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Combating Antimicrobial Resistance During the COVID-19 Pandemic: Perceived Risks and Protective Practices

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KEY POINTS

- The COVID-19 pandemic significantly disrupted efforts to combat antimicrobial resistance (AMR), undoing much of the progress achieved in recent years.
- Existing literature and expert opinion point to several interrelated factors that contributed to these disruptions, including patient- and facility-level issues (e.g., extended hospital stays, shifts in patient case-mix and comorbidities), healthcare workforce challenges (e.g., burnout from emotional, psychological, and physical strain), infection prevention and control (IPC) adherence challenges, and antimicrobial stewardship program (ASP) implementation issues, particularly in the early stages of the pandemic.
- To combat AMR during public health emergencies, experts advocated for timely access to AMR data, guidance, and diagnostics, through effective communication channels and relationships to support effective policies and treatment decisions.
- Lessons learned from the COVID-19 pandemic can help support the preparedness and proactive planning needed to ensure ongoing, effective antimicrobial stewardship during future public health emergencies.

INTRODUCTION

Antimicrobial resistance (AMR) is one of the greatest public health threats and leading causes of death globally [1]. Resistance to antimicrobial drugs develops when bacteria, viruses, fungi, or parasites evolve and no longer respond to treatments, and as a result the drugs become ineffective at treating infections. This is exacerbated by the overuse and misuse of antimicrobials, and can lead to increased spread of disease, more severe illness, and an increased risk of death [2]. Significant progress has been made in the United States in combating AMR through the development of collaborative national action plans, such as the U.S. National Action Plans for Combating Antibiotic-Resistant Bacteria (CARB) and the implementation of robust antimicrobial stewardship and infection prevention and control (IPC) programs [3]. In the United States, these efforts led to a 27 percent decrease in antimicrobial-resistant infections from 2012 to 2017 [4].

However, the COVID-19 pandemic (January 31, 2020 – May 11, 2023) resulted in large-scale disruption of efforts to combat AMR. Antimicrobial-resistant hospital-acquired infections (HAIs) increased 15 percent

between 2019 and 2020, largely negating recent progress. Changes in drug-resistant infection rates varied by pathogen, increasing up to 78 percent for some pathogens between 2019 and 2020 compared to the pre-pandemic period. Similarly, rates of resistant fungal infections increased by up to 60 percent [5, 6]. These increases in resistant infections paralleled increases in HAIs in general, and standardized infection ratios—a metric of hospital infection burden—indicate that HAIs occurred at greater rates than pre-existing facility- and patient-level risk factors would have predicted. Ultimately, antimicrobial-resistant infections, 40 percent of which were hospital-acquired, resulted in more than 29,000 deaths during the first year of the pandemic in the United States, an increase of at least 15 percent compared to pre-pandemic levels [5, 6]. Recent data from the U.S. Centers for Disease Control and Prevention (CDC) released in July 2024 also show continued elevation of bacterial antimicrobial-resistant HAIs through 2022 [7]. Of the seven pathogens described all but one rose by up to 20 percent during the COVID-19 pandemic period compared to pre-pandemic levels, peaking in 2021 and remaining above pre-pandemic levels in 2022. Additionally, cases of a resistant fungi, *C. auris*, surged nearly five-fold from 2019 to 2022 [7]. Several additional studies also reported a rise in antibiotic use and increase in resistance rates during the COVID-19 pandemic [8, 9].

Reducing AMR to pre-pandemic rates and continuing reductions into the future will require an understanding of what factors drove the increases in AMR observed during the pandemic. The current study focuses on factors relevant to healthcare facilities, given the proportion of resistant infections that are acquired while receiving healthcare. In healthcare facilities, the infection prevention and control (IPC) staff are responsible for developing and implementing infection control policies, monitoring infection rates, educating healthcare workers, investigating outbreaks, and promoting compliance with infection prevention measures to avoid or reduce disease transmission. Antimicrobial stewardship program (ASP) staff are responsible for optimizing the use of antimicrobials by promoting appropriate prescribing practices, monitoring antimicrobial resistance patterns, educating healthcare providers, and implementing strategies to reduce unnecessary antimicrobial use. Together, IPC and ASP staff share surveillance data, promote appropriate infection prevention measures, and implement strategies to ensure the effective use of antimicrobials while preventing the emergence and transmission of resistant organisms.

STUDY OBJECTIVES

The primary objective of this study is to better understand the range of factors that impacted efforts to fight AMR in hospital settings during the COVID-19 pandemic, by synthesizing published scholarly sources with insights from healthcare professionals involved in antimicrobial stewardship. The study also aims to characterize key lessons learned by these professionals that can be applied not only during future public health emergencies but also more broadly towards the continued fight against AMR. It is important to note that none of the literature cited here, nor the original data collected, attempts to establish a causal relationship between any specific changes in the efforts to fight AMR and changes in rates of AMR. Such an investigation would be difficult, if not impossible, given the complexity of AMR and healthcare practice. However, IPC and ASP are widely accepted as effective strategies to mitigate AMR, and we believe that understanding changes in these practices during the pandemic will be valuable and informative even in the absence of rigorous causal interpretations.

DATA SOURCES AND METHODS

The research team applied a mixed methods research strategy that used multiple sources of information to gain a comprehensive understanding of the range of factors that impacted efforts to fight AMR during the COVID-19 pandemic in the United States. We conducted a conceptual literature review of published studies in peer-reviewed as well as grey literature and semi-structured interviews with hospital and health system infectious disease (ID) physicians and pharmacists. Finally, we convened a virtual meeting with federal and non-federal stakeholders to gather participant perspectives on current and emerging research findings and lessons learned.

Conceptual Literature Review

Our conceptual literature review encompassed peer-reviewed studies as well as grey literature published since 2020 and aimed to categorize and describe the primary contributing factors that impacted efforts to fight AMR during the COVID-19 pandemic, as well as the potential relationships among those factors. The research team used keywords and terms including "AMR," "antimicrobial resistance," "COVID-19," "pandemic," "infection prevention and control," "IPC," "antimicrobial stewardship," "ASP," "healthcare workforce," "infectious diseases workforce," "infectious disease pharmacist," and "antimicrobial usage" to search PubMed and Google Scholar databases for relevant literature. The team also used a citation chaining approach to find additional literature from those referenced in initial search findings.

Key Informant Interviews of ID Physicians and Pharmacists with ASP Responsibilities

As described below, the literature review revealed a dearth of literature on ASP implementation among U.S. healthcare providers, relative to several studies focused on other countries. Therefore, our key informant (KI) interviews focused on the lived experiences of ASP staff with the management of AMR before, during, and after the COVID-19 pandemic. We conducted semi-structured interviews with nine infectious disease (ID) physicians and nine pharmacists with ASP responsibilities to better understand how resource availability and utilization (e.g., staffing, financial support), communication, and facility leadership influenced ASP implementation.[1] To identify candidates for the interviews, we collaborated with the CDC, the Society for Healthcare Epidemiology of America (SHEA), the Infectious Diseases Society of America (IDSA), and the Society of Infectious Diseases Pharmacists (SIDP). We contacted a total of 33 potential KIs (ID physicians and pharmacists combined). Thirteen out of the 33 contacted did not respond to our request and two (rural ID physicians) declined participation because they felt they were not qualified to respond to our questions. We recognize that ID physicians and pharmacists represent a sub-set of the healthcare professionals involved in IPC and ASP implementation; in particular, nurses play a key role in IPC at many facilities [10]. Exploring the experiences of other healthcare professionals, including nurses and environmental services staff, would be a valuable future step toward developing a comprehensive strategy to support the fight against AMR during public health emergencies.

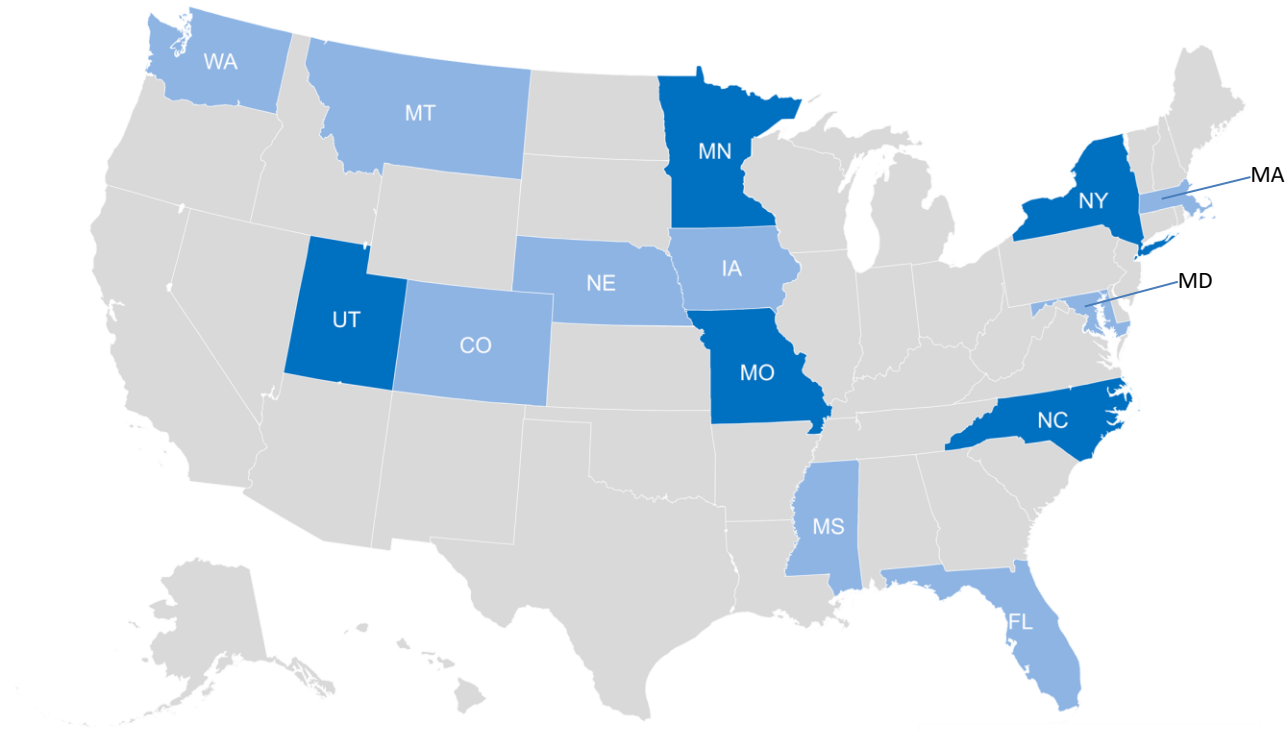
Our KI interview guide is provided in Appendix A. All interviews were conducted via Microsoft Teams in May and June 2024. Table 1 shows the KIs' localities and facility types, and Figure 1 shows the geographic distribution within the United States. KIs represented both hospitals and health systems of varying sizes in both urban and rural areas. Interviews were transcribed and the research team qualitatively analyzed the transcripts to identify key themes (see Appendix B for additional detail).

