Knowledge, attitudes and practices of administration of intravenous antimicrobial medicines among intensive care nurses: A descriptive cross-sectional study

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Background. Antimicrobial stewardship (AMS) has become integral to healthcare. In the case of antimicrobial medicines, nurses are responsible for preparing medication, and ensuring its correct and safe administration.
Objective. To describe intensive care nurses' knowledge, attitudes and practices of intravenous antimicrobial infusion administration in the context of access to AMS teaching.
Method. Convenience sampling was conducted of all 161 bedside nurses working in three general intensive care units. The nursing unit manager from each unit was requested to provide information detailing unit demographics and AMS activity within the unit (e.g. existence of AMS; nurse inclusion on the AMS team; frequency of AMS rounds; availability of AMS policies, protocols or guidelines; and training on the administration of intravenous antimicrobial medicines).
Results. Intensive care nursing management reported cessation of AMS programmes in all three units during COVID-19, with minimal activity in one intensive care unit even before the onset of the pandemic. Responses from bedside nurses emphasised the unavailability of in-service AMS teaching in the units (46.4%). Questions on antibiotic groups scored poorly (55.7%). Respondents (63.8%) indicated that the hospital intravenous antibiotic policy was useful but 21.7% reported that they had never seen this policy in their unit. Opportunities for training on intravenous administration of antimicrobial medications were provided on induction to the hospital (14.5%), or in-service (30.4%) by the clinical facilitators (34.8%), or by doctors (24.6%). Fifty-one percent of respondents reported administering antibiotics through a dedicated antibiotic infusion line. Forty-five percent of respondents used a non-dedicated line, and 56.5% of respondents flushed the line between doses.
Conclusion. Results suggest inadequate training. This, coupled with the evident poor access to policies and protocols, may adversely affect nurse knowledge of principles to prevent antimicrobial resistance.
Keywords. Antimicrobial infusions, antimicrobial stewardship, survey, intensive care nurses.

South Afr J Crit Care 2024:40(3):e1539. https://doi.org/10.7196/SAJCC.2024.v40i3.1539

Contribution of the study
This study highlights that a lack of antimicrobial stewardship guidance to bedside nurses persists; that nurses do not always have access to in-service training and policies, protocols, and guidelines; and that flushing the IV administration line following the administration of an intermittent antimicrobial infusion, should be viewed as best practice to ensure the complete delivery of the dose.

Global antimicrobial resistance (AMR) has directly impacted the efficacy of antimicrobial medicines and is of particular concern within intensive care units (ICUs) where critically ill patients are vulnerable to infection owing to the use of invasive devices and immune suppression associated with severe illness.[1] AMR results in difficult-to-treat infections, increasing ICU length of stay, and overall healthcare costs.[2] Prevention of the emergence of resistant pathogens and the spread of these organisms within the healthcare environment is therefore of the utmost importance.[3]

Literature on antimicrobial stewardship (AMS) suggests strongly that this initiative is ineffective without the inclusion of bedside nurses.[4,5] The importance of the AMS role for nurses in antimicrobial medicines administration was first identified in a Royal College of Nursing (RCN) position paper (2014)[6] on the nursing role in combating AMR (followed by other influential health bodies).[7-10] AMS has only recently been considered for inclusion in pre-registration training for nurses.[11,12] Therefore, nurses may not yet have the competencies to fully participate in this initiative.[11,13-16] It is possible that inadequate pre-registration exposure to AMS principles can best be corrected by in-service training. Access to AMS training in the clinical environment is therefore vital in preparing nurses for this clinical role.[12,17,18]

Nurses are responsible for preparing and administering medication, ensuring correct and safe administration.[5,16] Despite this role, the nurse antimicrobial medication knowledge base has been identified as inadequate, potentially adversely affecting optimal antimicrobial therapy and patient outcomes.[19] The medication administration process is a major area for medication errors, with nursing students scoring poorly, particularly with core science questions that address relationships between bacteria, antibiotics and bacterial infections.

