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Knowledge-Practice Gaps of Practicing Doctors on Antimicrobial Stewardship-A Single Center Experience

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Abstract: The overwhelming, irrational behaviour of using Antimicrobial (AM) has added to the amplification and spread of Antimicrobial Resistance (AMR) burden. Healthcare professionals can curtail the AMR by practicing Antimicrobial Stewardship (AMS). The single-centre hospital-based observational study aimed at accessing the knowledge, attitude and practice of practicing doctors towards AMS based on a free online open WHO course, a global action plan to combat AMR, laid down by WHO in a tertiary care hospital. The study was designed as a questionnaire-based cross-sectional one, conducted among practitioners (faculty, senior residents, junior residents) in different clinical departments. A validated self-administered questionnaire consisting of 29 questions was designed and shared among 200 participants through the mail and physically. Different subgroup analysis (surgeon vs physician, faculty vs senior resident vs junior resident, open WHO course participant vs open WHO course aware non-participant vs open WHO course unaware non-participants) was done for differences in responses to questions. Pearson Chi-square test was used for categorical data. Differences amongst groups were tested using the Chi-squared test. P-value <0.05 was considered statistically significant. Response rate was 62.5% (n = 200). Knowledge on AMS was observed among doctors' with >50% near correct responses in each question except for the question asking on IV route of AM administration. A significant knowledge gap was found when a comparison was made between faculty members, senior residents and junior residents ($p<0.001$) in the spectrum of activity of AM. Knowledge gap on ASP is observed among practicing doctors but significant differences were found among faculty, senior residents and junior residents, among open WHO course participants vs open WHO course unaware non-participants. The open WHO course may help in nullifying this gap.

Keywords: Antimicrobial Resistance, Antimicrobial Stewardship Practice, Open WHO course, Physician, Self-Administered Questionnaire

Introduction

The prevalence of infectious disease ranges from 28.05 to 29.57 per 1000 population, which is very high in a developing country like India (Banerjee and Dwivedi, 2016). Antimicrobial (AM) agents have played a critical role in reducing the burden of communicable diseases across the world with a good reason that many have considered them 'wonder drugs'(Antimicrobial). However, AM consumption has increased in recent decade. According to a study published in the proceedings of the National Academy of Sciences, total AM consumption has increased to 65% globally, which is mainly driven by low- and middle-income countries. The data from Indian Council of Medical Research (ICMR) states an increase in per capita consumption of AM in India by 66% in 2010 as compared to 2000. (Treatment, 2019) This increased use leads to the emergence of Antimicrobial Resistance (AMR) that is creating 'superbugs' that make treating basic infections difficult and AMR is one of the biggest threats to global health, food security and development today.

Antimicrobial resistance develops over time, usually through genetic changes when microorganisms are exposed to AM drugs (Antibiotic, 2018). Two main contributing factors - excessive use of AM and inadequate dose of AM have led to the ramification of resistant organisms (Aremu *et al*., 2021). New resistance mechanisms are emerging and spreading globally, threatening our ability to treat common infectious diseases. The cost of healthcare for patients with resistant infections is becoming higher than care for patients with non-resistant infections due to longer duration of illness, ICU stays

additional tests and the use of more expensive drugs (Mauldin *et al*., 2010; Sango *et al*., 2013; Nathwani *et al*., 2019). The third GLASS report presents the frequency of AMR in 2,164,568 patients with laboratory-confirmed infections in 66 countries, territories and areas in 2018. The rate of resistance to ciprofloxacin commonly used to treat urinary tract infections, varied from 8.4 to 92.9% for E. coli and from 4.1 to 79.4% for K. pneumonia respectively (Resistance, 2020). In 2013, CDC published the first AMR threat report, which rang the alarm for an overwhelming increase in AMR Furthermore, the lack of new antibiotics threatens global efforts to contain drug-resistant infections (Årdal *et al*., 2020). The estimated cost arising from AMR will exceed 1 trillion USD globally by 2050 if no significant action is taken (O'Neill, 2016). The World Bank predicts a profound increase in global poverty by 2050 and increase in healthcare cost from US$300 billion to more than US$1 trillion per year (WB, 2017, Ahmad and Khan, 2019).

The solution lies in Antimicrobial Stewardship (AMS), a coherent set of actions that promote the responsible use of AM (WHO, 2018). An Antimicrobial Stewardship Program (ASP) is an organizational or system-wide healthcare strategy to promote the appropriate use of AM through the implementation of evidence-based interventions. A broad range of interventions has been implemented to improve ASP, e.g., TARGET toolkit in the UK, open WHO course (TARGET, 2020; WHO, 2021). Till now many Knowledge, Attitude, Practice (KAP) studies on AMR have been conducted among community members, medical undergraduate students, which has shown AMR is an increasing national problem and the attitude of self-medication in about 46% of participants and the need for more educational tools in non-medical professionals (Nepal *et al*., 2019; Khajuria *et al*., 2019; Gupta *et al*., 2019; Pulcini *et al*., 2011; Fernández *et al*., 2013; Mincey and Parkulo, 2001; Navarro-San Francisco *et al*., 2013). All studies have shown AMR being a great problem (>90%) to public health as well as a national problem, but <60% rate it to be a real problem in their clinical practice (Pulcini *et al*., 2011). Very few, less than 30% knew the prevalence of multi-drug resistance in their hospitals (Pulcini *et al*., 2011). Few KAP studies have been done among doctors in tertiary care centres in India (Ghosh *et al*., 2016; Labi *et al*., 2018). In all these studies the authors have identified gaps of doctors towards AMR, which are important to promote the rational use of AM and to develop their hospital ASP, however, no one utilizes any specific guideline or online course content if they are practicing with respect to AMS/ASP.

