AMR Policy Accelerator

RAPID SCOPING REVIEW

The Effects of the COVID-19 Pandemic on the Three Core Drivers of AMR

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Global Strategy Lab

COVID-END
COVID-19 Evidence Network to support Decision-making ... in Canada

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To help Canadian decision-makers as they respond to unprecedented challenges related to the COVID-19 pandemic, COVID-END in Canada is preparing evidence syntheses like this one. This living evidence synthesis was commissioned by the Office of the Chief Science Officer, Public Health Agency of Canada, and was funded by the COVID-19 Evidence Network to support Decision-making (COVID-END) through an investment from the Government of Canada through the Canadian Institutes of Health Research (CIHR). The opinions, results, and conclusions are those of the team that prepared the evidence synthesis, and independent of the Government of Canada, CIHR, and the Public Health Agency of Canada. No endorsement by the Government of Canada, Public Health Agency of Canada or CIHR is intended or should be inferred.

For more on the Global Strategy Lab and the project team see page 32.

EXECUTIVE SUMMARY

Antimicrobial resistance (AMR) is a critical threat to global public health. The impacts of the COVID-19 pandemic on antimicrobial use (AMU), infection prevention and control (IPAC), and on the use of healthcare and related systems may have potentially profound implications for AMR. We conducted a rapid scoping review to identify linkages and evidence gaps in how these three drivers have impacted the emergence of new drug-resistant strains (AMR *emergence*), the spread of antimicrobial resistant organisms between hosts (AMR *transmission*), and the number and nature of infections due to antimicrobial resistant organisms (AMR *burden*).

National surveillance data from the early stages of the pandemic (2020) show that the impact of COVID-19 on AMR varies across geographic, resource, and healthcare and community settings. Surveillance data from Canada, the United Kingdom, and the European Union show an initial decrease in AMU, however different countries saw increasing, decreasing and mixed trends in AMR rates among their priority pathogens. The United States, one of the few countries that has released 2021 data on community and outpatient AMU, saw a significant initial decrease in AMU in 2020 related to lower outpatient prescribing, followed by an increase in 2021 to above 2019 levels.

Findings from our review suggest that AMR burden may have been mitigated by IPAC measures during the COVID-19 pandemic. Changes in AMU were not related to AMR burden in most studies, although most studies only considered a short time frame when measuring changes in resistance. We found no studies investigating the impact of COVID-19 changes in health system use on AMR burden, emergence, or transmission, and no studies looking at the impact of AMU on AMR emergence or transmission. Lack of research evidence on these areas of AMR represent a significant evidence gap and opportunity for future research.

Differences in observed AMU and AMR trends between regions and countries may reflect national differences in the implementation of COVID-19 related IPAC measures such as lockdowns, travel restrictions, and masking. Inconsistent findings across regions also reflect that the COVID-19 pandemic has produced both positive and negative effects on AMR, likely as the result of interactions between the three drivers of interest. For example, improved IPAC measures may have decreased health system use as well as AMU and AMR. Interpreting this web of interactions will require more contextual evidence on local COVID-19 dynamics and policies.

Despite the profound equity impacts of the COVID-19 pandemic, very few studies collected any data on gender, race, socioeconomic status or the other social determinants of health, and none evaluated differential AMR outcomes among marginalized populations. This represents a significant evidence gap considering the extent to which the COVID-19 pandemic compounded existing equity challenges.

Three key policy implications emerged from this review. First, the lack of available evidence underscores the need to strengthen global AMR and AMU surveillance systems and to use this data to explore community and population level drivers of AMR. Second, further work is needed to identify and address the potential inequitable distribution of the effects of AMR drivers given the extent to which COVID-19 has disproportionally affected low income, racial, ethnic, gender, and minority groups as well as migrant populations. Finally, there is a need to explore national level differences in AMU and AMR trends in the context of local policy responses during COVID-19 to better inform policy options to prevent AMR during future pandemics.

BACKGROUND

Objective

The Global Strategy Lab's (GSL) antimicrobial resistance (AMR) Policy Accelerator conducted a rapid scoping review to explore how (1) antimicrobial use, (2) infection prevention, and (3) health system changes have impacted the emergence, transmission, and burden of AMR during the COVID-19 pandemic (1).

Context

The COVID-19 pandemic has reshaped the landscape of healthcare around the world. Antimicrobial resistance (AMR) was already a critical pre-pandemic issue, and the COVID-19 pandemic has accelerated the need for concerted global action to address rising AMR rates (2). A recent study estimated that in 2019 almost 5 million deaths were attributable to bacterial AMR (3). The potential impact of the COVID-19 pandemic on AMR has been widely debated (4,5) and the World Health Organization estimates AMR caused at least one-third as many deaths as COVID-19 in 2020 (6).

AMR is driven by widespread antimicrobial use (AMU), and in the context of COVID-19, has also likely been impacted by changes in infection prevention and control measures (IPAC), and changes to health system use around the world (1). These drivers, including self-medication, handwashing, use of personal protective equipment, and changes to modes of access to healthcare services such as remote prescribing, can affect AMR through different mechanisms. Inappropriate or increased use of antimicrobials to treat secondary or co-infections (with bacterial, fungal, and other viral infections) in COVID-19 patients may directly influence AMR rates. Policy measures in response to the COVID-19 pandemic, such as reduced travel and improved infection prevention and control practices (in community and across healthcare systems), may have reduced AMR transmission (5), while hospital IPAC measures may have been negatively impacted by the re-distribution of resources from AMR to control of COVID-19 (7). In other contexts, the overprescribing and misuse of antimicrobials in COVID-19 patients with or without secondary bacterial and fungal infections, especially during initial pandemic waves (8), may have concurrently promoted AMR emergence and burden (4). The COVID-19 pandemic has also compounded existing societal and health inequities, such as limited or reduced access to vaccinations, reduced access to laboratory consumables, and reduced staff availability in healthcare systems in low-income communities, which may in turn drive inequitable AMR transmission (5,7).

METHODS

National surveillance data on AMR and AMU

We conducted a targeted scan of national surveillance reports that were published using data from March 2020 or later to provide background data on AMU and AMR rates. We searched for surveillance reports from key countries identified by the Public Health Agency of Canada. Key countries identified were Japan, EU countries, Canada, US, UK, Norway, Korea and Australia. GSL completed the data extraction in Excel, and results were descriptively summarized in *Table 1*.

The impact of COVID-19 on AMR drivers: AMU, IPAC and health system use

Search Strategy

GSL developed a detailed search strategy in consultation with the University of Ottawa's Knowledge Synthesis and Application Unit (KSAU) (*Appendix 3*) review team. Electronic searches were carried out using the World Health Organization (WHO) COVID-19 Research Database(9), which pulls records from across several databases include MEDLINE. The database was searched on the 19th of October 2022.

Eligibility Criteria

Studies published in English between March 2020 and October 2022 were eligible for inclusion. Studies that directly measured the impact of the driver on AMR rates (e.g., the impact of COVID-19 IPAC programs on AMR) or that attempted to show an association by measuring changes in the driver and AMR rates before and during the COVID pandemic (e.g., presenting AMU trends and AMR trends) were included. Non-systematic reviews, case reports, case series, surveys, modelling studies, commentaries, letters, conference abstracts, news reports and qualitative studies were excluded.

Study Selection and Data Extraction

A single reviewer completed both title and abstract screening and full-text screening. Data extraction and charting was completed in Covidence and Excel, respectively, and results summarized descriptively (*Table 2)*.

