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Antimicrobial resistance, antibiotic prescribing practices and antimicrobial stewardship in South Africa: a scoping review

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Introduction: Antimicrobial resistance (AMR) is an emerging global threat, with notable impact evident in low- and middle-income countries. Indiscriminate antibiotic prescribing is recognized as the key factor responsible for the continued spread of AMR.

Objectives: To comprehensively map published data of evidence of AMR in healthcare settings in South Africa, encompassing the exploration of antibiotic prescribing practices and the implementation of antimicrobial stewardship initiatives.

Methods: The scoping review methodology was based on the guidelines outlined by Arksey and O'Malley. The protocol for this scoping review has been registered in the Open Science Framework (https://doi.org/10.17605/OSF.IO/PWMFB). The search strategy was documented using the protocol outlined within the Preferred Reporting Items for Systematic Reviews and Meta-Analyses for Scoping Reviews (PRISMA-ScR). Databases used were Science Direct, Scopus, PubMed, Wiley, Directory of Open Access Journals; and health organizations such as the WHO. In addition, the Google search engine was used to search for grey matter. The search was restricted to peer-reviewed articles in English on human studies for the period 2019–24.

Results: The search yielded a total of 529 articles from electronic databases and search engines. Twenty-nine articles were accepted for inclusion following the application of the study protocol. The majority of the articles were primary research papers.

Conclusions: The findings reveal that South Africa has measures in place to combat AMR; however, inconsistencies were found between the private and public health sectors, in addition to the lack of adherence to guidelines and limitations in AMR education among healthcare workers and students.

Introduction

Global healthcare is facing an imminent crisis, in the form of antimicrobial resistance (AMR), which threatens the efficacy of life-saving antimicrobial drugs, aggravates the spread of communicable diseases, and jeopardizes patient outcomes.[1] Antibiotics have a fundamental role in the treatment of infectious diseases.[2,3] The optimal use of any medication necessitates patients receiving medication specific to their clinical needs, at the correct dosage and time so that it fulfils their individual requirements.[4] As early as 1947, Hoffman[5] pointed out the ease with which penicillin was used, often without attention to correct diagnosis or dosage, disregarding fundamental principles of medicine, surgery and dentistry in disease management. As such, healthcare practitioners stated, early on, the need to prudently prescribe antibiotics.[6] Since the initial introduction of penicillin in the twentieth century, there has been a steady increase in antibiotic prescribing in healthcare. The excessive and improper use of antibiotics promotes bacterial resistance, resulting in more complex treatment strategies for infectious diseases and an increased risk of treatment failure.[2]

AMR arises when various microorganisms, including bacteria, viruses, fungi and parasites, develop the ability to withstand the effects of antimicrobial medications. This resistance renders

antibiotics and other antimicrobial agents ineffective, posing significant challenges in the treatment of infections. Consequently, there is a heightened risk of disease transmission, severe illness, disability and mortality associated with these resistant microbes.[7–9]

AMR has been earmarked as a significant threat to the well-being of the global population, and may result in increased mortality rates, as well as increased medical care costs.[10] As the progress in developing newer antimicrobial agents has come to a halt, this is an ever-growing global concern.[11,12]

AMR spread is seen via the human population and the animal population, as well as the environment (water and air).[13] Although AMR is evident in all countries, there is a disproportionately higher burden in low- and middle-income countries.[14,15] Drivers of AMR in low- and middle-income countries are influenced by political, economic, socio-cultural and ecological factors that influence the profile of these countries.[16] Additionally, low- and middle-income countries bear a significant burden of communicable diseases, often facing limited resources and insufficient data on the epidemiology and impact of AMR. Factors such as the geographical distribution of AMR, underdeveloped laboratory capacity and the steering of comprehensive surveillance mechanisms hinder levels of AMR detection.[17] Inadequate surveillance programmes make it difficult to gauge the scale of AMR in low- and middle-income countries.[16] Between 2000 and 2015, low- and middle-income countries have seen a substantial increase in AMR rates due to the lack of access to clean water, sanitation and hygiene.[13]

AMR reportedly contributes to 1.2 million global deaths annually.[7,8,18,19] AMR is driven by various factors, of which the overuse of antibiotics is the most dominant.[1] Evidence shows that prescribing practices of antimicrobials vary among prescribers in most countries and may be influenced by the age, gender, education status and work experience of the prescriber.[20] Lack of undergraduate education and clinical training on AMR is also identified as contributors to incorrect prescribing among healthcare workers (HCWs).[21] Patient expectations regarding antibiotic prescriptions from HCWs have also been noted as an additional factor that influences the unnecessary prescribing of antibiotics among HCWs. Patient expectations could be related to a common misconception among the general public that antibiotics are needed to treat viral and fungal infections.[22,23]