This may reflect the difficulties of integrating biosciences within teaching and learning in pre-registration nursing education,[20] with implications for nurse understanding of dosing optimisation in nurse administration of intravenous (IV) antibiotics.[5,12,16,21-23] The present study aimed to describe ICU nurse knowledge, attitudes and practices (KAP) regarding IV antimicrobial treatment within the context of medication administration and AMS pre-registration training received, access to relevant nursing policies and protocols, and availability of related in-service teaching. For the purposes of this study, definitions of KAP were taken from the on-line Oxford Dictionary: 'knowledge' was defined as 'facts, information, and skills acquired through experience or education; the theoretical or practical understanding of a subject;' 'attitudes' was defined as 'a settled way of thinking or feeling about something;' and 'practices' was defined as 'the actual application or use of an idea, or method, as opposed to theories relating to it.'

Methods

Convenience sampling was conducted of all 161 bedside nurses (allocated to direct patient care) and three nursing unit managers working in the general ICUs of three urban hospitals (one private and two public) in one health district in KwaZulu-Natal, South Africa. Table 1 presents the inclusion/exclusion criteria. This cross-sectional survey was the initial part of a larger AMR observational study of optimal nurse administration of intermittent antimicrobial infusions in the selected ICUs.

Data collection

ICU nursing unit manager questionnaire.

The nursing unit managers of each ICU were requested to provide background information relating to ICU demographics and AMS activities within the units; the existence of AMS; nurse inclusion on the AMS team; frequency of AMS rounds; availability of AMS policies; protocols or guidelines; and training on the administration of IV antimicrobial medicines.

ICU nurse questionnaire.

ICU nursing managers notified nurses about the study and facilitated distribution of the questionnaire to nurses on each shift. The nurses received a package containing an information sheet and a consent form, and were invited to complete an enclosed two-page questionnaire including four demographic questions and 25 questions. The latter comprised knowledge (12), attitudes (6) and practices (7), intending to cover formal and informal training on administration of IV antimicrobial medicines and AMS. Nurses were requested to post the completed questionnaire and consent form in two separate envelopes in a sealed collection box. The investigator was present daily to answer questions about the study and to collect completed questionnaires.

Data analysis

Collected data from each study site were tabulated on a spreadsheet (Microsoft, USA) and a statistical analysis using Stata 17 (Stata Corp., USA) was conducted, with the assistance of a statistician. Descriptive statistics (frequencies and percentages) were used to summarise the research results. Results were stratified by hospital (private v. public), nurse qualifications (enrolled v. registered), years of nursing experience, and whether or not advanced training had been received; for e.g., ICU training. Responses were compared using Fisher's exact test. Statistical significance was taken at a threshold of $p \leq 0.05$.

Validity and reliability

In the absence of suitable questionnaires, the nurse KAP questionnaire was designed for this study by the authors and was completed and reviewed for validity and reliability by an expert group of ICU-trained nurses. Following this review, the questionnaire was reassessed, redesigned and several questions clarified. New questions included: (*i*) standard operating procedures (SOP); and (*ii*) further information on respondent completion of the questionnaire. The adjusted questionnaire was accepted by the expert group.

Ethical approval

Ethical approval to conduct the study was obtained from the Research Ethics Committee of the University of KwaZulu-Natal (ref. no. BE709/18) following approval by the Provincial Research Ethics Committee (ref. no. KZ 201905 032), Department of Health authorities and the private hospital group's research and ethics board. Permission to access the ICUs was obtained from hospital managers in both private and public hospitals. The aim of the study was explained during a scheduled meeting with unit management. All nurses working in the study ICUs were invited to take part in the study, were informed of its purpose, and had the right to withdraw at any stage. Written consent was obtained, and anonymity and confidentiality were maintained.

Results

Demographics

Nurse respondents (N=69) were employed in two public ICUs (n=25, 36.2% and n=28, 40.6%) and one private ICU (n=16, 23.2%). Most respondents (n=42, 60.9%) were between the age groups of 30 - 39 (n=24, 34.8%) years and 40 - 49 (n=18, 26.1%) years and were employed on a full-time basis by the hospitals (n=60, 87.0%). Twenty-five (36.2%) respondents had >10 years of nursing experience. Sixty-three respondents had a registered nurse qualification (91.3%) of which 55 (79.7%) were nursing diplomas and eight (11.6%) were nursing bachelor's degrees. Thirty-seven (53.6%) registered nurses additionally had achieved an ICU diploma. Four (5.8%) respondents (enrolled) had a two-year nurse certificate. In South Africa, the South African Nursing Council (2021) prohibits the use of enrolled nurses (ENs) for primary patient care within acute care areas such as ICUs.[24] Two respondents did not answer this question.