Health inequities were also considered for each study using the PROGRESS-Plus framework and PROGRESS-Plus factors were extracted for each study (*Appendix 2*). The PROGRESS-Plus framework identifies characteristics that stratify health opportunities and outcomes (10) including place of residence, race/ethnicity/culture/language, occupation, gender/sex, religion, education, socioeconomic status and social capital. "Plus" factors, including those used to refer to personal characteristics associated with discrimination (e.g., age, disability), features of relationships (e.g., smoking parents, excluded from school) and time-dependent relationships (e.g., leaving the hospital, respite care, other instances where a person may be temporarily at a disadvantage) was also recorded. Whether PROGRESS-Plus factors were collected and reported was recorded for each study (*Appendix 2*).

Synthesis

To better understand the influence of the COVID-19 pandemic on AMR, Knight et al (1) developed an analytical framework to describe three dimensions of AMR which may have been, and may continue to be, affected by the COVID-19 pandemic. They categorize these dimensions as: the emergence of new drug-resistant strains (AMR *emergence*), the spread of antimicrobial resistant organisms between hosts (AMR *transmission*), and the number and nature of infections due to antimicrobial resistant organisms (AMR *burden*). GSL classified included studies using this analytic framework (*Figure 1*) according to both the *driver* of AMR measured or reported and the *dimension* of AMR that was considered. *Drivers* are defined in accordance with Knight et al.'s framework as: AMU; community or hospital IPAC measures such as masking, improved hand hygiene, lockdowns, and travel restrictions; and/or changes to health systems use such as reduced numbers of elective procedures.

RESULTS

The impact of COVID-19 on AMR and AMU: National trends

AMR and AMU surveillance data from the high-income countries (HICs) including Canada (11), Japan (12), Norway (13), the United Kingdom (14), Denmark (15), and other countries in the European Union (16) found an initial decrease in AMU in 2020 (*Table 1)*. Early overall decreases in AMU were due to a substantial reduction in community or outpatient antimicrobial prescriptions or consumption. Overall decreases in AMU were seen despite increased in-patient prescribing in the UK (14) and the EU (16).

The United States stands out as one of the few countries that has released 2021 data on community and outpatient AMU (17). In its study on the impact of COVID-19 on AMR, the Center for Disease Control and Prevention (CDC) found an initial decrease in community AMU during 2020 followed by an increase in 2021 to higher than 2019 levels. The report also noted a 15% increase in the rates of resistant healthcare associated infections in 2020 compared to 2019, despite delayed or unavailable data for 9 of their 18 priority pathogens (17). Denmark also found a substantial decrease in AMU during the first wave of the COVID-19 pandemic (March-May 2020), however, AMU slowly increased through the later months of 2020 (15).

Different countries saw increasing, decreasing and mixed trends in AMR rates among their priority pathogens in 2020. The European Antimicrobial Resistance Surveillance Network found an increase in reported invasive isolates for all bacterial species under surveillance except for *Streptococcus pneumoniae* from 2019 to 2020 (16). The United Kingdom observed decreases in all key pathogens causing blood stream infections from 2019 to 2020 (14). Surveillance data pointed to a decreasing incidence of resistant *Klebsiella pneumoniae* in Denmark from 2019 to 2020 (15), *Streptococcus pneumoniae* in the EU (16) and in Japan (12) from 2019 to 2020, methicillin-resistant *staphylococcus aureus* (MRSA) in Norway (13) from 2019 to 2021, and extended spectrum beta-lactamase producing *Escherichia coli* in Australia (18) and Norway (13) both between 2019 and 2021. However, an increase in tuberculosis infections classified as multidrug resistant was reported from 2019 to 2020 in the UK and 2019 to 2021 in Norway.

The impact of COVID-19 driven changes in AMU, IPAC and health system use on AMR emergence, transmission and burden

Seventeen studies were identified that collected data on the impacts of COVID-19-related changes to AMU, IPAC, or health system use on AMR (*Figure 1*). Six studies explored the link between AMU and AMR burden (19–24) and ten studies investigated the link between COVID-19 related changes in IPAC measures and AMR burden (12,25–33). Significantly fewer studies looked at the impact of COVID-19 related changes in relation to AMR transmission and emergence; we identified one study each that looked at changes in IPAC measures as a driver of AMR transmission (34) and emergence (35), and no studies that looked at change in AMU as driver of AMR emergence of transmission. We found no studies that attempted to measure changes in health system use as a driver of AMR emergence, transmission, or burden.

COVID-19 IMPACTS	AMR EMERGENCE	AMR TRANSMISSION	BURDEN OF AMR ILLNESS
ANTIMICROBIAL USE	No Studies	No Studies	Cheng 2022, Jeon 2022, Meschiari 2022, Bork 2020, Chamieh 2021
INFECTION PREVENTION AND CONTROL	Jani 2021	Micozzi 2021	Chen 2021, Bentivegna 2021, Lo 2020, Wee 2021, Gisselo 2022, Guven 2021, Ochoa-Hein 2021, Endo 2022, Tham 2022, Lemenand 2021
HEALTH SYSTEM USE	No Studies	No Studies	No Studies

Figure 1. Included studies classified in accordance with Knight et al.'s framework (2021). Columns reflect AMR dimensions which may be affected by the COVID-19 pandemic (AMR emergence, AMR transmission and AMR burden). Rows reflect COVID-19 drivers of AMR (antimicrobial use (AMU); community or hospital infection prevention and control (IPAC); or changes to health systems use).

AMR burden

The majority of included studies looked at changes in AMR burden during the first 12 months of the pandemic, starting in March 2020. Only two studies (19,25) explore AMR burden in community settings; the majority of remaining studies were single-site hospital-based studies focused on healthcare associated infections.

AMU and AMR burden

We identified six studies that explored the link between AMU and AMR burden (19–24). Most did not directly evaluate the impact of changes in antimicrobial use on AMR, but instead measured changes in trends in both AMU and AMR, before and during COVID. The one community-based study on AMU, carried out in Hong Kong, reported a decrease in antimicrobial sales in 2020-2021 compared with 2012-2019 (19). The decreases in antimicrobial sales coincided with a significant decrease in the incidence of community-onset bacteremia due to *Streptococcus pyogenes*, *Streptococcus pneumoniae*, *Haemophilus influenzae*, and *Neisseria meningitidis* but a significant increase in community-onset bacteremia due to methicillin-sensitive *Staphylococcus aureus* (MSSA), methicillin-resistant *Staphylococcus aureus* (MRSA), and *Escherichia coli* (19).

Hospital-based studies largely found an increase in AMU (20,22,23); however, changes in AMU did not consistently correspond to higher or lower rates of AMR. For example, a study from a South Korean hospital identified an increase in both antibiotic use and incidence of multidrug resistant infections including MRSA, vancomycin-resistant *Enterococcus* (VRE), carbapenem-resistant *Enterobacteriaceae* (CRE), carbapenem-resistant *Acinetobacter baumannii* (CRAB), and carbapenem-resistant *Pseudomonas aeruginosa* (CRPA) from March 2020 to September 2021 when compared to the same period pre-pandemic in 2018 to 2019 (20). A study from Japan also found a weak increase in AMU that corresponded with a decreasing incidence of resistant infections in 2020 compared with 2019 (12). An interrupted time-series analysis from a university hospital in Italy from 2015 to 2021 found a decrease in antibiotic consumption during the COVID-19 pandemic while blood stream infections due to MRSA increased, albeit not significantly (22). A hospital based study from the USA (23) found that although antibiotic use was higher early in the pandemic, the incidence of resistant organisms did not significantly change during the early stages of the pandemic.

