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Knowledge, Attitude, and Practice of Healthcare Providers toward Antimicrobial Stewardship in Electronic Medical Record at Tertiary Health Care Hospital in Saudi Arabia

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Antimicrobial resistance is considered as one of the greatest threats to global health issues, and antimicrobial stewardship programs have been implemented worldwide to combat this major threat. In Saudi Arabia, the emergence of multi-drug-resistant strains is one of the growing problems in healthcare facilities. Although there are numerous reports about antimicrobial stewardship strategies in Saudi Arabia, there is limited information known about electronic medical records (EMR) based antimicrobial stewardship (AMS) modules. This study aimed to assess healthcare providers' knowledge, attitude, and practice toward an electronic medical record-based antimicrobial stewardship module in a tertiary hospital in Saudi Arabia. A cross-sectional study was conducted using pre-designed, tested, self-administered questionnaire. The questionnaire included specific sections to assess the participant's knowledge, attitude, and practices related to EMR based AMS. A total of 280 healthcare providers participated in this study. The majority of them 171 (61.1%) were females. Regarding the educational background, 152 (54.3%) of participants had a bachelor's degree. Only 128 participants (45.7%) reported being aware about the implemented antimicrobial stewardship applications within electronic medical records. Additionally, 102 (36.4%) of participants strongly agreed that having direct access to local antibiotic-related guidelines through electronic medical records will improve appropriate antibiotic use. However, only 62 (22.1%) of participants stated that they always review the hospital guidelines for recommended antibiotic choices for their patient's condition, while 37 (13.2%) of participants said that they never do so. The knowledge, attitudes, and practices related to EMR based AMS were found to be lower than expected. A comprehensive intervention, including education and training programs for healthcare professionals, is needed to enhance their knowledge, and positively influence their attitude and practice in the hospital.

Keywords: antimicrobial stewardship; electronic medical records; knowledge; attitude; practice

I. INTRODUCTION

Antimicrobial resistance is considered one of the greatest threats to human health and a major global health issue by the World Health Organization (So *et al.*, 2010). Antimicrobial resistance is attributed to many factors, but the most important factor is the misuse of antimicrobials, leading to the emergence of resistant strains of microbes (Almeleebia *et al.*, 2021; Alrasheedy *et al.*, 2020). To combat this major threat, antimicrobial stewardship (AMS) programs have been implemented around the globe, these programs have been effective in improving patient outcomes, the usage of antibiotics, and increase savings on healthcare costs (Kullar *et al.*, 2013). AMS programs are hospital-based interventions

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designed to improve the use of antimicrobials, reduce adverse events associated with antimicrobials, and increase the rate of correct prescription of antimicrobials (Davey *et al.*, 2013).

The emergence of multi-drug-resistant strains is one of the growing problems in hospitals and healthcare facilities in Saudi Arabia (Thabit *et al.*, 2023). Saudi Arabia is a regular destination for more than 10 million people, who travel annually from around the world to visit Medina and Makkah for the Umrah and pilgrimage. Additionally, Saudi Arabia hosts more than 10 million expats, composing more than 30% of the country's population (Alghamdi *et al.*, 2021). Moreover, hospitals in Saudi Arabia reported numerous antibiotic misuse practices (Zowawi, 2016). Being a global hub, the emergence of resistant strains, and the misuse of antibiotics, all of these factors combined not only contribute to the antimicrobial resistance problem in Saudi Arabia but also increase the risks for dissemination and globalisation of this public health threat, urging for the need for robust interventions (Alawi & Darwesh, 2016).

To address the challenges of antimicrobial resistance in Saudi Arabia, the Ministry of Health (MOH) developed a national AMS plan as part of the Arab Gulf regional strategy to face antimicrobial resistance, this plan includes the implementation of AMS strategies in MOH and private hospitals in Saudi Arabia (Alomi, 2017). After the development of this national plan, several reports emerged describing the successful implementation of AMS strategies in Several hospitals in the country (Alghamdi *et al.*, 2021). For decades, AMS strategies were based on using prospective audits and in-person feedback to monitor and promote the proper dispensing of antibiotics, however recently, a major change occurred by integrating AMS programs into patients' electronic medical records (EMR) leading to the emergence of EMR based AMS modules (Strahilevitz *et al.*, 2022).

Electronic medical records (EMR) use has become more common with clinical decision support and has been assisting antimicrobial stewardship (AMS) programs and clinician adherence to the clinical practice guidelines for several years (Pestotnik *et al.*, 1996). In recent years, information technology has significantly impacted the delivery of healthcare services. One significant example is the advocacy of the Infectious Disease Society of America and the Society for Healthcare Epidemiology of America for implementing information technology in AMS programs. Electronic medical records are health-related records managed by authorised staff within a healthcare organisation (Barlam *et al.*, 2016).

Physicians can utilise computerised systems to prescribe antimicrobials and use decision support systems for decision-making. The electronic medical record-based AMS applications were able to improve prescription accuracy and support AMS programs. However, few studies have explored the success of incorporating EMR functionalities to optimise AMS programs (Catho *et al.*, 2021). Implementing EMR reminders has led to decreased prescription errors and promoted adherence to antibiotic guidelines, including recommendations for the optimal treatment duration, resulting in reduced use of certain antibiotics (Kaul *et al.*, 2020). A study recommends the establishment of a mandatory protocol for prescribing antibiotics through electronic medical records to enhance accuracy and appropriateness, mainly due to variations in prescription suitability across different hospitals. Additionally, thorough documentation facilitates rapid assessment and standardisation of antimicrobial therapy by the AMS teams (van den Broek *et al.*, 2021).