ICU nursing unit manager questionnaire

All nursing unit managers (N=3, 100%) responded to the request for ICU demographics and AMS information. They reported no AMS activity during the COVID-19 pandemic. Prior to that, there was minimal AMS activity in ICU A (i.e. no team or programme), although the nursing unit manager reported that if any teaching occurred, it was given by the doctors. Nursing unit managers of both ICU B and C reported AMS programmes prior to the pandemic. Weekly AMS rounds were held in both these units, and the pharmacist was reported to be the person providing the most AMS activities. Only ICU C reported nurses on the AMS team, although AMS rounds and other activities were discontinued during the COVID-19 pandemic. Only this unit was reported to have a written AMS protocol. Nursing unit managers reported that none of the units had specific protocols guiding nurse administration of IV antimicrobial medicines, although ICU C's nursing unit manager reported that necessary information was given to nurses on induction to the hospital and then by the clinical facilitator (CF) within the unit.

ICU nurse questionnaire

Of the 161 KAP questionnaires distributed to nurses, 69 (42.9%) were completed (Supplementary Table 1; https://www.samedical.org/file/2309).

Knowledge

Less than 50% of nurses reported having received AMS teaching pre-registration (Q.11), with similar numbers (46.4%) reporting minimal access to further AMS training during their hospital employment (Q.12); described as 'once a month' (13.0%), 'once a year' (33.3%), or 'never' (49.3%) (Q.13). When AMS in-service training was given (Q.16), this was informal in the ICU; either at the bedside (37.7%) or in the duty room (27.5%). Most nurses (95.7%) received formal training pre-registration on antimicrobial medicines (Q.1), and administration of IV injections (92.8%) (Q.2), which provided opportunities for practice with antimicrobial infusions (73.9%) (Q.3). Further opportunities for training on IV administration of antimicrobial medications (Q.17) were provided on induction to the hospital (14.5%), or in-service (30.4%) by the CF (34.8%) or doctors (24.6%) (Q.18) (Supplementary Table 1).

Non-responses within the questionnaire were the highest (mean 20.9%) to questions testing basic knowledge of antimicrobial groups (Q.4 a - e). A significantly higher number of answers from private hospital nurses were correct in response to Q.4a 'Amoxicillin is a …'(75.0%, p=0.048; 95% confidence interval (CI) 47.6 - 92.7) and Q.4d 'Meropenem is a …' (81.3%, p=0.043; 95% CI 54.4 - 96.0). Nurses who had >10 years of nursing experience gave more correct answers to basic antimicrobial group knowledge, i.e., Q.4c 'Carbapenems include …' (84.0%, p=0.02; 95% CI 63.9 - 95.4). and Q.4e 'Augmentin contains …' (68.0%, p=0.004; 95% CI 46.5 - 85.1). Within the private hospital, hospital-employed nurses were more able to correctly answer Q.4b 'Zinacef is a …' than agency-employed nurses (100.0%, p=0.036; 95% CI 69.1 - 88.2) (Table 2).

Attitudes

Fifty-six respondents (81.2%) reported that they felt confident giving IV antimicrobial medicines to patients (Q.6). Those needing guidance with this (72.5%) (Q.8), referred mostly to three information resources: package inserts (68.1%), doctor (59.4%), and ICU shift leader (55.1%) (Q.7). Despite nursing unit managers stating that there were no specific hospital IV antimicrobial medicines policies, many nurse respondents said these were available and useful (78.3%) (Q.10) but had varying opinions on where they would be able to

Table 1. Inclusion and exclusion criteria

Inclusion criteria	• All nurses allocated to patient care/shift leading duties in the study ICUs • All nurses working day/night shift duties • All nurses registered/enrolled with the South African Nursing Council • All nurses employed by the study hospital on a permanent full/part-time basis • All nurses engaged by the study hospital as agency temporary nurses
Exclusion criteria	• Enrolled nursing auxiliary nurses* • Caregivers

*Enrolled nursing auxiliary nurses have a limited scope of nursing.

