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Original Article

Veterinary Medical Students' Perceptions, Attitude and Knowledge about Antibiotic Resistance and Stewardship: How Prepared Are Our Future Prescribers?

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Abstract

A cross sectional, multicentre survey utilizing a questionnaire was used to assess 6th- (final-) year veterinary medical students' perceptions, attitude and knowledge about antibiotic resistance (ABR) and stewardship (ABS) in 5 conveniently-selected veterinary schools in Nigeria. Data obtained were analyzed by Fischer's exact and χ^2 tests at a significance level of $P < 0.05$. Out of 175 final-year veterinary students, 95 (54.3% i.e., response rate) completed the survey. Of the 95, 17% have heard about ABS and 7% knew the meaning of ABS. Less than 10% knew the core principles and goals of ABS and less than 20% of the respondents knew the ideal members of an ABS team. All the respondents rightly knew that no antibiotic stewardship programme (ASP) exist in veterinary hospitals in Nigeria, nearly all of them (97%) reported that antibiograms are rarely used during antibiotic (AB) prescription in their institutional veterinary teaching hospital (VTH) and about two-third (65%) believed that ABs are overused in most veterinary hospitals in Nigeria. Most of the respondents believed that ABR is of greater concern at national level than in their institutional VTHs and majority of them (92%) believed that ABR is a global problem ($P = 0.009$). Minority of the respondents knew that inadequate personal hygiene, use of substandard ABs, prescription of ABs by non-veterinarians/professionals, poor infection control practices, treating self-limiting infections with ABs, suboptimal and incomplete AB doses ($P = 0.017$), are factors that promote ABR. Minority of the respondents knew that education on AB therapy (44%), development of antibiotic usage policies (35%), reduction of AB use (14%), establishment of national AB resistance surveillance (28%) and development of institutional guidelines for AB use (29%), are critical interventions to curb ABR. Only 17% of the respondents felt that their education on ABR is adequate for their veterinary career. Most of the respondents believed that strong knowledge of ABs is important for their future veterinary career and would like more education about ABR and ABS. Overall mean correct score of 29% on clinical knowledge vignettes with similar scores across the schools in all the areas, was recorded. This survey has shown that Nigerian veterinary students' perception and knowledge about ABR and ABS are poor and therefore creates doubt about their preparedness to practice ABS. There is urgent need for improved ABS education in Nigerian veterinary schools.

Keywords: antibiotic resistance; antibiotic stewardship; education; veterinary medical students

Introduction

Antibiotic resistance (ABR) occupies the centre stage in global public health agenda because it is a "tragedy of the commons" affecting both developed and developing nations (O'Neil, 2014; Lanza *et al*., 2017). The threat posed by ABR has been equated to climatic change and this is of grave concern globally (Castro-Sanchez *et al*., 2016; Friedman et *al*., 2016; Moran, 2017). It is known that ABR could potentially exert catastrophic economic and health impact which on a global scale is enormous and dreadful (Zaidi *et al*., 2004; Cisneros *et al*., 2014; O'Neil, 2014; Prestinaci *et al*., 2015; Fitchet and Antun, 2016).

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Amongst the numerous contributions to ABR, inappropriate use of antibiotics (ABs), especially wrong prescribing behavior by healthcare professionals, including veterinarians, have been identified as a major factor that promote ABR (Cotta *et al*., 2014; Wasserman *et al*., 2017). Lack of knowledge required for appropriate use of AB and scarce training offered to healthcare professionals, have been identified as the major cause of wrong use of AB by healthcare/veterinary practitioners (Cisneros *et al*., 2014). It is known that AB is prescribed by virtually all clinicians/veterinarians, including allied healthcare professionals, regardless of training or knowledge (Abbo *et al*., 2013; Wasserman *et al*., 2017).