Electronic prescription and referral systems and EMRs are now relied on heavily in modern healthcare practice, and they can help in providing AMS education, interventions, and data (Hebert *et al.*, 2012). This integration between EMR and AMS strategies has been laid out to fully optimise and make a long-term impact on patients' outcomes (Kullar *et al.*, 2013). The success of such a new system depends mainly on the perceptions and attitudes of the stakeholders, in this case, the healthcare providers (Strahilevitz *et al.*, 2022). Even though there are numerous reports about AMS strategies in Saudi Arabia, little is known about EMR-based AMS modules. This study aimed to assess healthcare providers' knowledge, attitude, and practice towards an EMR-based AMS module in a tertiary hospital in Saudi Arabia.

A. Hospital Electronic Medical Record (EMR) System with Antimicrobial Stewardship (AMS) Module

The incorporating EMR-based AMS functionalities has various features. These include a computerised system that the healthcare provider can utilise to prescribe antimicrobials. Additionally, there are decision support systems, mandatory protocols, and orders set for indications, dosage, duration, and route of administration of prescribing antimicrobials. Furthermore, it has a standardisation of antimicrobial therapy plans and restrictive prescriptive authority, where certain antimicrobials require prior authorisation for use.

There is also prospective review and feedback, where the antimicrobial stewards review active antibiotic orders and provide recommendations to clinicians based on the availability of microbiology results and clinical features. Also, the dose optimisation feature, which customises the treatment based on the patient's clinical characteristics, alert systems to identify patients who need review and de-escalation opportunities, visual analytics automated electronic antibiogram, and a computerised trigger tool for identifying patients who are candidates for an intravenous line (IV) to the oral antibiotic, as well as antimicrobial consumption, summary of the antimicrobial prescribing, and day of therapy summary (Weihs, 2020; Simpao *et al.*, 2018; Berrevoets *et al.*, 2017; Hamdan *et al.*, 2024).

II. MATERIALS AND METHOD

A. Study Setting and Design

This was a cross-sectional, facility-based study conducted at tertiary health care with 1100 beds, in Riyadh, Saudi Arabia. The study included critical care, emergency medicine, internal medicine, and surgery departments were involved in this study.

B. Study Population

The study population involved healthcare providers who are responsible for prescribing, dispensing, and administering antibiotics in the hospital, which include: physician pharmacists, and nursing staff. Participants who refused to participate or were unavailable during data collection were excluded from the study.

C. Recruitment

Participants were invited to the study by an invitation email sent to all eligible staff at the hospital. Along with a copy of the questionnaire and a survey cover page explaining the aim of the study, and voluntary participation. The participants who signed it went to the next step of questionnaire completion. Anonymity and confidentiality were maintained during the whole process of the research.

D. Study Tool

A structured online self-administered questionnaire in the English language was used as a data collection tool. The questionnaire was composed of four sections: the sociodemographic section (six items), the knowledge section (nine items), the attitude section (eleven items), and the practice section (nine items).

The first section gathered the socio-demographic characteristics of the respondents which include gender, age, education level, job title, years of experience, and service of each study participant. The second section was the Knowledge questions to measure participants' level of knowledge about the general understanding of AMS concepts and their application in the EMR. The scoring of this instrument was in the form of "Yes", "No", and "Don't know" responses for each question. Respondents were to choose either yes, no, or don't know by choosing one of them. Each "yes" response was scored of one (1) point score, while "no" or "not sure" responses were scored of zero (0) score. The third section focused on participant attitude toward applying the Electronic Medical Record (EMR) based antimicrobial stewardship (AMS) activities. The scoring of responses was based on the Likert scale from strongly disagree to strongly agree. Each of the items was scored based on the respondents from 1 to 5; with strongly disagree (1), disagree (2), neutral (3), agree (4), and strongly agree (5).

The fourth one focused on participant practice on the EMR-based AMS interventions towards improving appropriate antibiotic prescription and evaluation practices. The scale uses a 5-point scoring system ranging from Always to Never. To score, we assigned a numeric value to each response. For always score awarded was 5 while often (4), sometimes (3), never (2), and not applicable had a score of (1). Then the mean score was determined.

E. Reliability and Validity of the Questionnaire

The questionnaire was developed and reviewed by a panel of experts in AMS after an extensive review of the literature. The questionnaire was piloted for the pre-final version of the questionnaire on 30 participants to assess its validity and clarity. Cronbach's alpha for the questionnaire was estimated at 0.80.

F. Sample Size Estimate

The study population was stratified according to their professions into three groups: physicians, nurses, and pharmacists. To ensure appropriate representation from each group of healthcare providers, the proportionate population sampling method for nurses, physicians, and pharmacists, respectively, was used. Hence, 109 nurses, 86 physicians, and 55 pharmacists were approached on a random basis from each department and the total sample size was determined to be 250. To account for an anticipated 12% non-response rate, the final target sample was increased to 280 participants.

G. Data Analysis

The Statistical Package for Social Sciences (IBM SPSS) version 28 was used for data analysis. Categorical variables were presented as frequencies and percentages. Moreover, continuous variables were presented as means and standard deviations. To assess the association between categorical variables chi-square test was used. A p-value of less than 0.05 was considered statistically significant.

