consequence infectious diseases in the United Kingdom	A simulation study and consensus panel to identify a unified PPE ensemble for clinical response to possible high consequence infectious diseases in the United Kingdom. A simulation-based exercise was developed to assess the safety of PPE ensembles in use in the UK during first assessment of a patient with a possible high-consequence-infectious-disease. A mannequin was adapted to expose volunteer HCWs to synthetic bodily fluids (vomit, sweat, diarrhea and cough), each with a different colored fluorescent tracer, invisible other than under ultraviolet (UV) light. After exposure, HWs were examined under UV lights to locate fluorescent contamination, and were screened again after removing PPE (doffing) to detect any	Implementation	The simulation testing identified significant HCW contamination events after doffing, related to protocol failure or complications in PPE doffing. The consensus PPE ensemble were tested in the study; it attained no contamination events. In the ensemble, a disposable full-face visor was worn over the hood.

Author	Year	Study methods	Method details, measures or findings relevant to the extraction of contextual data	Data type	Contextual data
			personal contamination. The exercise was videoed, allowing retrospective analysis of contamination events and user errors.		

Table 3. Number of participants with fluorescent patches after various PPE protocols (Sources: Chughtai et al. 2018, use without permission) [9]

Donning/Doffing Protocol	Order of wearing eye protection PPE under/over head and neck cover PPE	Total participants	# participants with small patches	# participants with large patches	Contamination details
WHO, gown and N95	Under	3	0	0	
WHO, coverall and N95	Under	3	0	1	1 large patch on back of neck, 1 large patch on back of right forearm, 2 large patches on right and left of front shoulder
CDC, coverall and PAPR	Over	3	0	0	
CDC, coverall and N95	Over	3	1	0	1 small patch on back of right hand
ECDC, coverall and N95	Over	3	0	0	
Health Canada, gown and N95 [11]	Over	3	1	0	1 small patch on front neck
North Carolina, coverall and N95 [12]	Over	3	0	1	1 large patch on front forehead and 1 large patch on front right forearm
NSW DoH CEC, gown and N95 [13]	Over	3	0	0	
NSW DoH CEC, gown and PAPR [13]	Over	3	0	0	
MSF, coverall and N95 [14]	Over	3	0	0	
Total		10	2	2	

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Infection prevention and control measures for Ebola and Marburg Virus disease: A series of rapid reviews

KQ8 Personal Protective Equipment – Aprons - Initial Summary

(Version 1, 20 June 2022)

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Funding: Funding for this protocol and the subsequent reviews was provided by the World Health Organization (Funding # 202818287). The working group (WG) from the WHO/HQ Country Readiness Strengthening Health Care Readiness Unit will be consulted to develop and refine the scope, and review and approve the protocol. The WG will not be involved in the conduct of the review including selection of studies and data analysis but will advise as needed on priority population(s), interventions, and outcomes in an iterative process during the review process based on the available evidence. The WG will also comment on the draft report and provide input on interpretations of findings. AT is funded by a Tier 2 Canada Research Chair in Knowledge Synthesis. SM is funded by a Tier 2 Canada Research Chair in Mathematical Modeling and Program Science.

Competing interests: DM was involved in the 2015 rapid review by Hersi et al. [1] There are no other competing interests to acknowledge.

Acknowledgements: We thank Kaitryn Campbell, MLIS, MSc (St. Joseph's Healthcare Hamilton/McMaster University) for peer review of the Embase search strategy.

Key Question

KQ8: Should health workers using waterproof aprons to cover gowns or coveralls while providing direct or indirect care to patients with Ebola or Marburg virus disease, use disposable versus reusable versus biodegradable types of aprons?

Methods Summary

This is one of a series of rapid reviews answering 12 key questions related to three themes on infection prevention and control measures for filoviruses: (i) transmission/exposure (n=3 questions), (ii) personal protective equipment (PPE) (n=5), and (iii) decontamination and disinfection (n=4). Data sources include Medline, Embase, bio/medRxiv pre-print servers, Global Medicus Index, Epistemonikos, China National Knowledge Infrastructure (CNKI) and Wangfang database. We used an automation tool (CAL® tool) for titles/abstracts screening for relevant systematic reviews and primary comparative studies. Full-text screening, data extraction, risk of bias assessment, and GRADE (Grading of Recommendations Assessment, Development and Evaluation) for the certainty of evidence were completed independently by two reviewers with any disagreements resolved by consensus, with arbitration by a third reviewer, when needed.

Findings

A total of 120 studies were screened in the CAL tool software and 39 studies were included for full-text screening. No studies met the eligibility criteria. A list of excluded studies with reasons for exclusion can be found in Appendix 1.

Appendix 1. Excluded Studies List – By Reason for Exclusion:

Commentary (no outcome data)

Fischer WA, Weber DJ, Wohl DA. Personal Protective Equipment: Protecting Health Care Providers in an Ebola Outbreak. *Clinical Therapeutics*. 2015;37(11):2402-2410. doi:10.1016/j.clinthera.2015.07.007

Intervention not of interest

Bell T, Smoot J, Patterson J, Smalligan R, Jordan R. Ebola virus disease: The use of fluorescents as markers of contamination for personal protective equipment. *IDCases*. 2015;2(1):27-30. doi:10.1016/j.idcr.2014.12.003

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Drew JL, Turner J, Mugele J, et al. Beating the Spread: Developing a Simulation Analog for Contagious Body Fluids. *Simulation in Healthcare: The Journal of the Society for Simulation in Healthcare*. 2016;11(2):100-105. doi:10.1097/SIH.0000000000000157

Drews FA, Mulvey D, Stratford K, Samore MH, Mayer J. Evaluation of a Redesigned Personal Protective Equipment Gown. *Clinical Infectious Diseases*. 2019;69(Supplement_3):S199-S205. doi:10.1093/cid/ciz520

Eiras D, Echeverri A, Toale K, Tennill P, Evans L. Painting the Gown Red: Using a Colored Paint Quality Improvement Process to Evaluate Healthcare Worker Personal Protective Equipment for Highly Pathogenic Infections. *OFID*. 2017;4(Suppl 1).

Jinadatha C, Simmons S, Dale C, et al. Disinfecting personal protective equipment with pulsed xenon ultraviolet as a risk mitigation strategy for health care workers. *American Journal of Infection Control*. 2015;43(4):412-414. doi:10.1016/j.ajic.2015.01.013

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Koenig K, Majestic C, Burns M. Ebola Virus Disease: Essential Public Health Principles for Clinicians. *WestJEM*. 2014;15(7):728-731. doi:10.5811/westjem.2014.9.24011

Kogutt BK, Sheffield JS, Garibaldi BT. 680: Assessing effectiveness of PPE in a simulated SVD of a highly infectious disease patient. *American Journal of Obstetrics and Gynecology*. 2019;220(1):S451. doi:10.1016/j.ajog.2018.11.703

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Poller B, Hall S, Bailey C, et al. 'VIOLET': a fluorescence-based simulation exercise for training healthcare workers in the use of personal protective equipment. *Journal of Hospital Infection*. 2018;99(2):229-235. doi:10.1016/j.jhin.2018.01.021

Raj D, Hornsey E, Perl TM. Personal protective equipment for viral hemorrhagic fevers: *Current Opinion in Infectious Diseases*. 2019;32(4):337-347. doi:10.1097/QCO.0000000000000562

No information on PPE

Huber K, Jones I, Dousa T, et al. An Evidence Based Approach to Testing PPE for Enhanced Isolation Precautions during Ebola Virus Disease Preparedness Planning. *American Journal of Infection Control*. 2015;43(6):S69. doi:10.1016/j.ajic.2015.04.170

Lee M a, Huh K, Jeong J, et al. Adherence to Protocols by Healthcare Workers and Self-Contamination During Doffing of Personal Protective Equipment. *American Journal of Infection Control*. 2018;46(6):S11. doi:10.1016/j.ajic.2018.04.024

Maynard SL, Kao R, Craig D. Impact of personal protective equipment on clinical output and perceived exertion. *J R Army Med Corps*. 2016;162(3):180-183. doi:10.1136/jramc-2015-000541

No relevant comparisons

Andonian J, Kazi S, Therkorn J, et al. Effect of an Intervention Package and Teamwork Training to Prevent Healthcare Personnel Self-contamination During Personal Protective Equipment Doffing. *Clinical Infectious Diseases*. 2019;69(Supplement_3):S248-S255. doi:10.1093/cid/ciz618
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Garibaldi BT, Ruparelia C, Shaw-Saliba K, et al. A novel personal protective equipment coverall was rated higher than standard Ebola virus personal protective equipment in terms of comfort, mobility and perception of safety when tested by health care workers in Liberia and in a United States biocontainment unit. *American Journal of Infection Control*. 2019;47(3):298-304. doi:10.1016/j.ajic.2018.08.014

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Jaques PA, Gao P, Kilinc-Balci S, et al. Evaluation of gowns and coveralls used by medical personnel working with Ebola patients against simulated bodily fluids using an Elbow Lean Test. *Journal of Occupational and Environmental Hygiene*. 2016;13(11):881-893. doi:10.1080/15459624.2016.1186279

Kilinc FS. A Review of Isolation Gowns in Healthcare: Fabric and Gown Properties. *Journal of Engineered Fibers and Fabrics*. 2015;10(3):155892501501000. doi:10.1177/155892501501000313

Kwon JH, Burnham CAD, Reske KA, et al. Assessment of Healthcare Worker Protocol Deviations and Self-Contamination During Personal Protective Equipment Donning and Doffing. *Infect Control Hosp Epidemiol*. 2017;38(9):1077-1083. doi:10.1017/ice.2017.121

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Appendix 2. Eligibility Criteria

Setting	Health care facilities, ETU
Population	Staff working in health care facilities, ETU
Background interventions (Standard of care)	The choice of apron should be, in order of preference: • a disposable, waterproof apron • if disposable aprons are not available, heavy duty, reusable waterproof aprons may be used provided that they are appropriately cleaned and disinfected between patients
Intervention	Wear a disposable waterproof apron
Comparator(s)	1) wear a reusable waterproof heavy-duty apron, 2) wear a biodegradable waterproof apron
Outcome	Environmental impact of single-use disposable PPE, exposures while cleaning and disinfecting aprons, breaches in cleaning and disinfection practice infection/transmission of EVD, *PPE breaches/exposures, ease of doffing PPE*
Potential effect modifiers	*The design of apron, vaccination*

Contextual data

KQ8. Should health workers using waterproof aprons to cover gowns or coveralls while providing direct or indirect care to patients with Ebola or Marburg virus disease, use disposable versus reusable versus biodegradable types of aprons?

We conducted a rapid review for KQ 8, especially updating the Hersi et al. 2015 rapid review and the Verbeek et al. 2020 systematic review with respect to the use of aprons.[1] [2] There is very limited data to support the choice among disposable, reusable or biodegradable types of aprons. The data gap on this key question identified in the WHO recommendation in 2014 remains an issue today. [3]

Table 1 summarizes PPE recommendations regarding apron use by the WHO, US CDC and European CDC. Both the WHO and US CDC recommend the use of apron. [3] [4] The European CDC technical report did not mention the use of apron. [5]

Reidy et al. report on PPE solution for UK military medical personnel working in an Ebola treatment unit in Sierra Leone. [6] Aprons were included within the PPE solution to increase protection to the front of the wearer, as this area was considered to be at high risk of splashes/spills of contaminated material and, in addition, the coverall zip was set into permeable material. The properties stipulated were: length (below knee), plastic and lightweight design (minimum 16-mm thickness, so it would stay in place but could be torn off deliberately as part of the removal process), fluid repellent and disposable. The apron chosen was adjustable, and so could cover the zip completely, irrespective of body shape, and helped to minimize heat stress whilst giving the necessary protection. The recommendation was to change aprons and gloves between patients in order to reduce the risk of cross-contamination between patients.

With respect to the extraction of contextual data, the key findings are as follows (Table 2).

- *Disposable* (single-use) isolation gowns are designed to be discarded after a single use and are typically constructed of nonwoven materials alone or in combination with materials that offer increased protection from liquid penetration, such as plastic films. They can be produced using a variety of nonwoven fiber-bonding technologies (thermal, chemical, or mechanical) to provide integrity and strength rather than the interlocking geometries associated with woven and knitted materials. The basic raw materials typically used for disposable isolation gowns are various forms of synthetic fibers (e.g. polypropylene, polyester, polyethylene). Fabrics can be engineered to achieve desired properties by using particular fiber types, bonding processes, and fabric finishes (chemical or physical treatments). [7]
- *Reusable* (multi-use) gowns are laundered after each use. Reusable isolation gowns are typically made of 100% cotton, 100% polyester, or polyester/cotton blends. These fabrics are tightly woven plain weave fabrics that are chemically finished and may be pressed through rollers to enhance the liquid barrier properties. Reusable garments generally can be used for 50 or more washing and drying cycles. The number of laundering/drying cycles is suggested by the manufacturer. According to a guidance by the Association for the Advancement of Medical Instrumentation, a verifiable tracking system, such as a manual check off, bar code, or radio frequency chip, a verifiable tracking system, must be in place. [7]
- According to the setup of a simulation study, personal protective clothing PPC2 was composed of absorbent cotton fabric (zero value for water repellency and liquid penetration pressure) with the greatest thickness. [8] PPC1 and PPC3 had grades 4 and 5 of water repellency, high resistance to liquid water penetration, and thinner fabric. PPC2 carried the lowest contaminative hazards to the hands, shoes, and surroundings compared with PPC1 and PPC3. Cotton through its material and

properties can absorb droplet contaminants and thereby reduce opportunities for such contaminants to spread to the environment. However, the absorbent fabric likewise increased underwear contamination by liquid crossing outerwear.

- Plastic apron (PPC3) had a higher chance of contaminating the environment than PPC1 and PPC2. Because plastic had the lowest water-absorbing properties, the droplets that cannot be absorbed by the surface of the plastic might then drop to the floor or spread to the surrounding area, which especially increased contamination with large patches. The plastic apron had a smaller covered area, which also caused heavier underwear contamination (or the contamination of the next layer of the PPE ensemble). [8]
- The results of this simulation study indicate that the traditional cotton surgical gown (woven gown) can absorb liquid contaminants and thus reduces environmental contamination. The other gown (nonwoven gown) can resist the absorption of liquid contaminants when the covered area is sufficient and thus provides better physical barrier protection than the woven gown. However, the nonwoven gown has weak liquid absorption ability. The liquid contaminant may easily drop to the floor or splash to the surrounding environment during movement. More important, an extra force added to the movement, such as by pulling off the isolation gown without unfastening the ties, tearing off the plastic apron, or removing the gown or apron forcefully, spreads droplet contaminants that can splash not only to the surrounding environment but also to nearby patients. [8]
- The present results suggest that double gowns with outer absorbent cotton reduce the spread of contaminants to the environment, whereas inner water repellency gowns can resist contaminants and prevent them from penetrating into underwear and even the skin, providing better protection than a single gown in preventing HW from coming into contact with patients' blood and body fluids during splashing procedures. [8]
- Lee et al. 2021 assessed PPE needs for health workers by surveying a convenient sample of 200 HWs in the US. [9] PPE design features were assessed on a five-point Likert-type scale, ranging from "strongly disagree" (1) to "strongly agree" (5). The mean values of PPE were higher than 3 (on the 1-5 scale) for fit (mean = 3.45, SD = 0.56), comfort (M = 3.38, SD = 0.72), mobility (M = 3.44, SD = 0.69), and donning and doffing (M = 3.71, SD = 0.87), suggesting that HWs think that current PPE (scrubs, gowns, coveralls, and apron) for body protection meet their needs of fit, comfort, mobility, and donning and doffing.
- With respect to body protection, 31% of the participants considered comfortability as the biggest challenge when wearing PPE, followed by sizing and fit (27%), donning and doffing (14%), movement (12%), material durability (12%), and others (3%) such as easy to use and PPE weight. HWs are more likely "Strongly agree" than "Strongly disagree" to accept PPE based on the donning and doffing feature, odds ratio = 2.37, 95% confidence interval [0.48, 11.61], which means that the donning and doffing feature plays a vital role on HWs' overall PPE acceptance. [9]
- Poller et al 2018 conducted a simulation study and organized a consensus panel to identify a unified PPE ensemble for clinical response to possible high consequence infectious diseases in the United Kingdom. [10] The consensus ensemble provided full protection against contamination in the simulation study. This ensemble included wide, extra-long medium thickness plastic apron (such as those worn for endoscopy). A higher fit to protect the upper chest is desired and no such apron existed. Tearing the neck loop in the middle so both the neck and waist areas were tied was deemed an acceptable and simple modification, which significantly improved protection. Details regarding doffing assistance, instructions and training for the use of the PPE ensemble are captured in Table 2. [10]
- Kilinc-Balci et al. 2015 tested 22 commercial single-use isolation gowns for barrier and strength properties using American Society of Testing and Materials International ASTM (D5034, D5733,

D1683, F1671) and American Association of Textile Chemists and Colorists (AATCC 42 and 127) test methods and the Association for the Advancement of Medical Instrumentation (AAMI) PB70 liquid barrier classification standard requirements. [11] Testing results demonstrated that there is a large variation in the barrier and strength properties of existing isolation gowns in the marketplace. It was also found that nine (41%) of the 22 tested isolation gowns failed to meet the AAMI PB70 requirements for the liquid barrier performance at the level specified by the manufacturer. The results support the use of aprons for additional protection.

Simulation studies are needed to clarify apron choices - they are simple to do at a usability lab, may require few participants (e.g., 40), [12] and can be conducted at a reasonably low cost. The WHO may consider commissioning a simulation study with an experimental design to test the choices of aprons, as well as other PPE elements in KQ4 and KQ7. For example, the methods section of Drew et al. 2019 provides an example for the planning of such commission, and simulation platforms exist for training and evaluating how HWs use PPE.[13, 14]

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Table 1: Summary of PPE recommendations regarding apron use by WHO, US CDC and European CDC

Source	Apron use
WHO [3]	
Recommendation 8	Compared with other forms of protective body wear, the choice of PPE for covering clothing should be either a disposable gown and apron, or a disposable coverall and apron; the gown and the coverall should be made of fabric that is tested for resistance to penetration by blood or body fluids or to blood-borne pathogens. *Conditional recommendation, very low quality evidence comparing effectiveness of gowns and coveralls*
Recommendation 9	The choice of apron should be, in order of preference: □ Disposable, waterproof apron □ If disposable aprons are not available, heavy duty, reusable waterproof aprons can be used if appropriate cleaning and disinfection between patients is performed. *Strong recommendation, very low quality evidence comparing effectiveness of disposable and reusable apron* <u>Rationale and remarks:</u> An apron should be worn over the gown or coveralls; it is easier to remove a soiled apron compared to gowns and coveralls. An apron is generally worn for the entire time the health worker is in the treatment area. If the apron is visibly soiled, a disposable apron should be removed and changed. Feasibility issues, such as availability of new aprons and waste disposal within isolation areas, must be addressed. Health workers wearing a reusable apron should leave the ward to clean, disinfect and remove the apron.
US CDC [4]	Single-use (disposable) apron that covers the torso to the level of the mid-calf should be used over the gown or coveralls if patients with Ebola are vomiting or have diarrhea, and should be used routinely if the facility is using a coverall that has an exposed, unprotected zipper in the front. An apron provides additional protection, reducing the contamination of gowns or coveralls by body fluids and providing a way to quickly remove a soiled outer layer during patient care. Select an apron with a neck strap that can be easily broken or untied to avoid having to pull the strap over the head, which makes it easier to remove without self-contamination when exchanging a soiled apron during care or when removing the apron during the doffing procedure.
European CDC [5]	No mention of apron, the focus was on impermeable gown.

Table 2. Summary of contextual data

Author	Year	Study methods	Method details, measures or findings relevant to the extraction of contextual data	Data type	Contextual data
Guo [8]	2014	Simulation study with 50 participants	Simulation study aimed to examine the body contamination rates and environmental contamination levels during the removal of 3 types of personal protective clothing (PPC) by the individual accustomed removal method (IARM) and gown removal methods recommended by the Centers for Disease Control and Prevention (CDC).	Usability	Personal protective clothing PPC2 was composed of absorbent cotton fabric (zero value for water repellency and liquid penetration pressure) with the greatest thickness. PPC1 and PPC3 had grades 4 and 5 of water repellency, high resistance to liquid water penetration, and thinner fabric. PPC2 carried the lowest contaminative hazards to the hands, shoes, and surroundings compared with PPC1 and PPC3. Cotton through its material and properties can absorb droplet contaminants and thereby reduce opportunities for such contaminants to spread to the environment. However, the absorbent fabric likewise increased underwear contamination by liquid crossing outerwear.
		Simulation study with 50 participants	as above	Usability	Plastic apron (PPC3) had a higher chance of contaminating the environment than PPC1 and PPC2. Because plastic had the lowest water-absorbing properties, the droplets that cannot be absorbed by the surface of the plastic might then drop to the floor or spread to the surrounding area, which especially increased contamination with large patches. The plastic apron had a smaller covered area, which also caused heavier underwear contamination.
Guo	2014	Simulation study with 50 participants	as above		The results of this study and those of Wong et al indicate that the traditional cotton surgical gown (woven gown) can absorb liquid contaminants and thus reduces environmental contamination. The other gown (nonwoven gown) can resist the absorption of liquid contaminants when the covered area is sufficient and thus provides better physical barrier protection than the woven gown. However, the nonwoven gown has weak liquid absorption ability. The liquid contaminant may easily drop to the floor or splash to the surrounding environment during movement. More important, an extra force added to the movement, such as by pulling off the isolation gown without unfastening the ties, tearing off the plastic apron, or removing the gown or apron forcefully, spreads droplet contaminants that can splash not only to the surrounding environment but also to nearby patients.
Guo	2014	Simulation study with 50 participants	as above	Implementation	The present results suggest that double gowns with outer absorbent cotton reduce the spread of contaminants to the environment, whereas inner water repellency gowns can resist contaminants and prevent them from penetrating into underwear and even the skin, providing better protection than a single gown in preventing HW from coming into contact with patients' blood and body fluids during surgery and other splashing procedures.
Lee [9]	2021	Assessing PPE needs for health workers by surveying a convenient sample of 200 HWs in the US	This study showed the need for current PPE improvement in terms of fit, comfort, mobility, and donning and doffing for HCWs' safety and health. Donning and doffing plays an important role in HCWs' overall acceptance of PPE for body protection.	Usage	For body protection, 83% were using gowns, followed by 80.5% of scrubs including tops and pants, 31% of disposable aprons, 18.5% of coveralls, and 13.5% of reusable aprons.
Lee	2021	as above	PPE design features including 13 items of fit, 10 items of mobility, 6 items of comfort, 2 items of donning and doffing, and 2 items of aesthetic, and 1 item related to overall PPE acceptability. All measures were measured on a five-point Likert-type scale, ranging from "strongly disagree" (1) to "strongly agree" (5).	Usability	The study assessed the current PPE design features for body protection, including fit, mobility, comfort, donning and doffing, and aesthetic. The mean values of PPE were higher than 3 (on the 1-5 scale) for fit (mean = 3.45, SD = 0.56), comfort (M = 3.38, SD = 0.72), mobility (M = 3.44, SD = 0.69), and donning and doffing (M = 3.71, SD = 0.87), suggesting that HWs think that current PPE (scrubs, gowns, coveralls, and apron) for body protection meet their needs of fit, comfort, mobility, and donning and doffing.

Lee	2021	as above	PPE design features were also assessed using open-ended questions. Qualitative data were analyzed to identify thematic content.	Usability	With respect to body protection, 31% of the participants considered comfortability as the biggest challenge when wearing PPE, followed by sizing and fit (27%), donning and doffing (14%), movement (12%), material durability (12%), and others (3%) such as easy to use and PPE weight.
Lee	2021	as above	A categorical logit model was used to examine the effect of PPE design features (fit, mobility, comfort, donning and doffing, and aesthetic) and years of work experiences on overall PPE acceptability.	Acceptability	HCWs are more likely “Strongly agree” than “Strongly disagree” to accept PPE based on the donning and doffing feature, OR = 2.37, 95% CI [0.48, 11.61], which means that the donning and doffing feature plays a vital role on HCWs' overall PPE acceptance.
Lee	2021	as above		Implementation	This study also reveals that most HCWs dispose of their PPE in a trash can in a healthcare unit, and non-disposed PPE is laundered at home, which may expose family members to a health risk if a proper precaution is not followed.
Kilinc [7]	2015	Expert review	This paper reviews isolation gowns in healthcare settings, including the fabrics used, gown design and interfaces, as well as critical parameters that affect microorganism and liquid transmission through fabrics.	Implementation	Disposable (single-use) isolation gowns are designed to be discarded after a single use and are typically constructed of nonwoven materials alone or in combination with materials that offer increased protection from liquid penetration, such as plastic films. They can be produced using a variety of nonwoven fiber-bonding technologies (thermal, chemical, or mechanical) to provide integrity and strength rather than the interlocking geometries associated with woven and knitted materials. The basic raw materials typically used for disposable isolation gowns are various forms of synthetic fibers (e.g. polypropylene, polyester, polyethylene). Fabrics can be engineered to achieve desired properties by using particular fiber types, bonding processes, and fabric finishes (chemical or physical treatments).
Kilinc	2015	as above	as above	Implementation	Reusable (multi-use) gowns are laundered after each use. Reusable isolation gowns are typically made of 100% cotton, 100% polyester, or polyester/cotton blends. These fabrics are tightly woven plain weave fabrics that are chemically finished and may be pressed through rollers to enhance the liquid barrier properties. Reusable garments generally can be used for 50 or more washing and drying cycles. The number of laundering/drying cycles is suggested by the manufacturer. According to a guidance by the Association for the Advancement of Medical Instrumentation, a verifiable tracking system, such as a manual check off, bar code, or radio frequency chip, a verifiable tracking system, must be in place.
Poller [10]	2018	Simulation study and consensus panel to identify a unified PPE ensemble for clinical response to possible high consequence infectious diseases in the United Kingdom	A simulation-based exercise was developed to assess the safety of PPE ensembles in use in the UK during first assessment of a patient with a possible HCID. A mannequin was adapted to expose volunteer HCWs to synthetic bodily fluids (vomit, sweat, diarrhea and cough), each with a different colored fluorescent tracer, invisible other than under ultraviolet (UV) light. After exposure, HCWs were examined under UV lights to locate fluorescent contamination, and were screened again after removing PPE (doffing) to detect any personal contamination. The exercise was videoed, allowing retrospective analysis of contamination events and user errors.	Implementation	The simulation testing identified significant HCW contamination events after doffing, related to protocol failure or complications in PPE doffing, providing conclusive evidence that improvements could be made.
Poller	2018	as above	At a workshop with an expert stakeholder group, the data were examined and a unified PPE ensemble agreed.	Implementation	This ensemble was then tested in the same simulation exercise and no evidence of any HCW contamination was seen after doffing. Following further review by the working group, a consensus agreement has been reached and a unified ‘HCID assessment PPE’ ensemble, with accompanying donning and doffing protocols, is identified.
Poller	2018	as above		Implementation	Wide, extra-long medium thickness plastic apron (such as worn for endoscopy): although agreed that ideally PPE items should not be modified, a higher fit to protect the upper chest was desired and no such apron existed. Tearing the neck loop in the middle so both the neck and waist areas were tied was deemed an acceptable and simple modification, which significantly im- proved protection.