This study aimed to determine the knowledge, attitude and practice among doctors towards AMS as per online WHO course and to look for the impact of free open WHO course on AMS. The rationale behind the study is to make doctors in a tertiary care hospital aware of the open WHO course on AMS, which will improve the KAP of antimicrobials among doctors, the ultimate goal being the control of AMR.

Materials

Study Setting and Design

The study was conducted in All India Institute of Medical Science, Rishikesh, a tertiary care institute in North India. It serves as a referral centre for several primary and secondary care centres. It was a hospital-based observational cross-sectional study, conducted among doctors of different departments from July 2019 to September 2019 (a two-month period).

Study Population

The study population was defined as faculties (assistant professor, associate professor, additional professor), senior residents and junior residents from 2nd and 3rd-year post-graduate courses. They were selected from medicine and allied departments (internal medicine, paediatrics, obstetrics and gynecology, dermatology, cardiology, community and family medicine, gastroenterology, pulmonary medicine), surgery and allied departments (general surgery, ophthalmology, urology, orthopedics, ENT, plastic surgery, neurosurgery, pediatric surgery) having expertise in their field.

The sample size was determined by using KAP prevalence in a similar study done before by Chatterjee *et al*. (2015). The sample size of 200 was determined using the power of 80% and the margin of error of 5%. Participant selection was done by universal sampling method of all available doctors during the two months' period.

Assessment Material

The questionnaire was self-structured after searching medical literature for comparable studies and adapting questions based on the online open WHO course: Antimicrobial stewardship: A competency-based approach (freely available) (WHO, 2018). A total of 27 questions (having subsections) was devised. Face validation was done for the questionnaire by subject experts from the department of microbiology, pharmacology, infectious disease and medicine for its contents and relevance. This questionnaire had not been used in any other study, however, similar questions had been assessed for previous KAP studies.

The questions were evaluated on a 5-point Likert scale with response options of Strongly Disagree (SD)/Disagree(D)/Neither agree nor disagree/Agree (A)/Strongly Agree (SA).

Operational Definitions

The following definitions were used to select the participants enrolled in the study:

- Target population: All the practicing doctors in this single tertiary health care setting

- Junior resident: Postgraduate students in 2nd and 3rd year
- Senior resident: Those who have completed their post-graduation and pursuing super specialization (D.M/M.Ch)
- Faculty: Consultant (Assistant, Associate, Additional Professors and Professors)
- Physician: Participants from all medical and allied branches
- Surgeons: Participants from all surgery and allied branches
- Open WHO Participants: The members of the target population who completed the online WHO course on AMS

Open WHO Non-Participants: The members of the target population who did not complete the online WHO course on AMS:

- Responders: The participants who gave consent to participate in the study and returned the filled questionnaire were defined as the Responders
- Non-responder: Failing to fill the questionnaire after 3 subsequent visits
- Lost to follow-up: Those responders who did not return the questionnaire after 3 repeated reminders if they filled form incompletely at initial interaction

Methodology

The study was assessed and approved by the institutional ethical committee (No.143/IEC/STS/2019), AIIMS, Rishikesh before starting the survey. Members of the target population who were present within the period of the survey and gave consent by filling the google form shared to them by email and or WhatsApp were included in the study. The questionnaire was distributed to working doctors of all clinical departments who prescribes antimicrobials. Doctors from departments of Radiology, Anaesthesia, Psychiatry and Physical Medical Rehabilitation were excluded due to the rarity of antimicrobials use. Also, the Interns working in the hospital were excluded. Participants were visited during working hours and were given hard copies or online survey links of the questionnaire according to the participant's choice. Those who had not submitted in the first visit were re-visited or re-mailed up to three times after which they were decided as non-responder. No incentives were offered for participation. Availability of drug and therapeutic committee and hospital antibiotic policy was there.

Data Analysis

After collecting the questionnaire and obtaining the required data in Microsoft Excel® sheet, they were evaluated for completeness. All gathered data grouped into surgeon vs physician, faculty vs senior resident vs junior resident and open WHO participant vs aware non-participant vs unaware non-participant. Participants were also analysed in a subgroup based on the duration of medical experience after MBBS. Data analysis was done using the Statistical Package for Social Sciences (SPSS® 24.0, USA) and interpreted. Proportions were calculated. Pearson Chi-square test was used for categorical data. The final results were compared with the right answers for the questions and tables and diagrams were used to present the results. Differences amongst groups were tested using the Chi-squared test. P-value <0.05 was considered statistically significant.

To report our findings, we followed the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guideline.

Results

Basic Characteristics

The questionnaire was shared among 200 participants, either online (mail) or offline, 125 participants (response rate 62.5%) from sixteen departments completed the study and were analysed under categories of departments, positions, years of practice and user profile of open WHO course (Fig. 1). The data showed maximum participation from the Department of Medicine and most of the participants (77.6%) were non-participant of the open WHO course. On asking the reason for the same, most of them answer about the lack of information.

Knowledge about Antimicrobial Stewardship

After analysing the responses from the knowledge section, it was found that almost all participants considered a correct diagnosis, dose and duration as an important principle of AMS. However, 24% (Strongly disagree = 9.6%, Disagree = 14.4%) of doctors did not consider the route of administration of the drug as an AMS principle and 30.4% (n = 38) had no opinion for the given statement (Fig. 2). Less than fifty percent of doctors' (48.89%) didn't favour using the broadest spectrum of antimicrobials (D = 33.6%, SD = 15.29%) at the initial and 67.2% were against using broad-spectrum antimicrobials irrespective of the severity of infection (SD = 28%, D = 39.2%). The great majority 59.9% (SA = 15.5%, A = 44.4%) doctors agreed to the fact that the "Emergence of AMR is inevitable." While assessing doctors' knowledge on AMR mechanism, 34.4% of doctors consider increased influx of drug into the bacterial cell as one of the mechanisms by which micro-organisms acquire resistance. In an antimicrobial with concentration-dependent killing, more than fifty percent of doctors' (SA = 16%, A = 43.2%) consider large infrequent dosing as well as optimization of AM duration with a concentration over MIC (SA = 27.2%, A = 28%) as an

appropriate regimen. On questioning about the intervention types of AMS, the majority (64, 65%) don't know about pre-authorization and formulary restriction respectively.

