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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