Veterinary settings are reservoirs of zoonotic multidrug-resistant organisms, particularly in developing countries, including Nigeria, owing to inappropriate use of ABs (Van Boeckel *et al*., 2015; Moran, 2017). Therefore, veterinarians are expected to be in the frontline of the fight against ABR (Castro-Sanchez *et al*., 2016; Brink, *et al*., 2017; Moran, 2017; Dyar *et al*., 2018). Optimization of AM prescribing is the best way to checkmate escalating ABR worldwide and to preserve AB for future generations (Broom *et al*., 2016; Moran, 2017). Interventions that strengthen the concept of 'One-Health' at the human-animal interface such as antibiotic stewardship (ABS), have been established the best strategy to contain ABR (Cisneros *et al*., 2014; Bowater, 2015; O'Donnel and Guarrascio, 2016; Wasserman *et al*., 2017). Education (especially of the healthcare workers and the public) on AB therapy and ABR is considered one of the most important interventions/strategy of ABS (Wasserman *et al*., 2017; O'Donnel and Guarrascio, 2017; MacDougall *et al*., 2017). The World Health Organization (WHO) identified education of healthcare workers and health profession students on rational AB prescribing and ABS as an integral part of all ABR containment activities (Vickers, 2011; WHO, 2012; Abbo *et al*., 201; Hoque *et al*., 2016). It has been observed that ABS efforts in most parts of the world focused more on understanding the perceptions of practicing physicians/veterinarians and modifying their behaviors, with far less attention being paid to the education of medical and veterinary medical students (Abbo *et al*., 2013; Luther *et al*., 2013; MacDougall *et al*., 2017) . It is a well-established fact that for ABR to be contained, the next generation of healthcare professionals, particularly the physicians and veterinarians who are the major prescribers and/or dispensers of ABs, must be better prepared to use AB more judiciously (Abbo *et al*., 2013; Fairles, 2013; Schwartz, 2016; O'Donnel and Guarascio, 2017) . Thus, education of veterinary medical undergraduate students on ABS is critical for the control of ABR because these future veterinarians are to be in the frontline (as professionals and educators of other allied healthcare professionals, the public and their clients/patients) in infection control, development, establishment and implementation of ASPs (Delit *et al*., 2007; Wasserman *et al*., 2017; O'Donnel and Guarascio, 2017). A veterinarian with insufficient knowledge about ABs, ABR and ABS would neither be able to practice ABS nor lead others in stewardship programmes (Brink *et al*., 2017). Moreover, it is difficult for veterinarians to change habits that are untoward ABS once they are formed (Weier *et al*., 2017). Inadequate preparation at undergraduate level in veterinary schools may result in practices that are untoward ABS, particularly inappropriate AB use/prescribing (Wasserman *et al*., 2017); therefore, there is need to equip veterinary students with adequate ABS knowledge and skills prior to their entry into the veterinary workforce (MacDougal *et al*., 2017; Wasserman *et al*., 2017; Weier *et al*., 2017).

Assessing veterinary students' perception and level of knowledge about ABR and ABS and their preparedness to practice ABS is crucial for identifying gaps in knowledge; such information could be useful for policy makers in developing adequate ABS educational programmes for veterinarians, improving curricula in veterinary schools and development of effective ASPs in veterinary hospitals (Cotta *et al*., 2014; Gharbi *et al*., 2016; Hoque *et al*., 2016). Several studies have assessed medical/allied healthcare profession students' perceptions and knowledge about AB, ABR and/or ABS and their perceptions about how prepared they are to practice ABS (Minen *et al*., 2010; Pulcini *et al*., 2011; Abbo *et al*., 2013; Afzal Khan *et al*., 2013; Justo *et al*., 2013, Thriemer *et al*., 2013; Dyar *et al*., 2014; Harakeh *et al*., 2015; Tarao *et al*., 2015; Burger *et al*., 2016; Ferdoush *et al*., 2016; Haque *et al*., 2016; Hoque *et al*., 2016; Padmanabha *et al*., 2016; Yang *et al*., 2016; Weier *et al*., 2017; Dyar *et al*., 2018; Wasserman *et al*., 2017). These studies reported significant differences among the students in terms of perceptions and knowledge about ABS and ABR. Studies evaluating veterinary medical students' perceptions and knowledge about ABR and ABS and their preparedness to practice ABS, are rare in the literature. The only study which assessed veterinary students' perception and knowledge about ABR and ABS is that of Dyar *et al*. (2018) in the United Kingdom (UK). There have been calls (Wesse *et al*., 2015; Brink *et al*., 2017; Dyar *et al*., 2018) for studies evaluating veterinary students' perceptions and knowledge about ABR and ABS.

In Nigerian veterinary medical schools, courses on ABR are taught in the 3rd and 4th years in Microbiology and Pharmacology, and students are further exposed to AB sensitivity testing and prescription in the 6th (final) year during clinical postings/rotations in their respective institutional veterinary teaching hospitals (VTHs) (Anyanwu and Kolade, 2017). No study has evaluated Nigerian veterinary medical students' perceptions, attitude and knowledge about ABR and ABS. Likewise there are no data on the perception of Nigerian veterinary students about their preparedness to practice ABS. This study was, therefore, undertaken to assess final-year veterinary medical students' perceptions and knowledge about ABR and ABS.