Table 1. Key Informant Sample Characteristics

Facility Type	Role	Rural	Urban	Total
Health System	Physician	0	3	3
	Pharmacist	3	3	6
Hospital	Physician	3	3	6
	Pharmacist	0	3	3
Grand Total		6	12	18

[1] Given the number of interviews in each group, this collection was exempt from the Paperwork Reduction Act (PRA). The collection was also exempt from Institutional Review Board (IRB) oversight under the Common Rule; an official exemption from 45 CFR 46.104(d)(4(ii)) was obtained from Salus IRB, an independent non-profit IRB, on April 15, 2024.

Figure 1. Geographic Distribution of Key Informants



Note: Darker shades of blue indicate that more than one KI represented that state in our sample

Stakeholder Meeting

We held a virtual stakeholder meeting in July 2024 to review evidence about efforts to fight AMR during the COVID-19 pandemic and to obtain expert perspectives on forward-looking strategies to improve the fight against AMR in the future. The meeting brought together 34 participants, including federal researchers from the Department of Health and Human Services (HHS) Office of the Assistant Secretary for Planning and Evaluation (ASPE), CDC, National Institutes of Health (NIH), Food and Drug Administration (FDA), Agency for Healthcare Research and Quality (AHRQ), and the Centers for Medicare & Medicaid Services (CMS), as well as experts representing or suggested by IDSA, APIC, SHEA, and SIDP (Appendix C).

The meeting began by reviewing current research on rising AMR rates and their drivers during the COVID-19 pandemic, with researchers from CDC, NIH, and ERG presenting novel evidence about patient- and hospital-level factors related to increased AMR, ASP implementation changes, and potential strategies to mitigate these impacts in the future. Participants then discussed their reflections on these findings and summaries of the KI interviews relative to their own experiences, and what lessons could be applied to help return the fight against AMR to its pre-COVID state and help to plan for future public health emergencies.

FINDINGS

Gaining the ground lost in the fight against AMR during the COVID-19 pandemic requires a deeper understanding of the factors that hampered efforts to combat AMR and the interrelationships among them, and learning from, operationalizing, and implementing successful approaches developed during the pandemic. We discuss and provide the evidence base for the factors that contributed to AMR during the COVID-19 pandemic and the lessons learned for combating AMR now and during the next public health emergency in the following sections.

Factors that Contributed to AMR During the COVID-19 Pandemic

According to published literature, key informants, and stakeholders,[2] factors that contributed to challenges with combating AMR during the COVID-19 pandemic include the following inter-related categories:

- *Patient- and facility-level factors*, such as lengthy hospital stays, changes in case-mix and patient comorbidities, increased need for mechanical ventilation (a risk factor for healthcare-associated resistant infections), and increased case load;
- *Healthcare workforce factors*, such as burnout resulting from the emotional, psychological, and physical stress caused by the pandemic, resource constraints, increased workloads and deviations from typical responsibilities, and challenges associated with remote work and communication;
- *IPC adherence factors* including an overburdened workforce, variations in stewardship practices due to unique regional circumstances, uncertainty around best practices, and limited supplies of personal protective equipment (PPE) and other essential equipment; and
- *ASP implementation factors,* including lack of timely and clear national guidelines, and fear of under-treatment that contributed to more patients being prescribed antibiotics for longer durations, especially early on during the pandemic.

Patient- and Facility-level Factors

Between May 2020 and April 2021, an estimated 3.6 million COVID-19-related hospitalizations occurred in the United States, occupying up to 90 percent of all available inpatient beds in some hospitals [11, 12]. Moreover, the number of ICU beds increased by 8,772 (10.4 percent) from 2019 to 2020 [13]. On average, COVID-19 patients were hospitalized for over 14 days, and many underwent mechanical ventilation, a treatment associated with increased risk of antimicrobial-resistant HAIs [12, 14, 15, 16]. Overall, the combination of a large population of sicker patients, longer hospital stays, and increased usage of mechanical ventilation and similar intensive treatments may have played a role in rising AMR rates in the United States. However, AMR rates varied significantly across geographic regions, facilities, and individual wards during the pandemic, and these factors may not have played a role in all instances [12, 17].

> *Overall, resistance probably went up due to the novelty of the disease, increased antibiotic use without positive cultures, and a general fear of taking patients off antibiotics.*
>
> **Pharmacist KI 6**

Analyses indicate that rates of some AR infections and COVID-19 case burden both increased over the same time periods at many, though not all, hospitals [18, 19]. Infections from multi-drug resistant organisms (MDROs) were five times more likely to occur in COVID-19 wards compared to the non-COVID-19 wards, with incidence rates of 1.99 and 0.35, respectively [19]. Additionally, inpatients with COVID-19 had a higher risk of acquiring a resistant bacterial co-infection than inpatients without COVID-19, likely because COVID-19 infections generally resulted in longer hospital stays [20]. Unfortunately, even after COVID-19 patient surges had largely subsided, preliminary CDC analyses have indicated that AMR rates for several pathogen and infection-types continued to increase in 2021 [21, 22, 23], and remained elevated in 2022 above 2019 levels [7].

> *We have a very robust stewardship program especially downtown with resources that some academic medical centers lack, like advanced tech tools.*
>
> **Physician KI 4**

> *Our stewardship practices were more advanced than those in general rural hospitals.*
>
> **Pharmacist KI 2**

Unique facility-level factors may have also played a role [24, 25]. While antimicrobial susceptibility test (AST) data can be used to generate facility-level antibiograms that inform patient care [26], KIs from smaller hospital

[2] Statements by key informants and stakeholder meeting participants are cited with [25] and [26], respectively.

systems more frequently reported lacking the capacity to gather and analyze data to support guidance development at their facilities compared to larger ones. The ability to conduct regular surveillance for AR pathogens was also more likely to be challenging in smaller hospitals that lacked strong connections to other systems and/or resources [24].

Healthcare Workforce Factors: Burnout

In addition to the influx of severely ill patients, the COVID-19 pandemic dramatically disrupted the healthcare workforce and negatively impacted the emotional, mental, and physical health of healthcare workers. In a 2020 survey (fielded May 28 through October 1, 2020) of almost 21,000 U.S. healthcare workers, 61 percent of respondents reported fear of COVID-19 exposure or transmission to themselves or their families. Anxiety and depression, work overload, and burnout were reported by 38 percent, 43 percent, and 49 percent of respondents, respectively. Nursing assistants, medical assistants, and social workers, experiencing the highest levels of stress, and inpatient workers experienced more stress than their outpatient counterparts. Women (versus men), and Black and Hispanic/Latino workers (versus Whites) also reported higher stress and burnout [27]. In the first year of the pandemic (2019 to 2020-Q2), an estimated 5.2 percent U.S. healthcare staff, totaling about 1.1 million, left their jobs, though this loss largely, but not entirely, rebounded to pre-pandemic levels by the first quarter of 2021 [28]. Many healthcare professionals in senior leadership and specialized roles left their positions due to the stress and demands of the pandemic, either opting for early retirement or switching to another industry [24]. This not only created shortage of staff, but also the shortage of expertise and trust that is vital for facilities to function during a pandemic [24]. Rebmann and colleagues conducted an informative series of focus groups both early and later during the COVID-19 pandemic, to characterize the day-to-day experiences of infection preventionists from APIC [29, 30, 31]. Early in the pandemic, focus group members noted major pandemic-related IPC challenges including rapidly changing and/or conflicting guidance, a lack of infection prevention recommendations for non-acute care settings, insufficient PPE, healthcare personnel complacency with PPE and other IPC protocols, and increased workload burden [29].