Comparison of Knowledge

As shown in supplementary Table 1, there was a significant knowledge gap in considering 'appropriate dosage to site and type of infection' as an AMS component ($p = 0.002$) and inactivation of AM as a major mechanism of resistance ($p = 0.004$). There was not much significance in knowledge between surgeons and physicians except in four questions. Only six surgeons in comparison to eleven physicians strongly disagreed with the use of broad-spectrum AM ($p = 0.020$).

Comparison of knowledge among faculty, Senior Resident (SR) and Junior Resident (JR), showed a significant knowledge gap between them with faculty members giving a maximum number of correct answers followed by SRs and JRs which gave a different number of correct answers in different questions. Maximum significance was seen in questions asking factors to decide the spectrum of AM therapy ($p<0.001$). This indirectly shows the year of experience in clinical practice during which they would have treated the resistant organism.

Attitude Towards AMS

Almost all the participants agreed that ASP is a necessity in their hospital as well as it reduces healthcare cost and adverse effects of inappropriate AM prescription (Fig. 3).

The majority of participants who had participated in the open WHO course towards AMS agreed on the course to be made compulsory for all HCW (Fig. 4). Similarly, the majority preferred to take the course than seeking advice from the seniors. But almost half of the participants thought that the treatment options are not too ideal to be implicated in the daily practice.

Table 1: Practice habits of participants towards antimicrobial stewardship

Questions	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
Q.1 Principles of practices					
a) Antimicrobials are reviewed at regular intervals	19.20%	60.00%	13.60%	7.20%	0.00%
b) Antimicrobials are prescribed routinely when infections suspected	4.80%	36.00%	37.60%	17.60%	4.00%
c) Antimicrobials are prescribed with the help of ASP	6.40%	40.80%	25.60%	20.80%	6.40%
d) Microbiologist is guiding while prescribing antimicrobials	3.20%	13.60%	24.00%	45.60%	13.60%
e) Pharmacologist is guiding while choosing antimicrobials' dose	18.40%	70.40%	7.20%	4.00%	0.00%
On case scenarios					
Q.2 URINE CULTURE					
a) Urine culture should be collected	17.60%	52.80%	4.00%	19.20%	6.40%
b) Asymptomatic bacteriuria patients must be given treatment only in pregnancy and invasive urological procedures	27.20%	60.80%	6.40%	4.00%	1.60%
c) Fluoroquinolones should be used for uncomplicated UTI	12.80%	48.80%	15.20%	20.00%	3.20%
d) Antibiotics should be advised in the above case because of large growth of organisms	4.00%	20.00%	8.80%	48.00%	19.20%
Q.3 DIARRHEA					
a) Patient should be given empiric antimicrobial therapy	4.00%	32.80%	6.40%	40.80%	16.00%
b) Stool culture is not required in above case scenario	4.80%	24.80%	17.60%	38.40%	14.40%
c) Rehydration and watchful waiting without empiric antibiotics is d) sufficient in most cases of watery diarrhea	39.20%	44.00%	8.00%	8.80%	0.00%
Q.4 ACUTE BRONCHITIS					
a) The history of productive cough does not differentiate in URTI, acute bronchitis and community acquired pneumonia	11.20%	60.00%	10.40%	14.40%	4.00%
b) In acute bronchitis there is no need for chest X-ray, sputum culture, viral and serological analysis	4.80%	32.80%	16.80%	33.60%	12.00%
c) Antibiotics can help in early cure of patients with acute bronchitis	3.20%	25.60%	16.80%	40.00%	14.40%
d) In patients with acute bronchitis patient education is key	31.20%	54.40%	9.60%	4.00%	0.80%
Q.5 SUBCUTANEOUS ABSCESS					
a) Source control is the cornerstone of management in the above case	40.00%	58.40%	1.60%	0.00%	0.00%
b) Antimicrobial therapy must be given in this case	18.40%	56.00%	8.00%	16.00%	1.60%
c) Thorough cleaning of shared equipments and MRSA decolonisation should be done	36.80%	56.00%	4.00%	3.20%	0.00%
d) Culture samples should be avoided as contamination may lead to use of overly broad-spectrum antibiotics	8.80%	14.40%	17.60%	41.60%	17.60%
Q.3 Skin and Soft tissue Infection (SSI)					
a) Antimicrobial sealents should not be used for surgical site skin preparation for the purpose of reducing SSI	8.57%	27.14%	30.00%	22.86%	11.43%
b) Perioperative surgical antibiotic prophylaxis should be continued due presence of a wound drain for the purpose of preventing SSI	10.00%	61.43%	10.00%	11.43%	7.14%
c) Prolongation of post-operative antimicrobial prophylaxis decrease the risk of SSI	4.29%	14.29%	17.14%	45.71%	18.57%
d) Re-dosing of antimicrobials should be considered if blood loss in patient >1.5L	11.43%	41.43%	21.43%	20.00%	5.71%