H. Ethical Consideration

A full explanation of the study was presented to the respondents while taking consent for participation on the first page of the Web-based questionnaire. Maintaining confidentiality throughout the research has been reassured, and the participation remained voluntary. Ethical approval was obtained from the Institutional Review Board.

III. RESULT AND DISCUSSION

A. Demographic Characteristics

A total of 300 survey questionnaires were distributed to the healthcare providers of which 280 (93%) were returned and included in the analysis. The majority of participants 171 (61.1%) were female, while 109 (38.9%) were male. The mean age of the participants was 37.8 years. In terms of education, 152 (54.3%) of them had a bachelor's degree. Additionally, 124 (44.3%) of the participants were nurses. More than half of the health care providers 150 (53.6%) have more than 10 years of professional experience. 206 (73.6 %) of the healthcare providers were working in medical specialties, while 12 (4.3%) were in surgical specialties. Table 1. Shows the demographic characteristics of the study participants.

Table 1. The demographic characteristics of the study participants

Sociodemographic Characteristics	**n**	**%**
Gender		
Female	171	61.1
Male	109	38.9
Educational level		
Bachelor	152	54.3
Diploma	20	7.1
Doctorate	72	25.7
Masters	36	12.9
Job title		
Physicians	99	35.4
Pharmacists	57	20.4
Nurses	124	44.3
Years of professional experience		
> 2 – 4 Year	42	15.0
>10 Year	150	53.6
5-10 Year	71	25.4
Less than 2 Year	17	6.1
Service		
Critical Care	51	18.2
Emergency Room	11	3.9
Medical	206	73.6
Surgical	12	4.3

B. Knowledge Towards Antimicrobial Stewardship Module

Slightly more than half of the participants 144 (51.4%) stated that they know about antimicrobial stewardship programs and their components. In addition, 128 (45.7%) of the healthcare providers revealed that know about the implemented antimicrobial stewardship applications within EMR. Moreover, 144 (51.4%) of the respondents said that know about the extent of antimicrobial resistance in their hospital or unit. Furthermore, less than half of them stated that they knew how to access their hospital guidelines for appropriate antibiotics use through EMR. Table 2. Describes the knowledge of the participants regarding applying EMR-based antimicrobial stewardship.

Table 2. Participants' knowledge of applying EMR based antimicrobial stewardship

No.	Questions	Yes	No	Not sure
1.	I know about antimicrobial stewardship (AMS) programs and their component	144 (51.4%)	77 (27.5%)	59 (21.1%)
2.	I know about AMS best practices for appropriate antibacterial use	123 (43.9%)	78 (27.9%)	79 (28.2%)
3.	I know about the implemented antimicrobial stewardship applications within EMR	128 (45.7%)	91 (32.5%)	61 (21.8%)
4.	I know about the extent of antimicrobial resistance in my hospital/unit	144 (51.4%)	69 (24.6%)	67 (23.9%)
5.	I know about the number of antibiotics prescribed in my hospital/unit	112 (40.0%)	110 (39.3%)	58 (20.7%)
6.	I know about the concept of antibiotic time-out	130 (46.4%)	98 (35.0%)	52 (18.6%)
7.	I know that AMS interventions can improve patient outcomes	156 (55.7%)	62 (22.1%)	62 (22.1%)
8.	I know that AMS strategies can reduce the problem of antimicrobial resistance	136 (48.6%)	72 (25.7%)	72 (25.7%)
9.	I know how to access my hospital guidelines for appropriate antibiotic use through EMR	88 (31.4%)	106 (37.9%)	86 (30.7%)

C. Attitude Towards Antimicrobial Stewardship Module

As for the healthcare providers' attitude towards the EMR-based antimicrobial stewardship module, 99 (35.4%) of the healthcare providers agreed with the statement that their antibiotic use is appropriate. Moreover, 102 (36.4%) of them strongly agree with the statement that having direct access to local antibiotic-related guidelines through EMR will improve appropriate antibiotic use. Additionally, 98 (35.0%) of the participants state that they strongly agree with the statement that having a clinical decision support tool in EMR to assist with de-escalating antibiotics will be helpful. 87 (31.1%) of them agree with the statement that there is a structured process for antimicrobial stewardship team consultation and communication within EMR. Furthermore, 62 (22.1%) of the healthcare providers strongly agree with the statement that the current process for ordering restricted antimicrobials in EMR is appropriate, on the other hand, 37 (13.2%) strongly disagree with the same statement. Table 3. Describes the attitude of the participants regarding applying EMR-based antimicrobial stewardship.

Table 3. Participants' attitude toward applying EMR based antimicrobial stewardship