Managing AMR in low- and middle-income countries, such as those in Africa, proves challenging when compared with their high-income counterparts. Sub-Saharan African countries' efforts to implement effective and workable AMR stewardship programmes are often challenged by various factors, which include a lack of human resources, decreased investment and decreased infrastructural and institutional capacities,[24,25] In addition, the arrangement of healthcare systems, accessibility of diagnostic tests and suitable antibiotics, antibiotic prescribing practices and infection control practices display a marked difference between high-income countries and low- and middle-income countries. The surveillance of antimicrobial usage and intervention programmes requires time and financial support, as well as related knowledge in epidemiology, microbiology and communicable diseases, data management and analysis. The reality is that in these countries, especially in rural health facilities, routine microbiological culture and sensitivity tests cannot be routinely performed. This results in the empirical prescribing of antibiotics, which is less expensive, but can result in antibiotics being overused and incorrectly prescribed. The indirect result of this approach may result in the further rise and expansion of AMR.[21] Management of AMR requires antimicrobial stewardship (AMS) to drive down antibiotic prescribing rates. This includes increasing awareness of incorrect prescribing, increased education in prescribing practices, and adherence to guidelines.[12,26,27]

The lack of data on AMR complicates the management of AMR in sub-Saharan Africa.[25] Country-specific data is not routinely assembled and is often not shared with national regulatory bodies. This places limitations on the ability of these regulatory bodies to effect national action. In addition, AMR may be considered a low-priority concern when compared with other public health matters.[28,29]

In 2017, Tadesse *et al.*[30] found that data on AMR were not available for 42.6% of the countries on the African continent. The WHO has been proactive in addressing this concern, with the creation of an international system to report AMR patterns and document any global health security threats, by launching the Global AMR Surveillance System (GLASS) in 2015.[31] Additionally, the WHO endorsed a global action plan (GAP) for AMR in 2015, with the intent of highlighting national and global attention to AMR. The GAP policy recommended the development of country-specific national action plans (NAPs) against AMR.[28] The aims of the NAP in relation to AMR, as defined by the WHO, are to: increase the understanding and awareness of AMR; increase AMR surveillance and research; reduce infection rates through hygiene, and infection prevention and control; and optimally use antimicrobials in human and animal health.[32] Furthermore, in 2019, the WHO created a classification of antibiotics in order to promote AMS and decrease AMR. The WHO Access, Watch and Reserve (AWaRe) classification is available for hospital and outpatient antibiotic prescribing guidelines. This classification categorizes antibiotics by prioritizing antibiotics recommended for use while considering their AMR potential. The AWaRe classification was developed by the WHO to support AMS efforts globally, where each category is based on its effect on AMR. Antimicrobials in the Access category have a narrow spectrum of activity with fewer side effects and a reduced likelihood of AMR. Examples of Access classification antibiotics include penicillin, amoxicillin, amoxicillin with clavulanic acid, clindamycin and metronidazole. Those in the Watch category pose a higher risk of promoting AMR and these are reserved for more serious conditions, usually within a hospital setting. Examples of Watch classification antibiotics include azithromycin, ciprofloxacin and clarithromycin. Those in the Reserve category are usually used when treating severe infections caused by MDR pathogens, and are often used as a last resort in critical situations. These include ceftolozane, colistin and minocycline.[33]

The South African healthcare system includes both the private and public sectors, which have varying levels of infrastructure, resources and patient profiles. Approximately 84% of the South African population depends on the public healthcare system for their healthcare requirements.[25,34] The public health system provides ambulatory care for the majority of the population through a nurse-based, clinician-supported system, in the form of community health centres and primary health care clinics.[34,35]

The National Department of Health has recognized the threat of AMR, as South Africa exhibits some of the world's highest rates of antibiotic resistance, observed in both Gram-positive and

Gram-negative bacteria.[36] The organisms that are currently the focus of antimicrobial surveillance in South Africa include the following: *Enterococcus faecalis* and *Enterococcus faecium*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Acinetobacter baumannii*, *Pseudomonas aeruginosa* and *Escherichia coli* (ESKAPE pathogens).[37]