Table 2. Antibiotic group knowledge (Q.4)

Respondents *N*=69		(a) Amoxicillin is a… penicillin	(b) Zinacef is a… cephalosporin	(c) Carbapenems include… ertapenem	(d) Meropenem is a… carbapenem	(e) Augmentin contains… clavulanic acid
Correct answer		36 (n=60, 60.0%)	43 (n=49, 87.8%)	44 (n=57, 77.2%)	40 (n=54, 74.1%)	29 (n=53, 54.7%)
Incorrect answer		24 (n=60, 40.0%)	6 (n=49, 12.2%)	13 (n=57, 22.8%)	14 (n=54, 25.9%)	24 (n=53, 45.3%)
No answer		9 (n=69, 13.0%)	20 (n=69, 29.0%)	12 (n=69, 17.4%)	15 (n=69, 21.7%)	16 (n=69, 23.2%)
Hospitals, *N*=69	Private, n=16	12 (n=16, 75.0%)	13 (n=16, 81.3%)	13 (n=16, 81.3%)	13 (n=16, 81.3%)	6 (n=16, 37.5%)
	Public, n=53	24 (n=53, 45.3%)	30 (n=53, 56.6%)	31 (n=53, 58.5%)	27 (n=53, 50.9%)	23 (n=53, 43.4%)
	p-values	0.048	0.09	0.14	0.043	0.78
Years of nursing experience, n=56	>10 years, n=25	14 (n=25, 56.0%)	18 (n=25, 72.0%)	21 (n=25, 84.0%)	17 (n=25, 68.0%)	17 (n=25, 68.0%)
	<10 years, n=31	18 (n=31, 58.1%)	17 (n=31, 54.8%)	17 (n=31, 54.8%)	16 (n=31, 51.6%)	8 (n=31, 25.8%)
	p-values	0.247	0.45	0.02	0.45	0.004
Qualifications, n=69	ICU trained, n=29	11 (n=29, 37.9%)	20 (n=29, 69.0%)	19 (n=29, 65.5%)	18 (n=29, 62.1%)	15 (n=29, 51.7%)
	non-ICU trained, n=36	22 (n=36, 61.1%)	20 (n=36, 55.6%)	21 (n=36, 58.3%)	20 (n=36, 55.6%)	14 (n=36, 38.9%)
	EN, n=4	3 (n=4, 75.0%)	3 (n=4, 75.0%)	4 (n=4, 100%)	2 (n=4, 50.0%)	0 (n=4, 0%)
	p-values	0.139	0.51	0.34	0.86	0.13
Nurses with advanced training, n=65	RN with ICU training and/or degree, n=39	19 (n=39, 48.7%)	27 (n=39, 69.2%)	27 (n=39, 69.2%)	25 (n=39, 64.1%)	21 (n=39, 53.8%)
	RN, n=26	14 (n=26, 53.8%)	13 (n=26, 50.0%)	13 (n=26, 50.0%)	13 (n=26, 50.0%)	8 (n=26, 30.8%)
	p-values	0.80	0.13	0.13	0.31	0.08
Private healthcare sector only,* n=16	Hospital employed nurses,* n=10	9 (n=10, 90.0%)	10 (n=10, 100%)	9 (n=10, 90.0%)	9 (n=10, 90.0%)	5 (n=10, 50.0%)
	Agency nurses,* n=6	3 (n=6, 50.0%)	3 (n=6, 50.0%)	4 (n=6, 66.7%)	4 (n=6, 66.7%)	1 (n=6, 16.7%)
	p-values	0.12	0.036	0.52	0.52	0.31

EN = enrolled nurse; RN = registered nurse.

access these, namely the duty room (56.5%), the patient's file (20.3%), or the medication trolley (2.9%) (Q.9). Nine nurses (13.0%) reported that they had never seen the policy (Q.10), and six nurses (8.7%) stated that there was no policy in their ICU (Q.9) (Supplementary Table 1). Nurses were asked to indicate their education needs (Q.25); 65.2% indicated AMR, different groups of antibiotics (60.9%), antifungals (23.2%), how to give antibiotic infusions (15.9%) and other, AMS (1.4%) and antimicrobial medicine side-effects (1.4%) (Supplementary Table 1).

Practices

Although nurses administered antimicrobial medicines to patients by all routes, only 45 respondents (65.2%) reported that they administered IV infusions (Q.5), although 62 nurses (89.9%) reported that they commonly used an infusion pump (Q.20). Non-ICU-trained registered nurses (RNs) (42.3%, p=0.047; 95% CI 23.1 - 56.5) and nurses with <10 years of training (45.2%, p=0.003; 95% CI 27.3 - 64.0) reported that the CF instructed them on the use of infusion equipment. ICU-trained nurses (41.4%, p=0.011; 95% CI 23.5 - 61.1) or nurses with >10 years of training (40.0%, p=0.01; 95% CI 21.1 - 61.3) noted they would refer to the SOP for this information. ICU-trained nurses also indicated that they would interact with doctors regarding this (51.7%, p=0.022; 95% CI 32.5 - 70.6) (Table 3).