Poller	2018	as above		Implementation	**Doffing assistance:** A 'hands off' doffing buddy is essential to support staffing safe removal of PPE and to avoid buddy contamination. The buddy should talk the HW slowly through each step, instructing and mirroring each action face to face. This also allows the buddy to identify any slip of PPE, such as the mask or hood moving on the face, which ensures the person doffing avoids inadvertent contamination.
Poller	2018	as above		Implementation	**Instructions and signage:** Instruction posters (donning and doffing cards) for the new PPE ensemble are made. It is recommended that they are clearly visible in the donning and doffing area, but should not replace the support of a 'doffing buddy' to ensure all stages are followed safely. Clear zone demarcations are recommended, and can be reinforced visually at the zone boundaries by laminated cards stating the area (e.g. 'Red area: you are entering the dirty zone', 'Amber area: you are entering the doffing zone', 'Green area: you are entering a clean area'). Doffing areas should be sufficiently spacious to allow the HW to move freely without touching surfaces or walls.
Poller	2018	as above		Implementation	**Training**: In order to ensure familiarity of this PPE and sustain competency in its use, it is advised that a regular mandatory training program be in place.
Boon [15]	2014	Survey 44 frontline physicians and nurses deployed to West Africa between March and September of 2014.	To understand frontline physicians' and nurses' perspectives about personal protective equipment (PPE) use during the 2014-2016 EVD outbreak in West Africa and to incorporate these findings into the development process of a WHO rapid advice guideline.	Implementation	Both gowns and coveralls were associated with significant heat stress and dehydration. Heat and dehydration also were a significant or major issue for the majority of individuals using a gown (n=11, 73%) or coverall (n=26, 87%); however, there was no significant difference between the two groups (p=0.41). Another survey participant commented: "*The coverall would probably be better tolerated if we could breathe easier and see without problems*". Our study demonstrated that it was possible to incorporate primary data on end-users' preferences into a rapid advice guideline for a public health emergency in difficult field conditions. Health workers perceived a balance between transmission protection and ability to care for patients effectively while wearing PPE.
Kilinc-Balci [11]	2015	Evaluation of the Performance of Isolation Gowns	American Society of Testing and Materials International's (ASTM) F23 Committee started awork item in collaboration with the National Personal Protective Technology Laboratory to develop minimum performance and design criteria for isolation gowns to assist end users in correct isolation gown selection, assuring higher levels of protection than currently provided.	Implementation	Consumer complaints about strength properties of isolation gowns highlighted the need for a new standard that specifies minimum performance requirements.
Kilinc-Balci	2015	as above	Twenty two single-use isolation gowns were evaluated for barrier and strength properties using ASTM (D5034, D5733, D1683, F1671) and American Association of Textile Chemists and Colorists (AATCC 42 and 127) test methods and Association for the Advancement of Medical Instrumentation (AAMI) PB70 liquid barrier classification standard requirements.	Implementation	Testing results demonstrated that there is a large variation in the barrier and strength properties of existing isolation gowns in the marketplace. It was also found that nine (41%) of the 22 tested isolation gowns failed to meet the AAMI PB70 requirements for the liquid barrier performance at the level specified by the manufacturer.
Reidy [6]	2017	Narrative report	In September 2014, specialists from Public Health England, the National Ambulance Resilience Unit and the Ministry of Defence (MoD) worked together to identify the combination of PPE and donning and doffing protocols for PPE worn by military medical personnel working in a 12-bedded ETU in Kerry Town, Sierra Leone. Medical workers were protected by the combination of PPE, donning and doffing procedures, and working practices used within the facility.	Implementation	Aprons were included within the PPE solution to increase protection to the front of the wearer, as this area was considered to be at high risk of splashes/spills of contaminated material and, in addition, the coverall zip was set into permeable material. The properties stipulated were: length (below knee), plastic and lightweight design (minimum 16-mm thickness, so it would stay in place but could be torn off deliberately as part of the removal process), fluid repellent and disposable. The apron chosen was adjustable, and so could cover the zip completely, irrespective of body shape, and helped to minimize heat stress whilst giving the necessary protection. The recommendation was to change aprons and gloves between patients in order to reduce the risk of crosscontamination between patients.

Fischer [16]	2015	Expert commentary	Articles pertaining to filovirus transmission and PPE in filovirus outbreaks were reviewed and findings are presented.	Implementation	The use of a waterproof or impermeable apron worn over the gown/coverall is recommended to provide further protection against infectious body fluids. Both the CDC and the WHO recommend using a disposable apron if feasible because a reusable one will require decontamination after each use.

Infection prevention and control measures for Ebola and Marburg Virus disease: A series of rapid reviews

KQ9 Spraying vs. wiping for disinfection of surfaces/materials - Initial Summary

(Version 1, 2 September 2022)

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Funding: Funding for this protocol and the subsequent reviews was provided by the World Health Organization (Funding # 202818287). The working group (WG) from the WHO/HQ Country Readiness Strengthening Health Care Readiness Unit will be consulted to develop and refine the scope, and review and approve the protocol. The WG will not be involved in the conduct of the review including selection of studies and data analysis but will advise as needed on priority population(s), interventions, and outcomes in an iterative process during the review process based on the available evidence. The WG will also comment on the draft report and provide input on interpretations of findings. AT is funded by a Tier 2 Canada Research Chair in Knowledge Synthesis. SM is funded by a Tier 2 Canada Research Chair in Mathematical Modeling and Program Science.

Competing interests: DM was involved in the 2015 rapid review by Hersi et al. [1] There are no other competing interests to acknowledge.

Acknowledgements: We thank Kaitryn Campbell, MLIS, MSc (St. Joseph's Healthcare Hamilton/McMaster University) for peer review of the Embase search strategy.

Key Question

KQ9: Should surfaces and materials in healthcare facilities, ETUs and community settings providing care to patients with Ebola or Marburg disease be disinfected using a wiping method versus a spraying method?

Methods Summary

This is one of a series of rapid reviews answering 12 key questions related to three themes on infection prevention and control measures for filoviruses: (i) transmission/exposure (n=3 questions), (ii) personal protective equipment (PPE) (n=5), and (iii) decontamination and disinfection (n=4). Data sources include Medline, Embase, bio/medRxiv pre-print servers, Global Medicus Index, Epistemonikos, China National Knowledge Infrastructure (CNKI) and Wangfang database. We used an automation tool (CAL® tool) for titles/abstracts screening for relevant systematic reviews and primary comparative studies. Full-text screening, data extraction, risk of bias assessment, and GRADE (Grading of Recommendations Assessment, Development and Evaluation) for the certainty of evidence were completed independently by two reviewers with any disagreements resolved by consensus, with arbitration by a third reviewer, when needed.

Findings

A total of 80 studies were screened in the CAL tool software and 17 studies were included for full-text screening. One of the 17 studies was a recent systematic review published in 2021 that reviewed the efficacy of chlorine-based surface disinfection against seven pathogens (including Ebola virus).[1] For completeness, we reviewed the titles and abstracts of 89 laboratory studies included in the systematic review, as well 25 more recent studies that had cited the review. Four additional articles were deemed relevant and screened at the full-text screening stage.[2–5]

No studies met the eligibility criteria. Most articles excluded at the full-text stage examined the efficacy of different types of disinfection solutions for Ebola (e.g., chlorine, ethanol) in a controlled laboratory setting. We found no studies that provided data on the efficacy of wiping compared to spraying for any disinfection agent. A complete list of excluded studies with reasons for exclusion can be found in Appendix 1.

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5. Julian TR, Trumble JM, Schwab KJ. Evaluating Efficacy of Field-Generated Electrochemical Oxidants on Disinfection of Fomites Using Bacteriophage MS2 and Mouse Norovirus MNV-1 as Pathogenic Virus Surrogates. *Food Environ Virol*. 2014;6(2):145-155. doi:10.1007/s12560-014-9136-6

Appendix 1. Excluded Studies List – By Reason for Exclusion:

Does not examine Ebola or Marburg (or surrogate viruses)

Amadin, Jacob. Comparison of the Effectiveness of Disinfectant-Impregnated Wipes Versus Detergent Wipes for Surface Decontamination. University of South Florida; 2021.

Intervention not of interest

Calfee MW, Ryan SP, Abdel-Hady A, et al. Virucidal efficacy of antimicrobial surface coatings against the enveloped bacteriophage Φ6. *J of Applied Microbiology*. 2022;132(3):1813-1824. doi:10.1111/jam.15339

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Tomas ME, Cadnum JL, Jencson A, Donskey CJ. The Ebola Disinfection Booth: Evaluation of an Enclosed Ultraviolet Light Booth for Disinfection of Contaminated Personal Protective Equipment Prior to Removal. *Infect Control Hosp Epidemiol*. 2015;36(10):1226-1228. doi:10.1017/ice.2015.166

No relevant comparisons

Casey ML, Nguyen DT, Idriss B, Bennett S, Dunn A, Martin S. Potential Exposure to Ebola Virus from Body Fluids due to Ambulance Compartment Permeability in Sierra Leone. *Prehosp Disaster med*. 2015;30(6):625-627. doi:10.1017/S1049023X15005294

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Julian TR, Trumble JM, Schwab KJ. Evaluating Efficacy of Field-Generated Electrochemical Oxidants on Disinfection of Fomites Using Bacteriophage MS2 and Mouse Norovirus MNV-1 as Pathogenic Virus Surrogates. *Food Environ Virol*. 2014;6(2):145-155. doi:10.1007/s12560-014-9136-6

Park GW, Sobsey MD. Simultaneous Comparison of Murine Norovirus, Feline Calicivirus, Coliphage MS2, and GII.4 Norovirus to Evaluate the Efficacy of Sodium Hypochlorite Against Human Norovirus on a Fecally Soiled Stainless Steel Surface. *Foodborne Pathogens and Disease*. 2011;8(9):1005-1010. doi:10.1089/fpd.2010.0782

Poliquin PG, Vogt F, Kasztura M, et al. Environmental Contamination and Persistence of Ebola Virus RNA in an Ebola Treatment Center. *J Infect Dis*. 2016;214(suppl 3):S145-S152. doi:10.1093/infdis/jiw198

String GM, Kamal Y, Gute DM, Lantagne DS. Chlorine efficacy against bacteriophage Phi6, a surrogate for enveloped human viruses, on porous and non-porous surfaces at varying temperatures and humidity. *Journal of Environmental Science and Health, Part A*. 2022;57(8):685-693. doi:10.1080/10934529.2022.2101845

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Narrative review (Study design not of interest)

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Appendix 2. Eligibility Criteria

Question (9): Should surfaces and materials in healthcare facilities, Ebola treatment units (ETU) and community settings providing care to patients with Ebola or Marburg disease be disinfected using a wiping method versus a spraying method

Setting	Health care facility, ETU, community
Population	Staff and or patients in healthcare facilities (HCF), ETU and community
Background interventions (Standard of care)	Disinfection of surfaces daily and when visibly soiled
Intervention	spray surfaces with disinfectant
Comparator(s)	wipe surfaces with disinfectant
Outcome	Adverse effects associated with chemical exposure, coverage of surfaces with disinfectant, log reduction of virus or surrogate on surface, infection with Ebola, *psychological effects (stigma) associated with spraying of homes with disinfectants, patient experience (e.g. extensive chlorine smell in the environment/skin exposure, etc.,*
Potential effect modifiers	Disinfectant chemical used Design/spraying technology Adequacy of spraying (surface coverage) Surface cleaning first *Time of exposure to disinfectant* *Surface composition*

	Concentration of solution *Disinfectant product*

Contextual data

KQ 9 – "Should surfaces and materials in healthcare facilities, Ebola treatment units (ETU) and community settings providing care to patients with Ebola or Marburg disease be disinfected using a wiping method versus a spraying method?"

Guideline recommendations

Table 1 summarizes recommendations regarding cleaning and disinfection of surfaces and materials potentially contaminated with Ebola or Marburg viruses by the WHO, US CDC and European CDC.[1] [2] [3] [4]

As part of the cleaning process, the WHO 2014 guides suggest, "do not spray occupied or unoccupied clinical area with disinfectant. This potentially dangerous practice has no proven disease control benefit."[1]

The US CDC 2014 Considerations for Chlorine Use did not mention spray as a mode for disinfectant application.[2]

The US CDC 2014 Interim Guidance for Environmental Infection Control in Hospitals for Ebola Virus recommends the use of a U.S. Environmental Protection Agency (EPA)-registered hospital disinfectant with a label claim for a non-enveloped virus (norovirus, rotavirus, adenovirus, poliovirus) to disinfect environmental surfaces in rooms of patients with confirmed EVD or persons under investigation.[4] Although there are no products with specific label claims against the Ebola virus, enveloped viruses such as Ebola are susceptible to a broad range of *hospital disinfectants* used to disinfect hard, non-porous surfaces. In contrast, non-enveloped viruses are more resistant to disinfectants. As a precaution, selection of a disinfectant product with a higher potency than what is normally required for an enveloped virus is being recommended at this time. EPA-registered hospital disinfectants with label claims against non-enveloped viruses (norovirus, rotavirus, adenovirus, and poliovirus) are broadly antiviral and capable of inactivating both enveloped and non-enveloped viruses.

As part of a guide for General Considerations for Decontamination Surfaces in Airplanes, the European CDC suggests that liquid chemical disinfectants should be applied by manually wiping the surfaces.[3] The effects take place immediately while the surface is drying. Some chemical disinfectants evaporate quickly; they should be used with caution. If applied improperly, they could pose a fire hazard or damage avionic equipment.

Contextual data

Table 2 summarizes the contextual data from ten studies identified during the study selection process.

Gallandat et al. 2021 conducted a systematic review of chlorine-based surface disinfection efficacy to inform recommendations for low-resource outbreak settings.[5] Of the 89 studies investigated, the most common disinfectant application modes were pipetting (n = 54, 61%), immersion (n = 20, 22%), spraying (n = 8, 9%), or wiping (n = 5, 6%). Because disinfection is often combined with cleaning procedures, wiping was investigated and was found to have an effect on viruses and spores even in absence of disinfectant, suggesting that the mechanical action of wiping contributes to reducing contamination levels on surfaces. A study that compared wiping and spraying showed similar efficacies against C difficile spores, though spraying was considered less appropriate for health care settings as it required extended drying times and would not remove dirt and debris.[6] Ensuring contact between disinfectant and test organisms can be challenging with spraying. In addition, chlorine loss during spraying − from spray nozzle to the targeted surface − is a concern.

Lantagne et al. 2018 conducted an experimental study to test the efficacy of disinfectants to prevent emerging infectious disease transmission.[7] To support disinfection recommendations, three research strands were conducted: (1) impacts of chlorine chemistry; (2) efficacy of surface cleaning recommendations; and (3) safety and efficacy of handwashing recommendations. A testing matrix was developed that included various surface types that are relevant in emergency health responses (nitrile, heavy duty tarp, stainless steel); chlorine types (NaDCC, HTH, generated NaOCl, stabilized NaOCl); soil load (with and without); and factors that varied between the Médecins Sans Frontières (MSF), WHO and CDC recommendations, including exposure time (10, 15 min) and recommended pre-treatments (none, covering, wiping, covering/wiping). The bacteriophage that was most similar to the Ebola virus was left to dry for one hour on a disc with a surface diameter of 8 cm, disinfection was carried out with or without pre-treatment and the residual contamination on the disc was measured at the end of the exposure time.

Across the entire test matrix, there was always a reduction of > 99.9% in Phi6. [7] The results suggest that: (1) surface type influenced disinfection efficacy; (2) chlorine type and soil load did not impact disinfection efficacy when using 0.5% chlorine; (3) contact time did impact efficacy against Phi6; and (4) wiping or covering did not increase disinfection efficacy, but the latter could limit splashing. The authors suggest that surface cleaning with 0.5% chlorine solutions with a 15-min exposure time is efficacious in reducing transmission risk.

Gallandat et al. 2017 compared the efficacy of four chlorine solutions (sodium hypochlorite, sodium dichloroisocyanurate, hightest hypochlorite, and generated hypochlorite) for disinfection of three surface types (stainless steel, heavy-duty tarp, and nitrile) with and without pre-cleaning practices (pre-wiping, covering, or both) and soil load.[8] The test organisms were Escherichia coli and the Ebola surrogate Phi6. The results support the recommendation of a 15 min exposure to 0.5% chlorine, independently of chlorine type, surface, pre-cleaning practices, and organic matter, as an efficacious measure to interrupt disease transmission from uncontrolled spills in Ebola outbreaks.

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Table 1: Summary of guideline recommendations regarding disinfection of Ebola-exposed surfaces by the WHO, US and European CDC

Source	Should surfaces and materials in healthcare facilities, Ebola treatment units and community settings providing care to patients with Ebola or Marburg disease be disinfected using a wiping method versus a spraying method?
WHO [1]	2014
Recommendation - Cleaning process:	Environmental surfaces or objects contaminated with blood, other body fluids, secretions or excretions should be cleaned and disinfected as soon as possible using standard hospital detergents/disinfectants (e.g. a 0.5% chlorine solution or a solution containing 5 000 ppm available free chlorine)11. Application of disinfectants should be preceded by cleaning to prevent inactivation of disinfectants by organic matter. If locally prepared, prepare cleaning and disinfectant solutions every day. Change cleaning solutions and refresh equipment frequently while being used during the day, as they will quickly become contaminated (follow your hospital protocols if available). For preparing chlorine-based solutions, see instructions in Annex 6. Clean floors and horizontal work surfaces at least once a day with clean water and detergent. Cleaning with a moistened cloth helps to avoid contaminating the air and other surfaces with air-borne particles. Allow surfaces to dry naturally before using them again. **Do not spray (i.e. fog)** occupied or unoccupied clinical areas with disinfectant. This potentially dangerous practice has no proven disease control benefit.
US CDC [4]	2014 Interim Guidance for Environmental Infection Control in Hospitals for Ebola Virus Use a U.S. Environmental Protection Agency (EPA)-registered hospital disinfectant with a label claim for a non-enveloped virus (norovirus, rotavirus, adenovirus, poliovirus) to disinfect environmental surfaces in rooms of PUIs or patients with confirmed EVD. Although there are no products with specific label claims against the Ebola virus, enveloped viruses such as Ebola are susceptible to a broad range of hospital disinfectants used to disinfect hard, non-porous surfaces. In contrast, non-enveloped viruses are more resistant to disinfectants. As a precaution, selection of a disinfectant product with a higher potency than what is normally required for an enveloped virus is being recommended at this time. EPA-registered hospital disinfectants with label claims against non-enveloped viruses (norovirus, rotavirus, adenovirus, poliovirus) are broadly antiviral and capable of inactivating both enveloped and non-enveloped viruses.
US CDC Considerations for Chlorine Use[2]	2014 - Disinfection requires a wet contact time (amount of time the disinfectant is required to be left on the surface to be effective).
ECDC - Assessing and planning medical evacuation flights to Europe for patients with Ebola virus disease and people exposed to Ebola virus [3]	2014 - General considerations for decontaminating surfaces in airplanes • The cabin of an aircraft should be manually cleaned with cleansing agents and liquid chemical disinfectants; liquid chemical disinfections are suitable to decontaminate surfaces contaminated with Ebola virus or Ebola virus particles. • Surfaces should be resistant to the use of chemical disinfectants to avoid damage to the interior or avionic equipment. Flat, smooth surfaces can be disinfected relatively easily using traditional liquid chemical disinfectants. • Liquid chemical disinfectants should be applied by manually wiping the respective surfaces. The effects take place immediately while the surface is drying. • Some chemical disinfectants evaporate quickly and should be used with caution. If applied improperly, they could pose a fire hazard or damage avionic equipment.

Table 2. Summary of contextual data

Author	Year	Study methods	Method details, measures or findings relevant to the extraction of contextual data	Data type	Contextual data
Gallandat[5]	2021	Systematic review	A systematic review of chlorine-based surface disinfection efficacy to inform recommendations for low-resource outbreak settings. Of the 89 studies investigated, the most common disinfectant application modes were pipetting (n = 54, 61%), immersion (n = 20, 22%), spraying (n = 8, 9%), or wiping (n = 5, 6%). Because disinfection is often combined with cleaning procedures, wiping was investigated and was found to have an effect on viruses and spores even in absence of disinfectant, suggesting that the mechanical action of wiping contributes to reducing contamination levels on surfaces.49,74	Implementation	A comparison of wiping and spraying showed similar efficacies against C difficile spores, though spraying was considered less appropriate for health care settings as it required extended drying times and would not remove dirt and debris.
Gallandat[5]	2021			Implementation	With spraying, ensuring contact between disinfectant and test organisms can be challenging.75,76 Additionally, chlorine loss during the process − from spray nozzle to the targeted surface − is a concern.77 Ni et al (2016) found consistent increases in efficacy with increasing disinfectant spraying time from 0.5 to 2 minutes and keeping similar exposure times after spraying. A proposed explanation for variable efficacies observed between studies is the use of different spraying equipment, such as gas-powered pressurized sprayers producing high spray velocities and handheld spray bottles.78
Gallandat[8]	2017	Testing study	We compared the efficacy of four chlorine solutions (sodium hypochlorite, sodium dichloroisocyanurate, hightest hypochlorite, and generated hypochlorite) for disinfection of three surface types (stainless steel, heavy-duty tarp, and nitrile) with and without precleaning practices (prewiping, covering, or both) and soil load. The test organisms were Escherichia coli and the Ebola surrogate Phi6.	Implementation	Our results support the recommendation of a 15 min exposure to 0.5% chlorine, independently of chlorine type, surface, pre-cleaning practices, and organic matter, as an efficacious measure to interrupt disease transmission from uncontrolled spills in Ebola outbreaks.
Calfee [9]	2021	Testing study	Evaluate virucidal efficacy of antimicrobial surface coatings against the enveloped bacteriophage Φ6. Twenty antimicrobial coating products, predominantly composed of organosilane quaternary ammonium compounds, were applied to stainless steel coupons, dried overnight and evaluated for efficacy against Φ6, an enveloped bacteriophage. Liquid-based products were applied in accordance with product labels, using either an electrostatic sprayer, common trigger-pull hand-held sprayer, submersion, or a spray-then- wipe application. Twenty-six commercially available antimicrobial coatings, films or alloy products were evaluated for residual antiviral activity.	Usage	In general, enveloped viruses are more susceptible to disinfectants than non-enveloped viruses. Ebola is an enveloped virus. In a study evaluating virucidal efficacy of antimicrobial surface coatings against the enveloped bacteriophage Φ6, none of the spray-based products retained efficacy after subjecting the coating to abrasion with either a hypochlorite or quaternary ammonium-based solution applied in accordance with EPA Interim Guidance for Evaluating the Efficacy of Antimicrobial Surface Coatings. (N.B. For electrostatic sprayer applications, coupons were sprayed for 10 s from a 0.9–1.2- m distance with the electrostatic sprayer pointed towards the array of coupons at a ~0° to 30°angle and then allowed to dry overnight at ambient laboratory conditions, uncovered and inside a laboratory fume hood.)
Casey [10]	2015	Field study	Transporting ill persons from the community to Ebola care facilities can stop community spread. Vehicles used for patient transport in infectious disease outbreaks should be evaluated for adequate infection prevention and control. Problem: An ambulance driver in Sierra Leone attributed his Ebola infection to exposure to body fluids that leaked from the patient compartment to the driver cabin of the ambulance. Methods: A convenience sample of 14 vehicles used to transport patients with suspected or confirmed Ebola in Sierra Leone were assessed.	Usage	Many vehicles used by ambulance staff in Sierra Leone were not traditional ambulances, but were pick-up trucks or sport-utility vehicles that had been assembled or modified for patient transport. The wall separating the patient compartment and driver cabin in many vehicles did not have a waterproof seal around the edges. Staff responsible for cleaning and disinfection did not thoroughly clean bulk body fluids with disposable towels before disinfection of the patient compartment. Pressure from chlorine sprayers used in the decontamination process may have pushed body fluids from the patient compartment into the driver cabin through gaps around the wall. Ambulance design standards do not require a waterproof seal between the patient compartment and driver cabin. Sealing the wall by tightening or replacing existing bolts is recommended, followed by caulking of all seams with a sealant.
Casey [10]	2015	Field study		Usability	Staff responsible for cleaning and disinfecting ambulances often did not remove bulk body fluids with disposable towels before disinfecting with chlorine sprayers. Body fluids remained in the patient compartment during chlorine disinfection. Pressure from chlorine sprayers used in the