IPAC and AMR burden

Ten studies investigated the link between COVID-19 related IPAC measures and AMR burden (12,25–33). Counter to the argument that COVID-19 compromised hospital IPAC programs (4), most reported that improved IPAC measures introduced during the COVID-19 pandemic corresponded with reduced AMR. Studies from hospitals in Italy (26) and Lebanon (24) identified a significant reduction in multidrug resistant bacterial infection incidence attributed to pandemic-related infection prevention and control measures including improved PPE (masking, face shields, or disposable gowns) and improved hand hygiene (hand washing and hand sanitizer use). A similar evaluation in Taiwan examined the impact of universal face masking of hospital staff and enhanced hand hygiene on hospital acquired infection incidence. The study found an overall lower incidence density of multidrug resistant organisms, which was driven specifically by a lower incidence of CRAB and VRE in 2020 compared to 2018 and 2019. MRSA or CRPA incidence also decreased, although no statistically significant difference was seen (27). A study from Singapore that also evaluated the impact of a multimodal IPAC strategy designed for the containment of COVID-19 on hospital acquired infection rates found rates were mostly stable, but that hospital-wide MRSA acquisition rates declined significantly during the pandemic (28). A Danish study investigating the impact of IPAC measures set up to curb COVID-19 spread on VRE *Eneteroccocus faecium* outbreaks reported a 10-fold decrease in outbreak patients (29). Similarly, in Mexico a COVID-19 IPAC program resulted in a significant reduction in multidrug-resistant *Pseudomonas aeruginosa* but no other AMR pathogens (30). Some studies reported no change in AMR due to COVID-19 IPAC measures, including one from a hospital in Turkey (33) and an Australian single-hospital study of surgical patients (31). Additionally, an evaluation of a carbapenemase-producing *Klebsiella pneumoniae* IPAC programme in Italy found an increasing trend in hospital acquired carbapenemase-producing *Klebsiella pneumoniae* during COVID (36), although another Italian study found decreasing carbapenemase-producing *Klebsiella pneumoniae* trends in hospitalized patients (34). Similarly, a study from China examining the effect of the epidemic prevention and control requirements on hospital-acquired infections found MRSA infections were more common in 2020 but identified no significant changes among other infections (25). The increase in AMR reported by these two studies is concordant with the AMR increase reported by the USA (17).

AMR emergence

One study considered the role of COVID-19 IPAC measures in contributing to AMR emergence or the emergence of new drug resistant strains. No studies were identified that looked at the impact of AMU or health system use on AMR.

IPAC and AMR emergence

One study investigated the impact of lockdowns, travel restrictions, and reduced mass bathing events on bacterial-resistance genes in the Indian Godavari River. In India, religious mass bathing events attract millions of pilgrims from India and other countries each year and these events have been linked to increased drug resistant genes among river bacteria. Using pre-pandemic data from 2015 as a baseline, the study found the prevalence of genes associated with drug resistance decreased by 0.64-fold during a COVID lockdown in India (June 2020) suggesting the bacterial communities that were re-established during lockdown have lower prevalence of the gene families associated with drug resistance (35).

AMR transmission

One study considered the role of COVID-19 IPAC measures in reducing AMR transmission (34). No studies were identified that looked at the impact of AMU or health system use on AMR.

IPAC and AMR transmission

Only a single study considered the impact of COVID-19 IPAC measures on AMR transmission. It found significantly reduced horizontal transmission of carbapenemase-producing *Klebsiella pneumoniae* in hospitalized patients because of COVID-19 measures employed (34).

Equity: PROGRESS-Plus Framework

Most included studies did not collect data on PROGRESS-Plus factors. Only five of the 17 studies (25,30–32,34) collected data on at least some PROGRESS-Plus characteristics. One study collected data on place of residence (32), five collected gender/sex (25,30–32,34) and personal characteristics associated with disability (e.g., age) (25,30–32,34), and four collected information on time-dependent relationships (e.g., leaving the hospital or time to discharge, risk factors, or other instances where a person may be temporarily at a disadvantage) (25,30,31,34). No studies directly mentioned equity or social determinants of health.

DISCUSSION

Preliminary national surveillance data from 2020 shows that the impact of COVID-19 on AMR varies across geographic, resource, and healthcare and community settings (*Table 1*). International policy responses to COVID-19 and implementation of community IPAC measures such as lockdowns, physical distancing, travel restrictions, and masking varied widely, and these measures may explain observed differences in community associated resistant infection trends between countries. One national surveillance body hypothesized that a reduction in healthcare provision (reduced social mixing, reduced healthcare seeking, reduction in secondary care referrals and GP testing, and reduced diagnostic capacity) may have contributed to the reduced incidence of resistance for key pathogens (17). However, reduced testing and the overwhelmed diagnostic capacities of laboratory systems as a result of COVID-19 testing may also have affect reported AMR incidences, making reported trends difficult to interpret (37).

Using Knight et al.’s framework to identify preliminary linkages between these two health crises, our findings also suggest that the AMR burden may have been mitigated by IPAC measures during the COVID-19 pandemic. We did not find that antimicrobial use was related to AMR burden in most studies, and we identified substantial differences between AMR trends and AMU in different settings. We also identified several key research gaps, including a lack of evidence on the impact of COVID-19 changes in health system use on AMR burden, emergence, or transmission, and the impact of AMU on emergence or transmission (*Figure 1*).

Differences in observed AMU and AMR trends between regions and countries may reflect 1) differing policy responses to the COVID-19 pandemic across countries, 2) heterogeneity between included studies which differed in methods, analysis, and across settings, and, importantly, 3) that the pandemic has produced both positive and negative effects on AMR. Underlying national rates and trends in AMR prior to COVID-19 may also have affected observed trends. For example, increased antimicrobial use and misuse in COVID-19 patients may have increased AMR rates, while reductions in elective procedures and overall improvements in IPAC measures may have decreased AMR rates.

Studies examining the overall impact of COVID-19 on AMR (without reference to particular drivers) have also found differences across regions and settings. Studies from the USA (38–42), Brazil (43), Italy (26,44) and from a national referral hospital in Indonesia (45) have found increasing bacterial resistance related to COVID-19 while other studies from the USA (46,47), Italy (48), Australia (31) and China (25), have found no change in resistance. Conversely, studies from Japan (49), Singapore (28), Taiwan (27), France (32) and a study from a private laboratory in Indonesia (50) all report decreasing resistance during the pandemic. A pre-print of a meta-analysis also did not find a significant increase in bacterial antibiotic resistance during the COVID-19 pandemic although authors did note a non-significant increase in gram negative bacterial resistance. This increase was significantly associated with an absence of antibiotic stewardship initiatives and IPAC measures (51).

COVID-19 and AMU

AMU was not clearly associated with AMR burden in most studies. National surveillance data reported an overall decrease in AMU during the pandemic—mostly due to reductions in community prescribing (60). However, most studies reported an increase in hospital antibiotic consumption during the pandemic (52). This may be due to the acute nature of patients admitted during the pandemic as well as antibiotic use in COVID-19 patients, both because critically ill COVID-19 patients may develop infections that require antibiotics, but also because of inappropriate antibiotic use in milder cases. In some countries, for example Liberia and Ghana, antibiotics were also recommended for COVID-19 cases with mild or moderate symptoms (53). In future pandemics, rapid antimicrobial stewardship programs and guidelines will be essential to ensure stewardship across healthcare settings and to prevent inequitable AMR repercussions.