Thirty-five nurses (50.7%) reported using a dedicated antibiotic line, with 31 nurses (44.9%) stating that they used the IV-antibiotic line to deliver intermittent non-antibiotic medication such as IV paracetamol (Perfalgan) (Q.23). One respondent was uncertain (1.4%). Three respondents (4.3%) indicated that an intermittent infusion such as KCl would not be administered through the antimicrobial medicines dedicated line. In Q.24, 39 nurses (56.5%) (public ICU, 62.3%, private ICU, 37.5%) reported that the line was cleared between medication doses (Table 4). In response to Q.22, 57 nurses (82.6%) reported changing infusion lines every 72 hours (Supplementary Table 1). This showed a high level of respondents from the public ICUs (90.6%, p=0.004; 95% CI 79.3 - 96.9) and a positive correlation with nurses who had obtained advanced training i.e. nurses who were ICU trained and nurses with nursing degrees (92.3%, p=0.02; 95% CI 79.1 - 98.4) (Table 5).

Discussion

In order to reduce AMR in high-use antimicrobial medicines environments such as ICUs, it has been found that active stewardship raises awareness of best clinical practice.[5] All three ICU nurse managers reported a lack of AMS programmes and teaching available to nurses working in the ICUs both before and during the COVID-19 pandemic. This concern was supported by the nurse respondents.

Knowledge

The importance of referring to medication information resources cannot be overstated. Although respondents indicated receiving formal training on antimicrobial medicines, a short series of questions asking respondents to, identify which antibiotic group commonly used medicines belonged to showed inadequate knowledge. This supports the findings of Marath *et al.*[14] that nurse identification of antibiotics in various categories was poor. The high non-response rate and errors in this section suggest that respondents were uncertain about the answers, additionally suggesting that respondents either were not able to access information resources in the units to find the correct information, or did not know how to use commonly used medicine references guides such as *MIMS*.[25] An appreciation of various antimicrobial groups assists in understanding treatment, i.e. indications for a broad-spectrum antibiotic, and the necessity for optimal infusion of that medication.

Table 3. Who instructs you on which equipment to use? (Q.21)

Responses	(Multiple responses possible)	SOP	Shift leader	Clinical facilitator	Pharmacist	Doctor
Hospitals, *N*=69	Private hospital, *n*=16	5 (*n*=16, 31.3%)	7 (*n*=16, 43.8%)	6 (*n*=16, 37.5%)	1 (*n*=16, 6.3%)	4 (*n*=16, 25.0%)
	Public hospital, *n*=53	11 (*n*=53, 20.8%)	13 (*n*=53, 24.5%)	13 (*n*=53, 24.5%)	1 (*n*=53, 1.9%)	22 (*n*=53, 41.5%)
	p values	0.50	0.21	0.35	0.41	0.37
Years of nursing experience, *n*=56	>10 years, *n*=25	10 (*n*=25, 40.0%)	6 (*n*=25, 24.0%)	2 (*n*=25, 8.0%)	1 (*n*=25, 4.0%)	10 (*n*=25, 40.0%)
	<10 years, *n*=31	3 (*n*=31, 9.7%)	8 (*n*=31, 25,8%)	14 (*n*=31, 45.2%)	1 (*n*=31, 3.2%)	11 (*n*=31, 35.5%)
	p-values	0.01	1.00	0.003	1.00	0.79
Qualifications, *n*=69	ICU traine,- *n*=29	12 (*n*=29, 41.4%)	9 (*n*=29, 31.0%)	4 (*n*=29, 13.8%)	1 (*n*=29, 3.5%)	15 (*n*=29, 51.7%)
	Non-ICU trained, *n*=36	4 (*n*=36, 11.1%)	9 (*n*=36, 25.0%)	14 (*n*=36, 38.9%)	0 (*n*=36, 0%)	9 (*n*=36, 25.0%)
	Enrolled nurse, *n*=4	0 (*n*=4, 0%)	2 (*n*=4, 50.0%)	1 (*n*=4, 25.0%)	1 (*n*=4, 25.0%)	3 (*n*=4, 75.0%)
	p-values	0.011	0.58	0.058	0.052	0.022
Advanced training, *n*=65	RN with ICU training and/or degree *n*=39	14 (*n*=39, 35.9%)	12 (*n*=39, 30.8%)	7 (*n*=39, 17.9%)	1 (*n*=39, 2.6%)	17 (*n*=39, 43.6%)
	RN, *n*=26	2 (*n*=26, 7.7%)	6 (*n*=26, 23.1%)	11 (*n*=26, 42.3%)	0 (*n*=26, 0%)	7 (*n*=26, 26.9%)
	p-values	0.017	0.58	0.047	1.00	0.20
*Private healthcare sector only, *n*=16	Hospital employed nurses,* *n*=10	3 (*n*=10, 30.0%)	4 (*n*=10, 40.0%)	5 (*n*=10, 50.0%)	0 (*n*=10, 0%)	2 (*n*=10, 20.0%)
	Agency nurses,* *n*=6	2 (*n*=6, 33.3%)	3 (*n*=6, 50.0%)	1 (*n*=6, 16.7%)	1 (*n*=6, 16.7%)	3 (*n*=6, 50.0%)
	p-values	1.00	1.00	0.31	0.38	0.30