Author	Year	Study methods	Method details, measures or findings relevant to the extraction of contextual data	Data type	Contextual data
					decontamination process could push body fluids in the patient compartment through gaps around the separating wall into the driver cabin.
Cook [11]	2015	Testing study	Evaluating environmental persistence and disinfection of the Ebola Virus Makona variant. For the evaluation of disinfectants, EBOV/Mak in a simulated organic soil was dried onto stainless steel carriers and disinfected with 0.01% (v/v), 0.1% (v/v), 0.5% (v/v) and 1% (v/v) sodium hypochlorite solutions or 67% (v/v) ethanol at contact times of 1, 5 or 10 minutes.	Usage	Sodium hypochlorite and ethanol effectively decontaminate EBOV/Mak suspended in a simulated organic load; however, selection of concentration and contact time proves critical.
Cutts [12]	2020	Testing study	Microbicides play critical roles in infection prevention and control of Ebola virus by decontaminating high-touch environmental surfaces (HITES), interrupting the virus-HITES-hands nexus. We evaluated the efficacy of formulations containing different microbicidal actives for inactivating Ebola virus– Makona strain (EBOV/Makona) on stainless-steel carriers per ASTM E2197-11. Formulations of sodium hypochlorite (NaOCl) (0.05–1%), ethanol (70%), chloroxylenol (PCMX) (0.12–0.48% by weight) in hard water, and a ready-to-use disinfectant spray with 58% ethanol (EDS), were tested at contact times of 0, or 0.5 to 10 min at ambient temperature.	Implementation	The carrier inactivation data for EBOV/ Makona presented here demonstrate that a variety of microbicides should be useful for effective inactivation of Ebola virus on stainless steel surfaces. These microbicides include 70% ethanol at contact times ≥ 5 min, NaOCl at concentrations of 0.5% or greater, at contact times ≥ 5 min, PCMX at concentrations of 0.48% and contact time of ≥ 5 min, and a ready-to-use disinfectant spray with 58% ethanol (EDS) used as supplied at contact time ≥ 5 min. Under these conditions, no residual EBOV/ Mak virus was detectable (≥ 6.3 log10 inactivation) as indicated by the TCID50 assay and the plate safety assay.
Cutts [13]	2020	Testing study	Disinfectant pre-soaked wipes (DPW) containing activated hydrogen peroxide (AHP) or quaternary ammonium compounds (QAC) were tested using ASTM E2967-15 to determine removal, transfer, and inactivation of Ebola virus Makona variant (EBOV/Mak) and vesicular stomatitis virus (VSV) from contaminated stainless steel prototypic environmental surfaces.	Implementation	In the case of Ebola virus, it is essential that disinfectant pre-soaked wipes with an appropriate microbicidal active, following the appropriate contact time, be used to prevent unintended transfer of infectious virus to a clean secondary surface. Otherwise, there exists the possibility of dissemination of Ebola virus and the associated risk of transmission of Ebola virus disease.
Cutts [14]	2021	Testing study	The authors evaluated four disinfectant pre-impregnated wipes (DPW) for efficacy against Ebola virus Makona variant (EBOV) and vesicular stomatitis virus (VSV), Indiana serotype. Steel carriers were inoculated with the infectious virus and then were wiped with DPW in the Wiperator instrument per ASTM E2967-15. Following the use of J-Cloth impregnated with medium (negative control wipes) or the use of activated hydrogen peroxide (AHP)-, ethanol-, sodium hypochlorite (NaOCl)-, or single or dual quaternary ammonium compound (QAC)-based DPW, virus recovery from the carriers was assayed by titration assay and by two passages on Vero E6 cells in 6-well plates. The Wiperator also enabled the measurement of potential transfer of the virus from the inoculated carrier to a secondary carrier by the DPW or control wipes.	Implementation	DPW containing AHP, ethanol, NaOCl, or single or dual QAC as active microbicidal ingredients removed/inactivated ∼6 log10 of the virus, with minimal EBOV or no VSV virus transfer to a secondary surface observed. In Ebola virus outbreaks, a DPW with demonstrated virucidal efficacy, used as directed, may help to mitigate the unintended spread of the infectious virus while performing surface cleaning.
Lantagne[7]	2018	Experimental study to test the efficacy of surface cleaning	To provide evidence for the disinfection recommendations, three research strands were conducted: (1) impacts of chlorine chemistry; (2) efficacy of surface cleaning recommendations; and (3) safety and efficacy of handwashing recommendations. A testing matrix was developed that included various surface types that are relevant in emergency health responses (nitrile, heavy duty tarp, stainless steel); chlorine types (NaDCC, HTH, generated NaOCl, stabilized NaOCl); soil load (with and without); and factors that varied between the MSF, WHO and CDC recommendations, including exposure time (10, 15 min) and recommended pre-treatments (none, covering, wiping, covering/wiping) [13]. The bacteriophage that was most similar to the Ebola virus was left to dry for one hour on a disc with a surface diameter of 8 cm, disinfection was carried out with or without pre-treatment and the residual contamination on the disc was measured at the end of the exposure time.	Implementation	Across the entire test matrix, there was always a reduction of > 99.9% in Phi6 [13] The results suggest that: (1) surface type influenced disinfection efficacy; (2) chlorine type and soil load did not impact disinfection efficacy when using 0.5% chlorine; (3) contact time did impact efficacy against Phi6; and (4) wiping or covering did not increase disinfection efficacy, but the latter could limit splashing. Surface cleaning with 0.5% chlorine solutions with a 15-min exposure time is efficacious in reducing transmission risk.
Poliquin[15]	2016	Environmental surveillance study	This study conducted environmental surveillance in 2 ETCs in Freetown, Sierra Leone, during the 2014–2016 West African Ebola outbreak. Methods. ETCs were surveyed over a 3-week period. Sites to be swabbed were identified with input from field personnel. Swab samples were	Implementation	A finding of interest was the difference in the persistence of signal intensity between the vomitus that was sprayed with 0.5% chlorine solution compared with the unsprayed sample (Figure 2C). The counterintuitive, prolonged persistence of RNA in the sprayed sample may reflect the fact that natural RNA degradation enzymes (with or without

Author	Year	Study methods	Method details, measures or findings relevant to the extraction of contextual data	Data type	Contextual data
			collected and tested for the presence of EBOV RNA. Ebola-positive body fluid-impregnated cotton pads were serially sampled.		bacteria contamination) were inactivated by the 0.5% chlorine solution, thereby preserving the RNA. By extension this phenomenon might explain persistence of RNA on some other surfaces, such as concrete, although experimental evidence to support this conclusion is limited [15]

Infection prevention and control measures for Ebola and Marburg Virus disease: A series of rapid reviews

KQ10 Spraying vs. Wiping of Health Care Workers- Initial Summary

(Version 1, 6 September 2022)

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Funding: Funding for this protocol and the subsequent reviews was provided by the World Health Organization (Funding # 202818287). The working group (WG) from the WHO/HQ Country Readiness Strengthening Health Care Readiness Unit will be consulted to develop and refine the scope, and review and approve the protocol. The WG will not be involved in the conduct of the review including selection of studies and data analysis but will advise as needed on priority population(s), interventions, and outcomes in an iterative process during the review process based on the available evidence. The WG will also comment on the draft report and provide input on interpretations of findings. AT is funded by a Tier 2 Canada Research Chair in Knowledge Synthesis. SM is funded by a Tier 2 Canada Research Chair in Mathematical Modeling and Program Science.

Competing interests: DM was involved in the 2015 rapid review by Hersi et al. [1] There are no other competing interests to acknowledge.

Acknowledgements: We thank Kaitryn Campbell, MLIS, MSc (St. Joseph's Healthcare Hamilton/McMaster University) for peer review of the Embase search strategy.

Key Question

KQ10: Should health workers to patients with Ebola or Marburg disease be sprayed versus not sprayed during doffing of personal protective equipment (PPE)?

Methods Summary

This is one of a series of rapid reviews answering 12 key questions related to three themes on infection prevention and control measures for filoviruses: (i) transmission/exposure (n=3 questions), (ii) personal protective equipment (PPE) (n=5), and (iii) decontamination and disinfection (n=4). Data sources include Medline, Embase, bio/medRxiv pre-print servers, Global Medicus Index, Epistemonikos, China National Knowledge Infrastructure (CNKI) and Wangfang database. We used an automation tool (CAL® tool) for titles/abstracts screening for relevant systematic reviews and primary comparative studies. Full-text screening, data extraction, risk of bias assessment, and GRADE (Grading of Recommendations Assessment, Development and Evaluation) for the certainty of evidence were completed independently by two reviewers with any disagreements resolved by consensus, with arbitration by a third reviewer, when needed.

Findings

A total of 164 studies were screened in the CAL tool software and 32 studies were included for full-text screening. A list of excluded studies with reasons for exclusion can be found in Appendix 1 and the eligibility criteria for each question is in Appendix 2.

Two studies were included. One non-randomized parallel group simulation study[1] assessed viral self-contamination after health care workers performed a 16-step Ebola virus PPE doffing protocol. Participants were assigned to extra glove sanitization through spraying of the hands with hypochlorite solution or use of an alcohol-based hand rub (ABHR). The level of surrogate viruses, MS2 and bacteriophage Φ6, on the hands, face or scrubs of health care workers was ascertained following inner glove removal (Table 2). Overall, there was no detectable transfer of enveloped bacteriophage Φ6 for any participants and the certainty of evidence was judged to be very low comparing the effects of hypochlorite spray and ABHR for prevention of Φ6 transfer (Appendix 3). Additionally, there was low certainty of evidence that additional glove sanitization with hypochlorite prevented transfer of MS2 compared to ABHR (Appendix 3).

One retrospective cohort study[2] assessed the level of Ebola virus IgG antibody and prior exposure events among returned responders of the 2014-2016 West African Ebola epidemic. The study collected information on personal protective equipment used, including whether removal of Ebola PPE was performed with or without chlorine spray. Although reported in Table 3, the data is unreliable due to collinearity between use of spray and health care worker role. Almost all participants who reported performing clinical work used spray and almost all participants who did not use spray reported having a role in laboratory work. The difference in the likelihood of exposure between these two occupational groups makes it impossible to analyze the independent effect of spraying the PPE with chlorine. The overall certainty of evidence for the effectiveness of spraying PPE with chlorine prior to PPE removal to mitigate the risk of Ebola virus transmission was judged to be very low (Appendix 4).

Table 1. Characteristics of Included Studies

Citation [Author, Year]	Study Design	Funding Source	Virus Species	Setting	# Total Health Workers	# Health Care Facilities	Description of Health Worker Care/contact with patients	Study Objectives [as reported by study authors]
Casanova, 2016, [1]	Non-randomized simulation study	Non-profit organization (CDC)	Mixture of MS2 (non-enveloped virus surrogate) and Φ6 (enveloped virus surrogate) suspended in phosphate-buffered saline	Patient room in a large tertiary care academic medical center	15 HCWs from an Ebola care team (11 RNs and 4 MDs)[a]	1	Mixture of virus surrogate applied to four PPE sites on HCWs to simulate contamination through droplet exposure during patient care[b]	The goal of this research was to assess viral self-contamination of skin and clothes during a standard EVD PPE doffing protocol performed by trained HCWs using PPE artificially contaminated with 2 surrogate viruses: MS2 (a surrogate for non-enveloped human viruses) and bacteriophage Φ6 (a surrogate for enveloped viruses such as Ebola)
Houlihan, 2017, [2]	Retrospective cohort study	Non-profit organization (Wellcome Trust)	Level of Ebola virus IgG antibody (indicator of previous infection)	West Africa 2014-2016 (94% participants Sierra Leone, 4.5% Liberia, 1.1% Guinea)	268 UK/Irish workers who responded to 2014-2016 West African Ebola epidemic[c]	Not reported	Risk of Ebola virus disease exposure/ transmission ranged from high risk (n=1, 0%) to very low (n=27, 10%) risk	The aim of this project was to assess the prevalence of asymptomatic or pauci-symptomatic infection, and of exposure events, among returned responders to the West African Ebola epidemic 2014–2016

Abbreviations: HCW, health care workers, MD, medical doctor, PPE, personal protective equipment, RN, registered nurse

a. Members of the Ebola team were > 18 years of age and had undergone extensive training in a simulation laboratory in the use of EVD-specific PPE, including donning and doffing.
b. Mixture (25 μL in 5 drops of 5 μL) was applied to 4 sites: (1) the palm of the dominant hand, (2) the shoulder of the gown opposite the dominant hand, (3) the top side of the face shield on the same side as the dominant hand, and (4) the toe of the rubber boot opposite the dominant hand.
c. Roles included clinical (physician/nurse), laboratory, research, as well as management/operations, trainer, epidemiologist, community engagement/tracing, WASH staff, finance, engineer, pharmacist, and social worker/burial team/information technology/journalist/visitor/logistician/nutritionist.

Table 2. Summary of Findings: Transfer of Phi6 or MS2

Study details	***Intervention*** (Spraying with chlorine solution prior to removing PPE)	***Comparator(s)*** (No spraying with chlorine solution prior to removing PPE)	***Outcome in intervention group***	***Outcome in control group***	***Quality Assessment***[a]	***GRADE***	***Notes***
Transfer of Φ6 (n/N, %) to inner gloves, hands, face or scrubs following doffing protocol							
Casanova, 2016, [1]	Doffing protocol with extra glove sanitization with sprayed hypochlorite sanitizer[b]	Doffing protocol with alcohol-based hand rub for extra glove sanitization[c]	0/5, (0%)	0/10, (0%)	Moderate risk of bias	⊕◯◯◯ Very low	Hypochlorite spray or ABHR use for extra hand sanitization was the only alteration between doffing protocols
Transfer of MS2 (n/N, %) to inner gloves following doffing protocol							
Casanova, 2016, [1]	Doffing protocol with extra glove sanitization with sprayed hypochlorite sanitizer[b]	Doffing protocol with alcohol-based hand rub for extra glove sanitization[c]	0/5, (0%)	8/10, (80%)	Moderate risk of bias	⊕◯◯◯ Very low	Hypochlorite spray or ABHR use for extra hand sanitization was the only alteration between doffing protocols
Transfer of MS2 (n/N, %) to hands following doffing protocol							
Casanova, 2016, [1]	Doffing protocol with extra glove sanitization with sprayed	Doffing protocol with alcohol-based hand rub for extra glove sanitization[c]	1/5, (20%)	0/10, (0%)	Moderate risk of bias	⊕◯◯◯ Very low	Hypochlorite spray or ABHR use for extra hand sanitization was

Study details	***Intervention*** (Spraying with chlorine solution prior to removing PPE)	***Comparator(s)*** (No spraying with chlorine solution prior to removing PPE)	***Outcome in intervention group***	***Outcome in control group***	***Quality Assessment***[a]	***GRADE***	***Notes***
	hypochlorite sanitizer[b]						the only alteration between doffing protocols
Transfer of MS2 (n/N, %) to face following doffing protocol							
Casanova, 2016, [1]	Doffing protocol with extra glove sanitization with sprayed hypochlorite sanitizer[b]	Doffing protocol with alcohol-based hand rub for extra glove sanitization[c]	0/5, (0%)	0/10, (0%)	Moderate risk of bias	⊕◯◯◯ Very low	Hypochlorite spray or ABHR use for extra hand sanitization was the only alteration between doffing protocols
Transfer of MS2 (n/N, %) to scrubs following doffing protocol							
Casanova, 2016, [1]	Doffing protocol with extra glove sanitization with sprayed hypochlorite sanitizer[b]	Doffing protocol with alcohol-based hand rub for extra glove sanitization[c]	1/5, (20%)	0/10, (0%)	Moderate risk of bias	⊕◯◯◯ Very low	Hypochlorite spray or ABHR use for extra hand sanitization was the only alteration between doffing protocols

a. Quality assessment of studies was completed using the ROBINS-I tool for non-randomized studies.
b. For each glove sanitizing step in steps 1-12 of the 16-step doffing protocol, liquid hypochlorite (Fuzion Healthcare Disinfectant, Clorox Co., Pleasanton, CA) at a concentration of 1850 ppm was sprayed onto gloves. The final hand hygiene steps (Steps 13 and 16) that called for sanitizing bare hands were performed using ABHR.

c. For each glove sanitizing step in steps 1-12 of the 16-step doffing protocol, 70% ethanol gel was applied to gloves. The final hand hygiene steps (Steps 13 and 16) that called for sanitizing bare hands were performed using ABHR.

Table 3. Summary of Findings: Infection with Ebola virus

Study details	***Intervention*** (Spraying with chlorine solution prior to removing PPE)	***Comparator(s)*** (No spraying with chlorine solution prior to removing PPE)	***Outcome in intervention group***	***Outcome in control group***	***Quality Assessment***[a]	***GRADE***	***Notes***
IgG antibody against Ebola Virus [as an indicator of previous infection]							
Houlihan, 2017, [2]	PPE removal with chlorine spray	PPE removal without chlorine spray	33/132, (25%)	7/98, (7.1%)	High risk of bias (6/9 star rating)	⊕◯◯◯ Very low	Authors did not include PPE removal in their analysis since method of PPE removal was almost collinear with HCW role. Almost all HCWs in clinical roles were sprayed with chlorine and had assistance, and almost all HCWs in laboratory roles were not sprayed and removed PPE without assistance.

a. Quality assessment of studies was completed using the Newcastle Ottawa Scale (NOS) for observational studies. 7-9 stars was judged to be low risk of bias, 4-6 high risk of bias, and 0-3 stars very high risk of bias.

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2. Houlihan CF, McGowan CR, Dicks S, et al. Ebola exposure, illness experience, and Ebola antibody prevalence in international responders to the West African Ebola epidemic 2014–2016: A cross-sectional study. Boyles T, ed. *PLOS Med.* 2017;14(5):e1002300. doi:10.1371/journal.pmed.1002300

Appendix 1. Excluded Studies List – By Reason for Exclusion:

Does not examine Ebola or Marburg

Martin D, Balermpas P, Gollrad J, et al. RADIANCE – Radiochemotherapy with or without Durvalumab in the treatment of anal squamous cell carcinoma: A randomized multicenter phase II trial. Clinical and Translational Radiation Oncology. 2020;23:43-49. doi:10.1016/j.ctro.2020.04.010

Full-text unavailable

Drew J, Turner J, Cooper D, Zaiser R, Duncan T, Mugele J. Novel use of ultraviolet tracer contagion in multiple-patient simulation and the effect of personal protective equipment on contagion spread: A feasibility study. Academic Emergency Medicine. Published online 2015.

Garibaldi BT, Rainwater-Lovett K, Pilholski T, et al. Transmission of fluorescent aerosolized particles in a clinical biocontainment unit. American Journal of Respiratory and Critical Care Medicine Conference: American Thoracic Society International Conference ATS. Published online 2017.

Somers Y, Verbiest M. Suspecting ebola: When the dress code becomes life saving! Personal protective equipment-a practical demonstration. Anaesthesiology Intensive Therapy. Published online 2014.

Narrative review

Fischer WA, Weber DJ, Wohl DA. Personal Protective Equipment: Protecting Health Care Providers in an Ebola Outbreak. Clinical Therapeutics. 2015;37(11):2402-2410. doi:10.1016/j.clinthera.2015.07.007

Non comparative study

Casanova LM, Erukunuakpor K, Kraft CS, et al. Assessing Viral Transfer During Doffing of Ebola-Level Personal Protective Equipment in a Biocontainment Unit. Clinical Infectious Diseases. 2018;66(6):945-949. doi:10.1093/cid/cix956

Ortega R, Bhadelia N, Obanor O, et al. Putting On and Removing Personal Protective Equipment. N Engl J Med. 2015;372(25):2464-2465. doi:10.1056/NEJMc1504851

Lee M a, Huh K, Jeong J, et al. Adherence to Protocols by Healthcare Workers and Self-Contamination During Doffing of Personal Protective Equipment. American Journal of Infection Control. 2018;46(6):S11. doi:10.1016/j.ajic.2018.04.024

Lim SM, Cha WC, Chae MK, Jo IJ. Contamination during doffing of personal protective equipment by healthcare providers. Clin Exp Emerg Med. 2015;2(3):162-167. doi:10.15441/ceem.15.019

Russo N, Archer M, Kinzie L, Pfeiffer CD. Beyond Ebola: Standardizing the Approach to High Consequence Infection Preparation. American Journal of Infection Control. 2018;46(6):S110-S111. doi:10.1016/j.ajic.2018.04.196

No outcome data

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Systematic review (references screened)

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Appendix 2. Eligibility Criteria

Question (10): Should health workers to patients with Ebola or Marburg disease be sprayed versus not sprayed during doffing of personal protective equipment (PPE)?

Population	Staff in HCF, ETU and community (e.g., burial teams)
Background interventions (Standard of care)	Varies by organization. WHO recommends staff remove PPE in correct order, no spraying
Intervention	Staff spraying with chlorine solution prior to removing PPE
Comparator(s)	No Staff spraying with chlorine solution prior to removing PPE
Outcome	Adverse effects associated with chemical exposure, infection with Ebola virus or Marburg, *health worker confidence*
Potential effect modifiers	Decontamination method and the types of PPE, *Chlorine concentration, chlorine type*
Setting	Health Care Facilities, ETU *Contexts to consider: ETU use vs. healthcare facility; outbreak vs readiness vs. high alert scenario.

Appendix 3. GRADE Assessment: Transfer of Phi6 or MS2

Certainty assessment							№ of patients		Effect		Certainty	Importance
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	chlorine spray of PPE	no chlorine spray of PPE	Relative (95% CI)	Absolute (95% CI)		
Transfer of Phi6 to inner gloves, hands, face or scrubs following doffing protocol												
1	observational studies	not serious[a]	not serious[b]	serious[c]	very serious[d]	none	0/5 (0.0%)	0/10 (0.0%)	not estimable	-	⨁◯◯◯ Very low	
Transfer of MS2 to inner gloves following doffing protocol												
1	observational studies	not serious[a]	not serious[b]	serious[e]	very serious[f]	none	0/5 (0.0%)	8/10 (80.0%)	not estimable	-	⨁◯◯◯ Very low	
Transfer of MS2 to hands following doffing protocol												
1	observational studies	not serious[a]	not serious[b]	serious[e]	very serious[g]	none	1/5 (20.0%)	0/10 (0.0%)	not estimable	-	⨁◯◯◯ Very low	
Transfer of MS2 to face following doffing protocol												
1	observational studies	not serious[a]	not serious[b]	serious[e]	very serious[d]	none	0/5 (0.0%)	0/10 (0.0%)	not estimable	-	⨁◯◯◯ Very low	
Transfer of MS2 to scrubs following doffing protocol												
1	observational studies	not serious[a]	not serious[b]	serious[e]	very serious[g]	none	1/5 (20.0%)	0/10 (0.0%)	not estimable	-	⨁◯◯◯ Very low	

CI: confidence interval

Explanations

a. The overall risk of bias rated to be "moderate" using the ROBINS-I tool for non-randomized studies. The study was judged to be of low risk of bias for all but one domain. One domain was rated at moderate risk of bias due to a lack of blinding of the participants of the intervention and the trained monitor guiding participants through the doffing process.
b. Judged to be not serious as there was only one relevant study for this outcome.
c. Downrated once due to simulation study. Phi6 is a surrogate for enveloped viruses such as Ebola.
d. No events in either group, very small sample size and optimal information size (OIS) not met.
e. Downrated twice due to simulation study and use of MS2 as surrogate agent (non-enveloped virus surrogate).
f. Few events, very small sample size and OIS not met.
g. Only one event, very small samples size and OIS not met.

Appendix 4. GRADE Assessment: Infection with Ebola virus

Certainty assessment							№ of patients		Effect		Certainty	Importance
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	chlorine spray of PPE	no chlorine spray of PPE	Relative (95% CI)	Absolute (95% CI)		
Infection with Ebola Virus												
1	observational studies	serious[a]	not serious[b]	not serious	serious[c]	none	33/132 (25.0%)	7/98 (7.1%)	**RR 3.52** (1.62 to 7.58)	**180 more per 1,000** (from 44 more to 470 more)	⨁◯◯◯ Very low	

CI: confidence interval; **RR:** risk ratio

Explanations

a. Risk of bias was judged to be high using the Newcastle Ottawa Scale. The study was awarded 6/9 stars based on use snowball sampling for a convenience sample, relying on self-reports for ascertainment of exposures and lack of reporting of details on PPE equipment or doffing protocols used between HCW roles.
b. No inconsistency detected as only one study included for this outcome.
c. Optimal information size not met and not a large sample size.

Contextual data

KQ 10 – "Should health workers who have direct or indirect contact with patients who have Ebola or Marburg disease be sprayed versus not sprayed during the doffing of personal protective equipment?"