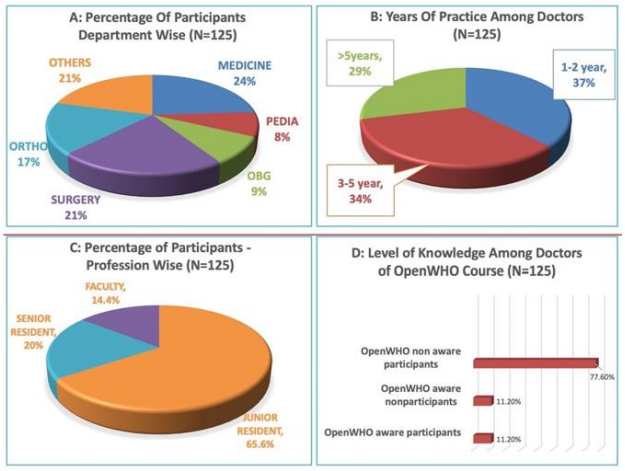

Fig. 1: basic characteristics of participants w.r.t. various sub-groups

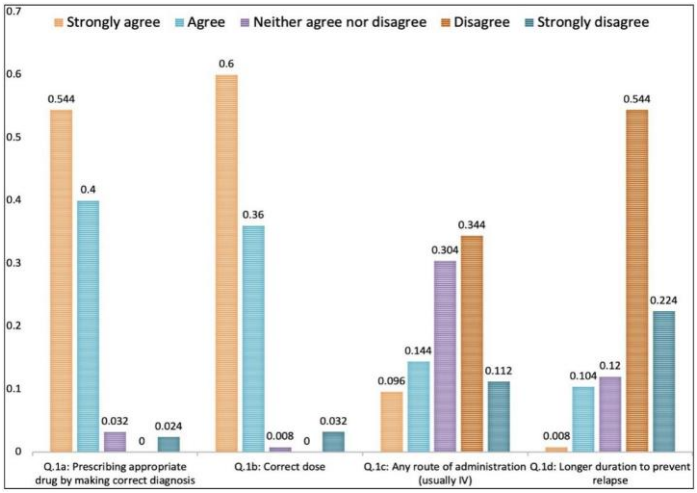

Fig. 2: Responses to questions on knowledge of basic principles of AMS

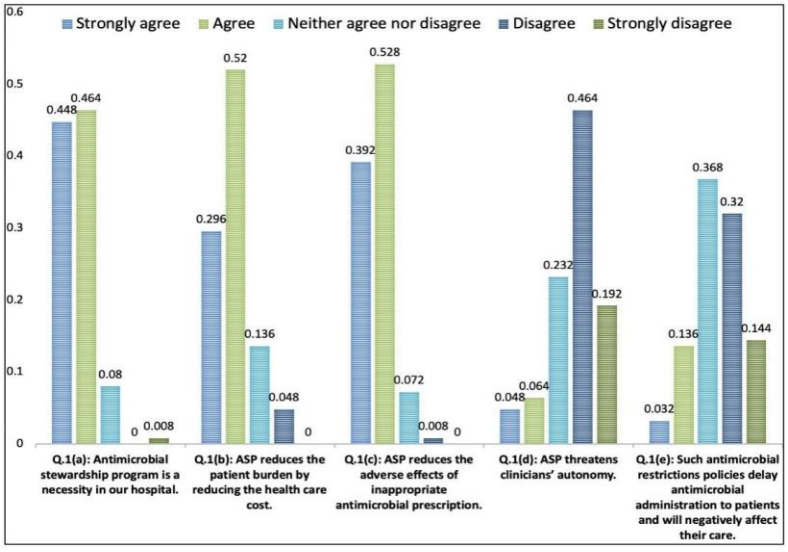

Fig 3: Responses to questionnaire on attitude towards antimicrobial stewardship program

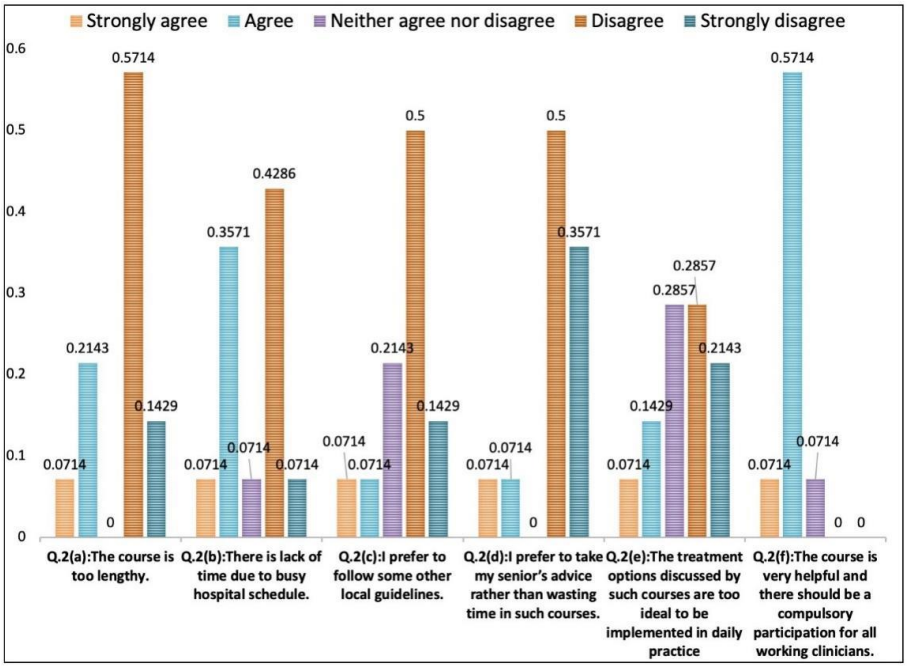

Fig.4: Responses to questionnaire on attitude towards AMS by open WHO participants

Supplementary Table 1: Comparison of Knowledge Among Surgeon Vs Physician, Faculty Vs Senior Resident (SR) Vs Junior Resident (JR), Open WHO Participants (X1) Vs Aware Non-participants (X2) Vs Unaware Non-participants (X3)