No.	Questions	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Mean ± SD
1.	I believe that my antibiotic use is appropriate	36 (12.9%)	14 (5.0%)	76 (27.1%)	99 (35.4%)	55 (19.6%)	3.4 ± 1.2
2.	I believe that having direct access to local antibiotic-related guidelines through EMR will improve appropriate antibiotic use	38 (13.6%)	8 (2.9%)	57 (20.4%)	75 (26.8%)	102 (36.4%)	3.7 ± 1.3
3.	I believe that having relevant clinical data displayed at the antibiotic prescription, dispensing, and administration window will assist proper dosing of antimicrobials (e.g., weight, allergies, labs, creatinine clearance)	44 (15.7%)	8 (2.9%)	43 (15.4%)	66 (23.6%)	119 (42.5%)	3.7 ± 1.4
4.	I believe that having specific antibiotic order sets that include all recommended orders for some antibiotics grouped (e.g., vancomycin + pre-vancomycin level + renal function) will be helpful	44 (15.7%)	10 (3.6%)	44 (15.7%)	73 (26.1%)	109 (38.9%)	3.7 ± 1.4
5.	I believe that having a dedicated section in the chart where antibiotic history, inflammatory markers, and microbiological data can be reviewed and trended in one place is useful	40 (14.3%)	9 (3.2%)	51 (18.2%)	72 (25.7%)	108 (38.6%)	3.7 ± 1.4
6.	I believe that having a structured section in the chart for documenting the 72-hour antibiotic time-out will improve appropriate antibiotic use	39 (13.9%)	8 (2.9%)	62 (22.1%)	75 (26.8%)	96 (34.3%)	3.6 ± 1.3
7.	I believe that clinical alerts for out-of-range antibiotic levels (e.g., vancomycin, aminoglycosides) are useful	43 (15.4%)	6 (2.1%)	54 (19.3%)	70 (25.0%)	107 (38.2%)	3.7 ± 1.4
8.	I believe that having a clinical decision support tool in EMR to assist with de-escalating antibiotics (i.e., from broad to narrow spectrum based on culture results) will be helpful	46 (16.4%)	7 (2.5%)	51 (18.2%)	78 (27.9%)	98 (35.0%)	3.6 ± 1.4
9.	I believe that having a clinical decision support tool to guide the best drug options for the isolated bug (drug-bug match), IV to PO switch recommendations will help improve appropriate antibiotic use	44 (15.7%)	11 (3.9%)	54 (19.3%)	69 (24.6%)	102 (36.4%)	3.6 ± 1.4
10.	I believe that there is a structured process for AMS team consultation and communication within EMR	39 (13.9%)	13 (4.6%)	80 (28.6%)	87 (31.1%)	61 (21.8%)	3.4 ± 1.3
11.	I believe that the current process for ordering restricted antimicrobials in EMR is appropriate	37 (13.2%)	23 (8.2%)	79 (28.2%)	79 (28.2%)	62 (22.1%)	3.4 ± 1.3

D. Practice Towards Antimicrobial Stewardship Module

Regarding the practice of the healthcare providers of EMR-based antimicrobial stewardship module, 62 (22.1%) of them revealed that they always review the hospital guideline on recommended antibiotic choice for their patient's condition, while 37 (13.2%) said that they never do that. In addition, 90 (32.1%) of the respondents said that they always select/document the appropriate indication of their patient antibiotic in EMR, on the other hand, 33 (11.8%) stated that they don't do that. Moreover, 97 (34.6%) of the healthcare providers revealed that they always consciously read EMR clinical alerts related to antibiotics, 64 (22.9%) of them reported that they often do that, while 43 (15.4%) stated that they never read EMR clinical alerts. 69 (24.6%) of the participants perform antibiotic time-out after 48-72 hours of first administration to patients, while 60 (21.4%) don't adhere to this practice. 74 (26.4%) of the respondents said that they always communicate with the antimicrobial stewardship team for questions regarding antibiotics for their patients, conversely, 66 (23.6%) of them reported that they don't adhere to this practice. Table 4. Shows the practice of the participants of EMR-based antimicrobial stewardship.

Table 4. Participants practice toward EMR based antimicrobial stewardship

No.	Questions	Not applicable	Never	Sometimes	Often	Always	Mean ± SD
1.	I review the hospital guidelines on recommended antibiotic choices for my patient's condition	43 (15.4%)	37 (13.2%)	86 (30.7%)	52 (18.6%)	62 (22.1%)	3.2 ± 1.3
2.	I review my patient's antibiotic history when making decisions about antibiotics	25 (8.9%)	33 (11.8%)	76 (27.1%)	54 (19.3%)	92 (32.9%)	3.6 ± 1.3
3.	I review the previous microbiology data of my patient before antibiotic use (e.g. culture, PCR, etc.)	18 (6.4%)	34 (12.1%)	58 (20.7%)	48 (17.1%)	122 (43.6%)	3.8 ± 1.3
4.	I review the recommended antibiotic dosing for my patient-specific clinical condition in the formulary	2 (0.7%)	37 (13.2%)	59 (21.1%)	54 (19.3%)	128 (45.7%)	4 ± 1.1
5.	I have selected/documented the appropriate indication of my patient's antibiotic in the EMR	20 (7.1%)	33 (11.8%)	64 (22.9%)	73 (26.1%)	90 (32.1%)	3.6 ± 1.2
6.	I document the antibiotic plan in the patient chart (e.g. planned duration of therapy, etc.)	26 (9.3%)	35 (12.5%)	56 (20.0%)	64 (22.9%)	99 (35.4%)	3.6 ± 1.3
7.	I consciously read EMR clinical alerts related to antibiotics (e.g. allergies, drug-drug interaction, duplicate therapy, out-of-range dose, etc.)	16 (5.7%)	43 (15.4%)	60 (21.4%)	64 (22.9%)	97 (34.6%)	3.7 ± 1.3
8.	I perform antibiotic time-out after 48-72 hours of first administration to my patient	33 (11.8%)	60 (21.4%)	65 (23.2%)	53 (18.9%)	69 (24.6%)	3.2 ± 1.3
9.	I communicate with the antimicrobial stewardship team for questions regarding antibiotics for my patients	27 (9.6%)	66 (23.6%)	58 (20.7%)	55 (19.6%)	74 (26.4%)	3.3 ± 1.3

E. Association Between Demographic Characteristics and Knowledge, Attitude and Practice regarding EMR based Antimicrobial Stewardship