Guideline recommendations

Table 1 summarizes recommendations regarding doffing of PPE by the WHO, US CDC and European CDC. [1] [2] [3]

Figure 1 and 2 displays the doffing procedures according to the WHO 2014 guides, including coverall and gown, respectively. These procedures do not involve spraying.[1]

Section 9C of the US CDC 2014 guides outlines the PPE doffing procedure for the Powered Air-Purifying Respirator (PAPR) option, including 19 steps and in particular, steps related to disinfecting of outer gloves, inner gloves and washable shoes with either a disinfectant wipe or alcohol-based hand rub (ABHR), and allow drying. Section 9D outlines the PPE doffing procedure for N95 respirator option, including 23 steps and in particular similar disinfecting steps. None of the disinfecting steps involves spraying. [2]

Section 5.3 of the European CDC 2014 guides describe the PPE doffing procedures, including 16 steps. None of the steps involves spraying. [3] The procedures call for using alcohol-based hand disinfectant or a disinfectant for non-enveloped viruses at various steps of the doffing process. The procedures suggest that during the doffing process, the assistant can wear up to four pairs of gloves on top of each other, which saves time on changing the gloves. Instead of having to put on a new pair of gloves every time, the assistant will simply remove the outer pair. The use of this approach needs to be balanced with its limitations, as wearing four layers might compromise tactility and motility.

Contextual data

Table 2 summarizes the contextual data.

Key findings

- We identified 14 studies describing steps of the doffing protocols. None of the doffing protocols includes a discrete step describing the practice of spraying PPEs. Eleven studies did not use the word "spray". Three studies mentioned the word "spray" as part of the study reporting.
- PPE can both protect and put health workers at risk for self-contamination throughout the doffing process, even among experienced HCWs doffing with a trained observer.
- During PPE doffing, common protocol deviations included touching outer gloves with inner-gloved hands and touching the outside of gloves with bare hands. Hand hygiene and glove removal are high-risk opportunities for health-worker self-contamination.
- Doffing protocols need to incorporate *highly effective glove and hand hygiene agents*. Optimizing doffing protocols may require reinforcing careful handling of scrubs and good glove/hand hygiene with effective agents.
- Hands-free alcohol based hand rub delivered directly into the HCWs' palm keeping the dispenser uncontaminated.
- In the UK, a consensus protocol calls for three layers of gloves: • Inner personal protection glove (standard short non-sterile glove) • Middle glove (long cuffed glove), taped to gown • Outer glove comprising either standard short non-sterile gloves for basic care, or heavier duty gloves for cleaning up of extreme bodily fluid episodes.

Casanova et al. 2016 conducted a practice simulation study in which 15 health workers donned PPE, surrogate virus was applied to PPE, and a trained monitor guided them through the doffing protocol.[4] Of the 15 participants, ten participants used alcohol-based hand rub (ABHR) for glove and hand hygiene and 5 used hypochlorite for glove hygiene and ABHR for hand hygiene. Inner gloves, hands, face, and scrubs were sampled after doffing. *For the last 5 subjects, each step that called for sanitizing gloved hands was performed with liquid hypochlorite at a concentration of 1,850 ppm (Fuzion Healthcare Disinfectant, Clorox Co., Pleasanton, CA) applied by spraying onto gloves*. The authors report that after doffing, MS2 virus was detected on the inner glove worn on the dominant hand for 8 of 15 participants, on the non-dominant inner glove for 6 of 15 participants, and on scrubs for 2 of 15 participants. *All MS2 on inner gloves was observed when ABHR was used for glove hygiene; none was observed when hypochlorite was used.* When using hypochlorite for glove hygiene, 1 participant had MS2 on hands, and 1 had MS2 on scrubs. According to the authors' conclusion, a structured doffing protocol using a trained monitor and ABHR protects against enveloped virus self-contamination. *Non-enveloped virus (MS2) contamination was detected on inner gloves, possibly due to higher resistance to ABHR*. Doffing protocols protective against all viruses need to incorporate *highly effective glove and hand hygiene agents*.

Casanova et al. 2017 assessed contamination of skin, gloves, and scrubs after doffing Ebola-level PPE contaminated with surrogate viruses: bacteriophages MS2 and Φ6.[5] In a medical biocontainment unit, HCWs (n = 10) experienced in EVD care donned and doffed PPE following unit protocols that incorporate trained observer guidance and alcohol-based hand rub (ABHR). A mixture of Φ6 (enveloped), MS2 (non-enveloped), and fluorescent marker was applied to 4 PPE sites, approximating body fluid viral load (Φ6, 10^5; MS2, 10^6). They performed a patient care task, then doffed. Inner gloves, face, hands, and scrubs were sampled for virus, as were environmental sites with visible fluorescent marker.

Among 10 HCWs there was no Φ6 transfer to inner gloves, hands, or face; 1 participant had Φ6 on scrubs at low levels (1.4×10^2). MS2 transfer (range, 10^1–10^6) was observed to scrubs (n = 2), hands (n = 1), and inner gloves (n = 7), where it was highest. Most (n = 8) had only 1 positive site. According to the authors' conclusion, among experienced HCWs, structured, observed doffing using ABHR protected against hand contamination with enveloped virus. Non-enveloped virus was infrequent on hands and scrubs but common on inner gloves, suggesting that inner gloves, but not necessarily ABHR, protect against hand contamination. Optimizing doffing protocols to protect against all types of viruses may require reinforcing careful handling of scrubs and *good glove/hygiene with effective agents*.

McLaws et al. 2016 reviewed video guidelines and guidelines considered to lead infection control globally and a modified Centers for Disease Control and Prevention (CDC) video and a local video from the New South Wales Ministry of Health.[6] Each video was reviewed with the intent of identifying exemplary doffing for the principle that no used PPE surface should come into contact with mucous membranes, face, or hair. Their review identified a lack of consensus for three critical areas: sequence, assistance, and environment.

The Médecins Sans Frontières video illustrates spraying the heavy duty apron with bleach, but later sequencing of the removal of the facial protection would improve the margin of error. For the removal of boots, that have already been decontaminated in a 0.5% chlorine footbath but that may have become re-contaminated during doffing of coveralls, the North Carolina video instructs the HCW to keep boots within the doffing zone while turning to sit on a chair that is located inside the clean zone. This modification to the CDC video includes an excellent additional step that prevents the environment outside the doffing area from becoming contaminated. This video also demonstrates the HCW standing in a basin of bleach for 1 minute before stepping onto a mat that is in accordance with the MSF guideline used in Ebola treatment units. The study authors suggest that *hands-free alcohol based hand rub (ABHR) delivered directly into the HCWs' palm keeping the dispenser uncontaminated*.

Reidy et al. 2017 describe the process of selecting the combination of personal protective equipment (PPE) together with donning and doffing protocols for British and Canadian military medical personnel in the Kerry Town Ebola Treatment Unit (ETU) in Sierra Leone.[7] *In the last step of the doffing protocol, the HWs step on rubber disinfection mat, scrape soles of boots on mat, step out of chlorine bath and boot-spraying area, and exit.* The doffing protocol calls for repeated washing gloved hands in 0.5% chlorine; clean tap by rinsing with chlorine before turning tap off.

Poller, 2018 conducted a simulation-based exercise to assess the safety of PPE ensembles in use in the UK during first assessment of a patient with a possible high-consequence infectious disease (HCID).[8] A mannequin was adapted to expose volunteer HCWs to synthetic bodily fluids (vomit, sweat, diarrhoea and cough), each with a different colored fluorescent tracer, invisible other than under ultraviolet (UV) light. After exposure, HCWs were examined under UV lights to locate fluorescent contamination, and were screened again after removing PPE (doffing) to detect any personal contamination. The exercise was videoed, allowing retrospective analysis of contamination events and user errors.

The simulation testing identified significant HCW contamination events after doffing, related to protocol failure or complications in PPE doffing, providing conclusive evidence that improvements could be made. At a workshop with an expert stakeholder group, the data were examined and a unified PPE ensemble agreed. This ensemble was then tested in the same simulation exercise and *no evidence of any HCW contamination was seen after doffing*. Following further review by the working group, a consensus agreement has been reached and a unified 'HCID assessment PPE' ensemble, with accompanying donning and doffing protocols, is presented here. *The final protocol used three layers of gloves: • Inner personal protection glove (standard short non-sterile glove) • Middle glove (long cuffed glove), taped to gown • Outer glove comprising either standard short non-sterile gloves for basic care, or heavier duty gloves for cleaning up of extreme bodily fluid episodes*.

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Table 1: Summary of guideline recommendations regarding disinfection of Ebola-exposed surfaces by the WHO, US and European CDC

Source	Should health workers who have direct or indirect contact with patients who have Ebola or Marburg disease be sprayed versus not sprayed during the doffing of PPE?
WHO	2014
Doffing procedure[1]	Figure 1 and 2 displays the doffing procedures including coverall and gown, respectively. The procedures do not involve spraying.
US CDC [2]	2014
Doffing procedure	Section 9C of the US CDC guides outlines the PPE doffing procedure for the Powered Air-Purifying Respirator (PAPR) option, including 19 steps and in particular, steps related to disinfecting of outer gloves, inner gloves and washable shoes with either an disinfectant wipe or alcohol-based hand rub (ABHR), and allow to dry. Section 9D outlines the PPE doffing procedure for N95 respirator option, including 23 steps and in particular similar disinfecting steps. None of the disinfecting steps involves spraying.
European CDC [3]	2014
Doffing procedure	Section 5.3 describes the PPE doffing procedures, including 16 steps. None of the steps involves spraying. The procedures call for using alcohol-based hand disinfectant or a disinfectant for non-enveloped viruses at various steps of the doffing process. The procedures suggest that during the doffing process, the assistant can wear up to four pairs of gloves on top of each other, which saves time on changing the gloves. Instead of having to put on a new pair of gloves every time, the assistant will simply remove the outer pair. The use of this approach needs to be balanced with its limitations, as wearing four layers might compromise tactility and motility.

Table 2. Summary of contextual data

Author, year	Study methods	Method details, measures or findings relevant to the extraction of contextual data	Data type	Contextual data
Casanova, 2016[4]	Testing study (N.B. Spraying for disinfecting purposes)	A total of 15 HCP donned EVD PPE for this study. Virus was applied to PPE, and a trained monitor guided them through the doffing protocol. Of the 15 participants, 10 used alcohol-based hand rub (ABHR) for glove and hand hygiene and 5 used hypochlorite for glove hygiene and ABHR for hand hygiene. Inner gloves, hands, face, and scrubs were sampled after doffing. **For the last 5 subjects, each step that called for sanitizing gloved hands was performed with liquid hypochlorite at a concentration of 1,850 ppm (Fuzion Healthcare Disinfectant, Clorox Co., Pleasanton, CA) applied by spraying onto gloves.**		**Results:** After doffing, MS2 virus was detected on the inner glove worn on the dominant hand for 8 of 15 participants, on the non-dominant inner glove for 6 of 15 participants, and on scrubs for 2 of 15 participants. **All MS2 on inner gloves was observed when ABHR was used for glove hygiene; none was observed when hypochlorite was used.** When using hypochlorite for glove hygiene, 1 participant had MS2 on hands, and 1 had MS2 on scrubs. **Conclusions:** A structured doffing protocol using a trained monitor and ABHR protects against enveloped virus self-contamination. Non-enveloped virus (MS2) contamination was detected on inner gloves, possibly due to higher resistance to ABHR. Doffing protocols protective against all viruses need to incorporate highly effective glove and hand hygiene agents.
McLaws, 2016 [6]	Review of video guidelines	We reviewed video guidelines and guidelines considered to lead infection control globally10-12 and a modified Centers for Disease Control and Prevention (CDC) video13 and a local video from the New South Wales Ministry of Health.14 Each video was reviewed with the intent of identifying exemplary doffing for the principle that no used PPE surface should come into contact with mucous membranes, face, or hair. Our review identified a lack of consensus for 3 critical areas: sequence, assistance, and environment (Table 1).	Implementation	The Médecins Sans Frontières video illustrates spraying the heavy duty apron with bleach, but later sequencing of the removal of the facial protection would improve the margin of error. For the removal of boots, that have already been decontaminated in a 0.5% chlorine footbath but that may have become re-contaminated during doffing of coveralls, the North Carolina video instructs the HCW to keep boots within the doffing zone while turning to sit on a chair that is located inside the clean zone. This modification to the CDC video includes an excellent additional step that prevents the environment outside the doffing area from becoming contaminated. This video also demonstrates the HCW standing in a basin of bleach for 1 minute before stepping onto a mat that is in accordance with the MSF guideline used in Ebola treatment units. The study authors suggest that **hands-free alcohol based hand rub (ABHR) delivered directly into the HCWs' palm keeping the dispenser uncontaminated.**
Reidy, 2017[7]	PPE protocol description	The combination of personal protective equipment (PPE) together with donning and doffing protocols was designed to protect British and Canadian military medical personnel in the Kerry Town Ebola Treatment Unit (ETU) in Sierra Leone. The PPE solution was selected to protect medical staff from infectious risks, notably Ebola virus, and chemical (hypochlorite) exposure. **In the last step of the doffing protocol, the HW steps on rubber disinfection mat and scrape soles of boots on mat. She/he then steps out of chlorine bath, boot-spraying area and exits.**	Implementation	The selected PPE maximized dexterity, enabled personnel to work in hot temperatures for periods of up to 2 h, protected mucosal membranes when doffing outer layers, and **minimized potential contamination of the doffing area with infectious material by reducing the requirement to spray PPE with hypochlorite**. Competency in using PPE was developed during a nine-day pre-deployment training program. This allowed over 60 clinical personnel per deployment to practice skills in PPE in a simulated ETU and in classrooms. Overall, the training provided: (i) an evidence base underpinning the PPE solution chosen; (ii) skills in donning and doffing of PPE; (iii) personnel confidence in the selected PPE; and (iv) quantifiable testing of each individual's capability to don PPE, perform tasks and doff PPE safely. (N.B. The doffing protocol calls for repeated washing gloved hands in 0.5% chlorine; clean tap by rinsing with chlorine before turning tap off)
Cummings, 2016 [9]	Practice reflection (N.B. No spraying for disinfecting purposes)	After admission of the first patient with EVD, a multidisciplinary team from the Centers for Disease Control and Prevention (CDC) joined the hospital's infection prevention to implement a system of occupational safety and health controls for direct patient care, handling of clinical specimens, and managing regulated medical waste. Existing engineering and administrative controls were strengthened. The personal protective equipment (PPE) ensemble was standardized, HCP were trained on donning and doffing PPE, and a system of trained observers supervising PPE donning and doffing was implemented. **Standardized PPE ensembles for all HCP. Instituted a system of trained observers (donning/doffing coaches), including a 22-step doffing procedure, which does not involve disinfection spraying.**	Implementation	The experiences of the authors and others informed national policies for the care of patients with EVD and protection of HCP, including new guidance for PPE, a rapid system for deploying CDC staff to assist hospitals ("Ebola Response Team"), and a framework for a tiered approach to hospital preparedness. **Hygiene of hands and gloved hands appear to be conducted with hospital-grade disinfecting chlorine wipes.**

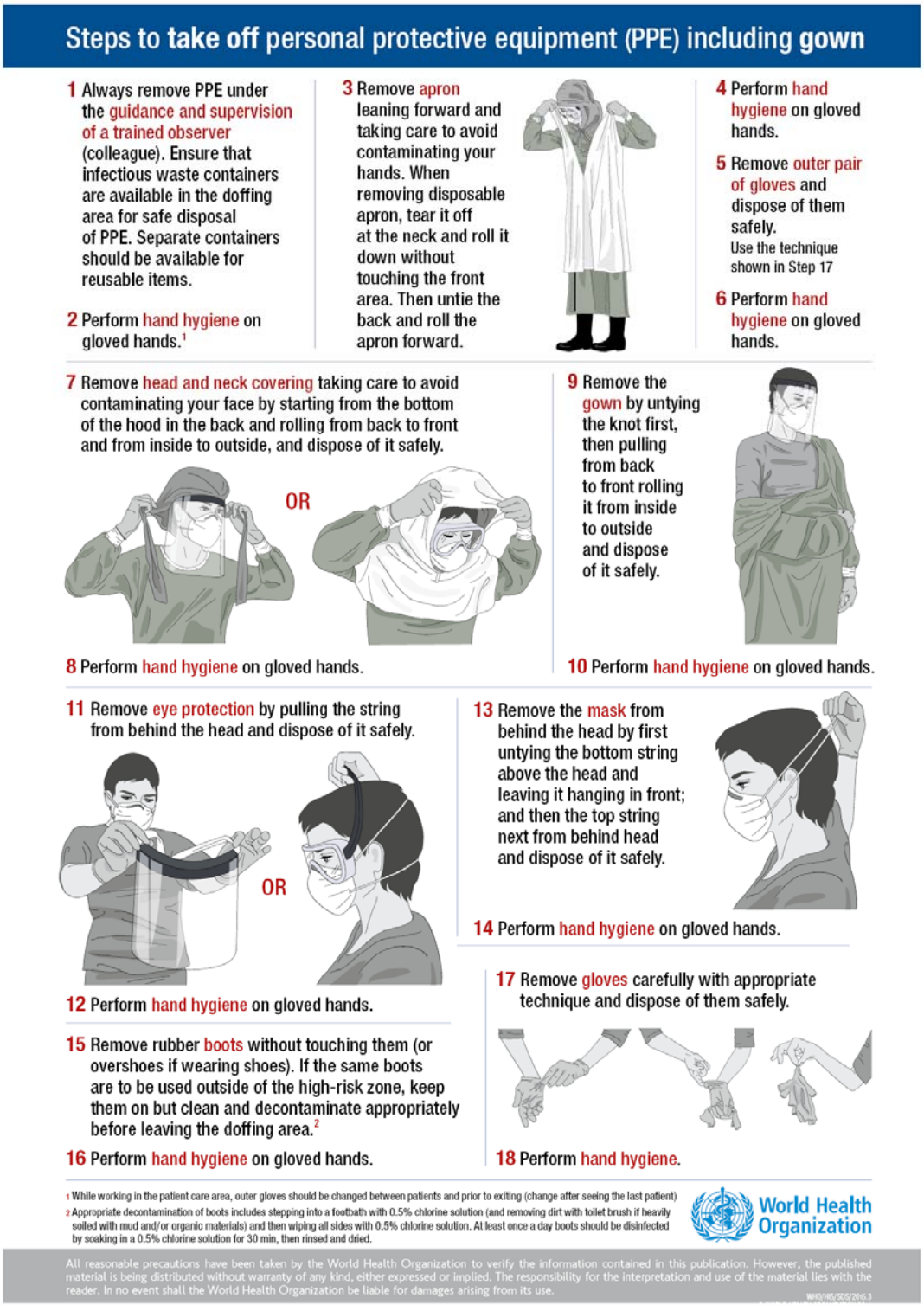
Casanova, 2017[4]	Testing study (N.B. No spraying for disinfecting purposes)	We assessed contamination of skin, gloves, and scrubs after doffing Ebola-level PPE contaminated with surrogate viruses: bacteriophages MS2 and Φ6. **Methods:** In a medical biocontainment unit, HCWs (n = 10) experienced in EVD care donned and doffed PPE following unit protocols that incorporate trained observer guidance and alcohol-based hand rub (ABHR). A mixture of Φ6 (enveloped), MS2 (non-enveloped), and fluorescent marker was applied to 4 PPE sites, approximating body fluid viral load (Φ6, 105; MS2, 106). They performed a patient care task, then doffed. Inner gloves, face, hands, and scrubs were sampled for virus, as were environmental sites with visible fluorescent marker.	Implementation	**Results.** Among 10 HCWs there was no Φ6 transfer to inner gloves, hands, or face; 1 participant had Φ6 on scrubs at low levels (1.4 × 102). MS2 transfer (range, 101–106) was observed to scrubs (n = 2), hands (n = 1), and inner gloves (n = 7), where it was highest. Most (n = 8) had only 1 positive site. **Conclusions**. Among experienced HCWs, structured, observed doffing using ABHR protected against hand contamination with enveloped virus. Non-enveloped virus was infrequent on hands and scrubs but common on inner gloves, suggesting that inner gloves, but not necessarily ABHR, protect against hand contamination. Optimizing doffing protocols to protect against all types of viruses may require reinforcing careful handling of scrubs and **good glove/hand hygiene with effective agents**.
Andonian, 2019 [10]	Randomized controlled trial (N.B. No spraying for disinfecting purposes)	A set of interventions based on previously identified failure modes was designed to mitigate the risk of self- contamination during PPE doffing. These interventions were tested in a randomized controlled trial of 48 participants with no prior experience doffing enhanced PPE. Contamination was simulated using a fluorescent tracer slurry and fluorescent polystyrene latex spheres (PLSs). Self-contamination of scrubs and skin was measured using ultraviolet light visualization and swabbing followed by microscopy, respectively. Doffing sessions were videotaped and reviewed to score standardized teamwork behaviors.	Implementation	An intervention package addressing the PPE doffing task, tools, environment, and teamwork skills significantly reduced the amount of self-contamination by study participants. These elements can be incorporated into PPE guidance and training to reduce the risk of pathogen transmission. None of the elements is related to spraying or not spraying for disinfection during PPE doffing.
Bell, 2015 [11]	Randomized controlled trial (N.B. No spraying for disinfecting purposes)	PPE testing has historically been done by individual component, rather than as a bundle for contact isolation. Fluorescent agents are commonly used in training for infection control techniques. The purpose of our study was to compare 2 PPE bundles and to evaluate the feasibility of fluorescent markers as an assessment tool for PPE effectiveness. Eight healthcare providers volunteered for this preliminary study. Participants were randomized to 1 of 2 PPE bundles that meet current 2014 CDC recommendations. A training mannequin was contaminated with fluorescent agents to simulate bodily fluids. Participants were then given clinical tasks to care for the EVD ‘‘patient.’’	Implementation	One participant in each PPE arm had evidence of contamination. One of the contamination events was suspected during the patient care exercise. The other contamination event was not suspected until black light examination. In spite of a large difference in cost of PPE, the two bundle arms performed similarly. Bundle testing using fluorescent markers could help identify optimal PPE systems. None of the PPE doffing procedures involves spraying for disinfecting purposes.
Chughtai, 2018[12]	Testing study (N.B. No spraying for disinfecting purposes)	Methods: We tested 10 different PPE donning and doffing protocols, recommended by various health organizations for Ebola. Ten participants were recruited for this study and randomly assigned to use 3 different PPE protocols. After donning of PPE, fluorescent lotion and spray were applied on the external surface of the PPE to simulate contamination, and ultraviolet light was used to count fluorescent patches on the skin.	Implementation	**Results:** After testing 30 PPE sequences, large fluorescent patches were recorded after using “WHO coverall and 95” and “North Carolina coverall and N95” sequences, and small patches were recorded after using “CDC coverall and N95” and “Health Canada gown and N95” sequences. Commonly reported problems with PPE use were breathing difficulty, suffocation, heat stress, and fogging-up glasses. Most participants rated PPE high (18/30) or medium (11/30) for ease of donning/doffing and comfort. PPE sequences with powered air-purifying respirators (PAPRs) and assisted doffing were generally associated with fewer problems and were rated the highest. **Conclusion:** This study confirmed the risk of self-contamination associated with the doffing of PPE. PAPR containing protocols and assisted doffing should be preferred whenever possible during the outbreak of highly infectious pathogens.
Kwon, 2017 [13]	Testing study	A total of 36 HCWs were included in this study: 18 donned/doffed contact precaution (CP) PPE and 18 donned/doffed Ebola virus disease (EVD) PPE. HCWs donned PPE according to standard protocols based on CDC recommendations. Fluorescent liquid and MS2 bacteriophage were applied to HCWs. HCWs then doffed their PPE. After doffing, HCWs were scanned for fluorescence and swabbed for MS2. MS2 detection was performed using reverse transcriptase PCR. The donning and doffing processes were videotaped, and protocol deviations were recorded.	Implementation	Hand hygiene and glove removal protocol deviations were common during doffing of both EVD and CP PPE (67% and 39% of HCWs made ≥1 error, respectively). *During EVD PPE doffing, common protocol deviations included touching outer gloves with inner-gloved hands and touching the outside of gloves with bare hands. Hand hygiene and glove removal are high-risk opportunities for HCW self-contamination.* For both the EVD and CP groups, we found fluorescence on HCW hands more often than any other site. HCWs may benefit from targeted training in the correct method for glove removal during EVD PPE doffing.