In response to the call by the WHO's GAP, the South African Department of Health drafted the National AMR Strategy Framework. This framework highlights the need for interdisciplinary efforts, AMS and the elevation of infection prevention and control.[36] Activities evident in South Africa, in an attempt to address AMR, include the following: introduction of the NAP;[36] publishing of the Guidelines for the Prevention and Containment of AMR in South African Hospitals;[38] updating of the Standard Treatment Guidelines (STG)/Essential Medicines List (EML) (Department of Health Republic of South Africa);[39] assessment and monitoring of prescribed antibiotics in ambulatory care in accordance with STG/EML (Department of Health, the Republic of South Africa STG/EML, Primary Healthcare Level 2020 edition);[40] and implementation of AMS activities (launch of the South African Stewardship Programme).[41]

The implementation of NAPs varies across African countries, with South Africa appearing to have made the most progress with implementing its NAP, which covers monitoring of antimicrobial usage and development of AMS programmes.[40,42,43] However, rising AMR rates in South Africa are still of concern, which is mostly exacerbated by a lack of adherence to prescribing guidelines, and inappropriate prescribing and dispensing practices among prescribers.[42,44,45]

Rationale for scoping review

South Africa is classified as a middle-income nation in sub-Saharan Africa, and faces serious challenges related to the public health crisis of AMR. The availability of prescribing guidelines and AMS practices differ across healthcare sectors, leading to inappropriate prescribing behaviours. Preliminary literature searches have identified existing reviews on AMS and AMR throughout Africa.[28,30] This scoping review aims to provide a comprehensive overview of AMR rates and evidence, antibiotic prescribing trends among healthcare providers, as well as the surveillance measures and stewardship programs implemented in South Africa. The objectives are to synthesize evidence on AMR awareness and knowledge among HCWs and students, antibiotic prescribing practising patterns, and the implementation of AMS and surveillance in the South African healthcare setting. The research questions were: (i) what is the current evidence of AMR in South Africa, including awareness and knowledge among HCWs and students?; and (ii) what are the current patterns of antibiotic prescribing, guideline compliance, and AMS and surveillance initiatives in South Africa?

Methods

The methodological framework by Arksey and O'Malley was used to conduct this scoping review.[46] The following steps were followed: identifying a clear research question; identifying related studies in the literature; selecting articles; data extraction; and summarizing, synthesizing and reporting on findings. The key research question leading this review was 'what is known from the literature about AMR in healthcare in South Africa?'

The research question was developed using the population concept context (PCC) framework, to ensure suitable study selection related to the research question.[46] (Table S1, available as Supplementary data at *JAC-AMR* Online).

To conduct this scoping review, two reviewers (S.A. and R.A.) developed a study protocol following the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA-SCR) approach for the selection of articles (Figure S1).[47]

An electronic search was conducted on the following databases and scientific working groups for relevant publications: PubMed, Scopus, Wiley, Directory of Open Access Journals and Science Direct and WHO database for articles from 2019 to 2024. To access grey/unpublished literature, the reviewers used Google to search for relevant literature. The following terms were used in a combination of key medical subjects headings (MeSH) terms and Boolean operators ('OR/AND'): (antibiotics OR antimicrobials) AND (antimicrobial OR antibacterial resistance) AND antimicrobial stewardship AND antibiotic prescribing AND South Africa.

Eligibility criteria

We included full-text articles in the period 2019–24 that were published in English and that explored AMR evidence in healthcare in South Africa. The inclusion criteria were full-text peer-reviewed journal articles, published in English, grey literature and human studies. Exclusion criteria were non-English articles, studies outside of South Africa, and animal and environmental studies.

Study selection

The two reviewers (S.A. and R.A.) independently searched the literature and assessed the suitability of the searched studies from the databases as determined by the eligibility criteria. The study eligibility and data extraction forms were used to guide the reviewers in selecting suitable documents and extracting data independently. The two sets of literature were compared. Study titles were screened to identify whether the criteria were met and duplicates removed. In instances where the study abstract did not relate to the focus question, these studies were excluded. Data extraction was completed manually. Full texts of the studies that were selected during the initial perusal were studied for the final study selection.

Data extraction

A data extraction form (Appendix 1) was created to assist in selecting suitable articles and to facilitate independent searches. Any differing opinions were resolved by consultation with the second reviewer if required. A third reviewer (R.Z.A.) assisted where consensus could not be reached. Data extraction was then completed from the full text including documents obtained from the different databases.

The data were organized and reported on, according to the following pertinent themes (Table S2): (i) the current AMR situation; (ii) antibiotic knowledge, prescribing patterns and guidelines; and (iii) management of AMR by stewardship and surveillance.

Data were extracted by the first reviewer (S.A.) and entered into a data extraction form (Excel®) and independently checked by the second reviewer (R.A.) to ensure quality.