Possession of more knowledge in some of the items regarding EMR-based antimicrobial stewardship was significantly associated with some factors such as 'Age'. Participants with age older than 40 years had more knowledge in certain areas, like antimicrobial stewardship best practices for appropriate antibacterial use (p-value: 0.003), that antimicrobial stewardship interventions can improve patient outcomes (p-value: 0.005), that they can reduce the problem of antimicrobial resistance (p-value: <0.001), and how to access their hospital guidelines for appropriate antibiotics use through EMR (p-value: 0.009). Additionally, knowledge of the participants was not significantly associated with gender. However, a higher level of knowledge was linked to individuals holding master's and doctorate degrees in certain items. Nurses were also found to possess more knowledge than other professions in certain items. Overall, having more years of professional experience was also significantly associated with more knowledge of certain items. Table 5 demonstrates the relationship between the demographic characteristics of the participants and their knowledge of EMR-based antimicrobial stewardship.

Having a positive attitude towards EMR-based antimicrobial stewardship was not significantly associated with the age and gender of the participants. However, participants with master's and doctorate qualifications had a statistically significant positive attitude toward certain items. Such as Having direct access to antibiotic-related guidelines (p-value = 0.006), and the usefulness of having a section for reviewing antibiotic history, inflammatory markers, and microbiological data (p-value = 0.043). Furthermore, physicians and pharmacists also had a statistically significant positive attitude in some of the items. On the other hand, there was no significant association found between the years of experience of the respondents and having a positive attitude. Table 6 describes the association between the demographic characteristics of the participants and having a positive attitude toward EMR-based antimicrobial stewardship.

Regarding positive practice towards EMR-based antimicrobial stewardship, there was no statistically significant association between having a positive practice and the age and gender of the participants. Conversely, participants with master's and doctorate qualifications. Conversely, for participants with different educational levels, had a statistically significant positive practice in certain items. Such as those with a Doctorate degree (90.3%) reported reviewing antibiotic history the most, followed by those with a bachelor's degree (78.3%) and others, with a p-value of 0.001 showing a statistically significant difference. Furthermore, physicians and pharmacists also had a statistically significant positive practice in some areas. Table 7 provides a detailed description of the association between the demographic characteristics of the participants and their positive practice toward EMR-based antimicrobial stewardship.

Table 5. Association between demographic characteristics of the participants and gaining more knowledge regarding EMR based antimicrobial stewardship

	Age (year)			**Gender**			**Educational level**					**Job title**				**Years of professional experience**				
Characteristic	**≤ 40**	**> 40**	**p-value**	**Female**	**Male**	**p-value**	**Bachelor**	**Diploma**	**Master**	**Doctorate**	**p-value**	**Physician**	**Pharmacist**	**Nurse**	**p-value**	**< 2 Year**	**> 2 – 4 Year**	**5-10 Year**	**>10 Year**	**p-value**
	189 (67.5)	91 (32.5)		171 (61.1%)	109 (38.9%)		152 (54.3)	20 (7.1)	36 (12.9)	72 (25.7)		99 (35.4)	57 (20.4)	124 (44.3)		5 (29.4)	16 (38.1)	41 (57.7)	82 (54.7)	
I know about antimicrobial stewardship (AMS) programs and their component.	91 (48.1)	53 (58.2)	0.187	90 (52.6)	54 (49.5)	0.66	82 (53.9)	7 (35.0)	19 (52.8)	36 (50.0)	0.132	47 (47.5)	21 (36.8)	76 (61.3)	0.009	0 (.0)	7 (16.7)	29 (40.8)	87 (58.0)	<0.001
I know about AMS best practices for appropriate antibacterial use	70 (37.0)	53 (58.2)	0.003	70 (40.9)	53 (48.6)	0.349	65 (42.8)	6 (30.0)	16 (44.4)	36 (50.0)	0.103	49 (49.5)	18 (31.6)	56 (45.2)	0.036	4 (23.5)	21 (50.0)	38 (53.5)	65 (43.3)	0.364
I know about the implemented antimicrobial stewardship applications within EMR	88 (46.6)	40 (44.0)	0.903	84 (49.1)	44 (40.4)	0.207	82 (53.9)	6 (30.0)	18 (50.0)	22 (30.6)	0.003	36 (36.4)	24 (42.1)	68 (54.8)	<0.001	8 (47.1)	18 (42.9)	40 (56.3)	78 (52.0)	0.039
I know about the extent of antimicrobial resistance in my hospital/unit	94 (49.7)	50 (54.9)	0.22	87 (50.9)	57 (52.3)	0.433	89 (58.6)	8 (40.0)	16 (44.4)	31 (43.1)	0.041	45 (45.5)	22 (38.6)	77 (62.1)	0.002	6 (35.3)	14 (33.3)	29 (40.8)	63 (42.0)	0.973
I know about the number of antibiotics prescribed in my hospital/unit	74 (39.2)	38 (41.8)	0.243	80 (46.8)	32 (29.4)	0.005	75 (49.3)	7 (35.0)	12 (33.3)	18 (25.0)	0.002	20 (20.2)	22 (38.6)	70 (56.5)	<0.001	9 (52.9)	24 (57.1)	28 (39.4)	69 (46.0)	0.508
I know about the concept of antibiotic time-out	87 (46.0)	43 (47.3)	0.676	83 (48.5)	47 (43.1)	0.104	81 (53.3)	9 (45.0)	18 (50.0)	22 (30.6)	0.001	31 (31.3)	27 (47.4)	72 (58.1)	<0.001	2 (11.8)	6 (14.3)	49 (69.0)	99 (66.0)	<0.001
I know that AMS interventions can improve patient outcomes	93 (49.2)	63 (69.2)	0.005	89 (52.0)	67 (61.5)	0.102	82 (53.9)	8 (40.0)	24 (66.7)	42 (58.3)	0.086	57 (57.6)	23 (40.4)	76 (61.3)	0.043	2 (11.8)	3 (7.1)	28 (39.4)	103 (68.7)	<0.001
I know that AMS strategies can reduce the problem of antimicrobial resistance	75 (39.7)	61 (67.0)	<0.001	77 (45.0)	59 (54.1)	0.077	70 (46.1)	5 (25.0)	18 (50.0)	43 (59.7)	0.007	53 (53.5)	17 (29.8)	66 (53.2)	0.001	2 (11.8)	2 (4.8)	21 (29.6)	63 (42.0)	<0.001
I know how to access my hospital guidelines for appropriate antibiotic use through EMR	50 (26.5)	38 (41.8)	0.009	50 (29.2)	38 (34.9)	0.433	55 (36.2)	6 (30.0)	12 (33.3)	15 (20.8)	0.114	24 (24.2)	12 (21.1)	52 (41.9)	<0.001	5 (29.4)	16 (38.1)	41 (57.7)	82 (54.7)	0.084