Lim, 2015 [14]	Doffing practice simulation study (N.B. No spraying for disinfecting purposes)	We recruited study participants among physicians and nurses of the emergency department of Samsung Medical Center in Seoul, Korea. Participants were asked to carry out doffing and donning procedures with a helper after a 50-minute brief training and demonstration based on the 2014 Centers for Disease Control and Prevention protocol. Two separate cameras with high-density capability were set up, and the donning and doffing processes were videotaped. A trained examiner inspected all video recordings and coded for intervals, errors, and contaminations defined as the outside of the equipment touching the clinician's body surface.	Implementation	For the doffing process, the average interval until the end was 183.7 seconds (SD, 38.4), and the most frequent errors occurred during disinfecting the feet (37.9%), discarding the scrubs (17.2%), and putting on gloves (13.7%), respectively. During the doffing process, 65 incidences of contamination occurred (2.2 incidents/person). The most vulnerable processes were removing respirators (79.2%), removing the shoe covers (65.5%), and removal of the hood (41.3%). Conclusion *A significant number of contaminations occur during the doffing process of personal protective equipment.*
Mumma, 2018 [15]	Doffing practice simulation study (N.B. No spraying for disinfecting purposes)	Eleven HCWs experienced with doffing Ebola-level PPE participated in simulations in which HCWs donned PPE marked with surrogate viruses (ϕ6 and MS2) and completed a clinical task. They were assessed for contamination after doffing. Simulations were video recorded, and a failure modes and effects analysis and fault tree analyses were performed to identify errors during doffing, quantify their risk (risk index), and predict contamination data. This protocol used a method for removing gloves and alcohol-based hand rub (ABHR) for all hand hygiene except after removing the inner gloves (final doffing step), when soap and water were used. HCWs used manual (patient's room) and automatic (anteroom) foam dispensers.	Implementation	Results. Fifty-one types of errors were identified, many having the potential to spread contamination. Hand hygiene and removing the powered air purifying respirator (PAPR) hood had the highest total risk indexes (111 and 70, respectively) and number of types of errors (9 and 13, respectively). ϕ6 was detected on 10% of scrubs and the fault tree predicted a 10.4% contamination rate, likely occurring when the PAPR hood inadvertently contacted scrubs during removal. MS2 was detected on 10% of hands, 20% of scrubs, and 70% of inner gloves and the predicted rates were 7.3%, 19.4%, 73.4%, respectively. Fault trees for MS2 and ϕ6 contamination suggested similar pathways. Conclusions. Ebola-level *PPE can both protect and put HCWs at risk for self-contamination throughout the doffing process, even among experienced HCWs doffing with a trained observer*. Human factors methodologies can identify error-prone steps, delineate the relationship between errors and self-contamination, and suggest remediation strategies.
Mumma, 2019 [16]	Doffing practice simulation study (N.B. No spraying for disinfecting purposes)	We observed 41 HCWs across 4 Ebola treatment centers in Georgia doffing PPE for simulated patients with serious communicable diseases. Using human factors methodologies, we obtained the details, sequences, and durations of doffing steps; identified the ways each step can fail (failure modes [FMs]); quantified the riskiness of FMs; and characterized the workload of doffing steps.	Implementation	Results. Eight doffing steps were common to all hospitals—removal of boot covers, gloves (outer and inner pairs), the outermost garment, the powered air purifying respirator (PAPR) hood, and the PAPR helmet assembly; repeated hand hygiene (e.g., with hand sanitizer); and a final handwashing with soap and water. Across hospitals, we identified 256 FMs during the common doffing steps, 61 of which comprised 19 common FMs. Most of these common FMs were above average in their riskiness at each hospital. At all hospitals, hand hygiene, removal of the outermost garment, and removal of boot covers were above average in their overall riskiness. Measurements of workload revealed that doffing steps were often mentally demanding, and this facet of workload correlated most strongly with the effort of a doffing step. Conclusions. We systematically identified common points of concern in protocols for doffing high-level PPE. Addressing FMs related to hand hygiene and the removal of the outermost garment, boot covers, and PAPR hood could improve HCW safety when doffing high-level PPE.
Poller, 2018[8]	Doffing practice simulation study (N.B. No spraying for disinfecting purposes)	A simulation-based exercise was developed to assess the safety of PPE ensembles in use in the UK during first assessment of a patient with a possible HCID. A mannequin was adapted to expose volunteer HCWs to synthetic bodily fluids (vomit, sweat, diarrhea and cough), each with a different colored fluorescent tracer, invisible other than under ultraviolet (UV) light. After exposure, HCWs were examined under UV lights to locate fluorescent contamination, and were screened again after removing PPE (doffing) to detect any personal contamination. The exercise was videoed, allowing retrospective analysis of contamination events and user errors.	Implementation	The simulation testing identified significant HCW contamination events after doffing, related to protocol failure or complications in PPE doffing, providing conclusive evidence that improvements could be made. At a workshop with an expert stakeholder group, the data were examined and a unified PPE ensemble agreed. This ensemble was then tested in the same simulation exercise and no evidence of any HCW contamination was seen after doffing. Following further review by the working group, a consensus agreement has been reached and a unified 'HCID assessment PPE' ensemble, with accompanying donning and doffing protocols, is presented here. The final protocol used three layers of gloves: • Inner personal protection glove (standard short non-sterile glove) • Middle glove (long cuffed glove), taped to gown • Outer glove comprising either standard short non-sterile gloves for basic care, or heavier duty gloves for cleaning up of extreme bodily fluid episodes

Suen, 2018[17]	Practice simulation study (N.B. No spraying for disinfecting purposes)	This study aimed to compare the efficacy of three PPE ensembles, namely, Hospital Authority (HA) Standard Ebola PPE set (PPE1), Dupont Tyvek Model, style 1422A (PPE2), and HA isolation gown for routine patient care and performing aerosol-generating procedures (PPE3) to prevent EVD transmission by measuring the degree of contamination of HCWs and the environment. Methods: 59 participants randomly performed PPE donning and doffing. The trial consisted of PPE donning, applying fluorescent solution on the PPE surface, PPE doffing of participants, and estimation of the degree of contamination as indicated by the number of fluorescent stains on the working clothes and environment. Protocol deviations during PPE donning and doffing were monitored.	Implementation	PPE2 and PPE3 presented higher contamination risks than PPE1. Environmental contaminations such as those originating from rubbish bin covers, chairs, faucets, and sinks were detected. Procedure deviations were observed during PPE donning and doffing, with PPE1 presenting the lowest overall deviation rate (%) among the three PPE ensembles ($p < 0.05$). Considering that hand hygiene methods using alcohol hand sanitizer fail to remove the fluorescent solution, handwashing with soap and water was performed by the participants. Although alcohol gel is commonly used nowadays during PPE donning/doffing, hand cleansing with soap and water is recommended in cases of visible contamination in various situations, such as when areas are contaminated by vomitus, respiratory secretions, or fecal matter.
Jinadatha, 2015 [18]	Testing study	Pulsed xenon ultraviolet (PX-UV) disinfection has been used to disinfect surfaces in hospital settings. This study examined the impact of PX-UV disinfection on an Ebola surrogate virus on glass carriers and PPE material to examine the potential benefits of using PX-UV to decontaminate PPE while worn, thereby reducing the pathogen load prior to doffing. Ultraviolet (UV) safety and coverage tests were also conducted.	Implementation	PX-UV exposure resulted in a significant reduction in viral load on glass carriers and PPE materials. Occupational Safety and Health Administration-defined UV exposure limits were not exceeded during PPE disinfection. Pre-doffing disinfection with PX-UV has potential as an additive measure to the doffing practice guidelines. The PX-UV disinfection should not be considered sterilization; all PPE should still be considered contaminated and doffed and disposed of according to established protocols.
Lee, 2018 [19]	Doffing practice simulation study	The study was conducted as a part of training of the dedicated response team for high-consequence emerging infectious diseases (HCEID). HCWs donned PPE that consisted of a coverall, an apron, double gloves, a powered air-purifying respirator (PAPR), and shoe covers. After donning, trainees conducted various simulated activities including intubation and insertion of central venous catheters. Before doffing the PPE, the surface of PPE was artificially contaminated with fluorescent fluid. Doffing of PPE was monitored by another trainee who verbally instructed each step using a checklist. Performance of each step was recorded by infection prevention. Self-contamination was evaluated by the visualization of fluorescent fluid on HCWs using a handheld ultraviolet light.	Implementation	Results: 75 subjects were evaluated. At least one violation of protocol was observed in 22.7% of subjects. Most common violation occurred during decontamination of shoes (9.3%), followed by doffing coverall (8.0%), doffing shoe covers (6.7%), visual inspection for gross contamination (5.3%), doffing gloves (4.0%), doffing PAPR (2.7%), and hand hygiene (1.3%). Self-contamination was detected in 64.0% of subjects. The neck was most commonly contaminated (45.3%), followed by arms (28.0%), hands (26.7%), and the head (20.0%). No specific type of violation was shown to be significantly associated with self-contamination. However, all subjects who missed decontamination of gloves or those who failed to doff gloves properly or PAPR were contaminated. Conclusions: Violation of doffing protocol was common during an intensive training session. Self-contamination was also common during PPE doffing.

Figure 1. Steps to take off personal protective equipment including coverall (Sources: WHO) [1]

Figure 2. Steps to take off personal protective equipment including gown (Sources: WHO) [1]



Infection prevention and control measures for Ebola and Marburg Virus disease: A series of rapid reviews

KQ11 Disinfection – Disinfection of hands or gloves - Initial Summary

(Version 1, 20 July 2022)

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Funding: Funding for this protocol and the subsequent reviews was provided by the World Health Organization (Funding # 202818287). The working group (WG) from the WHO/HQ Country Readiness Strengthening Health Care Readiness Unit will be consulted to develop and refine the scope, and review and approve the protocol. The WG will not be involved in the conduct of the review including selection of studies and data analysis but will advise as needed on priority population(s), interventions, and outcomes in an iterative process during the review process based on the available evidence. The WG will also comment on the draft report and provide input on interpretations of findings. AT is funded by a Tier 2 Canada Research Chair in Knowledge Synthesis. SM is funded by a Tier 2 Canada Research Chair in Mathematical Modeling and Program Science.

Competing interests: DM was involved in the 2015 rapid review by Hersi et al. [1] There are no other competing interests to acknowledge.

Acknowledgements: We thank Kaitryn Campbell, MLIS, MSc (St. Joseph's Healthcare Hamilton/McMaster University) for peer review of the Embase search strategy.

Key Questions

Question (11)-(a): Should health workers providing direct or indirect care to patients with Ebola or Marburg disease in ETUs and healthcare facilities wash hands (soap & water) OR wash the glove (soap & water) between patients?

Question (11)-(b): Should health workers providing direct or indirect care to patients with Ebola or Marburg disease in ETUs and healthcare facilities disinfect hands with ABHR OR disinfect the glove with ABHR between patients?

Question (11)-(c): Should health workers providing direct or indirect care to patients with Ebola or Marburg disease in ETUs and healthcare facilities disinfect hands (with chlorine) OR disinfect the glove (with chlorine) between patients?

Methods Summary

This is one of a series of rapid reviews answering 12 key questions related to three themes on infection prevention and control measures for filoviruses: (i) transmission/exposure (n=3 questions), (ii) personal protective equipment (PPE) (n=5), and (iii) decontamination and disinfection (n=4). Data sources include Medline, Embase, bio/medRxiv pre-print servers, Global Medicus Index, Epistemonikos, China National Knowledge Infrastructure (CNKI) and Wangfang database. We used an automation tool (CAL® tool) for titles/abstracts screening for relevant systematic reviews and primary comparative studies. Full-text screening, data extraction, risk of bias assessment, and GRADE (Grading of Recommendations Assessment, Development and Evaluation) for the certainty of evidence were completed independently by two reviewers with any disagreements resolved by consensus, with arbitration by a third reviewer, when needed.

Findings

A total of 250 studies were screened in the CAL tool software and 39 studies were included for full-text screening. No studies met the eligibility criteria (Appendix 2) for any of the three key questions. A list of excluded studies with reasons for exclusion can be found in Appendix 1.

Although no studies met the eligibility criteria for appropriate interventions and comparators, we noted evidence that addressed hand hygiene protocols for health care workers handling highly infectious diseases. Suen and colleagues[1] performed a simulation study to compare contamination when hand washing with soap and water was performed before/after each PPE doffing step (outer gloves, inner gloves, and bare hands) versus when the removal of both gloves was followed by hand washing with soap and water. Other evidence in this area includes the 2020 Cochrane systematic review by Verbeek and colleagues[2] that included evidence on simulated contamination for ABHR for glove sanitization vs. no glove sanitization. Two excluded studies examined relevant outcomes for varying doffing protocols with ABHR before/after each stage of glove doffing (outer gloves, inner gloves)[3,4]. Finally, several studies[5–7] were found that compared the effectiveness of different types of disinfectant agents for disinfection, including soap and water vs. ABHR vs. chlorine solutions[6,7].

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Appendix 1. Excluded Studies List – By Reason for Exclusion:

Not a relevant study (Neither Ebola, Marburg, nor a relevant surrogate outcome (COVID-19)

Haque M. Handwashing in averting infectious diseases: Relevance to COVID-19. *jptcp*. 2020;27(SP1):e37-e52. doi:10.15586/jptcp.v27SP1.711

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Population not of interest

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Squire JS, Conteh I, Abrahamya A, et al. Gaps in Infection Prevention and Control in Public Health Facilities of Sierra Leone after the 2014–2015 Ebola Outbreak. *TropicalMed*. 2021;6(2):89. doi:10.3390/tropicalmed6020089

Irrelevant method of disinfection

Cutts TA, Ijaz MK, Nims RW, Rubino JR, Theriault SS. Effectiveness of Dettol Antiseptic Liquid for Inactivation of Ebola Virus in Suspension. *Sci Rep*. 2019;9(1):6590. doi:10.1038/s41598-019-42386-5

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No comparator

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Reidy P, Fletcher T, Shieber C, et al. Personal protective equipment solution for UK military medical personnel working in an Ebola virus disease treatment unit in Sierra Leone. *J Hosp Infect*. Published online 2017.

No relevant comparisons

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Appendix 2. Eligibility Criteria

Question (11)-(a): Should health workers providing direct or indirect care to patients with Ebola or Marburg disease in ETUs and healthcare facilities wash hands (soap & water) OR wash the glove (soap & water) between patients?

Setting	Health care facilities, ETU
Population	Health workers working in health care facilities, ETU
Background interventions (Standard of care)	1) Disinfect outer gloves before removing them and 2) keep inner gloves on and disinfect them before putting on a fresh outer pair.
Intervention	Hand hygiene (including glove disinfection) between patients
Comparator(s)	1. Removal of outer glove and hand hygiene (inner glove) w/ soap and water 2. Removal of both gloves and hand hygiene w/ soap and water 3. Disinfecting outer glove w/ soap and water
Outcome	Dermatitis, PPE breaches/exposures, compliance, Ebola or Marburg virus infection, *human factors, health worker confidence*
Potential effect modifiers	May depend on the nature of the patient contact (e.g., if there was contact with blood/body fluids or if the outer glove is visibly dirty) Single-use versus reusable gloves *Type of gloves (e.g.: nitrile versus latex* *Number of times inner / outer gloves are disinfected*

	Health facility versus ETU Setting, vaccination

Question (11)-(b): Should health workers providing direct or indirect care to patients with Ebola or Marburg disease in ETUs and healthcare facilities disinfect hands with ABHR OR disinfect the glove with ABHR between patients?

Setting	Health care facilities, ETU
Population	Health workers working in health care facilities, ETU
Background interventions (Standard of care)	1) Disinfect outer gloves before removing them and 2) keep inner gloves on and disinfect them before putting on a fresh outer pair.
Intervention	Hand hygiene (including glove disinfection) between patients
Comparator(s)	1. Removal of outer glove and hand hygiene (inner glove) w/ alcohol-based hand rub 2. Removal of both gloves and hand hygiene w/ alcohol-based hand rub 3. Disinfecting outer glove w/ alcohol-based hand rub
Outcome	Dermatitis, PPE breaches/exposures, compliance, Ebola or Marburg virus infection, *human factors, health worker confidence*
Potential effect modifiers	May depend on the nature of the patient contact (e.g., if there was contact with blood/body fluids or if the outer glove is visibly dirty) Single-use versus reusable gloves

	Type of gloves (e.g.: nitrile versus latex *Number of times inner / outer gloves are disinfected* *Health facility versus ETU Setting, vaccination*

Question (11)-(c): Should health workers providing direct or indirect care to patients with Ebola or Marburg disease in ETUs and healthcare facilities disinfect hands (with chlorine) OR disinfect the glove(with chlorine) between patients?

Setting	Health care facilities, ETU
Population	Health workers working in health care facilities, ETU
Background interventions (Standard of care)	1) Disinfect outer gloves before removing them and 2) keep inner gloves on and disinfect them before putting on a fresh outer pair.
Intervention	Hand hygiene (including glove disinfection) between patients
Comparator(s)	1. Removal of outer glove and hand hygiene (inner glove) w/ chlorine 2. Removal of both gloves and hand hygiene w/ chlorine 3. Disinfecting outer glove w/ chlorine (concentration)
Outcome	Dermatitis, PPE breaches/exposures, compliance, Ebola or Marburg virus infection, *human factors, health worker confidence*
Potential effect modifiers	May depend on the nature of the patient contact (e.g., if there was

	contact with blood/body fluids or if the outer glove is visibly dirty) Single-use versus reusable gloves *Type of gloves (e.g.: nitrile versus latex* *Number of times inner / outer gloves are disinfected* *Health facility versus ETU Setting, vaccination*

Contextual data

KQ 11abc

11a) Should health workers providing direct or indirect care to patients with Ebola or Marburg disease in ETUs and healthcare facilities **wash hands** (soap & water) OR **wash the glove** (soap & water) between patients?

11b) Should health workers providing direct or indirect care to patients with Ebola or Marburg disease in ETUs and healthcare facilities **disinfect hands** with alcohol-based hand rub (ABHR) OR **disinfect the glove** with ABHR between patients?

11c) Should health workers providing direct or indirect care to patients with Ebola or Marburg disease in ETUs and healthcare facilities **disinfect hands** (with chlorine) OR **disinfect the glove** (with chlorine) between patients?

For extracting contextual data, we consider KQ11abc as composed of two queries as follows.

Query 1. For hand hygiene, what are the pros and cons of soap & water, ABHR and chlorine?

Query 2. For gloved hand hygiene, what are the pros and cons of soap & water, ABHR and chlorine?

- Query 2a. What are the options for disinfecting outer gloves?
  - Outer gloves are with intermediate thickness or heavy-duty gloves[1]
  - Some doffing procedures require that outer gloves be disinfected a few times (but not as many times as disinfecting inner gloves).[2]
- Query 2b. What are the options for disinfecting inner gloves?
  - Inner gloves are typically light latex or nitrile gloves[1]
  - Multiple disinfections of inner gloves are required during doffing procedures[2]

Guideline recommendations

Table 1 summarizes recommendations regarding hand hygiene by the WHO, US CDC and European CDC. These guidelines all recommend the widely adopted practice that all health workers should wear double gloves while providing clinical care for patients with filovirus disease in order to prevent virus exposure.[3 4 5 1]

The WHO 2014 guidelines recommended double gloves compared to single gloves to decrease the potential risk of virus transmission to the health worker due to glove holes and *damage to gloves from disinfectants such as chlorine.* Double gloving may also reduce the risk from needle-stick injuries and contamination of hands when removing PPE.[3]

According to the WHO 2014 guidelines, best IPC practice dictates that gloves should be changed between patients. However, feasibility issues (i.e. provision of clean gloves and waste disposal within the patient treatment and isolation area) were of concern. Because of this, the guideline development group did not reach consensus on the recommendation for changing gloves between patients inside the clinical area. Nine members were in favor of changing gloves between patients, two were against, and two members abstained.[3]

The WHO 2014 outlines a 2-step procedure to help facilitate changing gloves safely while providing clinical care for patients with filovirus disease: first, disinfect the outer gloves before removing them safely; and secondly, keep the inner gloves on and disinfect them before putting on a fresh outer pair.[3]

Alcohol-based hand rubs are preferred when disinfecting hands and gloved hands. If a glove becomes compromised, it should be changed using the described procedure.[3]

According to the US CDC recommendations, double gloving provides an easy way to remove gross contamination by changing an outer glove during patient care and when removing PPE.[4] Single-use (disposable) examination gloves with extended cuffs are recommended. Two pairs of gloves should be worn so that a heavily soiled outer glove can be safely removed and replaced during care. At a minimum, outer gloves should have extended cuffs. Double gloving also allows potentially contaminated outer gloves to be removed during doffing to avoid self-contamination.

PPE must remain in place and be worn correctly for the duration of work in potentially contaminated areas.[4] PPE should not be adjusted during patient care. In the event of a significant splash, the healthcare worker should immediately move to the doffing area to remove PPE. The one exception is that visibly contaminated outer gloves can be changed while in the patient room and patient care can continue. Contaminated outer gloves can be disposed of in the patient room with other Ebola-associated waste.

Healthcare workers should perform frequent disinfection of gloved hands using an ABHR, particularly after contact with body fluids.[4] If during patient care any breach in PPE occurs (e.g., a tear develops in an outer glove, a needle stick occurs, a glove separates from the sleeve), the health worker must move immediately to the doffing area to assess the exposure.

During PPE doffing that is supervised by a trained observer, the outer-gloved hands are disinfected with disinfectant wipe or ABHR before the outer gloves are removed and discarded, taking care not to contaminate inner gloves during removal process.[4] The "Inspect and Disinfect Inner Gloves" step requires first, inspect the inner gloves' outer surfaces for visible contamination, cuts, or tears.

- If an inner glove is *visibly soiled*, then disinfect the glove with either a disinfectant wipe or ABHR, remove the inner gloves, *perform hand hygiene with ABHR on bare hands*, and *don a new pair of gloves*.
- If no visible contamination is identified on the inner gloves, then disinfect the inner-gloved hands with either a disinfectant wipe or ABHR. If a cut or tear is detected on an inner glove, immediately review occupational exposure risk per hospital protocol.
- The inner gloves are disinfected multiple times (e.g., 4, see Figure 1 for a simple doffing procedure used in a simulated study, Casanova et al. 2018)[2] during the doffing of other PPE gears (e.g., face shield, surgical hood, gown or coverall, boots).
- At the end of the doffing procedures, disinfect inner gloves, remove and discard the gloves taking care not to contaminate bare hands during removal process, and then *perform hand hygiene with ABHR*.

According to the European CDC, PPE users should always use a minimum of two pairs of gloves.[5] The choice of gloves always needs to balance tactility (e.g. for medical interventions) and the level of protection (defined by mechanical resistance). The outer gloves can easily be adapted to different tasks or simply changed, in case there would be any doubt regarding their physical integrity. The cuffs of the inner gloves always need to be placed *above* of the coverall sleeves of the coveralls to prevent fluids from entering inside the sleeves.

Gloves are available in different thickness, textures, materials, colors and qualities. PPE users should consider the use of different gloves depending on the exposure risk associated with the planned intervention (Table 1).[5] Glove combinations adapted to specific tasks improve safety and provide the desired tactility or the needed robustness.

Figure 2 outlines the benefits and drawbacks of disinfectants used for hand hygiene (Lantagne et al. 2018).[6]

- Bar soap and water are widely available, widely acceptable and low cost; but its primary goal is to remove, not inactivate Ebola or Marburg virus, and it requires water.
- Alcohol-based hand sanitizer is portable and simple to use; but it is not widely available, not widely acceptable and expensive.
- Chlorine NADCC (sodium dichloroisocyanurate, pH=6) is easy to ship (powder) and inexpensive, has long shelf life of powder, and does not clog pipes. Chlorine HTH (calcium hypochlorite, pH=11) is easy to ship (powder) and inexpensive, has long shelf life of powder, but clog pipes and it can be explosive. Stabilized chlorine NaOCl (sodium hypochlorite, pH=11) can be locally produced, does not clog pipes; but has shorter shelf life of concentrate and is difficult to ship. Generated chlorine NaOCl (pH=9) can be produced on-site, does not clog pipes; but has shorter shelf life of concentrate, is difficult to ship and quality control.

Figure 3 outlines inconsistencies in international EVD chlorine recommendations, according to a study conducted in 2018 (Lantagne et al. 2018).[6]

- For chlorine solution type, Médecins Sans Frontières (MSF) recommended HTH, and recently changed to NaDCC; whereas the WHO and US CDC did not address solution type.
- For chlorine solution testing, the MSF did not recommend it; the the WHO and US CDC did not address it.
- As of 2018 and for hand washing, the MSF recommended 0.05% chlorine solution; the WHO and US CDC recommend soap, sanitizer and avoid chlorine solution.

Some of the recommendations appear to be not up-to-date. For example, the US CDC still states that chlorine solutions should not be used for routine hand hygiene, as they will eventually damage the skin.[4] Soap and water or alcohol-based hand rubs are preferred (here the US CDC cites the WHO Guideline on Hand Hygiene in Health Care, 2009 and the Healthcare Infection Control Practices Advisory Committee's Hand Hygiene in Healthcare Settings, 2002). The US CDC also states that alcohol-based hand rubs (ABHR) offer benefits when compared with using soap and water in skin tolerance, compliance, and, especially when combined with glove use, overall effectiveness for a wide variety of healthcare pathogens. However, if hands become visibly soiled, use soap and water, not alcohol-based hand rubs.

Contextual data summary

Tantum et al. 2021 characterize barriers and facilitators of hand hygiene in rural Liberian hospitals and evaluate readiness for sustainable, locally derived interventions to improve hand hygiene.[7] During spot checks, hospital staff reported that handwashing container water was always available in 89% of hospital wards, piped running water in 23%, and soap in 62%. The investigators observed 5% of *working* wall-mounted hand sanitizer dispensers and 95% of working pocketsize dispensers. In interviews, hospital staff described willingness to purchase personal hand sanitizer dispensers when hospital-provided supplies were unavailable. The authors suggest that low-cost, sustainable interventions should address supply and infrastructure-related obstacles to improve hospital hand hygiene.