Results

A total 528 documents were retrieved, of which 30 were duplicates. Duplicates were manually extracted. Following screening (by titles and abstracts), 460 were excluded (as they were unrelated to the topic of the scoping review). Full-text documents

($n=38$) were then screened for inclusion and eligibility. The final number of 29 were confirmed for inclusion, following the exclusion of 9 documents, which were excluded as the articles were not focused on the AMR scenario, AMR was not reported by country, or articles did not focus on South Africa. The final documents for inclusion included 23 full-text articles from peer-reviewed journals, 2 reports from health groups (WHO), 2 policy documents/reports from the South African Department of Health, 1 Master's dissertation and 1 website entry. The results of the review are characterized according to key themes of the study (Table S3).

Current AMR situation in South Africa

Five organisms were identified as closely associated with AMR in South Africa. These were *K. pneumoniae*, *S. aureus*, *Streptococcus pneumoniae*, *E. coli* and *A. baumannii*.[74] A Department of Health report listed the following AMR resistance patterns in humans: *K. pneumoniae*, MRSA, VRE, ESBL-producing Gram-negative bacteria, and carbapenemase-producing Enterobacterales.[76] According to the Institute for Health Metrics and Evaluation, South Africa reported 9500 deaths attributable to AMR and 39 000 deaths associated with AMR in 2019.[76]

AMR awareness and knowledge

The evidence on AMR awareness and knowledge among HCWs and students is drawn from primary research studies usually reported as cross-sectional surveys. Two studies were conducted among healthcare students (medical and nursing students), and one study among medical interns.[54,59,65] Of the medical interns, 85.9% felt that AMR posed a significant risk in South Africa, and 99% of the medical students felt that inappropriate antibiotic use contributed to AMR rates.[59,65] Various gaps were identified in AMR awareness and knowledge among some of the healthcare students. For instance, 98.1% of medical students felt that they understood the mechanism of AMR, compared with 22.6% of nursing students.[54,59,65]

Four studies were conducted among HCWs (doctors, nurses and pharmacists) at healthcare facilities in South Africa. It was interesting to note there was a difference between AMR awareness and knowledge between HCWs employed at academic and non-academic facilities. Seventy-four percent of HCWs at the academic hospital felt that AMR was of concern at their hospital, compared with 51.2% at the non-academic hospital.[50] Similar results were reported in the study by Balliram *et al.*,[61] where 93.4% of HCWs agreed that AMR is a global problem and 91.6% felt the increase in antibiotic prescribing contributed to AMR. Positively, 75% of HCWs felt confident in their AMR knowledge. In a study conducted at 26 public healthcare facilities in South Africa, 19.2% of these facilities felt that AMR was not a problem at their facility, and 88.5% of HCWs at these public healthcare facilities were aware of the National AMR Strategy Framework. Promisingly, 59.5% of public healthcare facilities reported compliance with the framework.[67] Continuous education on AMR by qualified health professionals has also been noted, where 81.6% of HCWs requested more education on AMR.[61] In a national study conducted across 26 healthcare facilities, only 42% of HCWs reported receiving continuous education on AMR.[64,67]

Antibiotic knowledge, prescribing patterns and compliance with antibiotic guidelines in South Africa

Twenty-one ($n=21$) full-text articles reported on antibiotic prescribing patterns, antibiotic use and compliance with antibiotic guidelines in South Africa, nine ($n=9$) of which were cross-sectional studies, seven were observational or point prevalence surveys, two were intervention studies, one was a prospective cohort study and one was a descriptive study. Studies reviewed showed that HCWs prescribed antibiotics empirically, with the study by Chetty *et al.*[55] reporting this at 91% of HCWs.

The study by Dramowski *et al.*[48] was conducted across seven public and seven private sector hospitals. The study revealed that 95.5% of empirically prescribed antibiotics at public hospitals followed local hospital recommendations. The study also looked at classification of prescribed antibiotics as it corresponded to the WHO AWaRe classification, and established that 64.1% of antibiotics prescribed were in the Access category, 33.9% were in the Watch category and 2% were in the Reserve category. A valuable conclusion of this study demonstrated the positive impact of multidisciplinary AMS efforts.