	Questions	Correct answer	Comparison 1	No of correct responses	P value	Comparison 2	No of correct responses	P value	Comparison 3	No of correct responses	P value
Q.1	a) Prescribing appropriate drug by making correct diagnosis	Strongly Agree	Surgeon	35	0.203	Faculty	11	0.817	X1	8	0.947
			Physician	33		SR	13		X2	8	
						JR	44		X3	52	
	b) Correct dose	Strongly Agree	Surgeon	41	0.403	Faculty	14	0.249	X1	9	0.548
			Physician	34		SR	14		X2	10	
						JR	47		X3	56	
	c) Any route of Administration (usually i.v.)	Strongly Disagree	Surgeon	6	0.293	Faculty	5	0.017	X1	3	0.025
			Physician	23		SR	0		X2	4	
						JR	9		X3	7	
	d) Longer duration to prevent relapse	Strongly Disagree	Surgeon	12	0.112	Faculty	8	0.052	X1	5	0.015
			Physician	29		SR	5		X2	7	
						JR	15		X3	16	
Q.2	a) Microbiology guides the therapy whenever possible	Strongly Agree	Surgeon	28	0.309	Faculty	14	0.006	X1	9	0.12
			Physician	27		SR	8		X2	8	
						JR	33		X3	38	
	b) Indications should be evidence based	Strongly Agree	Surgeon	40	0.748	Faculty	17	0.002	X1	11	0.049
			Physician	33		SR	11		X2	11	
						JR	45		X3	51	
	c) Use broadest spectrum of antimicrobials	Strongly Disagree	Surgeon	6	0.02	Faculty	7	0.01	X1	3	0.087
			Physician	13		SR	3		X2	5	
						JR	9		X3	11	
	d) Appropriate dosage to site and type of infection	Strongly Agree	Surgeon	32	0.002	Faculty	16	0.014	X1	11	0.039
			Physician	40		SR	14		X2	11	
						JR	42		X3	50	
	e) Minimise the duration of therapy	Strongly Agree	Surgeon	22	0.23	Faculty	14	< 0.001	X1	9	0.061
			Physician	23		SR	0		X2	4	
						JR	23		X3	32	
	f) Give polytherapy in most cases	Strongly Disagree	Surgeon	18	0.057	Faculty	10	0.084	X1	7	0.077
			Physician	23		SR	7		X2	6	
						JR	24		X3	28	
Q.3	a) Irrespective of severity of infection always start treatment with broad spectrum antibiotics.	Strongly Disagree	Surgeon	15	0.065	Faculty	12	< 0.001	X1	6	0.064
			Physician	20		SR	4		X2	6	
						JR	19		X3	23	
	Likely source of pathogen	Strongly Agree	Surgeon	17	0.297	Faculty	13	< 0.001	X1	6	0.006
			Physician	18		SR	4		X2	9	
						JR	18		X3	20	
	B) How likely the infection is due to drug resistant organism?	Strongly Agree	Surgeon	15	0.448	Faculty	12	< 0.001	X1	4	0.065
			Physician	15		SR	5		X2	8	
						JR	13		X3	18	
	Patient characteristics like drug allergies, hepatic and renal function.	Strongly Agree	Surgeon	26	0.744	Faculty	12	0.023	X1	7	0.031
			Physician	22		SR	7		X2	10	
						JR	29		X3	31	
	c) Laboratory Reports	Strongly Agree	Surgeon	21	0.589	Faculty	13	< 0.001	X1	4	0.465
			Physician	19		SR	6		X2	8	
						JR	21		X3	28	

Supplementary Table 1: Continue

Q.4	Emergence of antimicrobial resistance is inevitable	Strongly Agree	Surgeon Physician	12 7	0.495	Faculty SR JR	4 6 9	0.19	X1 X2 X3	1 2 16	0.376
Q.5	a) Alteration with antimicrobial target molecule	Strongly Agree	Surgeon Physician	17 19	0.209	Faculty SR JR	7 1 28	0.009	X1 X2 X3	7 4 25	0.082
	B) Increased import of drug into the bacterial cell or increased influx.	Strongly Disagree	Surgeon Physician	10 10	0.555	Faculty SR JR	3 3 14	0.801	X1 X2 X3	4 3 13	0.12
	c) Inactivation of antimicrobial	Strongly Agree	Surgeon Physician	11 21	0.004	Faculty SR JR	4 5 23	0.678	X1 X2 X3	8 4 20	0.005
Q.6	a) Large infrequent dosing	Strongly Agree	Surgeon Physician	10 10	0.555	Faculty SR JR	4 4 12	0.458	X1 X2 X3	5 0 15	0.233
	b) Optimising the duration of exposure with concentration in excess of MIC	Strongly Disagree	Surgeon Physician	19 4	0.471	Faculty SR JR	2 1 4	0.403	X1 X2 X3	3 0 4	0.035
Q.7	a) Your patient is hemodynamically stable	Strongly Agree	Surgeon Physician	12 9	0.908	Faculty SR JR	8 3 10	0.004	X1 X2 X3	4 2 15	0.294
	b) Irrespective of patients ability to tolerate enteral feeding, give i.v. antibiotics till patient is hospitalised.	Strongly Disagree	Surgeon Physician	24 22	0.511	Faculty SR JR	8 10 28	0.667	X1 X2 X3	6 9 31	0.057
	c) Your patient is able to adequately absorb orally administered medications.	Strongly Agree	Surgeon Physician	17 17	0.409	Faculty SR JR	8 6 20	0.206	X1 X2 X3	7 7 20	0.004
	d) There is an orally bioavailable antibiotic to treat your patient's condition.	Strongly Agree	Surgeon Physician	24 20	0.809	Faculty SR JR	9 9 26	0.337	X1 X2 X3	8 9 27	0.004
Q.8	a) Review of microbiologic data is not of much importance	Strongly Disagree	Surgeon Physician	18 22	0.089	Faculty SR JR	11 9 20	0.009	X1 X2 X3	9 6 25	0.003
	b) Verify the appropriate spectrum of therapy	Strongly Agree	Surgeon Physician	18 22	0.089	Faculty SR JR	13 7 20	< 0.001	X1 X2 X3	7 6 27	0.061
	c) Check for adverse effects	Strongly Agree	Surgeon Physician	22 20	0.562	Faculty SR JR	10 10 22	0.049	X1 X2 X3	6 8 28	0.097
	d) Evaluate route and duration of therapies	Strongly Agree	Surgeon Physician	19 22	0.129	Faculty SR JR	11 8 22	0.019	X1 X2 X3	9 6 26	0.004
Q.9	In formulary restriction type of intervention there is restriction of antibiotics by the trained staff before the therapy is initiated.	Strongly Agree	Surgeon Physician	5 11	0.033	Faculty SR JR	6 3 7	0.009	X1 X2 X3	4 3 9	0.025