Wolfe et al. 2016 conducted a randomized trial with 91 subjects who washed their hands 10 times a day for 28 days to evaluate *skin irritation* caused by frequent handwashing that may increase transmission risk in Ebola-affected communities.[8]

- They reported that subjects using sanitizer had the smallest increases, followed by higher pH chlorine solutions (HTH -calcium hypochlorite, high-test hypochlorite - and stabilized NaOCl -sodium hypochlorite), and soap and water.
- The greatest increases were among neutral pH chlorine solutions (NaDCC - sodium dichloroisocyanurate) and generated NaOCl.
- Signs of irritation related to higher transmission risk were observed most frequently in subjects using soap and least frequently by those using sanitizer or HTH.
- The investigators suggest that each handwashing method has benefits and drawbacks: soap is widely available and inexpensive, but requires water and does not inactivate the virus; sanitizer is easy-to use and effective but expensive and unacceptable to many communities, and chlorine is easy-to-use but difficult to produce properly and distribute.
- Overall, they recommend Ebola responders and communities use whichever handwashing method(s) are most acceptable, available, and sustainable for community handwashing.

Wolfe et al. 2017 conducted a randomized simulation study of handwashing and Ebola virus disease outbreaks to compare hand-washing protocols involving soap, hand sanitizer, and 0.05% chlorine solutions on the inactivation and removal of model organisms Phi6 and E. coli from hands and persistence in rinse water.[9] They used organisms E. coli and bacteriophage Phi6 to evaluate handwashing with and without organic load added to simulate bodily fluids. Hands were inoculated with test organisms, washed, and rinsed using a glove juice method to retrieve remaining organisms.

- HTH performed most consistently well, with significantly greater log reductions of organisms than other handwashing protocols.
- The magnitude of handwashing efficacy differences was small, suggesting protocols are similarly efficacious.
- The authors recommend responders use the most practical handwashing method to ensure hand hygiene in Ebola contexts, considering the potential benefit of chlorine-based methods in rinse water persistence.

Casanova et al. 2018 conducted a simulation study of PPE doffing practice.[2] In a medical biocontainment unit, HCWs (n = 10) experienced in EVD care donned and doffed PPE following unit protocols that incorporate trained observer guidance and alcohol-based hand rub (ABHR). A mixture of Φ6 (enveloped), MS2 (non-enveloped), and fluorescent marker was applied to 4 PPE sites, approximating body fluid viral load (Φ6, 10^5; MS2, 10^6). The HCWs performed a patient care task, then doffed. Inner gloves, face, hands, and scrubs were sampled for virus, as were environmental sites with visible fluorescent marker.

- Among 10 HCWs there was no Φ6 transfer to inner gloves, hands, or face; 1 participant had Φ6 on scrubs at low levels (1.4 × 102). MS2 transfer (range, 10^1–10^6) was observed to scrubs (n = 2), hands (n = 1), and inner gloves (n = 7), where it was highest. Most (n = 8) had only 1 positive site.
- Environmental samples with visible fluorescent marker (n = 21) were negative.
- Because gloves are repeatedly touching PPE during the doffing process, even use of ABHR on the outside of gloves between doffing steps may not completely prevent inner glove contamination with a non-enveloped virus.
- Human factors analyses suggest that the mishandling of certain items of PPE during doffing contributes considerably to the probability that a HCW's gloves, scrubs, and hands become contaminated.
- To minimize viral load on inner gloves, both careful doffing and control measures such as stronger glove-sanitizing agents (such as hypochlorite or povidone-iodine) may be needed, particularly if non-

enveloped viruses emerge as high-risk pathogens. However, whether units use ABHR or other hand sanitizers with demonstrated in vitro effectiveness against viruses, contact time and technique are still important. These results highlight the fact that even when wearing PPE that provides whole body coverage, hand hygiene after doffing is still critical, with hand hygiene agents that are effective against a range of organisms.

- In summary, among experienced HCWs, structured, observed doffing using ABHR protected against hand contamination with enveloped virus. Non-enveloped virus was infrequent on hands and scrubs but common on inner gloves, suggesting that inner gloves, *but not necessarily ABHR*, protect against hand contamination.
- Optimizing doffing protocols to protect against all types of viruses may require reinforcing careful handling of scrubs and good glove/hand hygiene with *effective agents*.

Casanova et al. 2016 conducted a simulation study of doffing practice with 15 HCW donned EVD PPE for the study.[10] Virus was applied to PPE, and a trained monitor guided them through the doffing protocol. Of the 15 participants, 10 participants used alcohol-based hand rub (ABHR) for glove and hand hygiene and 5 used hypochlorite for glove hygiene and ABHR for hand hygiene. Inner gloves, hands, face, and scrubs were sampled after doffing.

For the first 10 subjects, each step that called for sanitizing gloved hands, as well as the final hand hygiene steps (steps 13 and 16) that called for sanitizing bare hands, were performed using alcohol-based hand rub (ABHR) as a 70% ethanol gel (Purell, Gojo Industries, Akron, OH).[10] For the last 5 subjects, each step that called for sanitizing gloved hands was performed with liquid hypochlorite at a concentration of 1,850 ppm (Fuzion Healthcare Disinfectant, Clorox Co., Pleasanton, CA) applied by spraying onto gloves. The final hand hygiene steps that called for sanitizing bare hands were performed using ABHR.

- After doffing, MS2 virus was detected on the inner glove worn on the dominant hand for 8 of 15 participants, on the non-dominant inner glove for 6 of 15 participants, and on scrubs for 2 of 15 participants. All MS2 on inner gloves was observed when ABHR was used for glove hygiene; none was observed when hypochlorite was used. When using hypochlorite for glove hygiene, 1 participant had MS2 on hands, and 1 had MS2 on scrubs.
- Careful doffing of inner gloves in a manner that minimizes the risk of hand contamination is important. To minimize viral contamination of inner gloves, more conservative control measures may include sanitizing gloves with stronger agents such as hypochlorite. While hypochlorite use directly on hands may not be desirable, its use on gloves does not present the same issues.
- It is reasonable to recommend that HCW involved in care of patients with EVD post-doffing shower using an antiseptic such as chlorhexidine.
- A structured doffing protocol using a trained monitor and ABHR protects against enveloped virus self-contamination. Non-enveloped virus (MS2) contamination was detected on inner gloves, possibly due to higher resistance to ABHR. Doffing protocols protective against all viruses need to incorporate highly effective glove and hand hygiene agents.

Lantagne et al. 2018 conducted a multiple-thread research study to provide evidence for disinfection guidelines recommendations, including 3 research strands: (1) impacts of chlorine chemistry; (2) efficacy of surface cleaning recommendations; and (3) safety and efficacy of handwashing recommendations. [6]

- Strand 1 research found that the compound chemistry of the chlorine source has an impact on the chlorine solution shelf-life (<1 day–30 days), with testing of chlorine solutions recommended to ensure accuracy.

- Strand 2 research found that surface cleaning with 0.5% chlorine solutions with a 15-min exposure time is efficacious in reducing transmission risk.
- Strand 3 research found that community handwashing with chlorine solutions is as safe and efficacious as handwashing with soap and water or sanitizer, which offers a benefit of reducing pathogens in the rinsing water.
    - The safety and efficacy results indicate all handwashing methods were roughly equally efficacious in practice, although: (1) HTH (calcium hypochlorite, high-test hypochlorite) in particular was consistently more safe and efficacious; and (2) chlorine solutions, as compared to soap and water and sanitizer, offer the benefit of reducing pathogen persistence in rinsing water.
    - As all hand-washing methods have benefits and drawbacks (see Figure 4), it is recommended that EVD responders and communities use whichever handwashing method(s) are most acceptable, available and feasible for handwashing, considering that chlorine solutions may offer a benefit in reducing transmission risk from rinsing water.
    - Across all simulations, the chlorine source compound HTH performed particularly well, with chlorine solutions made from this product having the longest shelf life, the least hand irritation and the highest hand-washing efficacy. However, HTH has the operational challenges of being more explosive than NaDCC and having a precipitate form in mixing with water that can clog pipes. In well-maintained ETUs, this can be managed with appropriate training and maintenance. However, explosions did occur in ETUs that were managed by less experienced organizations in the West African outbreak, which poses a great risk to the health and safety of response personnel and patients.

Reidy et al 2017 conducted an expert review of PPE solutions for UK military medical personnel working in an Ebola treatment unit in Sierra Leone.[11]

- They suggest that tactility and dexterity through two pairs of gloves was of key importance. They chose 400-mm nitrile, powder-free gloves.
- Competency in using PPE was developed during a nine-day pre-deployment training program. This allowed over 60 clinical personnel per deployment to practice skills in PPE in a simulated ETU and in classrooms. Overall, the training provided:
    - An evidence base underpinning the PPE solution chosen;
    - Skills in donning and doffing of PPE;
    - Personnel confidence in the selected PPE;
    - Testing of each individual's capability to don PPE, perform tasks and doff PPE safely.

Gao et al. 2016 performed laboratory testing of gloves according to current US CDC guidance for the disinfection of gloved hands during the doffing of PPE following the care of an Ebola patient.[12] The guidance recommends multiple applications of alcohol-based hand rub (ABHR) on medical exam gloves. The investigators evaluated possible effects of ABHR applications on the integrity of thirteen brands of nitrile and latex medical exam gloves from five manufacturers. Two different ABHRs were used in the study.

In terms of study methods, a pair of gloves were worn by a test operator and the outside surfaces of the gloves were separately treated with an ABHR for 1–6 applications. Tensile strength and ultimate elongation of the gloves without any ABHR treatments (control gloves) and gloves after 1–6 ABHR applications were measured based on the ASTM D412 standard method.

- In general, tensile strength decreased with each ABHR application. *ABHRs had more effect on the tensile strength of the tested nitrile than latex gloves, while ethanol-based ABHR (EBHR) resulted in lesser changes in tensile strength compared to isopropanol-based ABHR (IBHR).*
- The results show that multiple EBHR applications on the latex gloves and some of the nitrile gloves tested should be safe for Ebola PPE doffing based on the CDC guidance.
- The investigators recommend appropriate hospital staff practice using ABHR applications and doffing gloves so that staff can become more familiar with changes in glove properties.

Table 1: Summary of guideline recommendations regarding hand hygiene by the WHO, US and European CDC

Source	Hand hygiene
WHO [3]	2014
Recommendation 5:	All health workers should wear double gloves while providing clinical care for patients with filovirus disease in order to prevent virus exposure. *Strong recommendation. Moderate quality evidence for double gloving as compared to single glove use.* Rationale and remarks Double gloves are recommended compared to single gloves to decrease the potential risk of virus transmission to the health worker due to glove holes and damage to gloves from disinfectants such as chlorine; double gloving may also reduce the risk from needle-stick injuries and contamination of hands when removing PPE. The confidence in effectiveness was assessed as moderate based on accumulated evidence for transmission of other blood-borne pathogens such as HIV and hepatitis viruses. … Preferably, the outer glove should have a long cuff, reaching well above the wrist, ideally to the mid-forearm. In order to protect the wrist area from contamination, the inner glove should be worn under the cuff of the gown/coverall (and under any thumb/finger loop) whereas the outer glove should be worn over the cuff of the gown/coverall. Best IPC practice dictates that gloves should be changed between patients. However, feasibility issues (i.e. provision of clean gloves and waste disposal within the patient treatment and isolation area) were of concern. Because of this, the GDG did not reach consensus on the recommendation for changing gloves between patients inside the clinical area. Nine members were in favour of changing gloves between patients, two were against, and two members abstained. The following 2-step procedure could help facilitate changing gloves safely while providing clinical care for patients with filovirus disease: 1) disinfect the outer gloves before removing them safely and 2) keep the inner gloves on and disinfect them before putting on a fresh outer pair. Alcohol-based hand rubs are preferred when disinfecting hands and gloved hands. If a glove becomes compromised, it should be changed using the procedure described above.
US CDC [4]	Principles of PPE … During Patient Care • PPE must remain in place and be worn correctly for the duration of work in potentially contaminated areas. PPE should not be adjusted during patient care. In the event of a significant splash, the healthcare worker should immediately move to the doffing area to remove PPE. The one exception is that visibly contaminated outer gloves can be changed while in the patient room and patient care can continue. Contaminated outer gloves can be disposed of in the patient room with other Ebola-associated waste. • Healthcare workers should perform frequent disinfection of gloved hands using an ABHR, particularly after contact with body fluids.

- If during patient care any breach in PPE occurs (e.g., a tear develops in an outer glove, a needle stick occurs, a glove separates from the sleeve), the healthcare worker must move immediately to the doffing area to assess the exposure.

Double-gloving provides an easy way to remove gross contamination by changing an outer glove during patient care and when removing PPE.

Section 7. Recommended PPE When Caring for a Patient with Confirmed Ebola or Unstable PUI
…
Single-use (disposable) examination gloves with extended cuffs. Two pairs of gloves should be worn so that a heavily soiled outer glove can be safely removed and replaced during care. At a minimum, outer gloves should have extended cuffs. Double-gloving also allows potentially contaminated outer gloves to be removed during doffing to avoid self-contamination.

Section 9. Recommended Sequences for Donning PPE
Section 9A. Donning PPE, PAPR Option
…
Put on Inner Gloves: Put on first pair of gloves.
Put on Gown or Coverall
Put on Outer Gloves: Put on second pair of gloves (with extended cuffs). Ensure the cuffs are pulled over the sleeves of the gown or coverall.

Section 9D. Doffing PPE, N95 Respirator Option
Engage Trained Observer
Inspect: Inspect the PPE to assess for visible contamination, cuts, or tears before starting to remove.
Disinfect Outer Gloves: Disinfect outer-gloved hands with either an *EPA-registered disinfectant wipe or ABHR.
Remove Apron (if used):
Inspect: After removing the apron, inspect the PPE ensemble for visible contamination or cuts or tears. If visibly contaminated, then clean and disinfect any affected areas by using an *EPA-registered disinfectant wipe.
Disinfect and Remove Outer Gloves: Disinfect outer-gloved hands with either an *EPA-registered disinfectant wipe or ABHR. Remove and discard outer gloves, taking care not to contaminate inner gloves during removal process.
Inspect and Disinfect Inner Gloves: Inspect the inner gloves' outer surfaces for visible contamination, cuts, or tears. If an inner glove is visibly soiled, then disinfect the glove with either an *EPA-registered disinfectant wipe or ABHR, remove the inner gloves, perform hand hygiene with ABHR on bare hands, and don a new pair of gloves. If no visible contamination is identified on the inner gloves, then disinfect the inner-gloved hands with either an *EPA-registered disinfectant wipe or ABHR. If a cut or tear is detected on an inner glove, immediately review occupational exposure risk per hospital protocol.
Remove Face Shield:
Disinfect Inner Gloves: Disinfect inner gloves with either an *EPA-registered disinfectant wipe or ABHR.
Remove Surgical Hood:
Disinfect Inner Gloves: Disinfect inner gloves with either an *EPA-registered disinfectant wipe or ABHR.
Remove Gown or Coverall: Remove and discard.
Disinfect Inner Gloves: Disinfect inner gloves with either an *EPA-registered disinfectant wipe or ABHR.
Remove Boot Covers:

	Disinfect and Change Inner Gloves: Disinfect inner gloves with either an *EPA-registered disinfectant wipeexternal icon or ABHR. Remove and discard gloves taking care not to contaminate bare hands during removal process. Perform hand hygiene with ABHR. Don a new pair of inner gloves. Remove N95 Respirator: Disinfect Inner Gloves: Disinfect inner gloves with either an *EPA-registered disinfectant wipe or ABHR. Disinfect Washable Shoes: Disinfect and Remove Inner Gloves: Disinfect inner-gloved hands with either an *EPA-registered disinfectant wipe or ABHR. Remove and discard gloves taking care not to contaminate bare hands during removal process. Perform Hand Hygiene: Perform hand hygiene with ABHR. Inspect: Both the trained observer and the healthcare worker perform a final inspection of healthcare worker for contamination of the surgical scrubs or disposable garments. … To remove coverall, tilt head back to reach zipper or fasteners. Unzip or unfasten coverall completely before rolling down and turning inside out. Avoid contact of scrubs with outer surface of coverall during removal, touching only the inside of the coverall. Disinfect Inner Gloves: Disinfect inner gloves with either an *EPA-registered disinfectant wipe or ABHR. Remove Boot Covers: Remove N95 Respirator: Disinfect Inner Gloves: Disinfect inner gloves with either an *EPA-registered disinfectant wipe or ABHR. Disinfect Washable Shoes: Disinfect and Remove Inner Gloves: Disinfect inner-gloved hands with either an *EPA-registered disinfectant wipe or ABHR. Remove and discard gloves taking care not to contaminate bare hands during removal process. Perform Hand Hygiene: Perform hand hygiene with ABHR.
US CDC [5]	Rationale and Considerations for Chlorine Use in Infection Control for Non- U.S. General Healthcare Settings Chlorine solutions should not be used for routine hand hygiene, as they will eventually damage the skin. Soap and water or alcohol-based hand rubs are preferred (see WHO Guideline on Hand Hygiene in Health Care, 2009 and the Healthcare Infection Control Practices Advisory Committee's Hand Hygiene in Healthcare Settings, 2002). Alcohol-based hand rubs (ABHR) offer benefits when compared with using soap and water in skin tolerance, compliance, and, especially when combined with glove use, overall effectiveness for a wide variety of healthcare pathogens. However, if hands become visibly soiled, use soap and water, not alcohol-based hand rubs.
European CDC [1]	3.3 Hand protection The choice of gloves always needs to balance tactility (e.g. for medical interventions) and the level of protection (defined by mechanical resistance). PPE users should always use a minimum of two pairs of gloves. • inner pair of gloves: covering the skin ('like a second skin') • outer pair of gloves: gloves on top of gloves ('working gloves') Gloves are available in different thickness, textures, materials, colors and qualities. PPE users should consider the use of different gloves depending on the exposure risk associated with the planned intervention. Glove combinations adapted to specific tasks improve safety and provide the desired tactility or the needed robustness.

Different types of gloves

Light latex or nitrile gloves | Intermediate thickness | Heavy duty gloves

Suggested steps for donning

Steps	Action
1	Putting on scrubs and hair cover
2	Perform hand hygiene
3	Putting on the coverall
4	Putting on foot protection
5	Perform hand protection
6	Wear respiratory protection and perform orientation fit test
7	Putting on the hood
8	Close the zipper
9	Close adhesive flaps
10	Put on eye protection
11	Perform inner glove disinfection and put on outer gloves
12	Put on apron (optional)
13	Test the fit of the PPE components together
14	Ready to pass through the yellow zone and to enter the red zone.*

Step 5: Hand protection
Double gloving can be seen as a well-balanced approach between the needs for flexibility, tactility and safety.
In this approach the external ‘working layer’ can easily be adapted to different tasks or simply changed, in case there would be any doubt regarding it's physical integrity.
The cuffs of ‘base layer’ or inner gloves always need to be placed above of the coverall sleeves of the coveralls to prevent fluids from entering inside the sleeves.

Suggested steps for doffing

Steps	Actions Contaminated staff (PPE user)	Actions Assistant (clean)* (Dark yellow zone)
1	Removing the optional apron. (Red zone)	
2	Step out of the red zone.	PPE inspection of the HCW ready for doffing to identify cuts or contamination; disinfect the PPE (wipe with disinfectant)
3	Removing the outer gloves.	**Use new pair of outer gloves.**
4	Stay relaxed and stand still so the assistant can easily access the components.	Removing tape from face area if present.
5		Removing the goggles.
6		Open the flaps.
7		**Use new pair of outer gloves.**
8		Open the zipper.
9		Removing the hood.
10		Roll down the coveralls.
11		Roll down the sleeves with the integrated gloves (taped).
12	Step out of the coveralls (with integrated foot section) and put on the light yellow-zone clogs.	Hold the coveralls and stay in the dark yellow zone.
13		**Use new pair of outer gloves**
14	Stand still in the light yellow zone while the assistant removes your mask from the dark yellow zone.	Removing the PPE user's respirator.
15	Hand hygiene and step into the green zone	
16	Take off the hair cover, re-hydrate and take a shower.	

Figure 1. Ebola-level PPE Doffing Procol tested in the study by Casanova et al. 2018

Location	Step	Required Action
Patient room	Step 1	Remove apron
Patient room	Step 2	Remove 1 bootie, then step onto chemical mat
Patient room	Step 3	Remove other bootie, then step onto chemical mat
Patient room	Step 4	Sanitize gloves
Patient room	Step 5	Remove outer gloves using the beaking method
Patient room	Step 6	Sanitize inner gloves
Patient room	Step 7	Remove tape
Patient room	Step 8	Sanitize inner gloves
Patient room	Step 9	Remove biohazard coverall
Patient room	Step 10	Sanitize inner gloves
Patient room	Step 11	Enter anteroom
Anteroom	Step 12	Remove powered air-purifying respirator hood
Anteroom	Step 13	Sanitize inner gloves
Anteroom	Step 14	Remove inner gloves using the beaking method
Anteroom	Step 15	Wash hands with soap and water
Anteroom	Step 16	Remove belt, battery, and motor

All steps indicating "sanitize" use alcohol-based hand rub.

Figure 2. Benefits and drawbacks of disinfectants used for surfaces and hands (Sources: Lantagne et al. 2018)

	Benefits	Drawbacks
Bar soap and water	Widely available Widely acceptable Low cost	Primary goal to remove, not inactivate Requires water
Alcohol Based Hand Sanitizer	Simple to use Portable	Not widely available Not widely acceptable Expensive
NaDCC (pH = 6)	Easy to ship (powder) Long shelf-life of powder Does not clog pipes Inexpensive	-
HTH (pH = 11)	Easy to ship (powder) Long shelf-life of powder Inexpensive	Clogs pipes Can be explosive
Stabilized NaOCl (pH = 11)	Can be locally produced Does not clog pipes	Shorter shelf-life of concentrate Difficult to ship
Generated NaOCl (pH = 9)	Can be produced on-site Does not clog pipes	Shorter shelf-life of concentrate Difficult to ship Quality control

Acronyms: NaDCC (sodium dichloroisocyanurate), HTH (calcium hypochlorite), NaOCl (sodium hypochlorite).

Figure 3. Inconsistencies in International Ebola Chlorine Recommendations (Sources: Lantagne et al. 2018)

	MSF [5]	WHO [6]	CDC [7]
Chlorine Solution Type	HTH, recently changed to NaDCC	Not addressed	Not addressed
Chlorine Solution Testing	Not recommended	Not addressed	Not addressed
Surface Cleaning	Apply 0.5% chlorine for 15 min	Pre-clean, apply 0.5% chlorine for 10 min.	For hospitals: pre-clean, apply a "chemical disinfectant for non-enveloped viruses". For households: cover spills, apply 0.5% chlorine for 15 min.
Handwashing	0.05% chlorine solution	Soap, sanitizer, avoid chlorine solution	Soap, sanitizer, avoid chlorine solution

Acronyms: MSF (Médecins Sans Frontèires); WHO (World Health Organization); CDC (Centers for Disease Control and Prevention, HTH (calcium hypochlorite, high-test hypochlorite), NaDCC (sodium dichloroisocyanurate).

Table 2. Summary of contextual data

Author	Year	Question	Study methods	Method details, measures or findings relevant to the extraction of contextual data	Data type	Contextual data
Tantum [7]	2021	11abc	Survey study	This study characterizes barriers to, and facilitators of, hand hygiene in rural Liberian hospitals and evaluates readiness for sustainable, locally derived interventions to improve hand hygiene.	Context	During spot checks, hospital staff reported that handwashing container water was always available in 89% (n = 42) of hospital wards, piped running water in 23% (n = 11), and soap in 62% (n = 29). Enumerators observed 5% of wall-mounted hand sanitizer dispensers (n = 8) and 95% of pocket-size dispensers (n = 53) to be working. In interviews, hospital staff described willingness to purchase personal hand sanitizer dispensers when hospital-provided supplies were unavailable. Low-cost, sustainable interventions should address supply and infrastructure-related obstacles to hospital hand hygiene improvement.
Wolfe [8]	2016	11abc	Simulation study	To evaluate skin irritation caused by frequent handwashing that may increase transmission risk in Ebola-affected communities, we conducted a randomized trial with 91 subjects who washed their hands 10 times a day for 28 days.	Acceptability	Subjects using sanitizer had the smallest increases, followed by higher pH chlorine solutions (HTH (calcium hypochlorite, high-test hypochlorite) and stabilized NaOCl (sodium hypochlorite)), and soap and water. The greatest increases were among neutral pH chlorine solutions (NaDCC (sodium dichloroisocyanurate) and generated NaOCl). Signs of irritation related to higher transmission risk were observed most frequently in subjects using soap and least frequently by those using sanitizer or HTH.
Wolfe [8]	2016	11abc	Simulation study	To evaluate skin irritation caused by frequent handwashing that may increase transmission risk in Ebola-affected communities, we conducted a randomized trial with 91 subjects who washed their hands 10 times a day for 28 days.	Implementation	Each handwashing method has benefits and drawbacks: soap is widely available and inexpensive, but requires water and does not inactivate the virus; sanitizer is easy-to use and effective but expensive and unacceptable to many communities, and chlorine is easy-to-use but difficult to produce properly and distribute. Overall, we recommend Ebola responders and communities use whichever handwashing method(s) are most acceptable, available, and sustainable for community handwashing.
Wolfe [9]	2016	11abc	Simulation study	Handwashing and Ebola virus disease outbreaks: A randomized comparison of soap, hand sanitizer, and 0.05% chlorine solutions on the inactivation and removal of model organisms Phi6 and E. coli from hands and persistence in rinse water. Model organisms E. coli and bacteriophage Phi6 were used to evaluate handwashing with and without organic load added to simulate bodily fluids. Hands were inoculated with test organisms, washed, and rinsed using a glove juice method to retrieve remaining organisms.	Usability	HTH performed most consistently well, with significantly greater log reductions than other handwashing protocols in three models. However, the magnitude of handwashing efficacy differences was small, suggesting protocols are similarly efficacious. The authors recommend responders use the most practical handwashing method to ensure hand hygiene in Ebola contexts, considering the potential benefit of chlorine-based methods in rinse water persistence.
Casanova [2]	2018	11b	Doffing practice simulation study	In a medical biocontainment unit, HCWs (n = 10) experienced in EVD care donned and doffed PPE following unit protocols that incorporate trained observer guidance and alcohol-based hand rub (ABHR). A mixture of Φ6 (enveloped), MS2 (non-enveloped), and fluorescent marker was applied to 4 PPE sites, approximating body fluid viral load (Φ6, 105; MS2, 106). They performed a patient care task, then doffed. Inner gloves, face, hands, and scrubs were sampled for virus, as were environmental sites with visible fluorescent marker.	Implementation	Among 10 HCWs there was no Φ6 transfer to inner gloves, hands, or face; 1 participant had Φ6 on scrubs at low levels (1.4 × 102). MS2 transfer (range, 101–106) was observed to scrubs (n = 2), hands (n = 1), and inner gloves (n = 7), where it was highest. Most (n = 8) had only 1 positive site. Environmental samples with visible fluorescent marker (n = 21) were negative. Among experienced HCWs, structured, observed doffing using ABHR protected against hand contamination with enveloped virus. Nonenveloped virus was infrequent on hands and scrubs but common on inner gloves, suggesting that inner gloves, but not necessarily ABHR, protect against hand contamination. Optimizing doffing protocols to protect against all types of viruses may require reinforcing careful handling of scrubs and good glove/hand hygiene with effective agents.
Casanova [2]	2018	11b	Doffing practice simulation study	See above	Implementation	Because gloves are repeatedly touching PPE during the doffing process, even use of ABHR on the outside of gloves between doffing steps may not completely prevent inner glove contamination with a non-enveloped virus. Human factors analyses suggest that the mishandling of certain items of PPE during doffing contributes considerably to the probability that a HCW's gloves, scrubs, and hands become contaminated.