Most national surveillance data reported initial decreases in community-prescribing, which is consistent with findings in the literature. Whether these reductions will be sustained remains to be seen, however, signals from the United States (17) and Denmark (15) suggest that other countries may also see a return to normal or above normal levels of prescribing in 2021. However, as of June 2021 other health services in the USA have seen sustained reductions in antibiotic prescriptions, such as pediatric primary care (54). Other challenges faced by hospitals such as reduced staff, longer patient visits, longer use of catheters and ventilators, and reduced IPAC measures during the pandemic may have all contributed to the increase in hospital associated AMR infections in the USA (17).

In hospital settings, excess use of antibiotics in treating COVID-19 patients and changes to antibiotic prescribing methods because of the pandemic, may contribute to the development of AMR. Reviews have found low rates of bacterial and fungal co-infections and secondary infections in hospitalized COVID-19 patients (3.5% and 14.3% of patients, respectively) (55–57). On average, only 24% of these are resistant bacterial infections (52) and 0.3% are resistant fungal infections (52). Despite these low rates of infection, according to a global systematic review about 75% of hospitalized COVID-19 patients admitted between March and October of 2020 received an antibiotic (8). A more recent global meta-analysis found 59% of hospitalized COVID-19 patients in high-income countries (HICs) and 89% in low-middle income countries (LMICs) consumed antibiotics (52). This high degree of AMU may exacerbate AMR. Misuse of antivirals and antibiotics like hydroxychloroquine and azithromycin (58) and the resultant increase in antimicrobial production to account for these uses may also promote AMR development (59).

COVID-19 and IPAC measures

The COVID-19 pandemic saw the unprecedented implementation of infection and prevention control measures (like physical distancing, lockdowns and masking) in both community and healthcare settings. Studies included in this review noted these IPAC measures contributed to reduced AMR incidence. In India, for example, a reduction in AMR genes found in rivers was attributed to COVID-19 restrictive measures like lockdowns in reducing mass bathing events (35). In the community, these measures may have reduced AMR transmission (5), especially for other respiratory pathogens like multidrug resistant tuberculosis (MDR-TB), which is the greatest contributor to global AMR burden (60). There may also be reduced numbers of hospital acquired infections due to fewer patients in secondary care, reduced elective surgical interventions, and because of increased hygiene, PPE, and control measures (61). Resource strains on the healthcare system, may have also negatively affected antimicrobial stewardship and IPAC activities through lack of PPE and staffing shortages (62). While lockdowns, travel restrictions, and mask-wearing may have also reduced transmission of influenzas and other respiratory viruses, limited capacity to provide service delivery and diagnosis for community-acquired diseases like human immunodeficiency virus (HIV), tuberculosis (TB), malaria, and STIs, as well as reduced global vaccination coverage (63) may be driving AMR.

There are likely interactions between the three AMR drivers of interest which have not been evaluated for their impact on AMR, however, which may ultimately reduce AMR. Interpreting this web of interactions will require more contextual evidence on local COVID-19 dynamics and policies. For example, in New Zealand, nonpharmaceutical IPAC like social distancing by restricting gathering sizes and travel and isolation of positive cases and close contacts were associated with a 39.1% decrease in ICU admission rates (64). A study from Spain found personal protection measures against COVID-19 transmission coincided with the greatest reduction in antibiotic prescriptions (65).

COVID-19 and health system use

We identified no studies that considered the impact of COVID-19 driven changes in health system use on AMR, so this should be an area of focus for future investigation. We know, however that changes to health-seeking behaviour and the raised threshold for seeing a general practitioner for symptoms, along with reliance on telemedicine during the COVID-19 pandemic, altered health-system use in many countries (66). In the USA and Canada, hospital and ICU admissions (67,68) and outpatient antibiotic prescriptions (69–71) fell steeply at the start of pandemic and in the

USA, avoidable emergency department visits declined consistently without rebound (72). Dental visits and antibiotic prescribing by primary-care dentists in the USA also showed an immediate significant decrease during 2020, although an increasing trend was seen the following year (73). However, some of these reductions in healthcare visits and prescriptions may not have been beneficial and for example, a study from a referral dental clinic in Iran (74) found lower numbers of dental visits but higher rates of self-medication with antibiotics during 2020.

The shift to telehealth has also affected antimicrobial prescriptions (75). Although a systematic review using data from earlier in the pandemic (2020) found no change in antibiotic prescription rates because of telehealth (75), a more recent global systematic review found telemedicine visits were associated with higher rates of antibiotic prescribing for only some infections (like otitis media and pharyngitis) but not for others (including urinary tract infections or upper respiratory tract infections) (76). Additional investigations into how prescribing rates have changed because of the move to remote consultations and the potential impacts on AMR are needed (77).

Equity impacts of COVID-19

Few of the studies included in this review collected data on social determinants of health, as defined by the PROGRESS-Plus framework (10). The COVID-19 pandemic has compounded existing equity challenges, such as limited or reduced access to vaccinations, reduced access to laboratory materials, and reduced staff availability which may be driving inequitable AMR transmission (5,7). Around the globe, COVID-19 has disproportionally affected low income (78), racial, ethnic (79), gender (80) and minority groups (81) as well as migrant populations. The COVID-19 pandemic has also inequitably impacted the ability of countries to develop and maintain strategies to address and mitigate AMR (64). In Italy for example, 50% of hospital centres reported a reduction or suspension of existing and pre-pandemic antimicrobial stewardship programs (82). This impact was particularly felt by in low- and middle-income countries: high-income countries, overwhelmed by COVID-19, reduced their capacity to support AMR partnerships and reduced funding to programs in low- and middle- income countries (7).

Limitations

This was a rapid scoping review with screening conducted by a single reviewer which increases the risk that relevant studies may be missed. Most studies included in this review were also observational single-site studies. Risk of bias assessment will be completed at a later stage of this project; however, many studies are likely to be assessed as at a high risk of bias.

No studies examined health-system use as a driver of any of the AMR dimensions (emergence, transmission, or burden) or of AMU as a driver of AMR emergence or transmission were identified, representing a significant evidence gap. As well, only a few studies considered IPAC measures as a driver of AMR emergence and transmission. Most studies focused on hospital settings in high-income countries, so studies from community settings and low-income countries are needed to fill these knowledge gaps. Finally given the paucity of studies identified that collecting data on social determinants of health (as defined by the PROGRESS-Plus framework) in this review, a focus of future studies should be on collecting data to identify potential inequitable effects of AMR drivers.

Studies to date have focused on data from 2020, during the early stages of the COVID-19 pandemic. Data from later stages of the pandemic are likely to find differences based on changes in AMU, IPAC practices, and health system access as governments relaxed the restrictions and public health measures that were imposed in 2020.

Finally, reduced laboratory capacity and a decrease in the total number of tested patients during the pandemic (due to reduced referrals and testing) may be underestimating reported AMR trends for most included papers. The USA, EU, UK and Norway all reported a decrease in numbers of culture and sensitivity tests performed during the COVID-19 pandemic compared to previous years as a potential confounder to their reported AMR trends. This reduction in cultures is likely due to a reduced number of elective procedures or chronically ill patients being admitted, the higher threshold of infection needed during COVID-19 for patients to seek medical care and reduced number of referrals provided by general practitioners (83). Similarly in many countries, laboratory capacity was overwhelmed by COVID-19 testing resulting in reduced reagents and consumable availability and staff availability to perform cultures (7,84).