Supplementary Table 2: Comparison of Attitude Among Surgeon Vs Physician, Faculty Vs Senior Resident (SR) Vs Junior Resident (JR), Open WHO Participants (X1) Vs Aware Non-participants (X2) Vs Unaware Non-participants (X3)

	Questions	Appropriate Attitude	Comparison 1	No of correct responses	P value	Comparison 2	No of correct responses	P value	Comparison 3	No of correct responses	P value
Q.1	a) Antimicrobial stewardship program is a necessity in our hospital.	Strongly Agree	Surgeon Physician	23 33	0.002	Faculty SR JR	11 10 35	0.314	X1 X2 X3	10 9 37	0.019
	b) ASP reduces the patient burden by reducing the health care cost.	Strongly Agree	Surgeon Physician	16 21	0.062	Faculty SR JR	11 8 18	0.004	X1 X2 X3	7 6 24	0.027
	c) ASP reduces the adverse effects of inappropriate antimicrobial prescription.	Strongly Agree	Surgeon Physician	23 26	0.101	Faculty SR JR	11 9 29	0.12	X1 X2 X3	10 8 31	0.006
	d) ASP threatens clinicians' autonomy.	Strongly Disagree	Surgeon Physician	12 12	0.727	Faculty SR JR	6 4 14	0.186	X1 X2 X3	4 6 14	0.045
	e) Such antimicrobial restrictions policies delay antimicrobial administration to patients and will negatively affect their care.	Strongly Disagree	Surgeon Physician	7 11	0.437	Faculty SR JR	6 1 11	0.768	X1 X2 X3	6 3 9	0.795
Q.2	a) The course is too lengthy.	Strongly Disagree	Surgeon Physician	0 2	0.425	Faculty SR JR	2 0 0	0.026	X1 X2 X3	2 0 0	X
	b) There is lack of time due to busy hospital schedule.	Strongly Disagree	Surgeon Physician	0 1	0.588	Faculty SR JR	1 0 0	0.129	X1 X2 X3	1 0 0	X
	c) I prefer to follow some other local guidelines.	Strongly Disagree	Surgeon Physician	1 1	0.588	Faculty SR JR	0 1 1	0.473	X1 X2 X3	2 0 0	X
	d) I prefer to take my senior's advice rather than wasting time in such courses.	Strongly Disagree	Surgeon Physician	1 4	0.287	Faculty SR JR	2 1 2	0.284	X1 X2 X3	5 0 0	X
	e) The treatment options discussed by such courses are too ideal to be implemented in daily practice	Strongly Disagree	Surgeon Physician	1 2	0.047	Faculty SR JR	2 1 0	0.129	X1 X2 X3	3 0 0	X
	f) The course is very helpful and there should be a compulsory participation for all working clinicians.	Strongly Agree	Surgeon Physician	2 3	0.207	Faculty SR JR	3 1 1	0.023	X1 X2 X3	5 0 0	X

Supplementary Table 3: Comparison of Practice Among Surgeon Vs Physician, Faculty Vs Senior Resident (SR) Vs Junior Resident (JR), Open WHO Participants (X1) Vs Aware Non-participants (X2) Vs Unaware Non-participants (X3)