We were all working more than normal, often in different roles, which made it hard to say 'no' to escalating or stopping antibiotics. There was a lot of fear, and we gave everything we could to try to save patients.
Physician KI 5

There was an underlying fear of not doing enough for these patients. Despite our best efforts, patients kept dying which perpetuated the use of antibiotics just in case they had resistant pathogens.
Pharmacist KI 4

The literature and our KIs noted that this burnout may have contributed to disruption of IPCs and ASPs. KIs noted a significant decrease in morale and de-prioritization of several activities including ASP, as exhausted staff focused on immediate patient care and their own well-being [24]. Nori and colleagues described how infection-related support staff, including hospital epidemiologists, infection preventionists, and antimicrobial stewards faced organizational challenges including a further diminishing workforce, slow adoption and implementation of IPC policies, and an unrelenting workload both during and after COVID-19 patient surges. [32]. In some cases, facilities operated severely understaffed, making it impossible to sustain all responsibilities, particularly those related to ASP [24]. These staffing challenges were not limited to ASPs but also affected broader healthcare operations, including IT support and laboratory services, further complicating efforts to manage AMR [24]. Even after the initial pandemic surges, workforce shortages persisted [24], continuing to limit what could be accomplished.

Healthcare Workforce Factors: Responsibilities

The roles of ASP personnel also expanded significantly, often extending well beyond their pre-pandemic responsibilities. Many ASP physicians and pharmacists were heavily involved in their institutions' COVID-19 response, taking on critical tasks such as leading testing, treatment, and vaccination efforts for entire communities [24]. As one physician KI described, "The medical leadership of this institution really was charged with managing the COVID response for the entire community. We became the public health department, so [we] took on testing and treatment and vaccines and kind of all of it" [24]. This shift sometimes meant focusing on administrative roles, such as leading incident command centers and managing COVID-related therapeutics including remdesivir and monoclonal antibodies [24]. Some facilities that saw an increase in their patient loads needed ASP physicians to increase the amount of direct patient care they provided, keeping them away from their ASP responsibilities [24]. Physicians and pharmacists alike were involved in developing guidelines, managing inventory shortages, and ensuring compliance with frequently updated regulations [24].

Professionally, staff faced rapid and confusing reprioritization of responsibilities that were often time consuming and undervalued by leadership and other colleagues. Societal tensions, often caused by confusing or conflicting guidance for community and healthcare settings, and waning public tolerance to IPC compliance, also played a role in healthcare workforce burnout. Lastly, healthcare workers were forced to face personal moral dilemmas when deciding how limited supplies were to be rationed among patients and when implementing organizational policies with little or incomplete data to guide them [32]. While some of these challenges pre-dated the pandemic, the pandemic exacerbated them. For example, many ASP personnel noted that distributing Remdesivir was a very ethically challenging task due to the shortage of the drug [24].

In addition to their finding of infection preventionist challenges early in the pandemic, the Rebmann et al. focus groups also noted that many rural infection preventionists faced additional challenges compared to their suburban and urban counterparts [29, 30, 31]. For example, rural participants identified inaccurate social media messages and generalized disbelief and disregard about the pandemic among rural community members as major challenges [30]. Later in the pandemic, focus group members emphasized the challenge of transitioning back to routine IPC while still responding to COVID-19, and supported by an overworked and dwindling workforce. During the Delta variant waves, IPC support staff duties rapidly expanded across practice settings, to include developing and communicating public and organizational policies and acting in emergency medicine and occupational health capacities. Recruitment, training, and retention of infection preventionists also became a challenge, with those still in their healthcare role experiencing overwhelming workplace stress, extensive burnout, and increasing presenteeism organization-wide [31].

Multiple KIs mentioned the challenge of translating clinical knowledge to practical, on-the-ground application without the ability to provide on-the-job training to new staff, which led to confusion and inefficiencies in integrating them into established workflows [24]. Many new hires were freshly graduated trainees, and although eager and equipped with current knowledge, they sometimes reverted to practices from their training programs rather than adapting to the specific protocols of their new environments [24]. Additionally, onboarding remotely, through Zoom interviews and virtual training, limited the ability to foster strong relationships and integrate new employees effectively [24]. Some reported that the lack of in-person interactions and face-to-face training made it challenging to build trust and camaraderie [24].

> *You don't have time to train somebody when you're drinking from a fire hose yourself, right? You're trying to bring new people on and get them up and going, but the demands of the day to day are incredibly demanding and make that challenging.*
>
> **Pharmacist KI 2**

> *We haven't received many applications from established professionals who are willing to relocate. Most of the movement we're seeing is still from trainees.*
>
> **Pharmacist KI 1**

Infection Prevention and Control Adherence

Like ASPs, IPC policies play a critical role in reducing AMR burden because preventing infections means fewer resistant infections and less need for antimicrobial use. Fortunately, implementation, adaptation, and adherence of established and novel IPC policies became important in inhibiting the spread of both COVID-19 and antimicrobial-resistant infections during the COVID-19 pandemic. Pre-existing AMR-related federal programs also aided in slowing the spread of COVID-19 by providing healthcare facilities with IPC expertise, outbreak prevention, and support for surveillance and data collection to track both antimicrobial-resistant and COVID-19 infections in hospitals and long-term care facilities.

We didn't know what COVID meant or whether people had coinfections, so everyone got antibiotics and supportive care. Fear drove us to give everything we could to try to save lives.
Physician KI 5

I remember tracking the rate of bacterial infections in COVID patients and telling providers we didn't need to give all these antibiotics. The secondary infection rate was low, but the focus on COVID led to overuse.
Pharmacist KI 2

Estimates from simulations suggest that implementation of COVID-19 IPC policies corresponded to 28 percent fewer predicted AMR infections overall and mitigated the effect of COVID-19 surges [33]. However, overwhelmed staff capacity during COVID-19 patient surges throughout the pandemic may have caused lapses of adequate IPC protocols [18]. In two noteworthy AMR outbreaks, state health departments found systematic breakdowns in IPC protocols, such as nonadherence to PPE guidelines and lapses in environmental cleaning and hand hygiene, likely contributing to the outbreaks [34, 35].

According to stakeholders, IPC adherence challenges during the pandemic were typically not due to a lack of training, but instead related to an overburdened workforce, or a limited supply of PPE and other essential equipment. The sheer patient volume sometimes resulted in the utilization of healthcare workers from other units or contract nurses, who may not have all the information needed to adhere to IPC [25]. Patient-facing staff such as physicians and registered nurses were more likely to report at least one PPE error, compared to staff at lower risk of contracting COVID-19 in the workplace [36]. While these results rely primarily on truthful self-reporting, they highlight the need for targeted staff engagement to reduce errors in IPC adherence.

Due to PPE shortages, we had to implement measures to help with PPE conservation, which sometimes led to lapses in standard infection prevention practices.
Pharmacist KI 8

We had shortages of PPE so there was less gowning and gloving happening than we might have liked.
Pharmacist KI 2

Antibiotic Stewardship Program Implementation Factors: Program Continuity

Adequate support for ASPs and those healthcare workers who implement them has long been central in the fight against AMR, because these programs improve appropriate antimicrobial prescribing and patient outcomes. The percent of U.S. hospitals with an ASP aligned with the CDC's Core Elements of Hospital Antibiotic Stewardship has steadily increased across the past 10 years, reaching 97 percent in 2022 [37, 38, 39]. Importantly, established ASPs were also valuable in controlling COVID-19 infections [40]. However, formal adoption of ASPs did not prevent increased use of antibiotics, which are ineffective treatments for COVID-19 and other viral pathogens. Antimicrobial prescriptions and total days of therapy rose dramatically during the first two years of the pandemic [41, 19], with an estimated 80 percent of COVID-19 hospitalized patients received an antibiotic between March and October 2020 [6, 42]. KIs echoed existing accounts that attributed this increase to the limited scientific understanding of appropriate COVID treatment, higher disease acuity, and prophylactic prescribing to prevent secondary infections, such as bacterial pneumonia [42, 6, 40].

While direct evidence from prior literature about ASP implementation in the United States is limited, evidence from other countries suggests significant challenges. British and Canadian ASP staff reported being asked to develop treatment guidelines and clinical pathways, anticipate and manage drug shortages, provide oversight for obtaining investigational use drugs, and cover other duties due to staff vacancies and illness, leading to decreased frequency of prescriber education, prescription auditing, and staff feedback [43, 44, 45]. Italian infectious disease units reported a 50 percent reduction of ASPs, with 40 percent reporting suspension of stewardship programs altogether [46]. While many healthcare facilities faced similar challenges worldwide, low- and middle-income countries had a particularly difficult time in continued ASP implementation [47].

We had a 100% suspension of ASP activities. Everything switched to COVID. The medical leadership of the institution was charged with managing the COVID response for the entire community.

Physician KI 1

In the United States, several published studies and our KIs reported changes to ASPs throughout the pandemic [48, 49, 50, 51]. KIs indicated that the formal adoption of an ASP did not guarantee that these programs were well-supported or effectively implemented [24]. Variability in pandemic preparedness across different facilities exacerbated these challenges, with some hospitals struggling to maintain their ASP activities while others were able to adapt [24]. Early in the pandemic, some healthcare facilities were forced to completely stop their ASP activities because of the overwhelming need to reallocate resources, particularly staffing, to manage the surge of COVID-19 patients. Although leadership in some of these facilities may have recognized the importance of ASPs, the focus on managing the acute crisis sometimes meant that ASP activities could not be sustained. Notably, KIs from facilities with both established and newer ASPs reported full stoppage of ASP implementation [24]. In other facilities, ASP activities were scaled back rather than completely stopped, maintaining some core functions while suspending or reducing others [52, 24]. In cases where all or some ASP activities were maintained, KIs reported that facility leadership recognized the importance of maintaining essential activities including case-by-case antibiotic reviews, multidisciplinary huddles, and rapid blood culture identification [24]. KIs who reported maintenance of ASP activities typically had well-established programs prior to the pandemic, and also often reported having adequate staffing levels, effective resource management, and leadership support.