Additionally, various studies established the utilization of facility-specific guidelines that were based on the STG. For instance, Chetty *et al.*[55,69] described that 65% of facilities used such guidelines in their practices. Balliram *et al.*[61] established that 72.5% of doctors used the STG, followed by the South African Medicines Formulary (SAMF) when prescribing. However, a retrospective observational study at a regional hospital in South Africa showed that only 46.2% of prescriptions were in accordance with prescribing guidelines and 5.6% of prescriptions were issued with no clear indications for use.[62] A national point prevalence survey demonstrated that 93.4% of prescribed antimicrobials complied with the STG/EML.[56] The data were further explored to determine accordance with the WHO AWaRe classification, and the results showed that 62.1% of prescriptions were in the Watch category and that 22% of prescribed antimicrobials were not classified under the current AWaRe system. Generally, it was found that doctors in South Africa used guidelines, but a variety of guidelines were in use. It also emerged from the same study that limited resources in the public health sector influenced prescribing practices.[63] Another study examining the variations in adherence to antibiotic prescribing guidelines in private and public hospitals indicated 55.6%–66.3% compliance with prescribing guidelines in public hospitals, while compliance with antibiotic prescribing guidelines in private hospitals was recorded at 46.4%–51.2%.[68]

Reviewing the studies among undergraduate healthcare students particularly (medical and nursing students) showed they both had similar outcomes: 64.5% of nursing undergraduates felt their education on antimicrobial prescribing was sufficient, while 87.5% of medical students were comfortable with determining the correct antimicrobial choice. However, 100% of the medical students indicated their desire for more education on appropriate antibiotic use.[54,59]

In a surveillance report for AMR and consumption of antimicrobials in South Africa, most public healthcare facilities prescribed penicillin (28%), trimethoprim/sulfamethoxazole (13%) and metronidazole (12%). The private sector, on the other hand, prescribed penicillin (41%), carbapenems (20%) and

third-generation cephalosporins (13%). Elevated broad-spectrum penicillin use was documented in both public and private sectors.[75] In the study by Salau *et al*.,[51] at a public academic tertiary hospital, the most commonly prescribed antibiotics were ampicillin, gentamicin and amoxicillin/clavulanic acid. This study also indicated the use of empirical prescribing at public health institutions.

Various studies reported on antimicrobial prescribing and conforming to the STG, with the majority of studies conducted in healthcare facilities.[52,53,63,64,68,73] The preferred prescribed antibiotic in public healthcare was amoxicillin or co-amoxiclav for single therapy, followed by co-amoxiclav and azithromycin for dual therapy.[49,56,62,69] However, in one study among five regional hospitals, the frequency ranking showed that metronidazole, ceftriaxone, amoxicillin, ampicillin and gentamicin were prescribed.[53] A difference was also evident between private and public healthcare in one study, where prescribing at public healthcare facilities favoured amoxicillin, and private healthcare facilities favoured amoxicillin and clavulanic acid, followed by clarithromycin.[52]

Alabi and Essack[57] analysed health insurance claims in an effort to assess antibiotic prescribing among GPs in private practice. This study demonstrated that 8.8% of antibiotics prescribed were deemed appropriate, 32% were potentially appropriate and 45.4% were inappropriate. The EML was not used in the private sector.

Management of AMR—surveillance and stewardship of antibiotic use

It is evident from the papers reviewed that healthcare facilities in South Africa are at varying phases of antimicrobial surveillance and stewardship. Studies confirmed that most facilities adhered to the STG, the EML, the South African Antibiotic Stewardship Programme guidelines or facility-specific guidelines.[56,60,61] In addition, various studies showed that most facilities had AMS committees.[55,56,60] This is encouraging as AMS and surveillance are recognized by the South African National AMR Strategy Framework as a method to address AMR. Examples of AMR stewardship and surveillance in some facilities include weekly AMS ward rounds, prescription charts for antimicrobials, surveillance reports, audits and analysis of antibiotic use.[50,55,60,70] In the study by Chetty *et al*.,[55] when studying adequate education on antimicrobials, 50% of HCWs in a non-academic setting felt their health facility provided adequate training, compared with 34.1% of HCWs in an academic setting. Evidence of AMS success is shown by improved prescribing by adhering to guidelines, as is the case in an observational study where prescribing in line with guidelines improved from 41% to 73%.[6] Additional evidence of positive AMS methods was apparent in an intervention study, where adherence to antibiotic prescribing guidelines over the intervention period increased from 19% to 47%. These surveillance and stewardship efforts resulted in decreased consumption of amoxicillin, azithromycin and flucloxacillin.[58]

Another encouraging development in South Africa is the increase of surveillance sites (which report to WHO). In the 2020 data call, South Africa had 737 surveillance sites, compared with 353 sites in 2019.[71,72]

Discussion

The escalating AMR public health crisis, globally and in South Africa, demands urgent action. Stark statistics reveal that in 2019, 9500 deaths were directly attributable to AMR in South Africa.[74] The global forecast estimates that by 2050, 10 million deaths could be attributed to AMR.[18] This scoping review aims to highlight the evidence of AMR and explore the AMS efforts carried out within healthcare settings in South Africa, which may assist in understanding the wide-ranging implications of AMR and contribute to formulating effective AMS responses.