POLICY CONSIDERATIONS AND IMPLICATIONS

This review synthesized current evidence on the impacts of COVID-19 on AMR with a focus on identifying trends due to pandemic-driven changes in AMU, IPAC measures, and health-system use. Policy implications were identified in three key areas.

First, the paucity of studies underscores the need to improve AMR surveillance systems. Improved AMR surveillance systems and capacity to collect data will ensure robust AMR data collection during future pandemics, allowing AMR trends to be identified quickly. The rapid identification of AMR trends will support the development of antimicrobial stewardship programs and guidelines to ensure antimicrobial stewardship is maintained across healthcare settings and to prevent AMR repercussions or negative AMR outcomes during future pandemics.

Second, because so few of the identified studies collected data on social determinants of health alongside AMR data there is a need to identify and address the potential inequitable effects of AMR drivers. Identifying populations with inequitable COVID-19 and AMR effects will allow the development of targeted policy initiatives and stewardship programs during the COVID-19 pandemic and during future pandemics as well.

Third, the findings highlights the need to address gaps in the evidence around AMR impacts of the COVID-19 pandemic. Few studies investigate the impact of COVID-19 driven changes in AMU and IPAC measures and no studies looked at the impact of health system use changes on AMR. This represents a significant evidence gap that must be addressed by future research.

Noting the societal, political, and economic infrastructure required to effectively respond to AMR, AMR mitigation and prevention measures should be examined in context. AMR trends during the COVID-19 pandemic varied across countries. While further comparative analysis of national AMR trends is needed, so too is targeted research to understand the context-specific conditions that produce these trends. Additionally, given that some countries saw increased AMU in response to the pandemic, further research on linkages to increased AMR would be useful. The particularity of the COVID-19 pandemic appears to suggest that countermeasures presented increase hospital AMU but decreased community AMU. Further studies from community settings that examine the broader implications of this dynamic are needed, as is additional research on AMR impacts in other sectors (e.g., environmental).

Finally, methodological and analytical heterogeneity across studies presented challenges to establishing a rigorous comparative assessment. The scientific community researching pandemics and the effects of the COVID-19 pandemic on other pandemics and healthcare systems should develop standardized methods for reporting AMR trends (using existing methodological and analytic expertise) that account for potential biases like the reduced reporting and testing seen during COVID-19.

CONCLUSIONS

The COVID-19 pandemic has changed the landscape of AMR in ways we still do not fully grasp. We know that COVID-19 impacted AMU, IPAC measures, and health system use differently across countries use in many ways, impacting AMR emergence, transmission, and burden. This scoping review synthesized current literature and national AMR surveillance data results. These results show substantial variation in the reported impact of COVID-19 on AMR, which seems expected given the variation in response to COVID-19 that was seen across countries and settings. Most results from the period of the COVID-19 pandemic are still preliminary and as additional data becomes available longer-term impacts and trends in AMR may also be identified. We identified three key areas where results may have policy implications - improving AMR surveillance, identifying and addressing the potential inequitable effects of AMR and addressing gaps in the global evidence base. Additional research, however, especially high-quality studies, is needed to fully elucidate the impact of COVID-19 driven changes in AMU, IPAC and health-system on AMR to ensure evidence-informed AMR policy solutions.

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REPORT TABLES

Table 1. Overview of national surveillance data on antimicrobial use trends, trends in key pathogen-antimicrobial combinations and the potential contributors to these reported trends during the COVID-19 pandemic

Country, publication year	Data collection interval	Antimicrobial use (AMU) trends	Antimicrobial resistance (AMR) trends in key pathogen-antimicrobial combinations	Potential contributors to reported trends	Name of report
Canada, 2021	2015 to October 2020	AMU decreased by 5% overall. The rate of antimicrobial prescribing decreased by 40%, with a 28% decrease in seniors and the largest decrease in paediatric population (70%). Community use of carbapenems increased by 68%.	2020 data not available yet.	Antimicrobial prescribing in the community during the first 8 months of COVID-19 pandemic was lower than previous years due to pandemic-driven changes in health system use.	Canadian antimicrobial resistance surveillance system report: Protecting and empowering Canadians to improve their health
United States, 2022	2019 to June 14, 2021	A significant increase in AMU was noted during the first year of the pandemic. Antibiotic use in the community dropped significantly in 2020 but rebounded in 2021 to be 3% higher than pre-COVID-19 levels. Antibiotic use in nursing homes spiked during the pandemic but was 5% lower than 2019 in 2021, which may be due to fewer nursing home residents.	A 15% overall increase was noted key hospital-acquired pathogen-antimicrobial combinations including: carbapenem-resistant *Acinetobacter*, extended-spectrum beta-lactamase- producing Enterobacterales, and vancomycin-resistant *Enterococcus*. Antifungal-resistant *Candida spp.* increased by 26%. There is a lack of data available on community-spread pathogens (eg. drug-resistant gonorrhea).	Reduced ability to follow IPAC measures as a result of COIVD-19 pandemic may have contributed to the increase in antimicrobial-resistant hospital infections. More and sicker patients during the pandemic may have also contributed. Long-term care facilities were significantly affected by COVID-19 outbreaks, burdens and staffing shortages. Health-seeking behaviour and access to outpatient clinics was limited.	CDC. COVID-19: U.S. Impact on Antimicrobial Resistance, Special Report 2022. Atlanta, GA: U.S. Department of Health and Human Services, CDC; 2022.

UK, 2020 to 2021	2016 to 2020 (BSI), 2018 to 2020 (LRTIs)	Overall, AMU decreased in hospital settings, although the rate of usage per admission in hospitals increased in April 2020 due to an influx of COVID-19 infected patients. Compared to 2019, in 2020, in-patient antibiotic consumption increased by 10.6%, while outpatient antibiotic consumption decreased by 5.2%.	BSI decreased for all key pathogens between 2019 and 2020, particularly for *S. pneumoniae* and *E. coli*. Although a reduction in the number of MDR tuberculosis cases was seen increasing percentage of MDR was reported.	The decrease in BSI was likely due to COVID-19 associate reduction in person-to-person contact and improvements in IPAC (such as PPE, hand washing and use of hand sanitizer), decreased community transmission (social distancing) and reduced international travel. Reduced healthcare provision (reduced social mixing, reduced healthcare seeking, reduction in secondary care referrals and GP testing or even reduced diagnostic capacity) may have also contributed. The increase in in-patient antibiotic prescription is likely due more acutely ill patients being admitted while elective procedures were cancelled.	English surveillance programme for antimicrobial utilisation and resistance (ESPAUR)
Denmark, 2020	2018 - 2020	A 7% decrease in antimicrobial consumption was observed from 2019 to 2020, driven by reduction in primary health care consumption. There was a sharp drop in respiratory prescriptions (12% lower in 2020 compared to 2019), most marked in children between 0 and 9 years of age (up to a 54% reduction). Following a significant decrease during the first wave of the pandemic, an increasing trend in primary care prescriptions was seen between the first and second waves, although total antimicrobial consumption in primary care remained lower in	Between 2019 and 2020 the number of ESBL isolates, resistant isolates of *Klebsiella pneumoniae* decreased. The number of vancomycin-resistant enterococci stayed stable, and the number of MRSA outbreaks was higher.	Consultation numbers in primary health care were 7% higher in 2020 compared to 2019 and shifted to remote consultations. Antimicrobial use per patient admitted to hospital was markedly higher during the pandemic compared to the same periods in 2018 and 2019.	Summary DANMAP 2020: Use of antimicrobial agents and occurrence of antimicrobial resistance in bacteria from food animals, food and humans in Denmark