Antimicrobial stewardship took a big hit when personnel were taken off-site. We were no longer part of the care team, which reduced the patience and time care teams had for us.

Pharmacist KI 1

We didn't stop doing all of the baseline practices at the bedside, but we stopped collecting and reviewing data and ceased our multidisciplinary huddles and pharmacy reviews.

Physician KI 1

We started doing handshake stewardship in 2021 to rebuild our credibility and let people see that the stewardship team is human and shares the same goals.

Pharmacist KI 1

Antibiotic Stewardship Program Implementation Factors: Responsibilities

In prior literature and our KIs, ASP staff reported increased pandemic-related duties, such as developing COVID-19 treatment guidelines and conducting COVID-19 education programming for staff allowing less time dedicated to ASP activities. Moreover, several studies found that ASP staff also experienced an increase in the ASP-related workload during the pandemic, including long lists of patients for whom post-prescription review was needed during patient surges [49]. In one study that directly asked ASP leaders about burnout, about 60 percent reported feeling emotionally drained at least a few times per week [51]. Additionally, ASP staff indicated that resource limitations, including limitations in lab capacity, sample collection tools (e.g., swabs), IT capacity, and facility finances, negatively impacted ASP activities. As was true for IPC, new ASP staff were often unfamiliar with specific facility

practices, which may have contributed to decreased adherence to ASP guidelines [52]. One strategy employed to overcome these barriers in various facilities was the re-structuring and staggering of ASP duties [24].

The impact of limited in-person contact on ASP activities emerged as a theme across studies and in our KIs. Several studies note that tele-stewardship activities began during this time [51, 52]. Our KIs also reported that facilities transitioned to virtual communication platforms such as Zoom and Teams, which disrupted established practices by complicating efforts to ensure consistent messaging and maintain team collaboration [24]. Before the pandemic, some facilities had leveraged strong relationships established in person to support the subsequent use of virtual communication platforms, but even these facilities struggled to establish new relationships entirely online during COVID-19 [24]. Overall, our KIs reported that online stewardship communication was not as effective or robust as it needed to be, especially during a crisis. However, in some cases, the necessity of moving online actually led to more frequent meetings, allowing for greater engagement with both the ASP team and across departments. Some KIs reported that they were able to interact with more people and build new relationships due to the online nature of their meetings, including with other regional facilities and partners [24].

Lessons Learned for Combating AMR in the Future

The challenges of the COVID-19 pandemic put intense stress on infection preventionists, ASP staff, and other healthcare providers working to combat AMR. Our KIs and stakeholder discussion participants also described many lessons learned from this experience, identifying strategies to return AMR rates in the United States to pre-pandemic rates and attempt to prepare for and mitigate AMR during future public health emergencies. The key learnings further discussed in the following sections included:

- Importance of timely access to AMR-related data, guidance, and diagnostics,
- Critical role of robust communication channels and relationships,
- Signficance of leadership, resources, and support for healthcare workers for strengthening ASPs and their impact,
- Lasting impact of the COVID-19 pandemic on healthcare delivery, and
- Value of preparedness and proactive planning for continuity of ASP activities along with patient care.

Effective Policies and Treatment Decisions Require Timely Access to AMR-related Data, Guidance, and Diagnostics

Healthcare workers and policymakers need comprehensive, timely and actionable data, especially during public health emergencies [25]. Some of the data sources mentioned during the stakeholder meeting include CDC's Antimicrobial Resistance Laboratory Network (ARLN) and National Healthcare Safety Network (NHSN) [25]. However, stakeholders noted a need for more detailed facility-level data on staffing, including the number of IPC staff at each facility, than what is currently available through NHSN annual surveys. Different stakeholders need different data; for example, physicians need data to understand trends across regions and types of facilities, whereas public health departments need data to customize and communicate local policies effectively across healthcare settings [25]. The current study was motivated by the lack of actionable data to inform federal policies that would aim to drive AMR rates back down to pre-pandemic rates. Stakeholders noted the need to institute data-sharing agreements that allow for timely access, and suggested requiring reporting at the state level, developing and implementing automated surveillance methods, and improving the frequency of communication with state-level public health department. Stakeholders also noted that receiving timely guidance allowed their facilities to better align their practices and control unnecessary antibiotic use. However, national guidance was cited as often lacking in specificity for local and rural settings, so more tailored, localized guidance would be beneficial [25]. Other recent work has highlighted the role of non-federal Communities of Practice, which provided a venue for public health agencies to share guidance and tools to support implementation of best practices that emerged during the pandemic [53]. Stakeholders in the current

study also advocated for implementing diagnostic stewardship early in a public health emergency to reduce unnecessary antibiotic use downstream and mitigate the development of resistance [25].

Effective Communication Channels and Strong Relationships are Critical for Combating AMR During Pandemics

Effective communication facilitates the coordination of response efforts across various levels, including within and between facilities, and among local, state, and federal governments. Given the interactions between IPC and ASP efforts and the ongoing flow of patient care at hospitals, stakeholders highlighted the need for new communication channels and formats that are clear and accessible. Automation, daily emails, and dashboards were suggested to improve information flow among healthcare workers, administrators, and policymakers. Virtual town halls were also suggested to foster open discussion and can effectively supplement one-way information dissemination. Stakeholders noted that human-centered design research focused on how information gets shared in organizations can offer insights on how to optimize information dissemination [25].

In addition to clear and accessible communication channels, strong relationships among healthcare workers were essential for effective communication during the pandemic. Pre-existing relationships were crucial in building trust in guidance from ASP staff and ensuring the continued implementation of ASPs as many organizations transitioned to online or hybrid models [24]. Additionally, leveraging community relationships, such as those with pharmacists, proved valuable in alleviating some of the workload burden on healthcare facilities [25].

Leadership, Resources, and Support for Healthcare Workers can Solidify and Strengthen ASPs and their Positive Impact

KIs and stakeholders consistently cited the importance of leadership recognition and valuing ASPs, including ensuring that they are adequately resourced. Strong ASP leadership and relationships with key staff, such as the ICU and frontline providers, helped to maintain personal connections and facilitate effective implementation of stewardship practices even under the stress of the pandemic. KIs and stakeholders noted that institutions with robust pre-pandemic ASPs typically benefited from well-developed relationships between ASP and non-ASP staff, resilient systems capable of operating with minimal disruption, and strong leadership support. During the pandemic, ASPs efforts to address challenges, such as supply shortages and the distribution of available medications, enhanced the visibility of ASPs to hospital leadership and heightened awareness of the specialized expertise of ASP staff. Their active participation in high-stakes decision-making and consistent communication regarding COVID-19 protocols also elevated their prominence within their institutions. Despite the challenges, the pandemic provided an opportunity for these physicians and pharmacists to play a pivotal role in navigating the crisis [24].

I really wanted to be involved... we saw a lot of leadership opportunities. We were excited about it. You know, we wanted to be the go-to people if we could.

Physician KI 7

I think we've established more "cred," so to speak, not only with frontline providers, but also [with] hospital leadership and executives.

Physician KI 8

Having them on the team, showing them the data, and providing extensive education helped change practices. By 2021 the frontline providers started trusting the process more and the practice improved significantly.

Physician KI 2

However, KIs and stakeholders also emphasized ASPs are often underfunded and not sufficiently prioritized within the budgets of hospitals and healthcare systems. The pandemic revealed disparities in resource allocation for ASPs, with some KIs noting that their programs received additional support during the pandemic while others did not. This was particularly evident when comparing leadership endorsement between health systems and stand-alone hospitals, with health systems generally receiving stronger leadership support. This higher level of

endorsement often facilitated the process of requesting and securing necessary resources. Furthermore, KIs from health systems were more likely to report adequate resources from the outset, including staff, PPE, and antibiotics than those from standalone hospitals [24]. KIs and stakeholders suggested that establishing strategic reserves and distribution networks could help to manage supply chain disruptions during emergencies. Additionally, stakeholders suggested that funding should be allocated to local health departments to support ASP initiatives in facilities beyond hospitals, such as nursing homes and other long-term care settings [25].

Our brand comes with a certain amount of buying power…so if you were working at, you know, a local medical center, you might have seen a very different thing. But we are resourced with an army of individuals whose sole job is to find the things we need and to figure out how to navigate these shortages.

Pharmacist KI 1

That's the benefit of a health system, right? Like you don't have to be alone, that the work can be divided. I can't even imagine what it be like to be at a single institution without the support of a team.