This scoping review revealed that the AMR landscape in South Africa is diverse with respect to AMR evidence and awareness, antibiotic prescribing trends and AMS and surveillance. There is no mistaking the global threat of AMR as articulated in numerous studies.[10,11,14] Studies have also indicated that the phenomenon of AMR varies between high-income and low- to middle-income countries, with more reporting focused on high-income countries.[15,77,78] South Africa, which is categorized as a middle-income country, is not exempt from the threat of AMR, which manifests itself in increased mortality rates, extended hospitalization, escalated cost of healthcare and expenditure of healthcare resources.[40,79]

It is clear from the findings of this scoping review that the evidence for AMR in South Africa has highlighted the resistant pathogen patterns in humans. In 2019, South Africa had 9500 deaths attributable to AMR and 39 000 deaths associated with AMR.[70] AMR rates and concerning resistance patterns underscore the need to implement action to address this public health threat. As reported previously, these numbers could be higher, as AMR reporting is often inadequate.[16,21] The lack of resources, limited microbiological laboratory testing, delay in feedback of results, and poor infrastructure are factors that hinder the accurate description of AMR rates in South Africa.[25,56] The South African Department of Health has identified pathogens associated with AMR, as well as prescribing trends amongst prescribers, in their surveillance reports. These reports hold significance, as these data may serve as a tool to educate prescribers on the AMR situation in South Africa, as well as highlighting the need for stewardship.[75] The findings have highlighted the lack of adequate surveillance of AMR, as previously revealed by various studies due to a variety of reasons, many of which are specific to low- to middle-income countries.[25,56] It is evident that the management of the increased burden of microbial infections in South Africa is constrained by AMR surveillance activities in low-resource settings. This represents the challenge that South Africa faces in order to adequately define and record AMR rates. An encouraging development in South Africa is the increase of surveillance sites, as part of the WHO's GLASS, where the number of surveillance sites in South Africa increased from 353 to 737 in 2020.[71,72]

AMS efforts in South Africa are evident from papers reviewed and reveal that healthcare facilities in South Africa are at varying phases of antimicrobial surveillance and stewardship. Studies confirmed that most facilities adhered to the STG, the EML, the South African Antibiotic Stewardship Programme guidelines or facility-specific guidelines.[52,53,63,64,68] Differences in prescribing patterns, guideline adherence and appropriate antibiotic selection are evident between the private and public healthcare sectors. Evidence of adherence to guidelines differed in various

studies, where van den Bergh *et al.*[68] demonstrated compliance with guidelines in public hospitals at 55.6%–66.3% and at 46.4%–51.2% in private hospitals. A study by de Vries *et al.*,[58] conducted in the public health sector, found that there was non-compliance with the STG at 30.1% and the EML at 31.7%. Non-compliance with prescribing guidelines would have an impact on AMR rates and associated repercussions, and this highlights the need to encourage compliance with antibiotic prescribing guidelines.[58,68] Limited resources in the public health sector could have an influence on this, which highlights the need for effective stewardship. When looking at this perspective, the study by de Vries *et al.*[58] has an optimistic process in low-resource settings, where stewardship and decreases antibiotic prescribing rates were achieved by multidisciplinary audit, and feedback discussions being integrated into clinical meetings. Antibiotic prescriptions were randomly selected and reviewed by the multidisciplinary team for adherence to guideline adherence and appropriate antibiotic selection. This highlights the need for low-cost and effective resolutions in low-resource public health settings.

In addition, various studies showed that most facilities had antimicrobial stewardship committees.[55,56,60] This is encouraging as AMS and surveillance are recognized by the South African National AMR Strategy Framework as a method to address AMR. Examples of AMR stewardship and surveillance in some facilities include weekly AMS ward rounds, prescription charts for antimicrobials, surveillance reports, audits and analysis of antibiotic use.[50,55,60,70] Evidence of AMS success is shown by improved prescribing by adhering to guidelines, as is the case in an observational study where prescribing in line with guidelines improved from 41% to 73%.[66] Integrated stewardship models using antimicrobial treatment, diagnostics and infection prevention have been reported to successfully implement stewardship, and this mindset could optimize patient care and simultaneously decrease infection spread.[55] It is evident from the findings that the effect of resource constraints and financial burdens in healthcare, as encountered in low- to middle-income countries, have an impact on antimicrobial surveillance and stewardship.