		2020 than 2018 and 2019.			
Australia, 2022	2015 to March 2022 (AMR data), November 2015 to October 2020 (AMU data)	One study found in primary care in Australia there was a 36% reduction in antibiotic dispensing from April 2020.	Overall, a mild decrease in ESBL *E. coli* from all settings was reported between 2020 and 2021 (lowest among paediatric patients and highest in persons aged over 64 years). During COVID-19 to 2021 there was an increase in ESBLs in aged care home residents.	The COVID-19 pandemic may have affected the reporting and analysis of results of AMR data through changes in access to community-based health care, hospital admission patterns and the range of hospital services offered such as outpatient clinics and elective surgery, antimicrobial prescribing practices, and movement of people into and within Australia.	Australian Passive Antimicrobial Resistance Surveillance: Third-generation cephalosporin resistance in Escherichia coli and Klebsiella pneumoniae: prevalence of extended-spectrum β-lactamase (ESBL) phenotype Gillies MB, Burgner DP, Ivancic L, Nassar N, Miller JE, Sullivan SG, Todd IMF, Pearson SA, Schaffer AL, Zoega H. Changes in antibiotic prescribing following COVID-19 restrictions: Lessons for post-pandemic antibiotic stewardship. Br J Clin Pharmacol. 2022 Mar;88(3):1143-1151.
Korea, 2021	March 2018 to September 2021 (AMU data), August 2016 and July 2020 (AMR data)	Overall, a 14-30% reduction in antibiotic use adjusting for respiratory tract infections was reported, with the largest reduction seen in pediatric populations.	National surveillance data is not yet available. A study looking at incidence of multidrug resistant infections from 2018 to 2021 in 4 hospitals found that during the COVID-19 pandemic the prevalence of hospital associated infections increased (including MRSA, VRE, CRE, and CRPA).	The reduction in antibiotic use may be due to reduced respiratory infections as a result of stringent public health interventions including social distancing measures. Changes in health-seeking behavior during the outbreak in South Korea may have reduced the propensity of individuals to seek care for symptoms consistent with upper respiratory symptoms that were not COVID-19.	Sukhyun Ryu, Youngsik Hwang, Sheikh Taslim Ali, Dong-Sook Kim, Eili Y Klein, Eric H Y Lau, Benjamin J Cowling, Decreased Use of Broad-Spectrum Antibiotics During the Coronavirus Disease 2019 Epidemic in South Korea, *The Journal of Infectious Diseases*, Volume 224, Issue 6, 15 September 2021, Pages 949–955. Jeon, K.; Jeong, S.; Lee, N.; Park, M.-J.; Song, W.; Kim, H.-S.; Kim, H.S.; Kim, J.-S. Impact of COVID-19 on Antimicrobial Consumption and Spread of Multidrug-Resistance in Bacterial Infections. Antibiotics 2022, 11, 535.

EU, 2020	2011 to 2020	Between 2014-2020, a 23% decrease in the total consumption of antibiotics was observed for the EU/EEA, with most of this decrease happening between 2019 and 2020. Most EU countries reported decreases in antibiotic consumption for both the community and the hospital sector, with a larger decrease in community sector. However if the total number of hospitalised patients decreased the apparent decrease in hospital antibiotic consumption expressed in 'DDD per 1 000 inhabitants per day' could actually become an increase, if expressed in 'DDD per 100 beddays'. Interpret changes with caution.	For all bacterial species under surveillance by the European Antimicrobial Resistance Surveillance Network (EARS-Net), except for *Streptococcus pneumoniae*, the number of reported bacterial invasive isolates increased in 2020 compared to 2019 (Including *Acinetobacter spp*. and *Enterococcus faecium)*. For *S. pneumoniae,* the number of reported invasive isolates decreased by 44%, with large decreases of 20% or more being reported in all but one EU/EEA country. Reduced testing and reduced laboratory capacity may affect AMR percentages and make the observed changes in AMR percentages difficult to interpret.	Interventions to curb the COVID-19 pandemic affected antibiotic consumption including infectious disease epidemiology (decreases in groups of antibiotics prescribed for respiratory infections and to the youngest age groups); non-pharmaceutical interventions (restrictions on movement, physical distancing, respiratory etiquette, hand hygiene and travel restrictions), reduced use of and difficulties in accessing primary care services, leading to a decrease in inappropriate prescribing for milder and self-limiting infection. COVID-19 also put pressures on hospitals (demand for intensive care beds, fewer elective surgery or chronic diseases admittances).	Antimicrobial Resistance in the EU/EEA: A One Health Response
Norway, 2021	2013 to 2020	In 2021, the total sales of antibacterial agents for use in humans decreased. Since 2012 there has been a decline in total antibiotic use of 33%.	There was a mild reduction in 2021 and 2020 in MRSA infections. Extended spectrum beta-lactamases (ESBL) prevalence including pf E. coli and Klebsiella spp has decreased. The number of patients with carbapenemase-producing P. aeruginosa remained unchanged whereas Acinetobacter spp. notifications decreased. The proportion of MDR tuberculosis isolates increased in 2021.	Reduction in antibiotics may be due to reduced use of antibiotics indicated for respiratory tract infections in primary care. IPAC measures may have decreased the incidence of infections, and the threshold for seeing a general practitioner for symptoms of infections may have been raised. Travel restrictions may have also critically reduced the number of travel-associated infections.	NORM/NORM-VET 2021. Usage of Antimicrobial Agents and Occurrence of Antimicrobial Resistance in Norway. Tromsø / Oslo 2022. ISSN:1502-2307 (print) / 1890-9965 (electronic).

Japan, 2022	2019 to 2020	Reported a reduction in antimicrobial sales in 2020 compared with preceding years (20% reduction).	Incidence of *Streptococcus pneumoniae* dramatically decreased from April 2020 onward, probably due to stringent non-pharmaceutical interventions against COVID-19. The incidence of healthcare associate *S. aureus* and *E. coli* did not show a change after the start of the COVID-19 pandemic.	Decrease in the incidence of microbial infections in 2020 compared with 2019 may have been driven primarily by a reduction in bed occupancy.	Endo A, Asai Y, Tajima T, Endo M, Akiyama T, Matsunaga N, Ishioka H, Tsuzuki S, Ohmagari N. Temporal trends in microbial detection during the COVID-19 pandemic: analysis of the Japan Surveillance for Infection Prevention and Healthcare Epidemiology (J-SIPHE) database. Journal of Infection and Chemotherapy. 2022 Sep 14.

Table 2. Characteristics of studies included in analysis of the impact of COVID-19 on AMR.