Pharmacist KI 7

Innovations in antimicrobial stewardship, such as handshake stewardship, the use of real-time data tools, and the implementation of antibiotic timeout alerts enhanced the efforts of ASPs and their credibility with frontline providers. One relatively novel strategy described by KIs and stakeholders to manage staff and resource shortages was electronic systems that automate critical functions such as monitoring antibiotic usage, tracking resistance patterns, and managing infection prevention workflows [24]. Electronic medical record (EMR) platforms, such as TheraDoc and Centricity, were used to provide real-time surveillance and alert staff to potential issues like inappropriate antibiotic use or emerging resistance trends [24]. These systems automated data analysis, allowing physicians and pharmacists to focus on more complex tasks and improve efficiency. Additionally, facilities utilized data dashboards integrated into platforms like Tableau to aggregate and visualize key AR metrics in real-time. KIs and stakeholders also described increased interest in potential uses for artificial intelligence (AI) and machine learning (ML) to help automate certain ASP practices [24, 25].

We secured a contract with TheraDoc to help with our infection prevention efforts. This made my ID pharmacist's job less manual, thanks to the algorithm work and the EMR changes.

Physician KI 3

We don't have a dedicated dashboard, but we do have one for the stewardship side. It allows us to look at trends in our antimicrobial use, and we submit our antimicrobial resistance data to NHSN. We also publish our antibiogram every year, making it available to all clinicians in the hospital.

Physician KI 5

Long-term, evidence-based interventions to support the health and well-being of frontline healthcare workers could include sharing resources widely, ensuring fair staffing levels and pay, prioritizing mental health, combating stigma, and involving frontline workers in policy decisions are crucial. Additionally, innovative technologies and research funding should be used to enhance training, preparedness, and resilience in the healthcare workforce [54]. In addition, providing psychological and emotional support to healthcare workers could include providing counseling services and stress management programs, clear communication of treatment guidelines, and developing and implementing mental health support programs as part of the healthcare facility's emergency preparedness plans. Better preparation for and reaction to emergency situations, as described by our KIs and stakeholders here, may help mitigate healthcare worker burnout [24, 25].

COVID-19 Pandemic May Have Altered Ongoing Healthcare Delivery Given Changes in the Patient Populations Served in Hospitals, Clinics, and Health Systems

During the pandemic, healthcare systems had to rapidly adapt to meet the needs of a sicker patient population that required more intensive and prolonged care. Published literature and stakeholder meeting participants observed that, even in the post-pandemic period, patients remain sicker than before the pandemic, [55, 56, 57]. KIs also shared that COVID-19 has led to a sustained increase in the patient load and complexity of cases, and that the patient population overall has changed with sicker patients presenting post-pandemic. Persistently higher rates of AMR after the pandemic may be related to this shift in the complexity of cases that healthcare systems now need to manage regularly. KIs also noted perceived increases in certain infections relative to immediately before or during the pandemic. Higher levels of antimicrobial use after the pandemic may reflect these changes in patient characteristics, as well as changes in how healthcare services are being utilized. However, further evidence is needed to characterize these changes and understand their implications for healthcare practice, including the fight against AMR.

Over the last 18 months as everything got back to normal and people resumed normal life, our anti-pseudomonal utilization has significantly increased. We have a pretty sick population, possibly because they didn't seek care during the pandemic, and now we're dealing with the repercussions.

Physician KI 9

Declining AMR rates prior to the pandemic provide evidence for the effectiveness of ASPs [25]. However, meeting participants noted that inconsistent application of these practices during the pandemic adversely affected the efforts to fight AMR [25]. While much ASP activity been reinstated in the post-pandemic era, evidence of persistent changes in relevant patient populations could prompt a need to revisit and adapt those practices [25]. Stakeholders noted that pre-pandemic IPC strategies were already plateauing with respect to their effectiveness in containing and controlling AMR, and that there should be a call for new practices and efforts to reduce colonization [25]. Applying the same practices to all pathogens can lead to negative outcomes, highlighting the need for diagnostic stewardship in the continued fight against AMR [25].

What we're really struggling with post-pandemic is seeing a tremendous amount of Group A strep infections. It's not really resistance, but a resurgence that we didn't see before or during the pandemic.

Physician KI 9

This year I noticed our quinolone resistance rates went up. Organisms showed increased resistance against quinolones, but overall, it hasn't been too bad.

Pharmacist KI 9

Preparedness and Proactive Planning can Facilitate Stewardship and Care Continuity

Preparedness for public health emergencies should include planning for AMR management [24]. In addition to maintaining adequate inventories of necessary resources, this preparation could include pre-establishing protocols and integrating stewardship practices into emergency response plans to ensure they continue even when resources are stretched [24]. Core antimicrobial stewardship activities that should be maintained during a public health emergency include prospective audits, feedback, and de-escalation practices. Innovative approaches to stewardship, such as handshake stewardship and the use of real-time data tools and dashboards, should be established during non-emergency periods so that then facilities can maintain effective stewardship practices during emergencies [25]. Relevant training for stewardship teams can help them to use flexible approaches and be adaptable in their operations, including the use of new technologies and workflows that can be quickly implemented when needed [24, 25]. Similarly, continuity of patient care is crucial during a public health emergency to avoid disruptions in treatment and the potential exacerbation of AMR. Proactive collaboration across multiple disciplines, including care teams, infectious disease specialists, pharmacists, epidemiologists, and IT professionals, can help to ensure that all aspects of patient care and AMR management are under control [25].

DISCUSSION

Reflecting on the experiences and outcomes of the pandemic is valuable for adapting and improving future healthcare practices. Facilities and policymakers should assess what worked, what didn't, and how they can better prepare for future challenges. The lessons presented here emphasize the importance of such reflection in combating AMR and improving healthcare delivery during and after public health emergencies.

If you really want to invest in pandemic preparedness, invest in stewardship. You can't build these capabilities during a pandemic; they need to be established beforehand.

Physician KI 7

Post-pandemic I feel like things have settled down. We've gotten things under control again with healthcare-associated infections, especially drug-resistant ones.

Physician KI 8

Clear, actionable data, particularly for smaller facilities lacking internal analytical capacity, can guide policy development and enhance response efforts. In addition to quantitative data, qualitative data such as that presented here can offer valuable insights into the real-world experiences of healthcare workers, shedding light on the human and relational effects of a pandemic. Establishing clear, evidence-based guidelines early in a public health emergency enables the appropriate use of antibiotics and other treatments, which helps prevent the overuse of antibiotics and mitigates the rise in AMR. Collaboration with and coordination among national and international health organizations can assist in the development and distribution of effective guidelines as quickly as possible. Further, while there are many ways in which better flow of information can benefit healthcare during public health emergencies, these strategies may help to address the challenges described above related to training and onboarding new IPC and ASP staff. Greater uptake of these tools could also help minimize any negative impact of virtual work on ASP implementation. Future research should investigate the impact of resource distribution on ASPs, to help inform regulatory and accreditation standards that define the essential components of an ASP, including the personnel and IT resources required to operate an effective program [25]. Leadership decisions to adequately resource ASP implementation should be complemented with support for the emotional and mental health needs of the healthcare workforce.

Our study raises questions about whether and how the hospital patient population has changed in the post-COVID-19 era, as well as the implications of these changes. Future research could examine shifts in pathogen prevalence and resistance patterns, which may have emerged as a result of the pandemic's impact on healthcare dynamics. Results from such research could inform the development and adoption of strategies such as advanced pathogen reduction techniques like decolonization and would provide valuable insights into optimizing ASPs and addressing AMR in a post-pandemic world.

Our study has several limitations. First, as this was a small-scale qualitative study, we were unable to disentangle the relative impacts of multiple factors on efforts to fight AMR, nor were we able to establish any direct, causal, or significant effect of the factors discussed here on actual rates of AMR. Our KI interviews were limited to a total of 18 one-hour interviews and are not representative of all hospital experiences. Understanding the experience of other healthcare professions, particularly nurses and environmental services staff, would be valuable for developing guidance that incorporates the full patient-care team. Likewise, investigating efforts to mitigate AMR during the pandemic at other kinds of facilities, particularly long-term care, would help inform targeted strategies relevant to those settings.

Second, our KI interviews were subject to recall bias because they were conducted in mid-2024, a year after the official end of the COVID-19 pandemic in May 2023 and several years after its peak. Our study therefore may be affected by the accuracy of recollections by KIs and stakeholder meeting participants. The ability to recall pertinent details, particularly from such a stressful period as the pandemic, tends to diminish over time.

Future research could aim to gather input from a nationally representative sample of healthcare facilities and link these data with facility-specific AMR rates reported to the NHSN. This approach could enable a more robust evaluation of the relative contributions and importance of ASPs in the fight against AMR. Additionally, it would be valuable to further investigate which specific components of ASPs should be prioritized when resources are limited. Understanding these priorities would offer critical insights into optimizing ASP effectiveness, particularly in resource-constrained settings, and would inform future strategies for managing AMR during times of crisis.

CONCLUSIONS

Many interconnected factors disrupted ongoing efforts to combat AMR during the COVID-19 pandemic [7]. This study synthesizes the available literature with new input from relevant stakeholders to characterize the lived experiences of healthcare providers and found that the many severely ill patients created challenges for healthcare workers at a scale and breadth that disrupted adherence to IPC practices and implementation of ASP activities. Better data, communication, resources, and planning can help move us back to pre-pandemic and lower rates of AMR and mitigate the impact of future public health emergencies on AMR. Effectively applying the lessons learned through this study and others will amplify the impact of healthcare workers' efforts during the pandemic.