Table 6. Association between participants' demographic characteristics and positive attitude towards EMR based antimicrobial stewardship

	Age (year)			Gender			Educational level					Job title				Years of professional experience				
Characteristic	≤ 40	> 40	p-value	Female	Male	p-value	Bachelor	Diploma	Master	Doctorate	p-value	Physician	Pharmacist	Nurse	p-value	< 2 Year	> 2 – 4 Year	5-10 Year	>10 Year	p-value
	189 (67.5)	91 (32.5)		171 (61.1%)	109 (38.9%)		152 (54.3)	20 (7.1)	36 (12.9)	72 (25.7)		99 (35.4)	57 (20.4)	124 (44.3)		17 (6.1)	42 (15.0)	71 (25.4)	150 (53.6)	
I believe that my antibiotic use is appropriate.	105 (55.6)	49 (53.8)	0.788	87 (50.9)	67 (61.5)	0.082	77 (50.7)	12 (60.0)	16 (44.4)	49 (68.1)	0.047	65 (65.7)	29 (50.9)	60 (48.4)	0.028	7 (41.2)	25 (59.5)	39 (54.9)	83 (55.3)	0.644
I believe that having direct access to local antibiotic-related guidelines through EMR will improve appropriate antibiotic use	118 (62.4)	59 (64.8)	0.696	99 (57.9)	78 (71.6)	0.021	84 (55.3)	12 (60.0)	24 (66.7)	57 (79.2)	0.006	74 (74.7)	39 (68.4)	64 (51.6)	0.001	7 (41.2)	28 (66.7)	44 (62.0)	98 (65.3)	0.251
I believe that having relevant clinical data displayed at the antibiotic prescription, dispensing, and administration window will assist proper dosing of antimicrobials (e.g., weight, allergies, labs, creatinine clearance)	126 (66.7)	59 (64.8)	0.762	106 (62.0)	79 (72.5)	0.071	94 (61.8)	13 (65.0)	22 (61.1)	56 (77.8)	0.111	72 (72.7)	42 (73.7)	71 (57.3)	0.021	10 (58.8)	31 (73.8)	49 (69.0)	95 (63.3)	0.513
I believe that having specific antibiotic order sets that include all recommended orders for some antibiotics grouped (e.g., vancomycin + pre-vancomycin level + renal function) will be helpful	122 (64.6)	60 (65.9)	0.82	106 (62.0)	76 (69.7)	0.186	91 (59.9)	13 (65.0)	22 (61.1)	56 (77.8)	0.067	73 (73.7)	39 (68.4)	70 (56.5)	0.022	9 (52.9)	29 (69.0)	48 (67.6)	96 (64.0)	0.644
I believe that having a dedicated section in the chart where antibiotic history, inflammatory markers, and microbiological data can be reviewed and trended in one place is useful	119 (63.0)	61 (67.0)	0.506	101 (59.1)	79 (72.5)	0.022	90 (59.2)	11 (55.0)	23 (63.9)	56 (77.8)	0.043	73 (73.7)	41 (71.9)	66 (53.2)	0.003	7 (41.2)	30 (71.4)	50 (70.4)	93 (62.0)	0.094
I believe that having a structured section in the chart for documenting the 72-hour antibiotic time-out will improve appropriate antibiotic use	114 (60.3)	57 (62.6)	0.709	95 (55.6)	76 (69.7)	0.018	88 (57.9)	11 (55.0)	21 (58.3)	51 (70.8)	0.266	65 (65.7)	41 (71.9)	65 (52.4)	0.022	9 (52.9)	29 (69.0)	45 (63.4)	88 (58.7)	0.548
I believe that clinical alerts for out-of-range antibiotic levels (e.g., vancomycin, aminoglycosides) are useful	119 (63.0)	58 (63.7)	0.9	102 (59.6)	75 (68.8)	0.121	88 (57.9)	12 (60.0)	21 (58.3)	56 (77.8)	0.031	71 (71.7)	41 (71.9)	65 (52.4)	0.004	7 (41.2)	30 (71.4)	47 (66.2)	93 (62.0)	0.162
I believe that having a clinical decision support tool in EMR to assist with de-escalating antibiotics (i.e., from broad to narrow spectrum based on culture results) will be helpful	117 (61.9)	59 (64.8)	0.635	100 (58.5)	76 (69.7)	0.058	88 (57.9)	13 (65.0)	20 (55.6)	55 (76.4)	0.044	68 (68.7)	41 (71.9)	67 (54.0)	0.023	8 (47.1)	27 (64.3)	48 (67.6)	93 (62.0)	0.46
I believe that having a clinical decision support tool to guide best drug options for the isolated bug (drug-bug match), IV to PO switch recommendations will help improve appropriate antibiotic use	114 (60.3)	57 (62.6)	0.709	97 (56.7)	74 (67.9)	0.062	87 (57.2)	9 (45.0)	22 (61.1)	53 (73.6)	0.049	66 (66.7)	39 (68.4)	66 (53.2)	0.055	7 (41.2)	28 (66.7)	47 (66.2)	89 (59.3)	0.225
I believe that there is a structured process for AMS team consultation and communication within EMR	101 (53.4)	47 (51.6)	0.779	87 (50.9)	61 (56.0)	0.406	79 (52.0)	10 (50.0)	16 (44.4)	43 (59.7)	0.476	55 (55.6)	32 (56.1)	61 (49.2)	0.548	7 (41.2)	24 (57.1)	39 (54.9)	78 (52.0)	0.704
I believe that the current process for ordering restricted antimicrobials in EMR is appropriate	92 (48.7)	49 (53.8)	0.418	83 (48.5)	58 (53.2)	0.446	78 (51.3)	10 (50.0)	13 (36.1)	40 (55.6)	0.289	47 (47.5)	32 (56.1)	62 (50.0)	0.578	7 (41.2)	24 (57.1)	33 (46.5)	77 (51.3)	0.608