Antibiotic prescribing practices, as highlighted in this review, lean towards empirical antibiotic prescribing practices, which is evident in many studies reviewed, with the study by Chetty *et al*. showing that 91% of HCWs prescribed empirically.[54,55,61] Although guidelines are available, the implementation of these guidelines varies between HCWs. In South Africa, notable distinctions can be seen in antibiotic prescribing in the public and private health sectors.[49,53,55,56,62] Balliram *et al.*[61] found that 72.5% of doctors used the STG, followed by the SAMF when prescribing. However, in a retrospective observational study at a regional hospital in the public sector in South Africa, only 46.2% of prescriptions were in accordance with prescribing guidelines, and 5.6% of prescriptions were issued with no clear indications for use.[62] Antibiotics that had a higher risk of resistance development were prescribed at a higher rate in the private sector compared with the public sector.[49,52,53,55,56,62] This can be attributed to patient demands and greater financial access to medication. The public sector healthcare facilities in South Africa receive medication via controlled procurement using the STG and EML, which is a possible explanation for higher adherence rates to STG in certain public healthcare facilities.[53] However, studies have also revealed that prescribing practices in the public health sector in South Africa are influenced by a lack of resources such as access to Wi-Fi, data availability and technical support. Prescribing guidelines are available throughout South Africa, but many public health facilities are unable to access these guidelines due to the inaccessibility of free Wi-Fi or data. This may result in the use of outdated hard-copy guidelines.[64]

Prescribing practices by HCWs are often shaped by multiple factors, including the influence of colleagues and the degree of clinical autonomy, both of which can affect antibiotic selection. This is more evident in the public health sector, where junior doctors often face challenges when challenging senior doctors' choices. In the private sector, inappropriate prescribing is also driven by financial incentives from pharmaceutical companies.[52,63] The lack of extensive data on antibiotic prescribing practices in the private sector presents a challenge when attempting to enumerate the extent of incorrect and overprescribing. Improved access to data in this sector will facilitate the identification of high-risk behaviours, trends and other patterns, which could support AMS initiatives.[52]

In 2021, Balliram *et al.* reported a significant variation in prescribing practices between doctors, nurses and pharmacists, where 59.7% of doctors were confident in selecting the correct antimicrobials, compared with 46.4% of nurses and 34.1% of pharmacists. Doctors showed greater confidence in prescribing antibiotics, likely due to their specialized training and familiarity with antibiotic prescribing guidelines. Lower confidence levels were observed among nurses and pharmacists, which shows the need for increased education and support in antimicrobial education and stewardship. Of concern in this study is that 16.5% of pharmacists and 8.9% of nurses prescribed antimicrobials without a licence.[61] This highlights the need for adequate stewardship and surveillance practices in healthcare settings, as accountability mechanisms, audits and appraisals can facilitate guideline adherence and also assist in restricting unauthorized practices. The differences in antibiotic prescribing between the private and public sectors are clear from above-mentioned studies, and demonstrate the need for improved and standardized guideline availability and dissemination across health sectors.

Awareness and education of AMR is an important first step in an effort to address and reduce this phenomenon.[80] Thus, improving awareness and understanding of AMR among HCWs and students is a key strategy of NAPs and GAP, in an effort to address AMR. Education is central in improving antibiotic prescribing, by facilitating a change in attitude and knowledge amongst prescribers. Judicious prescribing and stewardship should begin when behaviour and learning is being influenced.[54,81,82] Additionally, multidisciplinary collaboration in an effort to promote AMS is seen as a positive method to encourage evidence-based practices into routine clinical practice. This is an important strategy as various studies have seen an increased awareness of AMR and increased stewardship effort following multidisciplinary collaboration, which includes clinicians, microbiologists, pharmacists and infectious disease specialists.[68,83,84] The success of a pharmacist-driven stewardship programme using an audit and feedback strategy resulted in a reduction in antibiotic consumption over a specified period, which highlights the need for multidisciplinary collaboration to contribute to stewardship.[84] A multidisciplinary approach is an effective way to

encourage a culture of accountability and collective responsibility in antibiotic prescribing.