Table 4. Flushing infusion line between doses (Q.24)

Responses		Yes	No/sometimes
Hospitals, *N*=69	Private hospital, *n*=16	6 (*n*=16, 37.5%)	10 (*n*=16, 62.5%)
	Public hospital, *n*=53	33 (*n*=53, 62.3%)	19 (*n*=53, 35.8%)
	p values	0.086	
Years of nursing experience, *n*=56	>10 years- *n*=25	15 (*n*=25, 60.0%)	10 (*n*=25, 40.0%)
	<10 years, *n*=31	19 (*n*=31, 61.3%)	12 (*n*=31, 38.7%)
	p-values	1.00	
Qualifications, *n*=69	ICU trained, *n*=29	18 (*n*=29, 62.1%)	11 (*n*=29, 37.9%)
	Non-ICU trained, *n*=36	19 (*n*=36, 52.8%)	16 (*n*=36, 44.4%)
	Enrolled nurse, *n*=4	2 (*n*=4, 50.0%)	2 (*n*=4, 50.0%)
	p-values	0.794	
Advanced training, *n*=65	RN with ICU training and/or degree, *n*=39	25 (*n*=39, 64.1%)	14 (*n*=39, 35.9%)
	RN, *n*=26	12 (*n*=26, 46.2%)	13 (*n*=26, 50.0%)
	p-values	0.30	
*Private healthcare sector only, *n*=16	Hospital employed nurses,* *n*=10	2 (*n*=10, 20.0%)	8 (*n*=10, 80.0%)
	Agency nurses-* *n*=6	4 (*n*=6, 66.7%)	2 (*n*=6, 33.3%)
	p values	0.12	

RN = registered nurse.

Table 5. When is the IV antibiotic administration giving set changed? (Q.22)

Responses	(Multiple responses possible)	When it is contaminated	When the antibiotic infusion course is finished	When changing from gravity to infusion pump sets	Every 72 hours
Hospitals, *n*=69	Private hospital, *n*=16	2 (*n*=16, 12.5%)	2 (*n*=16, 12.5%)	0 (*n*=16, 0%)	9 (*n*=16, 56.3%)
	Public hospital, *n*=53	13 (*n*=53, 24.5%)	3 (*n*=53, 5.7%)	1 (*n*=53, 1.9%)	48 (*n*=53, 90.6%)
	p-values	0.49	0.33	1.00	0.004
Years of nursing experience, *n*=56	>10 years, *n*=25	7 (*n*=25, 28.0%)	1 (*n*=25, 4.0%)	0 (*n*=25, 0%)	22 (*n*=25, 88.0%)
	<10 years, *n*=31	7 (*n*=31, 22.6%)	4 (*n*=31, 12.9%)	1 (*n*=31, 3.2%)	22 (*n*=31, 71.0%)
	p-values	0.76	0.37	1.00	0.19
Qualifications, *n*=69	ICU trained, *n*=29	8 (*n*=29, 27.6%)	1 (*n*=29, 3.5%)	0 (*n*=29, 0%)	27 (*n*=29, 93.1%)
	Non-ICU trained, *n*=36	6 (*n*=36, 16.7%)	3 (*n*=36, 8.3%)	1 (*n*=36, 2.8%)	27 (*n*=36, 75.0%)
	Enrolled nurse, *n*=4	1 (*n*=4, 25.0%)	1 (*n*=4, 25.0%)	0 (*n*=4, 0%)	3 (*n*=4, 75.0%)
	p-values	0.50	0.22	1.00	0.097
Advanced training, *n*=65	RN with ICU training and/or degree, *n*=39	9 (*n*=39, 23.1%)	2 (*n*=39, 5.1%)	0 (*n*=39, 0%)	36 (*n*=39, 92.3%)
	RN, *n*=26	5 (*n*=26, 19.2%)	2 (*n*=26, 7.7%)	1 (*n*=26, 3.8%)	18 (*n*=26, 69.2%)
	p-values	0.77	1.00	0.40	0.02
*Private healthcare sector only, *n*=16	Hospital employed nurses,* *n*=10	1 (*n*=10, 10.0%)	0 (*n*=10, 0%)	0 (*n*=10, 0%)	5 (*n*=10, 50.0%)
	Agency nurses,* *n*=6	1 (*n*=6, 16.7%)	2 (*n*=6, 33.3%)	0 (*n*=6, 0%)	4 (*n*=6, 66.7%)
	p-values	1.00	0.13	n/a	0.63