Casanova [2]	2018	11b	Doffing practice simulation study	See above	Implementation	To minimize viral load on inner gloves, both careful doffing and control measures such as stronger glove sanitizing agents (such as hypochlorite or povidone-iodine) may be needed, particularly if non-enveloped viruses emerge as high-risk pathogens. However, whether units use ABHR or other hand sanitizers with demonstrated in vitro effectiveness against viruses, contact time, and technique are still important. These results highlight the fact that even when wearing PPE that provides whole body coverage, hand hygiene after doffing is still critical, with hand hygiene agents that are effective against a range of organisms.
Casanova[10]	2016	11bc	Simulation of doffing practice	A total of 15 HCP donned EVD PPE for this study. Virus was applied to PPE, and a trained monitor guided them through the doffing protocol. Of the 15 participants, 10 used alcohol-based hand rub (ABHR) for glove and hand hygiene and 5 used hypochlorite for glove hygiene and ABHR for hand hygiene. Inner gloves, hands, face, and scrubs were sampled after doffing.	Usage	After doffing, MS2 virus was detected on the inner glove worn on the dominant hand for 8 of 15 participants, on the non-dominant inner glove for 6 of 15 participants, and on scrubs for 2 of 15 participants. All MS2 on inner gloves was observed when ABHR was used for glove hygiene; none was observed when hypochlorite was used. When using hypochlorite for glove hygiene, 1 participant had MS2 on hands, and 1 had MS2 on scrubs.
Casanova[10]	2016	11bc	Simulation of doffing practice	For the first 10 subjects, each step that called for sanitizing gloved hands, as well as the final hand hygiene steps (steps 13 and 16) that called for sanitizing bare hands, were performed using alcohol-based hand rub (ABHR) as a 70% ethanol gel (Purell, Gojo Industries, Akron, OH). For the last 5 subjects, each step that called for sanitizing gloved hands was performed with liquid hypochlorite at a concentration of 1,850 ppm (Fuzion Healthcare Disinfectant, Clorox Co., Pleasanton, CA) applied by spraying onto gloves. The final hand hygiene steps that called for sanitizing bare hands were performed using ABHR.	Implementation	A structured doffing protocol using a trained monitor and ABHR protects against enveloped virus self-contamination. Non-enveloped virus (MS2) contamination was detected on inner gloves, possibly due to higher resistance to ABHR. Doffing protocols protective against all viruses need to incorporate highly effective glove and hand hygiene agents.
Casanova[10]	2016	11bc	Simulation of doffing practice	See above	Implementation	The presence of a low level of MS2 contamination on the hands of 1 participant who did not have detectable MS2 on their inner gloves suggests that random low-level contamination events are still possible. This highlights the importance of reinforcing the message that even when wearing multiple layers of PPE that provide whole-body coverage, hand hygiene after doffing is still critical, as is the careful selection of effective hand hygiene agents for this purpose. In addition, **it is reasonable to recommend that HCP involved in care of patients with EVD post-doffing shower using an antiseptic such as chlorhexidine.**
Casanova[10]	2016	11bc	Simulation of doffing practice	See above	Implementation	Careful doffing of inner gloves in a manner that minimizes the risk of hand contamination is important. **To minimize viral contamination of inner gloves, more conservative control measures may include sanitizing gloves with stronger agents such as hypochlorite. While hypochlorite use directly on hands may not be desirable, its use on gloves does not present the same issues.**
Lantagne [6]	2018	11abc	Multiple-thread research study	To provide evidence for the disinfection recommendations, three research strands were conducted: (1) impacts of chlorine chemistry; (2) efficacy of surface cleaning recommendations; and (3) safety and efficacy of handwashing recommendations.	Implementation	Strand 1 research found that the compound chemistry of the chlorine source has an impact on the chlorine solution shelf-life (<1 day–30 days), with testing of chlorine solutions recommended to ensure accuracy.
Lantagne [6]	2018	11abc	Multiple-thread research study	See above	Acceptability	Strand 2 research found that surface cleaning with 0.5% chlorine solutions with a 15-min exposure time is efficacious in reducing transmission risk. Strand 3 research found that community handwashing with chlorine solutions is as safe and efficacious as handwashing with soap and water or sanitizer, which offers a benefit of reducing pathogens in the rinsing water.
Lantagne [6]	2018	11abc	Multiple-thread research study	See above	Implementation	Using calcium hypochlorite as the chlorine source compound provided a particularly good performance in chemistry and handwashing studies.

Lantagne [6]	2018	11abc	Multiple-thread research study	See above	Implementation	Summary of Research Thread #1: Each chlorine source compound has benefits and drawbacks and it is recommended that responders choose the appropriate compound for their context, while ensuring chlorine solutions made from these source compounds are stored appropriately, used within their shelf-life, periodically tested by trained personnel using titration methods and tested daily with pH-resistant test strips. For example, in a large ETU, NaDCC powder may be the most appropriate chlorine source compound as the solutions would be used within a few hours. In a small ETU making solutions once per day or a community setting where solutions are made once per week, HTH (if powder is stored appropriately to mitigate explosive risk) or NaOCl may be most appropriate.
Lantagne [6]	2018	11abc	Multiple-thread research study	See above	Implementation	Summary of Research Thread 3: The safety and efficacy results indicate all handwashing methods were roughly equally efficacious in practice, although: (1) HTH (calcium hypochlorite, high-test hypochlorite) in particular was consistently more safe and efficacious; and (2) chlorine solutions, as compared to soap and water and sanitizer, offer the benefit of reducing pathogen persistence in rinsing water. As all handwashing methods have benefits and drawbacks (see Figure 4), it is recommended that EVD responders and communities use whichever handwashing method(s) are most acceptable, available and feasible for handwashing, considering that chlorine solutions may offer a benefit in reducing transmission risk from rinsing water.
Lantagne [6]	2018	11abc	Multiple-thread research study	See above	Implementation	Across all studies, the chlorine source compound HTH performed particularly well, with chlorine solutions made from this product having the longest shelf-life, the least hand irritation and the highest handwashing efficacy. However, HTH has the operational challenges of being more explosive than NaDCC and having a precipitate form in mixing with water that can clog pipes. In well-maintained ETUs, this can be managed with appropriate training and maintenance. However, explosions did occur in ETUs that were managed by less experienced organizations in the West African outbreak, which poses a great risk to the health and safety of response personnel and patients (personal communication, available from authors to protect privacy).
Reidy [11]	2017	11abc	Methods were not described	Personal protective equipment solution for UK military medical personnel working in an Ebola virus disease treatment unit in Sierra Leone	Implementation	Tactility and dexterity through two pairs of gloves was of key importance. In addition to complying with European standard EN 374-2:2003 for resistance to penetration by chemicals and micro-organisms, avoidance of allergic reactions was considered from both a patient and wearer perspective. These factors led to the choice of 400-mm nitrile, powder-free gloves.
Reidy [11]	2017	11abc	Methods were not described	Personal protective equipment solution for UK military medical personnel working in an Ebola virus disease treatment unit in Sierra Leone	Implementation	Competency in using PPE was developed during a nine-day pre-deployment training program. This allowed over 60 clinical personnel per deployment to practice skills in PPE in a simulated ETU and in classrooms. Overall, the training provided: (i) an evidence base underpinning the PPE solution chosen; (ii) skills in donning and doffing of PPE; (iii) personnel confidence in the selected PPE; and (iv) quantifiable testing of each individual's capability to don PPE, perform tasks and doff PPE safely.

Gao [12]	2016	11b	Laboratory testing of gloves	Current CDC guidance for the disinfection of gloved hands during the doffing of personal protective equipment (PPE) following the care of a patient with Ebola recommends for multiple applications of alcohol-based hand rub (ABHR) on medical exam gloves. To evaluate possible effects of ABHR applications on glove integrity, thirteen brands of nitrile and latex medical exam gloves from five manufacturers and two different ABHRs were included in this study. A pair of gloves were worn by a test operator and the outside surfaces of the gloves were separately treated with an ABHR for 1–6 applications. Tensile strength and ultimate elongation of the gloves without any ABHR treatments (control gloves) and gloves after 1–6 ABHR applications were measured based on the ASTM D412 standard method.	Usage	In general, tensile strength decreased with each ABHR application. ABHRs had more effect on the tensile strength of the tested nitrile than latex gloves, while ethanol-based ABHR (EBHR) resulted in lesser changes in tensile strength compared to isopropanol-based ABHR (IBHR). The results show that multiple EBHR applications on the latex gloves and some of the nitrile gloves tested should be safe for Ebola PPE doffing based on the CDC guidance.
Gao [12]	2016	11b	Laboratory testing of gloves	See above	Implementation	Appropriate hospital staff practice using ABHR treatment and doffing gloves is recommended to become more familiar with changes in glove properties. Changes in the way the gloves feel may be alarming to end users, so we recommend that hospital safety professionals conduct training and encourage practice of PPE doffing techniques periodically with the specific models of gloves and ABHR used in their hospital. This will help to reduce the chances that unexpected changes in glove properties would be surprising to the HCW during an actual event. Switching the type of glove or the type of ABHR product used may be necessary if decreased glove integrity (e.g., they start to tear or rip) or unusual changes (e.g., excessive stickiness, shrinking, or hardening) that would affect work-related tasks are observed during training and practice.

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Infection prevention and control measures for Ebola and Marburg Virus disease: A series of rapid reviews

KQ12 Disinfection vs. incineration of linens- Initial Summary

(Version 1, 2 September 2022)

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Funding: Funding for this protocol and the subsequent reviews was provided by the World Health Organization (Funding # 202818287). The working group (WG) from the WHO/HQ Country Readiness Strengthening Health Care Readiness Unit will be consulted to develop and refine the scope, and review and approve the protocol. The WG will not be involved in the conduct of the review including selection of studies and data analysis but will advise as needed on priority population(s), interventions, and outcomes in an iterative process during the review process based on the available evidence. The WG will also comment on the draft report and provide input on interpretations of findings. AT is funded by a Tier 2 Canada Research Chair in Knowledge Synthesis. SM is funded by a Tier 2 Canada Research Chair in Mathematical Modeling and Program Science.

Competing interests: DM was involved in the 2015 rapid review by Hersi et al. [1] There are no other competing interests to acknowledge.

Acknowledgements: We thank Kaitryn Campbell, MLIS, MSc (St. Joseph's Healthcare Hamilton/McMaster University) for peer review of the Embase search strategy.

Key Question

KQ12: Should heavily soiled linen resulting from care to patients with Ebola or Marburg in health care, ETUs or community settings be incinerated versus disinfected?

Methods Summary

This is one of a series of rapid reviews answering 12 key questions related to three themes on infection prevention and control measures for filoviruses: (i) transmission/exposure (n=3 questions), (ii) personal protective equipment (PPE) (n=5), and (iii) decontamination and disinfection (n=4). Data sources include Medline, Embase, bio/medRxiv pre-print servers, Global Medicus Index, Epistemonikos, China National Knowledge Infrastructure (CNKI) and Wangfang database. We used an automation tool (CAL® tool) for titles/abstracts screening for relevant systematic reviews and primary comparative studies. Full-text screening, data extraction, risk of bias assessment, and GRADE (Grading of Recommendations Assessment, Development and Evaluation) for the certainty of evidence were completed independently by two reviewers with any disagreements resolved by consensus, with arbitration by a third reviewer, when needed.

Findings

A total of 72 studies were screened in the CAL tool software and 20 studies were included for full-text screening. No studies met the eligibility criteria. The majority of studies excluded at the full-text were excluded because they were non-comparative studies that did not compare outcomes for incineration vs. disinfection of heavily soiled linens. Articles that discuss the implementation of current practices for disinfection or decontamination of heavily soiled/highly contaminated waste from Ebola virus or Lassa Fever patients were noted and are discussed in our contextual data. A list of excluded studies with reasons for exclusion can be found in Appendix 1.

Appendix 1. Excluded Studies List – By Reason for Exclusion:

Does not examine Ebola or Marburg (or surrogate viruses)

Rhee SW. Management of used personal protective equipment and wastes related to COVID-19 in South Korea. *Waste Manag Res.* 2020;38(8):820-824. doi:10.1177/0734242X20933343

Non-comparative study

Cummings KJ, Choi MJ, Esswein EJ, et al. Addressing Infection Prevention and Control in the First U.S. Community Hospital to Care for Patients With Ebola Virus Disease: Context for National Recommendations and Future Strategies. *Ann Intern Med.* 2016;165(1):41. doi:10.7326/M15-2944

Edmunds KL, Elrahman SA, Bell DJ, et al. Recommendations for dealing with waste contaminated with Ebola virus: a Hazard Analysis of Critical Control Points approach. *Bull World Health Organ.* 2016;94(6):424-432. doi:10.2471/BLT.15.163931

Garibaldi BT, Kelen GD, Brower RG, et al. The Creation of a Biocontainment Unit at a Tertiary Care Hospital. The Johns Hopkins Medicine Experience. *Annals ATS.* 2016;13(5):600-608. doi:10.1513/AnnalsATS.201509-587PS

Garibaldi B, Ernst N, Reimers M, et al. Establishing a New Biocontainment and Treatment Unit. *Chest.* 2015;148(4):248A. doi:10.1378/chest.2268190

Hewlett AL, Varkey JB, Smith PW, Ribner BS. Ebola virus disease: preparedness and infection control lessons learned from two biocontainment units. *Current Opinion in Infectious Diseases.* 2015;28(4):343-348. doi:10.1097/QCO.0000000000000176

Herstein JJ, Biddinger PD, Gibbs SG, et al. High-Level Isolation Unit Infection Control Procedures. *Health Security.* 2017;15(5):519-526. doi:10.1089/hs.2017.0026

Herstein JJ, Biddinger PD, Kraft CS, et al. Current Capabilities and Capacity of Ebola Treatment Centers in the United States. *Infect Control Hosp Epidemiol.* 2016;37(3):313-318. doi:10.1017/ice.2015.300

Haverkort JJM, Minderhoud ALC (Ben), Wind JDD, Leenen LPH, Hoepelman AIM, Ellerbroek PM. Hospital Preparations for Viral Hemorrhagic Fever Patients and Experience Gained from Admission of an Ebola Patient. *Emerg Infect Dis.* 2016;22(2):184-191. doi:10.3201/eid2202.151393

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McCulloch KL, Michael F, Goren M, et al. Creating an Environment of Safety for the Treatment of Patients with Ebola. *American Journal of Infection Control.* 2015;43(6):S73. doi:10.1016/j.ajic.2015.04.193

Otter JA, Barnicoat M, Down J, Smyth D, Yezli S, Jeanes A. Hydrogen peroxide vapour decontamination of a critical care unit room used to treat a patient with Lassa fever. *Journal of Hospital Infection*. 2010;75(4):335-337. doi:10.1016/j.jhin.2010.02.025

Onoh R, Adeke A, Umeokonkwo C, Ekwedigwe K, Agboeze J, Ogah E. Knowledge and practices of health-care waste management among health Workers in Lassa fever treatment facility in Southeast Nigeria. *Niger Med J*. 2019;60(5):257. doi:10.4103/nmj.NMJ_161_18

Perpoint T, Valour F, Gerbier-Colomban S, et al. Knowledge Attitude and Practice (KAP) on Ebola Virus Disease (EVD) Among Health Care Workers (HCWs) From the Lyon Teaching Hospitals, France. *Open Forum Infectious Diseases*. 2016;3(suppl_1):602. doi:10.1093/ofid/ofw172.465

Sarti AJ, Sutherland S, Robillard N, et al. Ebola preparedness: a rapid needs assessment of critical care in a tertiary hospital. *CMAJ Open*. 2015;3(2):E198-E207. doi:10.9778/cmajo.20150025

Sisler L, Hanlon V. Supporting Emerging Infectious Disease Education Through Utilization of "At-A-Glance" Guides for Infection Prevention and Containment Unit Staff. *American Journal of Infection Control*. 2016;44(6):S124-S125. doi:10.1016/j.ajic.2016.04.151

No relevant comparisons

Garibaldi BT, Reimers M, Ernst N, et al. Validation of Autoclave Protocols for Successful Decontamination of Category A Medical Waste Generated from Care of Patients with Serious Communicable Diseases. McAdam AJ, ed. *J Clin Microbiol*. 2017;55(2):545-551. doi:10.1128/JCM.02161-16

PDF not found

Bangura I, Conteh C. The Impact of Quality Improvement Methodology to Improve Infection Control Practices. Antimicrobial Resistance & Infection Control. 2019;8(1):P405.

Bustamante ND, O'Keeffe D, Bradley D, Pozner CN. Targeted interprofessional simulation-based training for safe patient management of Ebola virus disease. Academic Emergency Medicine. Published online 2015.

Cazares M, Hutson M, Lakhani U, Herndon D. Implementation of an infectious disease control plan requiring category-a personal protective equipment. Journal of Burn Care and Research. Published online 2016.

Appendix 2. Eligibility Criteria

Question (12): Should heavily soiled linen resulting from care to patients with Ebola or Marburg disease in health care, ETUs or community settings be incinerated versus disinfected?

Setting	Health care facility, ETU, community (e.g., burial team)
Population	Staff working in Health care facility, ETU, community
Background interventions (Standard of care)	Heavily soiled, contaminated linen should preferably be incinerated or processed by autoclaving. Washing contaminated linen by hand should be discouraged, if washing machines are not available or power is not ensured, take the soiled linen out of the container and empty it into a large drum container of water and soap. Soak the linen in this drum and make sure it is totally covered with water. Use a stick to stir; then throw out the water, refill the drum with chlorine 0,05% (a solution containing 500 ppm available free chlorine) and soak for 15 minutes.
Intervention	Incineration of heavily soiled linen
Comparator(s)	Laundering heavily soiled linen
Outcome	Staff exposure during handling and laundering of linens, transmission of Ebola and Marburg
Potential effect modifiers	Investment in cleaning, decontamination, and sterilization Use of mechanical washers versus manual (by hand) washing, infra-estructure for proper laundry Type of disinfectant used (toxicity, corrosion, environmentally safe to use) *Quality of linens for re-use.* *vaccination*

KQ12 Contextual data

KQ 12 – "Should heavily soiled linen resulting from care to patients with Ebola or Marburg in health care, ETUs or community settings be incinerated versus disinfected?

- Risks related to staff/person handling the linens (washing manually or by machine wash).

Previous Guideline recommendations

Table 1. summarizes recommendations regarding cleaning and disinfection of surfaces and materials potentially contaminated with Ebola or Marburg viruses by the WHO, US CDC and European CDC.[1] [2] [3] A guidance document from the European CDC cites the US CDC guidance on Ebola waste management. [2] [3] Texts that are deemed to be relevant to Key Question 12 are highlighted in yellow below.

The WHO 2014 Interim infection prevention and control guidance makes the following recommendations: [1]

Personal protective equipment

• Wear heavy duty/rubber gloves, impermeable gown, closed shoes (e.g. boots) and facial protection (mask and goggle or face shield), when handling infectious waste (e.g. solid waste or any secretion or excretion with visible blood). Goggles provide greater protection than visors from splashes that may come from below when pouring liquid waste from a bucket. Avoid splashing when disposing of liquid infectious waste.

Waste management procedures

• Waste should be segregated at point of generation to enable appropriate and safe handling.

• Collect all solid, non-sharp, infectious waste using leak-proof waste bags and covered bins. Bins should never be carried against the body (e.g. on the shoulder).

• Waste should be placed in a designated pit of appropriate depth (e.g. 2 meters or about 7 feet) and filled to a depth of 1–1.5 m (or about 3–5 feet). After each waste load, the waste should be covered with a layer of 10 –15 cm deep soil.

• An incinerator may be used for short periods during an outbreak to destroy solid waste. However, it is essential to ensure that total incineration has taken place. Caution is also required when handling flammable material and when wearing gloves due to the risk of burn injuries if gloves get ignited.

According to the US CDC Procedures for Safe Handling and Management of Ebola-Associated Waste,[2] the safe handling and in-hospital management of waste generated through the care of patients with Ebola is based on three main principles.

1. Safe containment and packaging of waste should be performed as close as possible to the point of generation. Staff should avoid opening containers to manipulate the waste after primary containment.

2. Limit the number of personnel entering the Ebola patient care area and those handling generated waste before and after primary containment.

3. Always use appropriate personal protective equipment (PPE) and procedures for handling waste until the onsite inactivation or transport away from the hospital for offsite inactivation.

In the section titled “Preparing a Waste Management Plan as Part of Ebola Patient Care”, the CDC guides specify

1. Comply with your State and local regulation for handling, storage, treatment, and disposal of Ebola-associated waste.

2. Determine whether Ebola-associated waste will be inactivated onsite at the hospital or transported offsite for inactivation.

3. Identify a dedicated waste management team with specific training on standardized procedures for waste handling, including wearing appropriate PPE, and protocols for safely bagging and packaging waste, storing waste, and transporting packaged waste.

- Onsite inactivation: Ebola-associated waste may be inactivated through incineration or by autoclaving using properly maintained equipment with appropriate biological indicators.
- Offsite inactivation: Comply with regulations for packaging, transport and disposal of Ebola-associated waste.

US CDC 2019 Ebola-Associated Waste Management [3]

- Ebola-associated waste that has been appropriately incinerated, autoclaved, or otherwise inactivated is not infectious, does not pose a health risk, and is not considered to be regulated medical waste or a hazardous material under federal law.

Inactivation or incineration of Ebola-associated waste within a hospital system may be subject to state, local, and OSHA regulations.

- On-site inactivation
  - Ebola-associated waste may be inactivated through the use of appropriate autoclaves. Other methods of inactivation (e.g., chemical inactivation) have not been standardized and would need to consider worker safety issues, as well as the potential for triggering other federal safety regulations.
- On-site incineration
  - Ebola-associated waste may be incinerated. The products of incineration (i.e., the ash) can be transported and disposed of in accordance with state and local regulations and standard protocols for hospital waste disposal.

Contextual data

Table 2. summarizes the contextual data from six studies that were identified during study selection. Texts in the excerpts below are highlighted green if they are deemed to be relevant to KQ 12.

In Edmunds et al. 2016, a team with expertise in the Hazard Analysis of Critical Control Points framework identified waste products from the care of individuals with Ebola virus disease and constructed, tested and confirmed flow diagrams showing the creation of such products. [4] After listing potential hazards associated with each step in each flow diagram, the team conducted a hazard analysis, determined critical control points and made recommendations to mitigate the transmission risks at each control point. They identified 13 critical control points – i.e. 13 points at which there is an opportunity to adopt measures to reduce the risks of transmission (Figure 1).

Critical control point 2 - Washing and cleaning - The level of concern about washing and cleaning fomite contaminated with blood is high (Figure 1). [4] The level of concern about washing and cleaning fomite contaminated with contaminated bodily fluids other than blood is medium. The concern is with contamination of cleaners (Figure 1). Use water and detergent for cleaning, followed by 0.5% chlorinated water for disinfecting. The concern for wastewater contamination is low. Wastewater is to be managed with Critical Control Point 12 in Figure 1.