A common theme relating to AMR awareness and knowledge that emerged in this review showed that healthcare students recognized the role they had to play in curbing AMR in South Africa.[59,65] However, various gaps were identified in AMR awareness and knowledge among some of the healthcare students. There seemed to be a distinct difference in AMR awareness and knowledge between the medical and nursing students, especially relating to understanding the mechanism of AMR, where 98.1% of medical students felt that they understood the mechanism of AMR, compared with 22.6% of nursing students.[54,59,65] Varying confidence among nursing students around antibiotic prescribing was observed. This emphasizes the need to improve the knowledge and understanding of nursing students around antibiotic prescribing, AMS and AMR, as they make up the largest category of HCWs in public sector.[49] The discrepancy in knowledge and awareness could be attributed to the difference in curriculum, clinical exposure and educational focus between the undergraduate programmes. Targeted educational campaigns and interprofessional collaboration could be a means to bridge the gap in AMR awareness and knowledge among different disciplines.

HCWs in South African healthcare facilities, both academic and non-academic, demonstrated differences between AMR awareness and knowledge. A higher percentage of HCWs at academic hospitals felt that AMR was of concern at their facilities and the majority of HCWs attributed increased antibiotic prescribing as a contributing factor to AMR. The discrepancy between HCWs in academic and non-academic hospital settings could be associated with potential institutional disparities.[50] This review revealed that both undergraduate students and HCWs requested more education on AMR.[50,53,54] This could be perceived as a shortcoming in undergraduate education, as in a study by Engler *et al*.[67] many HCWs could not recall receiving training on AMR in their undergraduate education. Previously, undergraduate healthcare curricula did not emphasize AMR and AMS; however, studies indicate that this is changing. In recent years, greater emphasis has been placed on antibiotic prescribing in the healthcare curriculum.[70,85,86] Education is an important aspect of changing attitudes and improving knowledge as it relates to antibiotic prescribing. Importance is therefore placed on healthcare curricula to ensure that graduates are adequately prepared in prudent antibiotic use.[59,70] AMR awareness among healthcare students and HCWs presents a complex picture. These studies underline the importance and need for increased targeted education and training to elevate awareness and knowledge around AMR among the healthcare profession (including undergraduate training) in South Africa.

Mitigating AMR means that adequate AMS and surveillance needs to be in place, thus the standardization of AMS practices and improved education around AMR are necessary to resolve this crisis. As mentioned, most healthcare facilities demonstrate adherence to guidelines, and include the establishment of antimicrobial stewardship committees to report and manage AMR. Significant improvements have been noted in healthcare facilities, where prescribing of antibiotics is aligned with guidelines. The increase of surveillance sites suggests an increased commitment to observing antimicrobial use and AMR trends. This scoping review highlights the challenges of managing AMR through education and AMS in the medical field. Most studies have focused on medicine.[50,53,54,61] Evidence on the contributions of other disciplines, such as dentistry, pharmacy and nursing, to AMR rates and stewardship efforts is limited, underscoring the need for further investigation into their roles in AMR management and strengthening stewardship initiatives within these fields.

Limitations

Although comprehensive mapping has been done in this scoping review, there could be an under-representation of the studies, as there is a large volume of published material on this subject. This scoping review also revealed minimum publications on the subject of AMR in the private health sector in South Africa, thus the findings may not fully reflect the complexities between private and public healthcare settings. In addition, this scoping review has not yielded any studies investigating patient awareness of AMR and antibiotic use, which is an additional contributor to AMR.

Conclusions

This comprehensive scoping review of AMR in South Africa describes the complex nature of this global public health threat. South Africa, which is categorized as a middle-income country, faces substantial challenges associated with this global threat. This review highlights the current efforts to address AMR but also reveals the limitations across various sectors. This is evident in the awareness and knowledge gap among healthcare students, especially when it relates to the mechanism of AMR. HWCs, which include doctors, pharmacists and nurses, exhibit diverging levels of awareness and knowledge as well. This is particularly related to institutional settings and resource deficits between the public and private sectors. Encouragingly, both healthcare students and HCWs acknowledge the impact of inappropriate prescribing. The need for standardized prescribing practices is highlighted, as although most facilities use guidelines, there are still discrepancies in guideline adherence. Antibiotic stewardship and surveillance practices are crucial to aid in combatting AMR. This scoping review offers insight into the multilayered challenges that exist in South Africa as it tries to curb AMR. This effort requires an inclusive approach, which links education, stewardship and surveillance across healthcare sectors.

In conclusion, this scoping review provides valuable insights into the multifaceted challenges posed by AMR in South Africa. Addressing these challenges requires a comprehensive approach encompassing education, stewardship and surveillance efforts across healthcare settings. By implementing interventions based on evidence-based practices, as well as collaboration between various stakeholders, progress can be made in mitigating the impact of AMR in South Africa.

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Transparency declarations

None to declare.

Supplementary data

Figure S1 and Tables S1 to S3 are available as Supplementary data at *JAC-AMR* Online.

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