IV = intravenous; RN = registered nurse.

Less than 50% of respondents reported receiving teaching on AMS during pre-registration training and since qualifying as a nurse. Nurse respondents' comments referencing inadequate access to AMS resources supported the nursing unit managers' reports of unavailability of AMS teaching to nurses in the units.

Nurse educational needs should be met through active AMS programmes, which include ward rounds and access to AMS protocols, policies and guidelines. Abbas *et al.*[26] reported the absence of AMS training among 81.5% of bedside nurses, supporting the findings of an integrative review of the nurses' roles and contribution to AMS, within 52 published papers. These identified nursing knowledge, learning needs, and education as one of five major themes, with concerns about limited nurse knowledge of antimicrobials and stewardship[4] – this despite AMS guidelines[12] recommending that AMS nurse training should be offered during undergraduate education,[7] and undergraduate **and** postgraduate education.[6] Additional recommendations were for audit feedback from AMS,[27] and in-service training.[7,10] This additionally supports opportunities for continuing professional development (CPD) by hospitals and AMS interest groups.

Attitude

Although nursing unit managers reported that there were no protocols guiding nurse administration of IV antimicrobial medicines, there were contradicting responses: with some nurse respondents reporting that the hospital IV antimicrobial medicines policy was useful. Others were unsure that there was such a document, or where to access it. The few responses from nurses reporting informal training on IV administration by CFs, calls into question the effectiveness of bedside training. Nurse management

reports of minimal AMS guidance in the study ICUs were corroborated by the low numbers of respondents who reported receiving in-service training on AMS. Multidisciplinary health professionals' perceptions of nurse-initiated AMS in a general ICU are that nurses were unable to fully participate in AMS owing to inadequate exposure to AMS teaching during formal education and hospital induction. This, together with few in-service training opportunities owing to staffing constraints, affected nurse capacity to participate in AMS discussions. Without exposure to the broader principles of AMS during formal education, hospital induction, and in-service training, and without access to AMS policy guidelines, participation in AMS ward rounds, or CPD opportunities, nurses are not empowered to support AMS strategies or collaborate effectively with other healthcare staff.[15] Nursing education regarding the nature of AMR and how it can be contained is a necessity in all healthcare settings.[6,10,26] This should also include education on optimal administration of antimicrobial therapy and the link with patient safety.[8]

Practice

Not all respondents indicated that they administered IV antimicrobial medicines via infusions, an unlikely response as the common mode of administration for these medicines was by infusion (using infusion pumps) in all the ICUs under study. Aspects of reported practice complied with standard operating practices within the study hospitals but these practices may not reflect current global recommendations. Respondents reported compliance with local hospital recommendations for infusion administration line changes every 72 hours. Current guideline recommendations from the Royal College of Nursing (UK)[28] and the Infusion Nurses Society (INS) (USA)[21] are that administration sets used for a continuous infusion should be changed at 96-hour intervals, and primary intermittent infusion sets, every 24 hours. The INS acknowledges that there is still confusion regarding line changes. There is an absence of studies addressing administration-set changes for intermittent infusions. When an intermittent infusion is repeatedly disconnected and reconnected for infusion delivery/administration, there is an increased risk of contamination at the spike end.[21] However, Rickard *et al.*[29] in a randomised controlled trial of central line changes (administering crystalloids, non-lipid parenteral nutrition, and medication infusions), advise that infusion set use can be extended to 7 days. Findings were 1.8% of catheter-related blood stream infection for a 7-day line change group compared with 1.5% for a 4-day change group (showing an absolute risk difference of 0 - 32% (95% CI -0.73 - -1.37). These recommendations should be considered in the light of discarded medication in changed administration lines in the absence of flushing practice.