Materials and Methods

Study design, site and population

This cross-sectional, multicentre descriptive survey was carried out between June and August, 2017 in 5 (out of 10 registered) Universities in Nigeria offering Veterinary Medicine (VM): the University of Nigeria, Nsukka in Enugu State southeastern region, the Michael Okpara Federal University of Agriculture, Umudike in Abia State southeastern region, the Ahmadu Bello University, Zaria in

Kaduna State northwest region, the Federal University of Agriculture, Markurdi in northcentral region and the University of Abuja in the Federal Capital Territory. The University of Nigeria, Nsukka served as the coordinating site. The participating schools were selected by convenience sampling. The total number of registered final-year veterinary medical students (VMS) in these five participating schools as at the period of the study was 175 (Table 1). The target population comprised of all registered final-year VMS in the various schools. Only those who were willing to participate in the survey and provided written informed consent were included in the study. The 6th-year was selected purposefully for this survey because it is the last (final) year of undergraduate studies in VM schools in Nigeria and a good estimation of the knowledge of veterinary students about ABR and ABS could be obtained at this level since these students have completed their pre-clinical and clinical years, including rotations in their respective institutional VTHs.

Ethical approval

Ethical approval was not necessary for this study; however, permission to conduct the study was obtained from the University of Nigeria Research Ethics Committee. Permission to conduct the study in each of the participating sites was obtained from the lecturer who served as the Head/Coordinator of the final-year class. Informed consent of all participants involved in the study was obtained and confidentiality and anonymity of the data obtained was ensured.

Data collection

Information about students' demographics, knowledge/perceptions of principles, goals and development strategies of ABS, ABR and AB use/prescribing, resources used for AB education and clinical knowledge vignettes, was collected using a self-administered structured questionnaire. The questionnaire was developed after thorough review and modification (to adapt for veterinary students) of comparable studies (Abbo *et al*., 2013; Burger *et al*., 2016; Yang *et al*., 2016; Wasserman *et al*., 2017) and validated by a pilot study on 15 fresh VM graduates from the 5 veterinary schools. Knowledge was assessed using 11 validated clinical vignettes (Abbo *et al*., 2013; Yang *et al*., 2016). The surveys were administered to final-year VM students during whole class lectures at the participating veterinary schools. The students were instructed to abstain from using resources or consulting peers in filling the survey (Thriemer *et al*., 2013; Justo *et al*., 2014; Wasserman *et al*., 2017). They were also asked to fill the questionnaires on-site within 4 hours to ensure that consultation of resources and peers are precluded (Thriemer *et al*., 2013). No incentives were given to the participants. Participation was voluntary and responses were anonymous.

Data analysis

The participating veterinary medical schools were de-identified as "A", "B", "C", "D" and "E" in order to conduct blinded data analysis. Answers to questions that used a 5-point Likert scale were merged into two dichotonomous categories (strongly agree/agree and strongly disagree/disagree/neutral, often/occasionally/sometimes and rarely/never, very good/good and poor/very poor/neutral) (Abbo *et al*., 2013; Justo *et al*., 2014; Yang *et al*. 2016). Data were entered into Microsoft Excel sheet version 15.0 and exported to SPSS version 15.0 for analysis. Frequencies and percentages of all variables were calculated. Non parametric tests were used to assess for the presence of any significant difference among the students' response from the 5 survey sites. The Fischer's exact and χ^2 tests were used to compare the parameters as appropriate and statistical significance was set at $P < 0.05$. An overall knowledge score was evaluated by calculating the total percentages (each counts one point) of correct answers for the vignette-based questions (Aboo *et al*., 2013; Yang *et al*., 2016).

Results

Response rate

Ninety five final-year VMS out of a total of 175 registered students in the 5 veterinary schools completed the survey for an overall response rate of 54.3% (range across schools, 31.7%-100%). Response rate by schools are shown in Table 1.

Student demographics

Overall, 65.3% (62/95) of the respondents were males while 34.7% (33/95) were females. More than two-third (70.5%, 67/95) of the respondents were between the ages of 20 and 25 years, 26.3% (25/95) were between 26 and 30 years while 3.2% (3/95) were 30 years and above.

Background knowledge and perceptions of antibiotic stewardship

Respondents' background knowledge and perceptions about ABS are summarized in Table 2. Overall, a low proportion (17%) of the respondents agreed that they have heard of ABS, with 8%, 2%, 3%, 7% and 1% of these having heard or learnt about ABS from lecturer(s), peers, senior

Table 1. Response rate by school

University	Number of final-year Veterinary Medicine students	Response rate	
		Number (n)	Percentage
A	45	25	55.6
B	63	20	31.7
C	32	19	59.4
D	22	18	81.8
E	13	13	100
All	175	95	54.3

Table 2. Veterinary medical students' background knowledge and perceptions of antibiotic stewardship