	Questions	Correct answer	Comparison 1	No of correct responses	P value	Comparison 2	No of correct responses	P value	Comparison 3	No of correct responses	P value
Q.1	a) Antimicrobials are reviewed at regular intervals	Strongly Agree	Surgeon Physician	9 15	0.042	Faculty SR JR	10 2 12	0.002	X1 X2 X3	3 5 16	0.321
	b) Antimicrobials are prescribed routinely when infections suspected	Strongly Agree	Surgeon Physician	6 0	0.026	Faculty SR JR	1 4 1	0.081	X1 X2 X3	1 0 5	0.992
	c) Antimicrobials are prescribed with the help of ASP	Strongly Agree	Surgeon Physician	6 2	0.263	Faculty SR JR	0 3 5	0.654	X1 X2 X3	0 1 7	0.358
	d) Microbiologist is guiding while prescribing antimicrobials	Strongly Agree	Surgeon Physician	3 1	0.437	Faculty SR JR	0 3 1	0.469	X1 X2 X3	0 0 4	0.309
	e) Pharmacologist is guiding while choosing antimicrobials' dose	Strongly Agree	Surgeon Physician	14 9	0.602	Faculty SR JR	6 8 9	0.006	X1 X2 X3	2 4 17	0.925
Q.2	a) Urine culture should be collected	Strongly Disagree	Surgeon Physician	6 2	0.263	Faculty SR JR	4 1 3	0.011	X1 X2 X3	2 2 4	0.071
	b) Asymptomatic bacteriuria patients must be given treatment only in pregnancy and invasive urological procedures	Strongly Agree	Surgeon Physician	19 15	0.987	Faculty SR JR	5 9 20	0.52	X1 X2 X3	7 4 23	0.049
	c) Fluoroquinolones should be used for uncomplicated UTI	Strongly Disagree	Surgeon Physician	0 4	0.022	Faculty SR JR	1 0 3	0.974	X1 X2 X3	2 1 1	0.006
	d) Antibiotics should be advised in the above case because of large growth of organisms	Strongly Disagree	Surgeon Physician	13 11	0.84	Faculty SR JR	4 3 17	0.826	X1 X2 X3	4 5 15	0.095
Q.3	a) Patient should be given empiric antimicrobial therapy	Strongly Disagree	Surgeon Physician	12 8	0.694	Faculty SR JR	4 3 13	0.681	X1 X2 X3	2 2 16	0.794
	b) Stool culture is not required in above case scenario	Strongly Agree	Surgeon Physician	4 2	0.59	Faculty SR JR	2 0 4	0.542	X1 X2 X3	1 0 5	0.992
	c) Rehydration and watchful waiting without empiric antibiotics is sufficient in most cases of watery diarrhea	Strongly Agree	Surgeon Physician	24 25	0.204	Faculty SR JR	8 11 30	0.71	X1 X2 X3	7 8 34	0.194
Q.4	a) The history of productive cough does not differentiate in URTI, acute bronchitis and community acquired pneumonia	Strongly Agree	Surgeon Physician	7 7	0.631	Faculty SR JR	6 2 6	0.006	X1 X2 X3	2 3 9	0.332
	b) In acute bronchitis there is no need for chest X-ray, sputum culture, viral and serological analysis	Strongly Agree	Surgeon Physician	2 4	0.252	Faculty SR JR	3 0 3	0.081	X1 X2 X3	1 0 5	0.992
	c) Antibiotics can help in early cure of patients with acute bronchitis	Strongly Disagree	Surgeon Physician	7 11	0.114	Faculty SR JR	5 1 12	0.443	X1 X2 X3	2 4 12	0.459
	d) In patients with acute bronchitis patient education is key	Strongly Agree	Surgeon Physician	17 22	0.06	Faculty SR JR	7 7 25	0.728	X1 X2 X3	6 4 29	0.405
Q.5	a) Source control is the cornerstone of management in the above case	Strongly Agree	Surgeon Physician	28 22	1	Faculty SR JR	8 7 35	0.388	X1 X2 X3	9 5 36	0.143
	b) Antimicrobial therapy must be given in this case	Strongly Disagree	Surgeon Physician	1 1	0.563	Faculty SR JR	0 0 2	0.345	X1 X2 X3	1 0 1	0.159
	c) Thorough cleaning of shared equipments and MRSA decolonisation should be done	Strongly Agree	Surgeon Physician	26 20	0.929	Faculty SR JR	8 9 29	0.767	X1 X2 X3	5 5 36	0.991
	d) Culture samples should be avoided as contamination may lead to use of overly broad spectrum antibiotics	Strongly Agree	Surgeon Physician	6 5	0.116	Faculty SR JR	3 3 5	0.687	X1 X2 X3	3 3 5	0.242
Q.6	a) Antimicrobial sealents should not be used for surgical site skin preparation for the purpose of reducing SSI	Strongly Agree	Surgeon Physician	6 6	X	Faculty SR JR	1 2 3	0.437	X1 X2 X3	1 0 5	0.711
	b) Perioperative surgical antibiotic prophylaxis should be continued due presence of a wound drain for the purpose of preventing SSI	Strongly Disagree	Surgeon Physician	5 5	X	Faculty SR JR	3 2 0	<0.001	X1 X2 X3	0 1 4	0.645
	c) Prolongation of post-operative antimicrobial prophylaxis decreases the risk of SSI	Strongly Disagree	Surgeon Physician	13 13	X	Faculty SR JR	3 3 7	0.205	X1 X2 X3	0 1 12	0.098
	d) Re-dosing of antimicrobials should be considered if blood loss in patient >1.5L	Strongly Agree	Surgeon Physician	8 8	X	Faculty SR JR	2 3 3	0.081	X1 X2 X3	1 1 6	0.123

Comparison of Attitude

The study didn't show any significant differences between surgeons and physicians in attitude habits (supplementary Table 2). But there were significant differences among faculty and senior resident in the attitude habit, on health care cost reduction by implementing AMS ($p<0.004$). There were significant differences in attitude habit among open WHO aware participants than open WHO unaware participants ($p<0.05$)

Practice Assessment of Participants

The detailed responses of all the participants were noted (Table 1). Nearly 79.2% of participants reviewed AM at regular intervals. 40.8% of doctors routinely prescribed AM in suspected infections. Only 16.8% of doctors were guided by microbiologists while 88.8% of them were guided by pharmacologists in their daily clinical practice. Most of the doctors' performed poorly when questions were asked based on a clinical scenario.

Comparison of Practice Habits

No significant differences were found in practice habits of surgeons and physicians' except in one question asking about the use of fluoroquinolones in uncomplicated urinary tract infections in which surgeons lag behind physicians' ($p = 0.022$) (supplementary Table 3). Similarly, a significant difference in practice habits among faculty members, SRs and JRs was found in: Need to collect a urine sample in asymptomatic female ($p = 0.011$), the significance of history to differentiate between community-acquired pneumonia, acute bronchitis and URTI ($p = 0.006$) and prolongation of post-operative AM prophylaxis to reduce surgical site infection ($p<0.001$). All three questions were performed better by faculty members as seen in the knowledge section. Open WHO Participants performed better than aware non-participants and unaware non-participants with a significant difference in only two questions asking the use of AM in asymptomatic bacteriuria in pregnant patients ($p = 0.049$) and the use of fluoroquinolones in uncomplicated UTI ($p = 0.006$).

Discussion

Antimicrobial Resistance (AMR) created as a 'superbug' now has become one of the most worrisome issue in the health care setup. The perfect knowledge of antimicrobials' spectrum of activity and its relation with resistance can help health care workers in the correct use of antimicrobials and therefore reducing AMR (Chatterjee *et al*., 2015). To combat the same WHO has initiated the open WHO online platform: "Antimicrobial stewardship: A competency-based approach" a basic free course having fundamentals on AMS and can be a better way to assess doctors' from a wide variety of specialties, with variable experience profiles regarding AM in their clinical practice (WHO, 2018). Therefore, in this cross-sectional study, we decided to evaluate the KAP of practicing doctors based on this open WHO course on AMS.