ABBREVIATIONS

AHRQ	Agency for Healthcare Research and Quality
AMR	Antimicrobial resistance
APIC	Association of Professionals in Infection Control and Epidemiology
AR	Antimicrobial resistance
ARLN	CDC Antimicrobial Resistance Laboratory Network
ASP	Antibiotic stewardship program
ASPE	HHS Office of the Assistant Secretary for Planning and Evaluation
CARB	Combating Antibiotic-Resistant Bacteria
CDC	Centers for Disease Control and Prevention
CMS	Centers for Medicare and Medicaid Services
COVID-19	Coronavirus Disease 2019
CRE	Carbapenem-resistant *Enterobacterales*
ESBL	Extended-spectrum beta-lactamase
FDA	Food and Drug Administration
HAI	Healthcare-associated infection
HHS	U.S. Department of Health and Human Services
ID	Infectious disease
IDSA	Infectious Diseases Society of America
IPC	Infection prevention and control
KI	Key informant
MDR	Multidrug resistant
MDRO	Multi-drug resistant organism
MRSA	Methicillin-resistant *Staphylococcus aureus*
NHSN	CDC National Healthcare Safety Network
NIH	National Institutes of Health
PPE	Personal protective equipment
SHEA	Society for Healthcare Epidemiology of America
SIDP	Society of Infectious Diseases Pharmacists
VRE	Vancomycin-resistant *Enterococcus*

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AUTHOR CONTRIBUTIONS

HHS/ASPE Contributions:
C.S. led the project team.
C.S., C.R.F., and L.G. devised and developed the research project.
C.R.F. conducted the conceptual literature review.
C.S., C.R.F., and L.G. developed and revised the key-informant interview protocol.
L.G. reviewed key-informant interview thematic analysis.
C.S., C.R.F., and L.G. planned and moderated the stakeholder meeting.
C.S., C.R.F., and L.G. reviewed and edited the final report.

ERG Contributions:
A.S., A.B., and S.M. developed and revised the key-informant interview protocol.
A.S., A.B., and S.M. conducted key-informant interviews and thematic analysis.
A.S., A.B., and S.M. planned and moderated the stakeholder meeting.
A.S., A.B., and S.M. drafted the final report.

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APPENDIX A: KI INTERVIEW PROTOCOL

A.1 Pharmacist Questions

Introductory & Contextual Questions

1. Can you briefly describe your role, how long you have been in your current role, and the type of facility at which you work? Please indicate whether your role title and/or the facility at which you are based has changed between March 2020 and the current date. If you work at multiple facilities or consult for any other facilities, please also indicate type and duration of employment with each facility with which you work.

   Interviewer Probes:
   - *Probe on how their role contributes to ASP at their facility*

2. Could you please discuss any changes to the interventions and/or activities implemented by your facility's ASP (e.g., prospective auditing & feedback, pre-authorization, antibiotic timeouts, antibiotic de-escalation, handshake stewardship, etc.) over the course of the pandemic with respect to either the activities themselves or their frequency?

   Interviewer Probes:
   - *Probe for driving factors for these changes, particularly those specific to the workplace (e.g., implementation capacity, work-from-home)*
   - *Probe for how changes impacted the overall goal of the ASP and AMR rates in the interviewee's facility.*
   - *Probe for whether any halted activities have been re-instated and what events or changes led to re-instatement.*
   - *Probe for any newly implemented activities, triggers for their introduction, and whether these activities are still being implemented.*

3. From your perspective as a pharmacist, what happened to AMR rates (e.g., increased, decreased, stayed the same) at your facility over the course of the pandemic and in the aftermath of the pandemic?

   Follow-Up Questions:
   - *Inquire about the types of multi-drug resistant (MDR) bacteria if not brought up by the interviewee.*
   - *If increased: What do you think were the most impactful workforce factors that contributed to the increase? Did these factors noticeably change at any point during the pandemic and if yes, were there any major events that triggered this change?*
   - *If increased: What do you think are the most impactful workforce factors that could have prevented the increase?*
   - *If stayed/decreased:* What do you think were the most impactful workforce protective factors that prevented an increase in AMR?

4. Could you please discuss any supply shortages that may have impacted your ASP at any point during the pandemic?

   Interviewer Probes:
   - *Probe for which supplies (e.g., antibiotic drugs, diagnostics) were in shortage and the length of each shortage.*
   - *Probe for whether any ASP program activity changes were made on the basis of shortages.*

- *Probe for how managing supply shortages may have impacted pharmacist workload and availability to work on ASP duties.*

ASP Communications & Interactions with Staff Questions

5. Could you describe how the pandemic impacted the relationship between ASP and non-ASP staff at your facility?

6. Could you please discuss how, at your facility, the pandemic impacted communication (e.g., communication channels, communication practices, and reception to communication) regarding antimicrobial stewardship between ASP pharmacists and other clinical staff?

   Interviewer Probes:
   - *Probe on how communication changes impacted ability to implement day-to-day ASP activities.*
   - *Probe on whether there was any point at which communication notably improved or notably worsened and what prompted this shift.*

7. Could you please discuss any increase in turnover of pharmacists and/or physicians working closely on ASP at your facility during the pandemic and how that impacted your ASP work?

   Interviewer Probes:
   - *Probe on main drivers of turnover and whether there was any point at which turnover notably improved or worsened.*
   - *Probe on whether there were any increased challenges onboarding or training new personnel as compared to pre-pandemic.*

ASP Governance and Prioritization Questions

8. Can you please describe any additional responsibilities (whether related to ASP or not) which you did not have prior to the pandemic which you, or any other staff involved in day-to-day ASP implementation, were asked to take on during the pandemic and how these responsibilities impacted your ASP work?

   Interviewer Probe:
   - *Probe on whether any new responsibilities were related to COVID-focused work such as COVID guideline development.*

9. After the pandemic, were you able to transition back to your pre-pandemic responsibilities or did you maintain any new responsibilities?

10. In your role as a pharmacist, could you please discuss how ASP activities are endorsed by facility leadership and staff and whether that changed during the pandemic? By endorsement, we mean advocating for the ASP program by leadership in ways such as public statements of support, dedicated human, financial, and technological resources or policy implementations to name a few.

    Interviewer Probes:
    - *Probe on whether support notably improved or notably worsened at any point and what events prompted this change.*
    - *Probe on whether there were changes to financial support from facility leadership.*

- *Probe on what aspects of support were most beneficial in facilitating implementation of ASP activities and what areas of insufficient support were most detrimental in facilitating implementation of ASP activities.*

ASP Lessons Learned Questions

11. From your perspective as a pharmacist, are there any major lessons learned from the pandemic that can be applied to future ASP activities when not experiencing a public health emergency?

12. From your perspective as a pharmacist, what recommendations would you give to prevent or mitigate a rise in AMR at facilities during future public health emergencies? Is there anything that you feel your facility did right with regards to preventing or mitigating a rise in AMR that you would recommend to other facilities in future crises?

13. What kinds of data/research information or interventions were most helpful to you in your efforts to optimize/reduce unnecessary antibiotic use during the pandemic?

14. In your opinion, during the pandemic, how aligned do you think your facility's ASP practices were to other facilities of similar size and/or geography? Probe for specific examples of where their facility may deviate from practices or implementation at other facilities.

A.2 Physician Questions

Introductory & Contextual Questions

1. Can you briefly describe your role, how long you have been in your current role, and the type of facility at which you work? Please indicate whether your role title and/or the facility at which you are based has changed between March 2020 and the current date. If you work at multiple facilities or consult for any other facilities, please also indicate type and duration of employment with each facility with which you work.

   Interviewer Probes:
   - *If interviewee does not specify relation of role to ASP: Can you briefly indicate how your role contributes to ASP at your facility?*

2. From your perspective as a physician, what happened to AMR rates (e.g., increased, decreased, stayed the same) at your facility over the course of the pandemic and in the aftermath of the pandemic?

   Follow-Up Questions:
   - *If increased: What do you think were the most impactful workforce factors that contributed to the increase? Did these factors noticeably change at any point during the pandemic and if yes, were there any major events that triggered this change?*
   - *If increased: What do you think are the most impactful workforce factors that could have prevented the increase?*
   - *If stayed/decreased: What do you think were the most impactful workforce protective factors that prevented an increase in AMR?*

ASP Activities Questions

3. From your perspective as a physician, could you please discuss any partial or full suspensions of the ASP at your facility that occurred at any point during the pandemic?

Interviewer Probes:

- *Probe for motivating factors that the interviewee felt led to suspension.*
- *Probe for any major impacts to ASP employees, with particular attention to job loss or change (e.g., furloughs, mandatory PTO, changes to job description).*
- *Probe for the length of program suspension and experience with restoration (e.g., facilitators, challenges).*

4. Relative to your facility's adherence to ASP guidelines prior to the pandemic, discuss your facility's adherence during the pandemic.

Follow-Up Questions:

- *Was there any point at which adherence notably improved or notably worsened? If yes, what do you think prompted this shift?*
- *If there was any change in ASP adherence, what would you consider the key influencing factors?*
- *If you felt that your facility's ASP adherence decreased during the pandemic, what areas of the program do you think suffered most?*
- *If you felt that your facility's ASP adherence increased during the pandemic, what areas of the program do you think improved most?*

5. Could you please discuss any changes, at your facility, to the method by which AMR data were tracked and reported during the pandemic and how, if at all, this influenced your ability to utilize AMR data for decision-making?

Interviewer Probes:

- *Probe on major drivers for these changes.*
- *Probe on whether these changes have persisted in the aftermath of the pandemic.*

6. Could you please discuss any changes to the level of your or other physicians' involvement in the design and implementation of ASP over the course of the pandemic?