In the varying responses to the study survey questions regarding other management of administration lines, over a third of respondents reported that they did not have an antibiotic 'dedicated' line and that this line was not always cleared of other medication before an intermittent dose of antibiotic. Relevant to this finding is Van Huizen *et al.*'s[5] assertion that nursing practices within AMS should also include judicious care with infusions of IV antimicrobial medicines, and in particular the use of a post-administration flush to complete the administration of a full dose. Although the study questionnaire did not specifically use the term 'flushing', questions related to flushing practice and may be significant in discarding unflushed administration lines that still hold antimicrobial medication.[5,21-23,30] There is a need to consider AMR with reference to nurse administration of antimicrobial medicines.[22,23] At present, the nurse's role in optimal antimicrobial medicines use is identified as monitoring the practice of prescribing clinicians, i.e. identifying the use of broad-spectrum antibiotics, duration of antibiotic prophylaxis, appropriate antibiotic timeout, de-escalation to oral therapy, and appropriate discharge instructions and follow-up in the outpatient setting.[18] However, the importance of using best administration practices of IV antimicrobial medicines is gaining recognition in meeting the challenge of dose optimisation as a tool to slow the development of drug-resistant bacteria.[5]

Conclusion

AMS is a proactive worldwide initiative to reduce AMR through appropriate use of antimicrobial therapy, including strict compliance with the dosing regimen. Both nursing managers and nurse respondents indicated the unavailability of AMS teaching in the units. While responses of nurses in the questionnaire suggest nurses are inadequately trained with insufficient knowledge of AMR and AMS, this may reflect the low numbers of ICU-trained nurses within the ICUs. While respondent ENs' numbers were small, it is also concerning that ENs were assigned to primary care of patients. Additionally, IV medications should only be administered by RNs. Access to in-service training and written policies should be facilitated by hospital and unit management. The way IV antimicrobial medications are administered may impact the efficacy of the drugs, and hence basic medication safety measures must be ensured by educating nurses about the link between AMS and AMR. SOPs should clarify the requirement to provide an antibiotic-'dedicated' administration line, flushing practices, and line changes. Current recommendations for 72-hour administration line changes should be interrogated in the literature with regard to the current uncertainty of flushing/non-flushing of lines to address the potential problem of loss of antimicrobial dose.

Study limitations

The questionnaire was reviewed by an expert ICU nurse group but was not validated by pre-testing within the intended study sites. Data collection was affected by the COVID-19 pandemic and could recommence only once conditions within the hospitals had stabilised. The small response rate is a further limitation. The questionnaire was designed with 'mark the box' areas for responses and may have been better designed with options for written responses. Questionnaires posted together in the sealed response box on some shifts showed that identical errors had been made in the knowledge section, suggesting that respondents had asked each other for assistance. Only three units were included in the study which was conducted in one area of SA. While the study hospitals are typical of many state and private hospitals in the country, our findings may not be generalisable to ICUs with different patient or staffing profiles; further testing is therefore needed. The nature of the questionnaire developed did not make it possible to provide an overall analysis on the current level of knowledge, attitude and practices of the respondents.

Declaration. None.

Acknowledgements. None.

Author contributions. JR, SE and PB contributed to the conceptualisation, development and outline of this manuscript. JR collected the data, conducted the analysis of the data, wrote the analysis, and drafted and revised the paper. SE and PB conducted an analysis and revised the article.

Data availability. The datasets generated and analysed during the present study are available from the corresponding author (GM) on reasonable request. There is no restriction on the anonymised data set.

Funding. This study is supported by funding from the South African Research Chairs Initiative of the Department of Science and Technology and National Research Foundation of South Africa (Grant No. 98342), and from the Critical Care Society of Southern Africa.

Confl cts of interest. None.

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Received 15 September 2023; accepted 2 October 2024.