Author, Year	Country or region	Type of study	Brief description of study itself	Setting	Pathogen type(s) reported, measure of AMR reported and change to AMR *	Reference
Cheng 2022	Hong Kong	Retrospective observational	Data of blood cultures of patients admitted to public hospitals collected by the Hospital Authority in Hong Kong for the last 10 years, were analyzed.	Community and hospital	Mean episodes of community-onset bacteremia due to MRSA per year was higher during two pandemic years (2020, 2021) then pre-pandemic years (2012-2019) (1154 vs. 1288, $p = 0.001$).	(19)
Chen 2021	China	Retrospective observational	Examined the effect of the COVID-19 prevention and control requirements (implemented May 2020) on HAI and CAI in China during 2018, 2019, and 2020.	Hospital and community	Analysis of HAI by MDROs indicated MRSA infections were more common in 2020 than in 2018 and 2019 (both $P < 0.05$), but there were no significant changes in infections by VRE, CRE, CRAB, or CRPA.	(25)
Jani 2021	India	Retrospective observational	Examined the impact of lockdowns and travel restrictions on changes in antibiotic-resistant strains of bacteria the Godavari River in India.	Community	Functional profiling found a reduction in infection and drug resistance genes by−0.71-fold and−0.64-fold, respectively.	(35)
Bentivegna 2021	Italy	Retrospective case–control	Examined the incidence of MDRO infections while using pandemic-related preventive measures (from 2017 to 2020) in St. Andrea Hospital, Rome.	Hospital	A significant reduction in the incidence of total MDRO infections was observed during the pandemic compared to in pre-pandemic years ($p < 0.05$). Significantly higher incidence of MDR bacterial infections in COVID-19 departments compared with other medical departments.	(26)
Chamieh 2021	Lebanon	Retrospective observational	Analyzed the trends of the overall isolates, the antimicrobial susceptibilities of blood isolates (BSI), BSI, carbapenem-resistant *Enterobacteriaceae* (CRE) BSI, and restricted antimicrobial consumption as daily-defined-	Hospital	The isolation density of carbapenem-resistant *Enterobacteriaceae* (CRE) BSI/1000 patient-days decreased by 64% from 2019 to 2020, while VRE- *Enterococcus faecium* BSI decreased by 34%. There was a significant decrease of 80% in antibiotic isolates (p-value < 0.0001).	(24)

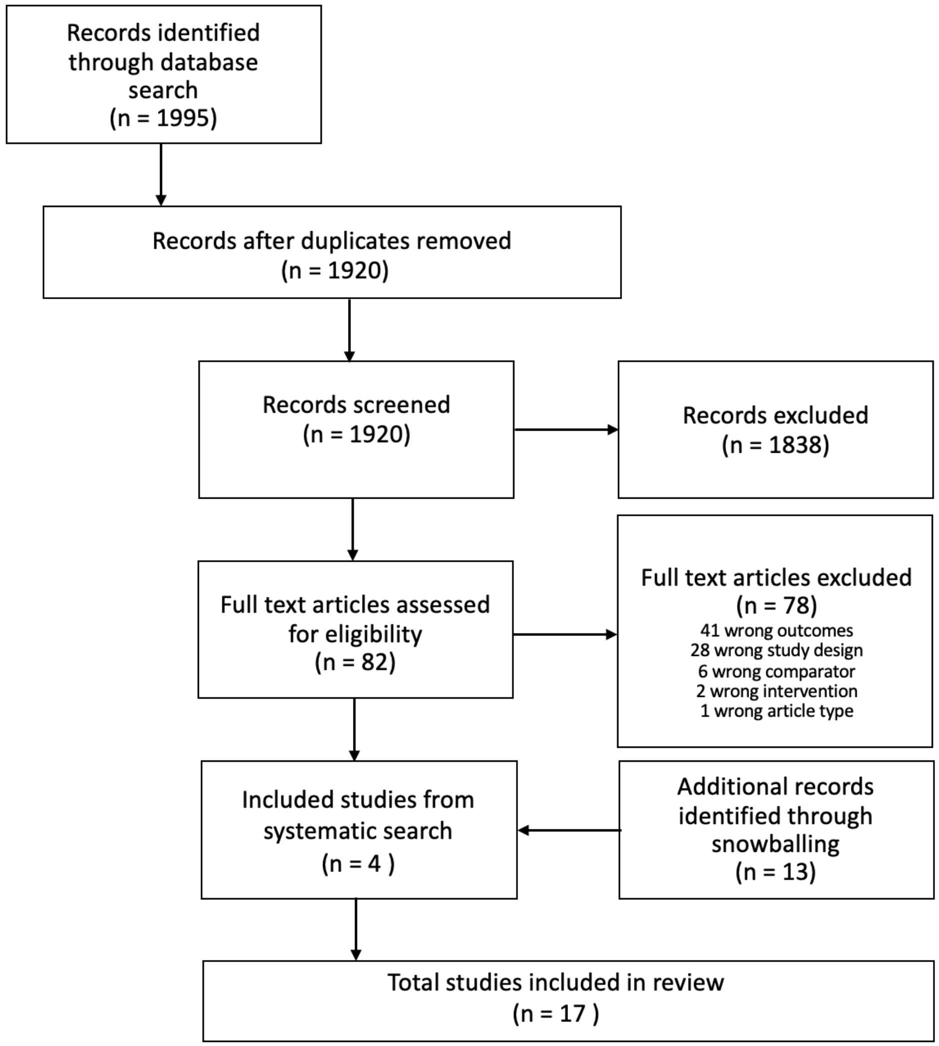
			dose/1000 patient-days from 1 January 2015-31 December 2020.			
Gisselo 2022	Denmark	Prospective observational	Outbreak data set were collected prospectively from April 2, 2014 to August 13, 2020 on VRE *Enterococcus faecium* at Copenhagen University Hospital Bispebjerg, Denmark.	Hospital	When comparing the first 5 months of the COVID-19 pandemic with the corresponding period in 2019, there was a 10-fold decrease in VRE *Enterococcus faecium* outbreak patients and median outbreak duration decreased from 56 to 7 days (88%).	(29)
Guven 2021	Turkey	Retrospective observational	Evaluated the nosocomial infection rates over the first 3 months of the COVID-19 compared to the same time frame of the previous year.	Hospital (oncology ward)	The rate of nosocomial infections caused by multidrug-resistant bacteria was similar between periods ($p = 0.677$).	(33)
Jeon 2022	South Korea	Retrospective observational	Examined the prevalence of MDR bacteria during the COVID-19 pandemic (March 2020 to September 2021) compared to in the pre-pandemic period (March 2018 to September 2019) in four university hospitals.	Hospital (ICU and wards)	The prevalence of MRSA (4.7%), VRE (49.0%), CRE (22.4%), and CRPA (20.1%) isolated in clinical samples from the ward and VRE (26.7%) and CRE (36.4%) isolated from the ICU were significantly increased. Only CRE (38.7%) in surveillance samples increased in the wards.	(20)
Lemenand 2021	France	Interrupted time series	Compared ESBL-*E.coli* rates of patients in primary care and nursing home residents before and after the general lockdown in March 2020.	Community	In primary care, 3.1% of E. coli isolates from clinical samples were producing ESBL before March 2020 and 2.9% since May 2020 ($p < 0.001$). In nursing home, the ESBL-E.coli rate was 9.3% before March 2020 and 8.3% since May 2020 ($p < 0.001$).	(32)
Lo 2020	Taiwan	Retrospective observational	Investigated the impact of IPAC measures on the incidence rates of HAI and MDRO in a Taiwan medical center.	Hospital	Incidence density of MDRO was significantly lower in 2020. CRAB and VRE were significantly lower in 2020 than in 2018 and 2019 ($p = 0.011$, $p = 0.005$ respectively), and MRSA or CRPA incidence slightly decreased with no statistically significant difference.	(27)
Micozzi 2021	Italy	Retrospective observational	Evaluated the potential effects of IPAC measures against COVID-19 on KPC-KP transmission in Italy.	Hospital	During March–August 2020, 15.5% of hospitalized patients were KPC-KP positive, compared with 52.5% in November 2019–February 2020 ($P < 0.0001$).	(34)