Interviewer Probes:

- *Probe on driving factors for any changes described.*
- *Probe on how changes impacted the overall performance of ASP activities.*

ASP Communications & Interactions with Staff Questions

7. Could you describe how the pandemic impacted the relationship between ASP and non-ASP staff at your facility?

8. How, if at all, was your ability to communicate new ASP interventions and educate staff on new ASP policies/guidelines impacted by the pandemic?

Follow-Up Questions:

- *What role, if any, did the increased use of telemedicine play in any changes in communication among staff?*
- *Did telemedicine present any opportunities to expand or advance ASP knowledge or activities?*

9. Could you please discuss any rapid staff turnover, layoffs, and/or an influx of new staff or volunteers from outside of the facility which your facility experienced during the pandemic and how, if at all, this impacted your ability to communicate and educate staff on ASP?

Interviewer Probes:

- *Probe on any facilitators which eased or which the interviewee believes could have eased communication, training, or education of ASP procedures and tools for new staff.*

ASP Governance and Prioritization Questions

10. Can you please discuss the feasibility of managing your COVID-19 workload alongside your ASP workload?

    Interviewer Probe:

    - *Probe on prioritization between ASP activities and COVID-19 work.*

    Follow-Up Question:

    - *After the pandemic, were you able to transition back to your pre-pandemic responsibilities or did you maintain any new responsibilities? Does this impact your ability to work on AMR?*

11. In your role as a physician, could you please discuss how ASP activities were supported by facility leadership and staff and whether that changed during the pandemic?

    Interviewer Probes:

    - *Probe on whether support notably improved or notably worsened at any point and what events prompted this change.*
    - *Probe on whether there were changes to financial support from facility leadership.*
    - *Probe on what aspects of support were most beneficial in facilitating implementation of ASP activities and what areas of insufficient support were most detrimental in facilitating implementation of ASP activities.*

ASP Lessons Learned Questions

12. From your perspective as a physician, are there any major lessons learned from the pandemic that can be applied to future ASP activities when not experiencing a public health emergency?

13. From your perspective as a physician, what recommendations would you give to prevent or mitigate a rise in AMR at facilities during future public health emergencies? Is there anything that you feel your facility did right with regards to preventing or mitigating a rise in AMR that you would recommend to other facilities in future crises?

14. In your opinion, during the pandemic, how aligned do you think your facility's ASP practices were to other facilities of similar size and/or geography? Probe for specific examples of where their facility may deviate from practices or implementation at other facilities.

APPENDIX B: THEMATIC ANALYSIS OF KI INTERVIEWS

Coding Process

Interview transcripts were imported into NVivo v.11 and assigned classifications based on the attributes of the key informant (KI) and the facility they worked in (e.g., urban/rural, pharmacist/physician, hospital/health system). The coding process began with the application of a preliminary coding framework derived from the study's research questions and objectives. Codes were applied line-by-line to each interview transcript to ensure detailed data capture. NVivo's coding stripes were used to visually track coded sections for ease of review. As the analysis progressed, additional themes emerged, leading to the creation of new codes. This iterative process involved multiple reviews of the transcripts, with new codes being organized into parent and child categories using NVivo's hierarchical node structure. Similar or overlapping codes were then identified and merged to streamline the coding framework.

Data Synthesis and Analysis

To explore patterns and relationships between codes, NVivo's query functions were employed, including:

- Coding Queries to identify the frequency and distribution of themes across the data.
- Matrix Coding Queries to compare themes across participant classifications (e.g., urban vs. rural, physician vs. pharmacist).
- Text Search Queries to locate specific terms or phrases and their contexts within the data.

The final coded data was then synthesized by systematically reviewing frequently occurring codes and identifying overarching themes. A combination of NVivo's tools and Excel was used for visualization. Coding matrices within NVivo allowed for comparison of themes across different participant classifications. Excel was used to create detailed graphs that depicted the frequency and distribution of key themes.

Coding Comparison Query

An intercoder reliability check was conducted using NVivo's coding comparison query feature to ensure the consistency and reliability of the coding process. A representative portion (2 pharmacist and 2 physician interview transcripts) of the interview transcripts were selected and double-coded by two independent coders. Each coder applied the established coding framework to the same set of transcripts without consulting each other during the initial coding phase, ensuring that any variations in coding were the result of different interpretations rather than collaborative bias. Once the double-coding was completed, NVivo's coding comparison query was run to assess the level of agreement between the two coders. The Kappa Coefficient produced by this query was 0.79, which suggests that the coders were largely consistent in their application of the coding framework, with only minor discrepancies that did not significantly impact the overall analysis. To address any discrepancies identified during the intercoder reliability check, a reconciliation process was undertaken. The coders reviewed the instances of disagreement, discussed their interpretations, and reached a consensus on how the codes should be applied.

APPENDIX C: STAKEHOLDER MEETING AGENDA AND ATTENDEES

Table 2. ASPE Stakeholder Meeting: Combating Antimicrobial Resistance During the COVID-19 Pandemic Meeting Agenda – July 10, 2024

Agenda Topic	Time (EDT)
1. Welcome and introductions	9:30am - 9:40am (10 min)
2. Presentations	9:40am - 11:25am (90 min)
Epidemiology of antimicrobial resistance during the COVID-19 pandemic – Centers for Disease Control and Prevention	*9:40am - 10:10am*
Pandemic Increases in Antimicrobial Resistance in U.S. Hospitals: Unpacking the "why" –National Institutes of Health	*10:15am - 10:45am*
Combating Antimicrobial Resistance During COVID-19: The Role of Antibiotic Stewardship Programs - ERG	*10:50am - 11:20am*
3. Breakout session on presentations	11:30am - 12pm (30 min)
Break	12pm - 1pm (45 min)
4. Welcome back and setting the stage for discussion	1pm - 1:15pm (15 min)
5. Small group discussions	1:15pm - 2pm (45 min)
6. Small group report-out	2pm - 2:30pm (30 min)
7. Group discussion	2:30pm - 2:50pm (20 min)
8. Closing	2:50pm – 3pm (10 min)

Table 3. Count of Stakeholder Meeting Attendees, by Organization

Organization	Count of Attendees
ASPE – *Project Team*	5
ERG – *Project Team*	5
Center for Disease Control and Prevention (CDC)	6
National Institutes of Health (NIH)	2
Agency for Healthcare research and Quality (AHRQ)	1
Centers for Medicare & Medicaid Services (CMS)	1
U.S. Food and Drug Administration (FDA)	2
Infectious Diseases Society of America (IDSA)	4
Association for Professionals in Infection Control and Prevention (APIC)	4
The Society for Healthcare Epidemiology of America (SHEA)	3
Society of Infection Diseases Pharmacists (SIDP)	2
Total	**35**

APPENDIX D: STAKEHOLDER MEETING POLL QUESTIONS AND ANONYMIZED RESPONSES

In one sentence or less: What is one thing that stood out to you during the presentations?

Group A Responses

- How completely opposite the responses were – who got more funding and who less.
- Always encouraging to hear results are coalescing.
- Hospital AMR is still above pandemic rates. What will be next steps?
- Happy to see some confirmation bias. Interesting results about antibiotic exposure and AMR. Makes defining stewardship level that should be sustained during pandemic key.
- Not surprised by results. New question – is there a changing demographic with respect to colonization.
- Hospital rates are still above pre-pandemic levels. How much public awareness is there about this?
- Importance of data. Lobbying for increased funding of NHSN. Allowed for collection of data. Good confirmation for [the] work they do.
- Responding about public awareness comment – […] recognizing that we don't have solutions to totally cover the problem – but what was modifiable? Not the sick patients (other than vaccine/preventive measures). A good chunk we cannot do [anything] about.
- How to discuss that kind of messaging – especially when IPC communications funding is going away.
- Cannot prevent some infections, important to develop treatments.
- Need to provide funding at local health department to provide stewardship at facilities other than hospitals that have these programs, such as nursing facilities.
- Noted a lot more evidence on ground now but only until 2022.
- Early on in pandemic did not know about co-infection rates, could have done more about that. Also, could have not used antibiotics on the less sick. This is the difference between short-term thinking vs. long-term implications. Could do more as a community to bring the numbers down.
- As we started to have a better understanding, what would have been helpful to receive from CDC and other agencies?
- Messaging was primarily about COVID, could have done more to focus on AMR.
- Units nationwide saying they were overwhelmed and saying infections like MRSA are not a problem right now.
- Lack of resources, need to balance providing information and adding to the noise. AMR was not in content coming out.
- People were overwhelmed during COVID, so we need to focus on what we do before, not when, the pandemic hits. Strong ASP programs did well.
- Where structures were in place, those facilities did better. Need to focus on trying to strengthen all the processes.
- Seeing the same issues that dropped off during COVID – expensive and time-consuming to re-engage with members to reprioritize. There is so much noise.
- People prioritize what we pay for – stewardship is not valued. How to use some of the available levers to prioritize.
- Wanted staffing calculators to help provide information for facilities on what levels are needed to maintain stewardship levels. Did not receive funding.

Group B Responses

- The importance of needing to really understand frontline healthcare workers' experiences during the pandemic, as it can be qualitative data that can hopefully help explain further the quantitative data we have on HAIs and AR.