Table 7. Association between participants' demographic characteristics and positive practice towards EMR-based antimicrobial stewardship

	Age (year)			Gender			Educational level					Job title				Years of professional experience				
Characteristic	**≤ 40**	**> 40**	**p-value**	**Female**	**Male**	**p-value**	**Bachelor**	**Diploma**	**Master**	**Doctorate**	**p-value**	**Physician**	**Pharmacist**	**Nurse**	**p-value**	**< 2 Year**	**> 2 – 4 Year**	**5-10 Year**	**>10 Year**	**p-value**
	189 (67.5)	91 (32.5)		171 (61.1%)	109 (38.9%)		152 (54.3)	20 (7.1)	36 (12.9)	72 (25.7)		99 (35.4)	57 (20.4)	124 (44.3)		17 (6.1)	42 (15.0)	71 (25.4)	150 (53.6)	
I review the hospital guidelines on recommended antibiotic choices for my patient's condition	138 (73.0)	62 (68.1)	0.397	129 (75.4)	71 (65.1)	0.063	118 (77.6)	10 (50.0)	27 (75.0)	45 (62.5)	0.015	62 (62.6)	39 (68.4)	99 (79.8)	0.016	12 (70.6)	31 (73.8)	51 (71.8)	106 (70.7)	0.982
I review my patient's antibiotic history when making decisions about antibiotics	148 (78.3)	4 (81.3)	0.56	135 (78.9)	87 (79.8)	0.861	119 (78.3)	10 (50.0)	28 (77.8)	65 (90.3)	0.001	88 (88.9)	36 (63.2)	98 (79.0)	0.001	13 (76.5)	30 (71.4)	62 (87.3)	117 (78.0)	0.203
I review the previous microbiology data of my patient before antibiotic use (e.g. culture, PCR..etc.)	150 (79.4)	78 (85.7)	0.201	136 (79.5)	92 (84.4)	0.307	121 (79.6)	11 (55.0)	28 (77.8)	68 (94.4)	<0.001	90 (90.9)	39 (68.4)	99 (79.8)	0.002	16 (94.1)	28 (66.7)	59 (83.1)	125 (83.3)	0.039
I review the recommended antibiotic dosing for my patient-specific clinical condition in the formulary	163 (86.2)	78 (85.7)	0.905	147 (86.0)	94 (86.2)	0.949	126 (82.9)	16 (80.0)	31 (86.1)	68 (94.4)	0.107	92 (92.9)	46 (80.7)	103 (83.1)	0.045	14 (82.4)	34 (81.0)	65 (91.5)	128 (85.3)	0.398
I have selected/documented the appropriate indication of my patient's antibiotic in the EMR	152 (80.4)	75 (82.4)	0.69	136 (79.5)	91 (83.5)	0.410	116 (76.3)	15 (75.0)	28 (77.8)	68 (94.4)	0.01	89 (89.9)	43 (75.4)	95 (76.6)	0.02	13 (76.5)	31 (73.8)	61 (85.9)	122 (81.3)	0.428
I document the antibiotic plan in the patient chart (e.g. planned duration of therapy..etc.)	147 (77.8)	72 (79.1)	0.799	133 (77.8)	86 (78.9)	0.825	114 (75.0)	10 (50.0)	28 (77.8)	67 (93.1)	<0.001	90 (90.9)	33 (57.9)	96 (77.4)	<0.001	14 (82.4)	30 (71.4)	61 (85.9)	114 (76.0)	0.24
I consciously read EMR clinical alerts related to antibiotics (e.g. allergies, drug-drug interaction, duplicate therapy, out-of-range dose..etc.)	147 (77.8)	74 (81.3)	0.496	137 (80.1)	84 (77.1)	0.541	121 (79.6)	11 (55.0)	28 (77.8)	61 (84.7)	0.038	81 (81.8)	36 (63.2)	104 (83.9)	0.004	13 (76.5)	32 (76.2)	58 (81.7)	118 (78.7)	0.9
I perform antibiotic time-out after 48-72 hours of first administration to my patient	127 (67.2)	60 (65.9)	0.834	114 (66.7)	73 (67.0)	0.958	105 (69.1)	10 (50.0)	25 (69.4)	47 (65.3)	0.378	65 (65.7)	31 (54.4)	91 (73.4)	0.04	13 (76.5)	25 (59.5)	49 (69.0)	100 (66.7)	0.598
I communicate with the antimicrobial stewardship team for questions regarding antibiotics for my patients	128 (67.7)	59 (64.8)	0.631	118 (69.0)	69 (63.3)	0.323	105 (69.1)	10 (50.0)	23 (63.9)	49 (68.1)	0.378	63 (63.6)	33 (57.9)	91 (73.4)	0.086	12 (70.6)	24 (57.1)	48 (67.6)	103 (68.7)	0.545