Critical control point 3 - Reuse or shared use of fomites - The level of concern about contaminated fomites with blood is high (Figure 1). [4] The level of concern about contaminated fomites with bodily fluids other than blood is medium. The concern with reuse or shared use of fomite is inadequate cleaning. Avoid reuse where possible and dispose as per Critical Control Point 8 in Figure 1. If reuse is essential, wear full PPE when washing reusable materials or products. Check fomite for damage and suitability for reuse. If reuse is possible, clean fomite using a moist single-use cloth, which should then be incinerated. Following cleaning, if possible, with a wash with water at >60 °C. If not possible, soak in 0.5% chlorine solution for a minimum of 30 min, after removing most organic material, and then let air-dry before transporting for reuse.

Critical control point 8 - Burning of waste - The concern with burning of waste contaminated with blood or bodily fluids other than blood is low (Figure 1). [4] The concern is with incomplete combustion. If waste is to be burned, use an incinerator – that reaches sufficient complete burning temperatures and meets environmental emission standards – according to manufacturer's operating manual. If an incinerator is not available, burn in a barrel or pit with sufficient additional combustible material to ensure complete combustion. If large volumes of waste need to be burned, divide into smaller volumes before burning. PPE should be worn but extreme caution needs to be taken to avoid the handler's PPE catching alight.

Garibaldi et al 2016 describe a biocontainment and treatment unit at Johns Hopkins Medicine to care for patients with EVD. [5] They examined published literature and guidelines, visited two existing U.S. biocontainment units, and contacted national and international experts to inform the design of the physical structure and patient care activities of the unit. The Johns Hopkins Biocontainment Unit (BCU) has an onsite waste-handling room with two pass-through autoclaves (Primus Sterilizer, Omaha, NE). Infectious material is loaded into the autoclaves on the contaminated side and, once sterilized, is removed on the clean side for processing as regular medical waste. Biological and chemical indicators are used with every autoclave cycle to ensure sterilization before transport off the unit. Autoclave protocols were derived from guidelines for Biological Safety Level BSL-3 and BSL-4 laboratories.

According to Garibaldi et al., there are few data on the use of autoclaves for decontamination of clinical and patient-related waste. [5] The BCU autoclave protocols were developed and validated through a

rigorous process that used biological indicators embedded within mock patient trash loads. This ensures that effective kill of organisms is achieved in solid trash, liquid waste, and soiled linens.

Items that are reused on the BCU are transported to a room off the waste-handling area, where they undergo disinfection with a hydrogen peroxide vapor system (Bioquell, Horsham, PA). [5] This system also decontaminates patient care areas after discharge (20–23). The elevator is cleaned with hospital disinfectant and can undergo decontamination with vaporized hydrogen peroxide if a spill occurs during transport. The plumbing is resistant to hospital disinfectants and has a dedicated wastewater conduit to the hospital's main sanitary system. This allows dilution of waste materials with disinfectants and protects the floors below in the case of a plumbing disruption.

Garibaldi et al. 2017 conducted a validation study of autoclave protocols for successful decontamination of category A medical waste generated from care of patients with serious communicable diseases. [6] The most difficult loads to sterilize were those containing saturated linens (soaked with 1 liter of water) comprising a cotton blanket, sheets, and pillow cases, which required a vacuum cycle of a minimum of 60 min to achieve adequate sterilization using the settings as described for other dry waste. Nine of nine runs (100%) containing multiple saturated linens and using a shorter sterilizing time (3 runs each of 15, 30, and 45 min) failed.

While autoclave sterilization may be an effective and safe way to process infectious waste for transport and disposal, this study shows that factory default settings and laboratory waste guidelines are likely insufficient to adequately sterilize pathogens in the center of medical waste autoclave loads.[6] Autoclave parameters may need to be adjusted, with particular attention paid to the way that waste loads are packaged prior to treatment.

Haverkort et al. 2016 report how the Major Incident Hospital of the University Medical Centre of Utrecht prepared for admitting Ebola patients. [7] An assessment of the hospital's preparations for an outbreak of viral hemorrhagic fever and its experience during admission of a patient with Ebola virus disease showed that the use of the buddy system, frequent training, and information sessions for staff and their relatives greatly increased the sense of safety and motivation among staff. Differing procedures among ambulance services limited the number of services used for transporting patients. Waste management was the greatest concern, and destruction of waste had to be outsourced.

Preparations for waste management were a major concern given the expected amount of waste and the time consuming procedures involved (replacing a single waste container in the isolation unit can take as long as 20 minutes). [7] Designated, sealable, 60-L waste containers would be used for waste storage, and waste management procedures were strictly protocolled and repeatedly conveyed through training. In-hospital autoclave capacity appeared insufficient; therefore, waste destruction would be outsourced to an external facility. In accordance with transportation laws, one specific 20-L container had been approved for transport by public road (5). However, these containers were too small, and opening and closing them presented a safety risk. Therefore, category A medical waste (UN2814) containers were chosen; these were to be packed in a large plastic drum and the waste stored in a guarded and certified cooled sea container outside the hospital before transport.

Otter et al. 2010 report the use of a hydrogen peroxide vapor decontamination of a critical care unit room used to treat a patient with Lassa fever. [8] They based their decontamination strategy on a UK 1996 Health Protection Agency guidance document for the management and control of viral hemorrhagic fevers which states that 'In some circumstances VHF [viral hemorrhagic fever] viruses can survive for two weeks or even longer on contaminated fabrics and equipment.' They therefore decided to decontaminate the critical care unit room, which was contaminated with blood and body fluids, with hydrogen peroxide vapour, a sporicidal and virucidal vapour-phase method that is being used increasingly in healthcare settings.

References

1. World Health Organization. *Interim infection prevention and control guidance for care of patients with suspected or confirmed filovirus haemorrhagic fever in health-care settings, with focus on Ebola.* World Health Organization;2014.
2. Center for Disease Control. Procedures for Safe Handling and Management of Ebola-Associated Waste. https://www.cdc.gov/vhf/ebola/clinicians/cleaning/handling-waste.html.
3. Control CfD. Ebola-Associated Waste Management. 2019; https://www.cdc.gov/vhf/ebola/clinicians/cleaning/waste-management.html.
4. Edmunds KL, Elrahman SA, Bell DJ, et al. Recommendations for dealing with waste contaminated with Ebola virus: a Hazard Analysis of Critical Control Points approach. *Bulletin of the World Health Organization.* 2016;94(6):424-432.
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6. Garibaldi BT, Reimers M, Ernst N, et al. Validation of Autoclave Protocols for Successful Decontamination of Category A Medical Waste Generated from Care of Patients with Serious Communicable Diseases. *Journal of clinical microbiology.* 2017;55(2):545-551.
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Table 1: Summary of guideline recommendations regarding disinfection of Ebola-exposed surfaces by the WHO, US and European CDC

Source	Should heavily soiled linen resulting from care to patients with Ebola or Marburg in health care, ETUs or community settings be incinerated versus disinfected? Risks related to staff/person handling the linens (washing manually or by machine wash).
WHO [1]	2014
Recommendations	Interim infection prevention and control guidance for care of patients with suspected or confirmed filovirus haemorrhagic fever in health-care settings, with focus on Ebola 4. WASTE MANAGEMENT Personal protective equipment Wear heavy duty/rubber gloves, impermeable gown, closed shoes (e.g. boots) and facial protection (mask and goggle or face shield), when handling infectious waste (e.g. solid waste or any secretion or excretion with visible blood). Goggles provide greater protection than visors from splashes that may come from below when pouring liquid waste from a bucket. Avoid splashing when disposing of liquid infectious waste. Waste management procedures Waste should be segregated at point of generation to enable appropriate and safe handling. Sharp objects (e.g. needles, syringes, glass articles) and tubing that has been in contact with blood or body fluids should be placed inside puncture resistant waste containers (as described above). These should be located as close as practical to the patient care area where the items are used, similarly in laboratories. Collect all solid, non-sharp, infectious waste using leak-proof waste bags and covered bins. Bins should never be carried against the body (e.g. on the shoulder). Waste should be placed in a designated pit of appropriate depth (e.g. 2 meters or about 7 feet) and filled to a depth of 1–1.5 m (or about 3–5 feet). After each waste load, the waste should be covered with a layer of soil 10 –15 cm deep. An incinerator may be used for short periods during an outbreak to destroy solid waste. However, it is essential to ensure that total incineration has taken place. Caution is also required when handling flammable material and when wearing gloves due to the risk of burn injuries if gloves are ignited. Placenta and anatomical samples should be buried in a separate pit. The area designated for the final treatment and disposal of waste should have controlled access to prevent entry by animals, untrained personnel or children. Waste, such as faeces, urine and vomit, and liquid waste from washing, can be disposed of in the sanitary sewer or pit latrine. No further treatment is necessary.
US CDC [2]	Procedures for Safe Handling and Management of Ebola-Associated Waste The safe handling and in-hospital management of waste generated through the care of patients with Ebola is based on three main principles. 1. Safe containment and packaging of waste should be performed as close as possible to the point of generation. Staff should avoid opening containers to manipulate the waste after primary containment. 2. Limit the number of personnel entering the Ebola patient care area and those handling generated waste before and after primary containment.

	3. Always use appropriate personal protective equipment (PPE) and procedures for handling waste until onsite inactivation or transport away from the hospital for offsite inactivation. **Preparing a Waste Management Plan as Part of Ebola Patient Care** 1. Comply with your State and local regulation for handling, storage, treatment, and disposal of Ebola-associated waste. 2. Determine whether Ebola-associated waste will be inactivated onsite at the hospital or transported offsite for inactivation. 3. Identify a dedicated waste management team with specific training on standardized procedures for waste handling, including wearing appropriate PPE, and protocols for safely bagging and packaging waste, storing waste, and transporting packaged waste. o Onsite inactivation: Ebola-associated waste may be inactivated through incineration or by autoclaving using properly maintained equipment with appropriate biological indicators. o Offsite inactivation: Comply with regulations for packaging, transport and disposal of Ebola-associated waste.
US CDC	2019 Ebola-Associated Waste Management [3] • Ebola-associated waste that has been appropriately incinerated, autoclaved, or otherwise inactivated is not infectious, does not pose a health risk, and is not considered to be regulated medical waste or a hazardous material under federal law. Inactivation or incineration of Ebola-associated waste within a hospital system may be subject to state, local, and OSHA regulations. • On-site inactivation o Ebola-associated waste may be inactivated through the use of appropriate autoclaves. Other methods of inactivation (e.g., chemical inactivation) have not been standardized and would need to consider worker safety issues, as well as the potential for triggering other federal safety regulations. • On-site incineration o Ebola-associated waste may be incinerated. The products of incineration (i.e., the ash) can be transported and disposed of in accordance with state and local regulations and standard protocols for hospital waste disposal.
European CDC	2019 Health emergency preparedness for imported cases of high-consequence infectious diseases [9] No specific recommendations. This document cites the US CDC guides regarding Ebola-Associated Waste Management

Table 2. Summary of contextual data

Author, year	Study methods	Method details, measures or findings relevant to the extraction of contextual data	Data type	Contextual data
Cummings, 2016 [10]	Practice reflection	After admission of the first patient with EVD, a multidisciplinary team from the Centers for Disease Control and Prevention (CDC) joined the hospital's infection prevention to implement a system of occupational safety and health controls for direct patient care, handling of clinical specimens, and managing regulated medical waste. Existing engineering and administrative controls were strengthened.	Implementation	**Engineering Controls -** A designated waste anteroom was constructed by adding a second zippered wall separating the hot zone from adjacent nursing stations. Throughout their shifts, nurses in the hot zone brought double-bagged medical waste directly to the waste anteroom and placed it in 55-gallon Department of Transportation– approved category A lined cardboard drums (category A — contaminated with EVD and other highly infectious pathogens—). Environmental services staff removed the full drums from the waste anteroom and replaced them with empty drums daily. The waste anteroom allowed EVS staff to avoid an earlier practice of entering the hot zone to collect the drums. **Administrative Controls and PPE -** The addition of solidifier to liquid waste (urine, vomitus, and feces) before bagging minimized the potential for the biohazard bags to leak. Nurses were asked to fill biohazard bags until they were only onehalf to three-quarters full to help ensure that they would safely fit in the drums without excessive manipulation. When a biohazard bag was ready to be disposed, 100 mL of a 0.5% chlorine solution was added, the bag was hand-tied, and the outside was disinfected using hospital-grade disinfecting chlorine wipes. The bag was placed in a second biohazard bag, which was hand-tied, externally disinfected using chlorine wipes, and placed in a drum in the waste anteroom. When the drum was full, the liner was secured with a zip tie and the lid was secured with a metal band clamp. Drums were transported off-site by a contractor for incineration. Once environmental services staff no longer entered the hot zone, their recommended PPE ensemble was limited to skin protection. However, having previously worn respiratory protection in the hot zone, they chose to wear disposable N95 respirators when transporting waste.
Edmunds, 2016 [4]	Hazard analysis	A team with expertise in the Hazard Analysis of Critical Control Points framework identified waste products from the care of individuals with Ebola virus disease and constructed, tested and confirmed flow diagrams showing the creation of such products. After listing potential hazards associated with each step in each flow diagram, the team conducted a hazard analysis, determined critical control points and made recommendations to mitigate the transmission risks at each control point.	Implementation	Findings The collection, transportation, cleaning and shared use of **blood-soiled** fomites and the shared use of latrines contaminated with blood or bloodied feces appeared to be associated with particularly **high levels of risk** of Ebola virus transmission. More moderate levels of risk were associated with the collection and transportation of material contaminated with **bodily fluids other than blood**, shared use of latrines soiled with such fluids, the cleaning and shared use of fomites soiled with such fluids, and the contamination of the environment during the collection and transportation of blood-contaminated waste. Conclusion The risk of the waste-related transmission of Ebola virus could be reduced by the use of full PPE, appropriate hand hygiene and an appropriate disinfectant after careful cleaning.

Author, year	Study methods	Method details, measures or findings relevant to the extraction of contextual data	Data type	Contextual data
Garibaldi, 2016 [5]	Description of a biocontainment and treatment unit	Johns Hopkins Medicine (JHM) created a new biocontainment and treatment unit (BCU) to safely care for patients with EVD. The unit team examined published literature and guidelines, visited two existing U.S. biocontainment units, and contacted national and international experts to inform the design of the physical structure and patient care activities of the unit.		An onsite laboratory and an autoclave waste management system minimize the transport of infectious materials out of the unit. The Johns Hopkins Biocontainment Unit (BCU) has an onsite waste-handling room with two pass-through autoclaves (Primus Sterilizer, Omaha, NE). Infectious material is loaded into the autoclaves on the contaminated side and, once sterilized, is removed on the clean side for processing as regular medical waste (Figure 5). Biological and chemical indicators are used with every autoclave cycle to ensure sterilization before transport off the unit. Autoclave protocols were derived from guidelines for BSL-3 and BSL-4 laboratories (19). There are few data on the use of autoclaves for decontamination of clinical and patient-related waste. The BCU autoclave protocols were developed and validated through a rigorous process that used biological indicators embedded within mock patient trash loads. This ensures that effective kill of organisms is achieved in solid trash, liquid waste, and soiled linens. Items that are reused on the unit are transported to a room off the waste-handling area, where they undergo disinfection with a hydrogen peroxide vapor system (Bioquell, Horsham, PA). This system also decontaminates patient care areas after discharge (20–23). The elevator is cleaned with hospital disinfectant and can undergo decontamination with vaporized hydrogen peroxide if a spill occurs during transport. The plumbing is resistant to hospital disinfectants and has a dedicated wastewater conduit to the hospital's main sanitary system. This allows dilution of waste materials with disinfectants and protects the floors below in the case of a plumbing disruption.
Garibaldi, 2017 [6]	Validation study	Validation of autoclave protocols for successful decontamination of category A medical waste generated from care of patients with serious communicable diseases	Implementation	The most difficult loads to sterilize were those containing saturated linens (soaked with 1 liter of water) comprising a cotton blanket, sheets, and pillow cases, which required a vacuum cycle of a minimum of 60 min to achieve adequate sterilization using the settings as described for other dry waste. Nine of nine runs (100%) containing multiple saturated linens and using a shorter sterilizing time (3 runs each of 15, 30, and 45 min) failed. While autoclave sterilization may be an effective and safe way to process infectious waste for transport and disposal, this study shows that factory default settings and laboratory waste guidelines are likely insufficient to adequately sterilize pathogens in the center of medical waste autoclave loads. Autoclave parameters may need to be adjusted, with particular attention paid to the way that waste loads are packaged prior to treatment.
Haverkort, 2016 [7]	Report of a hospital preparations for Ebola patients	An assessment of the hospital's preparations for an outbreak of viral hemorrhagic fever and its experience during admission of a patient with Ebola virus disease showed that the use of the buddy system, frequent training, and information sessions for staff and their relatives greatly increased the sense of safety and motivation among staff. Differing procedures among ambulance services limited the number of services used for transporting patients. Waste management was the greatest concern, and destruction of waste had to be outsourced. The admission of an Ebola patient proceeded without incident but led to considerable demands on staff. The maximum time allowed for wearing personal protective equipment was 45 minutes to ensure safety, and an additional 20 minutes was needed for recovery.	Implementation	Preparations for waste management were a major concern given the expected amount of waste and the time-consuming procedures involved (replacing a single waste container in the isolation unit can take as long as 20 minutes). Designated, sealable, 60-L waste containers would be used for waste storage, and waste management procedures were strictly protocolled and repeatedly conveyed through training. In-hospital autoclave capacity appeared insufficient; therefore, waste destruction would be outsourced to an external facility. In accordance with transportation laws, one specific 20-L container had been approved for transport by public road (5). However, these containers were too small, and opening and closing them presented a safety risk. Therefore, category A medical waste (UN2814) containers were chosen; these were to be packed in a large plastic drum and the waste stored in a guarded and certified cooled sea container outside the hospital before transport.

Author, year	Study methods	Method details, measures or findings relevant to the extraction of contextual data	Data type	Contextual data
Otter, 2010 [8]	Report of a decontamination method	Hydrogen peroxide vapour decontamination of a critical care unit room used to treat a patient with Lassa fever		We based our decontamination strategy (Figure 1) on a 1996 Health Protection Agency guidance document for the management and control of viral hemorrhagic fevers which states that 'In some circumstances VHF [viral hemorrhagic fever] viruses can survive for two weeks or even longer on contaminated fabrics and equipment.' 5 We therefore decided to decontaminate the CCU room, which was contaminated with blood and body fluids, with hydrogen peroxide vapor (HPV), a sporicidal and virucidal vapor-phase method that is being used increasingly in healthcare settings.6e8

Figure 1. Summary of potential hazard by critical control point (Source Edmunds et al. 2016) [4]

Table 1. **Summary of the Hazard Analysis of Critical Control Point (HACCP) assessment for the disposal of waste potentially contaminated with Ebola virus**

Potential hazard by critical control point	Level of concern about contaminated materials		Recommendations[b]
	with blood	with bodily fluids other than blood[a]	
1. Latrine use			
Contamination of environment	High	Medium	– Suspected and confirmed cases use isolated and segregated latrines and keep pit secure for 7 days[10,24] after last use by suspected case. – Avoid surface water inflow by using external channels or concrete surroundings, and ensure adequate quality of construction to limit risk of collapse and contamination of groundwater sources.[17] – Using a single-use cloth – which should subsequently be incinerated – clean surfaces with water and detergent. Then wipe 0.5% chlorine solution[16,18–21] over all surfaces, including door handles, toilet seat, floor and walls.[7] Wash hands with soap and water after using latrine.
2. Washing and cleaning			
Contamination of cleaner	High	Medium	– Provide proper training of cleaners and ensure experienced supervision. – Use water and detergent for cleaning, followed by 0.5% chlorinated water for disinfecting.[10,18,19] – Treat wastewater as per CCP12.
3. Reuse or shared use of fomite			
Inadequate cleaning	High	Medium	– Avoid reuse where possible and dispose as per CCP8. If reuse is essential, wear full PPE when washing reusable materials or products.[c] – Check fomite for damage and suitability for reuse. If reuse is possible, clean fomite using a moist single-use cloth, which should then be incinerated. Following cleaning, if possible, with a wash with water at > 60 °C.[16,22] If not possible, soak in 0.5% chlorine solution[18,19] for a minimum of 30 min, after removing most organic material,[10,16,21,22] and then let air-dry before transporting for reuse.
4. Transport			
Splashing on handler	High	Medium	– Avoid handling fresh waste. If unavoidable, wear full PPE and employ appropriate hand hygiene measures.[c]
Contamination of vehicles and/or containers	High	Medium	– At end of each transportation or shift, using a moist single-use cloth that should subsequently be incinerated, clean vehicles and containers with water and detergent. Following cleaning, disinfect using 0.5% chlorine solution.[16,18,19,21] If cloth must be reused, wash with warm water and detergent while wearing appropriate PPE to remove organic matter. Then soak in 0.5% chlorine solution for a minimum of 30 min and rinse with cold water.[23] – Always wear full PPE when cleaning vehicles and containers and disinfect or burn PPE after use.
Contamination of environment	Medium	Low	– Use leak-proof containers – e.g. plastic barrels with secure lids – for contaminated items.[17] – Using a single-use cloth that should subsequently be incinerated, clean outer surfaces of vehicles and containers before and after use with water and detergent. If cloth must be reused, wash with warm water and detergent, while wearing appropriate PPE, to remove organic matter. Then soak in 0.5% chlorine solution for a minimum of 30 min and rinse with cold water.[23] Following cleaning, disinfect using 0.5% chlorine solution.[10,18,19,21] – Enclose and/or isolate site. – Spills should be covered first with a cloth, to avoid splashing or dispersion of fluids. Then wipe up spill with rags and dispose of rags through incineration. Clean the area with a detergent and water and then disinfect by wiping with 0.5% chlorine solution.[18,19]
5. Disposal of sharps			
Contamination of handler	High	Low	– Sharps should be segregated from other waste at point of generation,[17,21,23] placed in puncture-resistant, sealed biohazard-labelled containers and disposed of appropriately, as local facilities allow.[17,23]

Figure 1. Summary of potential hazard by critical control point (Continued)

Potential hazard by critical control point	Level of concern about contaminated materials		Recommendations[b]
	with blood	with bodily fluids other than blood[b]	
6. Emptying of latrine when more than two thirds full			
Contamination of handler	Variable, depending on age of waste, construction of latrine etc.	Variable, depending on age of waste, construction of latrine etc.	– Wait a minimum of 7 days after last use by a known case before desludging.[19,24] – If not possible to wait 7 days, wear full PPE.[25–27,b]
7. Storage			
Exposure to contaminated waste	Variable, depending on age of waste	Variable, depending on age of waste	– Segregate waste into a secure nonporous container and destroy within 24 h.[19]
8. Burning of waste			
Incomplete combustion	Low	Low	– If waste is to be burned, use an incinerator – that reaches sufficient complete burning temperatures and meets environmental emission standards – according to manufacturer's operating manual. If an incinerator is not available, burn in a barrel or pit with sufficient additional combustible material to ensure complete combustion.[19] – If large volumes of waste need to be burned, divide into smaller volumes before burning.[19] – PPE should be worn but extreme caution needs to be taken to avoid the handler's PPE catching alight.
9. Cleaning and disinfecting of non-human waste			
Theft and reuse	Low	Low	– For fabric waste – e.g. bed linen and clothing – discard if possible. If reuse necessary, wash with warm water and detergent, while wearing appropriate PPE, to remove organic matter. Then soak in 0.5% chlorine solution for a minimum of 30 min and rinse with cold water. – For hard waste – e.g. crockery and buckets – wash with a detergent, while wearing appropriate PPE, to remove organic matter. Then soak in 0.5% chlorine solution for a minimum of 10 min and rinse with cold water. – Items can be reused if not damaged. For items not suitable for reuse, dump in a secure area and limit animal access to the secure area.[10,16,18,19,21]
10. Burial of waste			
Digging up or theft of health-care waste	Low	Low	– Bury in reliably secure areas, with limited access to animals, and keep secure for 14 days after last disposal. Acidify or soak in 0.5% chlorine solution for 30 min[10,16,18,19,21] before dumping.
11. Disposal on ground			
Contamination of food crops	Low	Low[13]	– Prevent disposal onto ground used for food crops and ensure that all crops are handled and prepared according to appropriate food safety guidelines.[28]

Figure 1. Summary of potential hazard by critical control point (Continued)

Potential hazard by critical control point	Level of concern about contaminated materials		Recommendations[b]
	with blood	with bodily fluids other than blood[a]	
Contamination of water supply	Low	Low	– Ensure water supply point is designed to prevent contamination following principles of sanitary assessments included in water safety plans.[12] – Encourage safe water handling and storage practices and encourage proven household water treatment methods – e.g. filtration, chlorination or boiling.[12,19]
12. Discharge and treatment of wastewater through sewer			
Contact of general public with virus via open sewers	Low	Low	– Give public health education to community representatives and construct physical barriers.[12] Ensure appropriate conditions of carriage – in many places effluent streams are used by neighbours[17] – by following sanitation safety planning guidelines.[17,29]
Contact of sewage workers with virus	Low	Low	– Ensure standard PPE and hygiene practices are followed.[30]
13. Open defecation			
Human and animal contact with virus via human excrement	Low	Low	– Discourage open defecation and encourage pit latrine use. Remove excrement to a pit latrine or bury at a minimum depth of 0.5 m. If unavoidable, dump excrement in secure area.

CCP: critical control point; PPE: personal protective equipment.

[a] Including urine, faeces and wash water.

[b] During the execution of this recommendation, appropriate hand hygiene must be employed and full PPE worn, with the correct protocols observed. After each use, PPE should be treated as an infected fomite and either disinfected or burned.

[c] Due to the nature of Ebola viruses, there must be 100% compliance with this recommendation.