Ochoa-Hein 2021	Mexico	Retrospective observational	Hospital-associated infection rates were compared before (January 2019-February 2020) and after (April-July 2020) the COVID-19 hospital surge capacity response.	Hospital	MRSA, CPE, ESBL producers, AmpC producers and Carbapenem-resistant *Enterobacteriaceae* showed no significant changes while multidrug-resistant *P. aeruginosa* showed a significant reduction (p=0.004) between these two periods.	(30)
Tham 2022	Australia	Retrospective cohort	Determined the effect of the COVID-19 pandemic-related escalation in IPAC measures on the incidence of hospital acquired infection in surgical patients in a low COVID-19 environment in Australia.	Hospital (surgical)	There were no major changes in the types of microorganisms involved in HAI across the two study periods. Counts of MDRO including MRSA and ESBL *Escherichia coli* were similar across both time periods.	(31)
Wee 2021	Singapore	Retrospective observational	Evaluated the impact of a multimodal IPAC COVID-19 strategy on the rates of HAI from February-August 2020 across a large health care campus in Singapore.	Hospital	No increase in CP-CRE acquisition, and rates of other HAIs were stable. Hospital-wide MRSA acquisition rates declined significantly during the pandemic (incidence-rate-ratio = 0.54, 95% CI = 0.46-0.64, *P*< .05).	(28)
Meschiari 2022	Italy	Interrupted time series	Evaluate the impact of COVID-19 on AMR in the University Hospital of Modena from January 2015 to October 2021.	hospital	Significant increase only in the level of BSIs due to carbapenem-susceptible *Pseudomonas aeruginosa* (*p* = 0.032). MRSA had a non-significant increase in resistance	(22)
Bork 2020	United States	Interrupted time series	Examined multidrug-resistant gram-negative acquisition relative to COVID-19 at an academic hospital.	Hospital	Multidrug-resistant gram-negative incidence did not differ significantly during the 2020 post-onset period compared to the same period in 2019.	(23)
Endo 2021	Japan	Retrospective observational	Assessed the temporal changes in AMR-related metrics before and after the start of the COVID-19 pandemic.	Hospital	Decrease in the incidence of microbial infections in 2020 compared with 2019, driven by a reduction in bed occupancy with incidence showing a constant or even slightly increasing trend after adjusting for bed occupancy. Incidence of *Streptococcus pneumoniae* decreased from April 2020 onward. Antimicrobial use showed a weak increasing trend. Hand sanitizer use increased by about 50%.	(12)

Healthcare-associated infections (HAI), community-acquired infections (CAIs) central-line–associated bloodstream infections (CLABSIs), catheter-associated urinary tract infections (CAUTIs), bloodstream infections (BSI), Vancomycin-resistant Enterococcus (VRE), methicillin-resistant Staphylococcus aureus (MRSA), carbapenemase-producing Klebsiella pneumoniae (KPC-KP), extended-spectrum beta-lactamase (ESBL) , carbapenem-resistant Enterobacteriaceae (CRE), carbapenem-resistant Acinetobacter baumannii (CRAB), carbapenem-resistant Pseudomonas aeruginosa (CRPA), fluconazole-resistant Candidasis parapsilosis (FRCP)

APPENDIX

Appendix 1. Study selection process for review



Appendix 2. PROGRESS-Plus factors for each study

Study author, year	PROGRESS								PLUS		
	Place of residence	Race, ethnicity, culture, or language	Occupation	Gender/sex	Religion	Education	Socioeconomic status	Social capital	Personal characteristics associated with discrimination (e.g. age, disability)	Features of relationships (e.g. smoking parents, excluded from school)	Time-dependent relationships (e.g. leaving the hospital, respite care, other instances where a person may be temporarily at a disadvantage)
Cheng 2022	no	no	no	no	no	no	no	no	no	no	no
Chen 2021	no	no	no	yes	no	no	no	no	yes	no	yes
Jani 2021	no	no	no	no	no	no	no	no	no	no	no
Bentivegna 2021	no	no	no	no	no	no	no	no	no	no	no
Chamieh 2021	no	no	no	no	no	no	no	no	no	no	no
Gisselo 2022	no	no	no	no	no	no	no	no	no	no	no
Guven 2021	no	no	no	no	no	no	no	no	no	no	no
Jeon 2022	no	no	no	no	no	no	no	no	no	no	no
Lemenand 2021	yes	no	no	yes	no	no	no	no	yes	no	no
Lo 2020	no	no	no	no	no	no	no	no	no	no	no
Micozzi 2021	no	no	no	yes	no	no	no	no	yes	no	yes
Ochoa-Hein 2021	no	no	no	yes	no	no	no	no	yes	no	yes
Tham 2022	no	no	no	yes	no	no	no	no	yes	no	yes
Wee 2021	no	no	no	no	no	no	no	no	no	no	no
Meschiari 2022	no	no	no	no	no	no	no	no	no	no	no
Bork 2020	no	no	no	no	no	no	no	no	no	no	no
Endo 2021	no	no	no	no	no	no	no	no	no	no	no

ABOUT THE GLOBAL STRATEGY LAB

The Global Strategy Lab uses an intensely interdisciplinary approach to undertake innovative research to advise governments and public health organizations on how to design laws, policies and institutions that address transnational health threats and make the world a healthier place for everyone.

Based at York University and University of Ottawa, GSL's research division focuses on three streams: antimicrobial resistance, global legal epidemiology and public health institutions. GSL's policy division provides specialized evidence-based advisory services to governments and civil society organizations.

There are three unifying features underpinning our research and policy action:

1. **Interdisciplinarity**. We are intensely interdisciplinary and equity-minded in leveraging research for better policies and a healthier world.
2. **Research methodology**. We are globally oriented in our methods, as we develop new analytic, empirical, and big data tools to drive our research.
3. **Knowledge translation**. We translate research into evidence-informed action by developing global strategies and training the next generation of leaders in global governance, law and politics.

The AMR Policy Accelerator

The AMR Policy Accelerator advises the world's governments, public health institutions and decision-makers on effective and equitable policies to ensure sustainable antimicrobial use for everyone. We undertake rigorous research, develop practical resources and tailor custom advisory services to comprehensively support equitable, evidence-informed policymaking on antimicrobial resistance at the national and global level. The AMR Policy Accelerator is a Wellcome-funded initiative hosted at Global Strategy Lab.

The AMR Policy Accelerator has three programs of work:

1. **Advisory Services** are designed to enhance real-time decision-making and rapidly respond to urgent AMR policy needs. We provide clients with timely, authoritative research and advice based on international best practices to achieve effective AMR policies and National Action Plan implementation. Our solutions are scaled to our clients' timelines, needs and resources from 3- to 90-day windows.
2. **Policy Research** uses our in-house expertise and leverages a global network of experts to critically examine AMR policy issues using a One Health approach. We incorporate scientific and policy engagement activities in our proposal process and disseminate the resulting research, policy findings and knowledge products to support informed AMR decision-making.
3. **Capacity Building** supports policy learning and research around the world. We host policy internships, fellowships, knowledge mobilization workshops and short courses aimed at strengthening AMR capacity among policymakers and emerging leaders, especially from low- and middle-income countries (LMICs).

Project Team

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