Antimicrobial Stewardship (AMS) is a process of improving and changing antibiotic use by applying various, which is considered beneficial, however, AMS might be considered as an intrusive process that Interferes with the healthcare providers' autonomy and authority, this could appear evident, especially with the introduction of a new system such as the EMR-based module (Duncan *et al.*, 2020). Our aim in this study was to evaluate the knowledge, beliefs, and practices of healthcare providers towards this module. We found that more than half of the healthcare providers know about the AMS and its applications within the EMR system. Furthermore, approximately a third of the participants strongly believed that their antibiotic prescription was appropriate, and having a clinical decision support tool in EMR to assist with de-escalating antibiotics was helpful. Additionally, less than half of the participants said they always adhere to the recommended EMR-based AMS guidelines. Similar results have been reported in a study conducted in the eastern province of Saudi Arabia, where more than half of the participants lacked awareness about AMS, and more than two thirds of them didn't have any experience with AMS (Baraka *et al.*, 2019).

On the other hand, a study conducted in the southern province of Saudi Arabia found that 67% of the participants had a good level of AMS practice compared to a lower adherence to good practice in our study (Alqahtani *et al.*, 2024). However, similar findings were reported in studies conducted in Pakistan and Indonesia, in which the practice of AMS strategies among healthcare providers was very limited (Setiawan *et al.*, 2022; Atif *et al.*, 2021).

The inadequate levels of adherence to AMS guidelines reported in our study could be because this EMR-based AMS module is relatively new to healthcare providers. This suggests that increasing the knowledge of healthcare providers about this AMS module and its strategies might help in increasing their adherence to AMS practices. Training and educational programs might play a crucial role in enhancing the knowledge of AMS, raising understanding, and promoting better AMS practice among healthcare workers, these educational programs can include conferences, seminars, workshops, and webinars, in which healthcare providers can learn from experts in the field about AMS, discuss challenges, and provide solutions for better implementation of EMR-based AMS module (Vernooy *et al.*, 2022). Additionally, AMS strategies could be introduced into medical school curricula so that medical students will be familiar with it and could be incorporated into new healthcare providers' indications at the start of their work in hospitals, this will ensure gaining more knowledge and skills for better implementation of AMS (Sayegh *et al.*, 2021).

Implementing and adopting AMS practices in hospitals is a complex process with many challenges that need to be addressed. Some hospitals might lack the required information technology resources and personnel to integrate AMS practices (Kapadia *et al.*, 2018). Also, the lack of adequate funding remains a constant challenge to the efforts of AMS, it has been found that only a few countries have dedicated funding for AMS programs (Beović *et al.*, 2018). Moreover, one of the major challenges to AMS programs in hospitals is the shortage of AMS teams and infectious diseases doctors in hospitals, this shortage needs to be addressed in order of the AMS programs to function properly (Alghamdi *et al.*, 2019). Another important factor in the success of AMS is the institutional legislation of AMS programs, and enforcing them into hospital structures, which is crucial in improving implementation rates and proper antibiotic use (Johnson *et al.*, 2016). An additional factor is patient demand, which could be a promotion or a barrier to the AMS programs, patients need to be engaged in AMS programs which can help in the implementation efforts (Ewers *et al.*, 2017).

F. Study Limitations

One of the limitations of this study is that it was conducted at a single facility, which may limit the generalisability of the results. Nevertheless, this study provides valuable insights on the knowledge, attitude, and practice of healthcare providers regarding the EMR-based AMS module. The findings also encourage other hospitals in the Kingdom of Saudi Arabia (KSA) to conduct similar research to assess the gaps in knowledge, attitudes, and practices among their staff. Future research is essential to address the barriers and facilitators associated with implementing the AMS program in hospitals.

IV. CONCLUSION

The aim of this study was to evaluate the knowledge, attitude, and practice of healthcare providers regarding an electronic medical record (EMR)-based antimicrobial stewardship (AMS) program in a tertiary hospital in Saudi Arabia. The results revealed that there are lower levels of adherence to AMS guidelines. Further research is needed to address the barriers and facilitators of effective AMS implementation in the hospital. Moreover, a comprehensive intervention including education and training programs, are needed to enhance the knowledge, attitude and practices related to AMS among healthcare providers.

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