The response rate of 62.5% can be attributed to the lack of time as well as interest among the study population. However, all the study populations were revisited three times for ensuring compliance. A similar response rate (65% of the total population) was seen by a previous study done by Chatterjee *et al*. (2015).

The study results showed, that very few residents and faculty are aware of the availability of such course and quite less participation was observed in this online platform among those who were aware. However, the study showed a positive impact of knowledge and experience of faculty members on AMS than the senior and junior residents. It was also proved that open WHO participants gave correct answers in managing the real-world clinical scenario than open WHO non-participants. To the best of our knowledge, this represents the only study investigating these factors while considering the impact of a massive free online open WHO course in an Indian tertiary care setup.

A study conducted by Byrne *et al*. (2019) on the fact of 'overuse and misuse of antibiotic: Drivers behind consumer behaviour amongst the general population shows 74% of the individual is on AM for the last year (Firouzabadi and Mahmoudi, 2020). In our study too, 19.2% of the doctors agreed upon starting broad-spectrum antimicrobials irrespective of the severity of the infection. Some doctors did not consider the route of administration as an AMS principle (24%) which represents a lack of basic knowledge of AMS in tertiary care doctors' too. So, this high burden of use of AM can only be rationalized by thorough knowledge of AMS and its basic principle - timeliness, appropriateness, adequacy, route and duration of AM usage.

In the present study, fair theoretical knowledge was seen among doctors. More than 50% near correct responses in each basic question on principles of AMS were obtained except for the question asking 'IV route of AM administration is most commonly preferred irrespective of the severity of infection' which was strongly disagreed by 11.2%. This has been similar in many studies with fair theoretical knowledge among doctors on AM use (Ghosh *et al*., 2016; Chatterjee *et al*., 2015; Byrne *et al*., 2019). This must-have resulted in higher use of IV uses of AM in the hospital. This hints at the early practice of low-hanging fruits of ASP like IV to oral switch, STOP order.

A sufficient knowledge gap was also seen in questions asking about the use appropriate dosing regimen of AM having concentration-dependent killing. Similar results have been seen from the KAP study of that showed the question

regarding dose adjustments had the highest frequency of wrong answers of 40 vs 43% in our study (Gonzalez-Gonzalez *et al*., 2015). This indicates there is an urgent unmet need (maybe mandatory) for better training for residents and faculties on this topic in the curriculum. This will result in good clinical practices and avoid inappropriate AM dosing. In few tertiary care institutions in India, it is already a foundation course for residents before appearing in the final master's degree examination.

As mentioned in Fig. 1, participation in the open WHO course is very low among doctors. A study conducted by Ghosh *et al.* (2016) showed that 12.5% of doctors had attended a training program in the last 1 year, though it was not based on the open WHO course, still, it gives an impression of the very low percentage of doctors are aware as well as seek to participate in such academic/knowledge update curriculum (Ghosh *et al*., 2016). This is highly unacceptable since the course is freely available and in this tertiary care hospital, it was mandatory to be certified with this course by the director 1year before this study initiation. Hence, human behavior of less up to date needs to be analyzed and immediate preventive actions to be ascertained.

In the present study, the participants showed a better practice attitude towards common illness than similar studies done before. A study by Ghosh *et al.* (2016) showed 46.87% of doctors didn't prescribe AM for simple URTI compared to 71.2% of doctors in the present study (Ghosh *et al*., 2016). In our study, 56.8% of doctors were against using AM in uncomplicated diarrhoea compared to 59.38% of doctors in the above study, which is comparable. However, to be 100% compliant with AMS, we need better practice attitudes ahead then only AMR can be prevented in to.

There is not much difference between surgical and non-surgical participants, in the knowledge, attitude and practice survey of this study except in questions concerning appropriate dosage to site and type of infection and promoting the use of broad-spectrum antibiotics. Hence surgeon needs to focus training on the right dose and spectrum of AM to consider. However, there is a significant difference among faculty, senior resident and junior residents, which supports higher years of experience and knowledge in faculty members. Faculties outperform in various questions in knowledge and practice sections involving deciding AM based on route and duration. Faculty were better able to make decisions when to use broad-spectrum AM. There were significant attitude differences among faculty and senior resident on health care cost reduction by implementing ASP, while a similar study was done comparing junior and senior doctors have shown significant attitude and practice differences in the resistant organism (Khajuria *et al*., 2019; Labi *et al*., 2018). This emphasizes that the treatment decision must be taken by the faculty. And faculty should be prima facie while AM is chosen, not by free-hand residents in most Indian hospitals.

This study for the first time evaluated the AMS based on open WHO course and compared the KAP survey in aware and unaware non-participants. As the total participant were only 11.2% and being a single centre study, the study didn't show the actual result, so can't be generalized to the whole population of doctors. In another way, the study reflected true KAP results without any theoretical biases. Being a KAP study, the number of participants, selection bias due to the nature of the KAP study and involvement of self-volunteering in answering the questions can be mentioned. A limitation of KAP studies is the probability that participants may give socially desirable answers rather than their actual beliefs. Studies taking place in teaching hospitals can be more prone to this limitation.

Conclusion

Antimicrobial stewardship is to be led by faculty among practicing residents' cohort and freely available open WHO course is the need of the hour to make more steward to combat the growing antimicrobial resistance.

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Author's Contributions

Simardeep Kaur and Prativa Sethi: Literature search, formulating protocol, collection of data, statistical analysis, writing the manuscript and final approval.

Prasan Kumar Panda: Literature search, designing the study, critical reviewing and final approval.

Ethical Approval

The study was approved by the Institutional Ethics Committee, All India Institute of Medical Sciences (AIIMS), Rishikesh (No.143/IEC/STS/2019), India under short term studentship program by Indian Council of Medical Research, India (Reference id: 2019-03933).

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