- I overall was not surprised by any of the data shared; it resonated with me as what we saw locally and across our health system (and are still seeing some of the effects of) for both antimicrobial use and infection control/healthcare-associated infections.
- Size/type of institution did not impact AMR during pandemic; little mention of therapeutic guidelines (presence or lack thereof) as the pandemic progressed
- Increase of [AMR] from pre-pandemic levels/state.
- There are multiple areas that will need to be addressed and strengthened for the US to be better prepared for the next healthcare emergency/pandemic.
- National data reflecting our own local experience in NYC. Nothing surprising or unexpected either in the AMR data or in the qualitative interview responses.

Group C Responses

- HA-MRSA rate did not increase as much as I would have expected.
- The gram negative increase is alarming. Was it due to bacterial factors alone?
- How do we make our interventions more resilient (not just to future pandemic, but generally seamless to implement)[?]
- It's interesting to see that [antibiotic] resistance is still elevated a couple years after the pandemic but not terribly surprising.
- Pandemic impact on AMR that persisted and challenges/struggles in ASP during the pandemic.
- While hospital-onset [AMR] infections increased and remain elevated, it seems like the causes are multi-factorial and varied substantially across the nation.
- The disparity in how ASP programs were supported or not supported during or after the pandemic.

Did the information conveyed in the presentations align with your experience?

Group A Responses

[poll responses unavailable due to polling platform issue]

Group B Responses

Response Option	Count	Total Votes	Results
Yes	6	6	100%
Somewhat	0	6	0%
No	0	6	0%
NA - The content of the presentations didn't directly correspond with my current role as it relates to AMR	0	6	0%

Group C Responses

Response Option	Count	Total Votes	Results
Yes	5	8	63%
Somewhat	2	8	25%
No	0	8	0%
NA - The content of the presentations didn't directly correspond with my current role as it relates to AMR	1	8	13%

What should we do differently concerning AMR, based on the way that facilities, professional societies, and government agencies responded to COVID-19 pandemic?

Group A Responses

- Strengthen core IPC practices across all healthcare settings and healthcare providers.

- Need to make specialized AMR testing (e.g., carbapenemase testing) easily accessible.
- More rapidly disseminate/describe changes in epidemiology.
- Pay for prevention.
- […F]ocus on culture stewardship and more timely data regarding [AMR]
- Incidence/prevalence would be useful.
- Establish and/or maintain existing communications mechanisms that prioritize actionable information (try to define "actionable" first!).
- Earlier 'official' statements about the lack of value of antibiotics in proven [COVID]
- Reinforcement that use of agents for nosocomial pathogens on admission from home (cefepime, carbapenems etc.) is not indicated
- […E]xtra resources specifically for stewardship in the midst of all the other essential demands to deal with the pandemic.
- Better education of patients and policymakers about how actions/treatments/responses related to an emerging pathogen or pandemic also impact AMR and the subsequent consequences of AMR.
- We have traditionally thought about healthcare in a siloed fashion--acute care, or single hospital. COVID highlighted the interconnection between settings, facilities, geographic areas, etc. I think we need more research into how to intervene in a more integrated fashion. (CDC's recent SHIELD study as an example)
- I'm not sure that there was a specific intervention that would have made a difference during the peaks of the pandemic. Information overflow was happening constantly, and with so many other areas of focus, I'm not sure how much time would have been available for clinicians to pay attention to AMR messaging.
- Improve data systems so that we continue to collect data on AMR during pandemics
- Continue to improving messaging to healthcare providers.
- Strengthen IPC capacity before the next pandemic so that it is implemented as second nature during emergency situations.
- Ensure adequate staffing for antimicrobial stewardship and infection prevention and control (including ID physicians, ID pharmacists, IPs, clin micro, etc.) by having targeted staffing levels and investing in the workforce.
- Establish ongoing, "automated" surveillance for AMR with publicly accessible dashboards - not just relying on intermittent publications.

Group B Responses

- Supply chain issues most likely severely impacted IPC capabilities too.
- Stewardship pharmacists had a complete job refocus and could not assist or minimally assist in helping to control AMR during the pandemic, as they were pulled to help manage pandemic-related medications and IPC activities.
- Expand focus to include outpatient practices where possible; it took MAJOR lobbying by pharmacy organizations to allow community pharmacies to prescribe/monitor Paxlovid.
- Share data. Tell why it's important.
- [Share] success stories on how [AMR] can be reduced. What can each facility/hospital etc. do...identify what is needed to move in right direction.
- Improve reporting processes (already mentioned): inter-operability continues to be a goal across health care/EHRs - - maybe focus inter-operability goals /mandates on antimicrobial use/AMR reporting.
- This is such a hard question, because of course prevention of a pandemic is key. But if we do find ourselves in a pandemic situation again, I think there will be heightened awareness of support needed for front-line workers (not just FTE support, but those who have the training to support leadership

roles in pandemic response which includes continuing antimicrobial stewardship and IP best-practices).
- Continue to do a better job at communicating IPC guidelines and recommendations to the very varied audience of frontline healthcare workers.
- Improve education and trainings - making them readily available. IPC isn't just a checklist you ask someone to complete, it takes people learning how to recognize risk and having the knowledge about what to do to mitigate that risk and stop the spread.
- Preparedness across all of the needed topics is key and ensuring is maintained and sustained on a continual basis.
- […N]ew innovations for prevention and control, so we step up our current actions against AMR.
- Having appropriate reimbursement/compensation for activities for all professionals involved combined with adequate staffing to support the increased workload could help.

Group C Responses

- Better understand how the AMR message can resonate with the public [and] tap into that.
- Fight back on politicization of evidence-based practices - vaccines, masking. I have no idea how to do this.
- Not only more timely data, but also more timely and responsive feedback to issues related to AMR.
- Resilient systems which require less work from human factor. Maybe AI integration?
- Continue to advocate for enough PPE and IPC resources, better surveillance, and overarching diagnostic stewardship efforts.
- Develop new tools that can are easier to implement (pathogen reduction, automation, etc.).
- Collaboration and consensus among professional societies and government agencies during practice guidelines development to minimize discrepancies in recommendations.

What should we carry forward concerning AMR, based on the way that facilities, professional societies, and government agencies responded to COVID-19 pandemic?

Group A Responses

- Continued investments in data systems with a focus on real-time data.
- Continue and expand investments in all areas of AMR prevention and response, including subscription model for drug development, recognizing not all infections can be prevented.
- Continued research into novel approaches to IP/AS/implementation.
- Continue investments in health departments and data systems.
- What we learned about how changes in patient populations - that we can't control - may impact changes we see in HAI and AR rates.
- Can we better empower and guide clinicians to educate patients who have resistant infections about AMR, so those patients (once they recover) can help build more of an AMR patient advocacy community (similar to what we see in other disease areas)? This is something to do BEFORE the next pandemic hits.
- Focus on more effective communication of science and data with partners, policy makers and general public.
- Stronger USG interagency relationships (e.g., between CMS and CDC).
- (If we had the funding) expanded health department IPC, stewardship, training, NHSN capacities.
- I think the work [ASPE is] doing now, looking thoughtfully back over time and trying to understand the drivers, barriers, etc. is critical. Use of the "retrospectoscope" is a great practice and allows continuous improvement.
- Having systems in place, and advance planning, which are flexible enough to pivot to whatever emergency comes up.

- Establish collaborative relationships, diverse teams, etc.
- I think we have made progress in understanding what [information] we need and some progress in how to report, mandating reporting to AUR for example. I'd like to see the other carry forward to continue to support state and local health departments because the local data and communication is so essential and often more useful than national data.
- […]Hardwiring IP and AS processes (as well as QI infrastructure) in times before/between crises periods helps healthcare organizations be resilient in times of crisis/stress.
- Continued ongoing communication of resistance and adaptation to therapeutic response.
- Shared "mission-driven" response by individuals and societies.
- Use of EUA-type approvals for new drugs to treat AMR as threats emerge?
- The federal government (I think largely through CDC) very effectively built and leveraged partnerships with community based organizations, faith-based organizations, etc. to promote COVID vaccination. Can we further leverage these partnerships to improve public education on AMR?

Group B Responses

- We have data to show that successes in HAI/[AMR] reduction was happening prior to the pandemic, but in some instances numbers were leveling off even before the pandemic hit. So, we know that the tools we have do work and should continue to be used, but we also realize that innovation of new tools for further advancement is required as far as prevention efforts across the board (e.g., new IPC activities, colonization reduction).
- Continuing to measure resistance and drill downs to different regional areas and types of facilities.
- Serving as a resource to facilitate sharing of data and best practices.
- Utilization of all healthcare workers in all facilities/settings.
- Ensure resources are readily available, trainings continue on IPC, and data continues to be collected in a way that can be accessed and analyzed to inform strategy.
- Regular updates and unified actions.

Group C Responses

- The pandemic opened new(ish) lines of communication among professional societies and government agencies that have sustained beyond the acute phase and support communications on topics other than COVID and AMR. It has improved our ability to keep members and the clinical community informed.
- Using new communications tools (example: podcast, social media) to rapidly communicate messages.
- The increased emphasis on actionable data that was near real-time, though maybe less so for AMR, should continue.
- Continue using the consensus model to drive practice.
- Even if problematic or not always perfect, there was a [greater] flow of information between facilities and public health. Harnessing [it] for future would be ideal.
- Ability to rapidly respond & pivot based on changing conditions [and] building consensus.
- Emphasis on diagnostic stewardship!

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