Background knowledge	Percentage (rounded) of students per university who strongly agree/agree						*P* value
	School						
	All (n = 95)	A (n = 25)	B (n = 20)	C (n = 19)	D (n = 18)	E (n =13)	
I am familiar with the term or have heard about antibiotic stewardship	17%	24%	20%	16%	6%	15%	0.621[a]
I know the meaning of antibiotic stewardship	7%	8%	15%	5%	0%	8%	0.567[a]
Source/Means from which antibiotic stewardship was heard/learnt							
Lecturer	8%	20%	0%	5%	0%	15%	0.050[a]
Peers (other students)	2%	0%	5%	0%	6%	0%	0.596[a]
Senior colleague	3%	0%	10%	0%	0%	8%	0.134[a]
Mass media (newspaper, magazine, radio, television, internet)	7%	8%	10%	16%	0%	0%	0.362[a]
Scientific journals	1%	0%	5%	0%	0%	0%	0.737[a]
Seminar/conference/symposium	0%	0%	0%	0%	0%	0%	N[c]
Principles of antibiotic stewardship							
Timely collection of appropriate specimens for microscopy, culture and sensitivity	4%	8%	0%	5%	0%	8%	0.551[a]
Using antibiotic only when needed	5%	8%	5%	0%	6%	8%	0.821[a]
Choosing the proper antibiotic for specific infection	7%	16%	0%	11%	0%	8%	0.173[a]
Timely administration of antibiotics at the appropriate dose and route	7%	8%	5%	16%	0%	8%	0.515[a]
Administering antibiotic for appropriate duration in every case	7%	20%	5%	0%	0%	8%	0.065[a]
Therapeutic monitoring of antibiotic use	4%	8%	0%	5%	0 0%	8%	0.551[a]
Improved hygiene and infection control	3%	8%	0%	0%	0%	8%	0.331[a]
The study of antibiotics	3%	12%	0%	0%	0%	0%	0.116[a]

[a]Fischer's exact test
N[c]: Not calculable

colleagues, mass media and scientific journals, respectively. Only 7% of the respondents agreed that they know the meaning of ABS. Regarding perceptions and knowledge about the principles of ABS, 4% of the respondents agreed that ABS involves therapeutic monitoring of AB use and timely collection of appropriate specimens for microscopy, culture and sensitivity while 7% knew that ABS involves choosing the proper AB, timely administration of AB at the appropriate dose and route, and administering AB for appropriate duration in every case. Five percent of the respondents perceived that using AB only when needed is among the principles of ABS while 3% of the respondents knew that ABS involves improving hygiene and infection control, and the study of AB.

Perceptions and attitudes about antibiotic use/prescribing and resistance

Respondents' perceptions and attitude about AB use/prescribing and resistance is summarized in Table 3. The majority of the respondents (72%) (range across institutions, 44%-100%; $P = 0.009$) agreed that ABR is a global problem while far less minority of the respondents (9%) (range across institutions, 0%-4%; $P = 0.030$) agreed that ABR is not a significant problem in Nigeria. Concerning factors that promote ABR, slightly above half (55%) of the respondents agreed that widespread/overuse of AB in humans/animals promotes ABR. Very little proportion of the respondents (8%) knew that poor hand washing practice and poor infection control practices are also contributors to ABR. Minority of the respondents agreed that substandard quality of ABs (15%), administration of inappropriate quantity of AB for inadequate duration (23%), use of broad-spectrum AB for treating animals when narrow-spectrum is available (26%) and use/prescription of ABs by non-veterinarians/professionals (29%), respectively, are also factors and practices that promote ABR. Two-third of the respondents (65%) agreed that prescribing and use of ABs in veterinary hospitals are not appropriate in Nigeria. About one-third of the respondents (35%) agreed that they have prescribed/have been allowed to prescribe AB in their institutional VTH where they have rotated while nearly all the respondents (97%) indicated that antibiograms are rarely used during prescription in their institutional VTH where they have rotated. Less than one-third (28%) of the respondents reported that ABs are overused in their institutional VTH where they have rotated but a majority of the respondents (73%) reported that ABR is not a significant problem in their institutional VTH where they have rotated. A high proportion of the respondents (78%) agreed that better use of ABs will reduce problems with ABR and majority of the respondents (73%) also indicated

Table 3. Veterinary medical students' perceptions and attitude about antibiotic use and resistance

Perceptions and attitude	Percentage (rounded) of students per university who strongly agree/agree						*P* Value
	School						
	All (n = 95)	A (n = 25)	B (n = 20)	C (n = 19)	D (n = 18)	E (n = 13)	
Antibiotic resistance is a global problem	72%	68%	70%	84%	44%	100%	0.009[b]
Inappropriate use of antibiotics can directly harm patients	84%	96%	70%	95%	72%	85%	0.047[a]
Antibiotic resistance is not a significant problem in my institutional Veterinary Teaching Hospital where I have rotated	73%	56%	70%	79%	83%	85%	0.210[b]
Antibiotic resistance is not a significant problem in Nigeria	9%	4%	20%	0%	22%	0%	0.030[a]
Contributors/promoters of antibiotic resistance							
Widespread/overuse of antibiotics in humans and animals	55%	48%	55%	74%	61%	31%	0.168[b]
Unnecessary use of broad-spectrum antibiotic for treating animals when narrow-spectrum antibiotic is available	26%	36%	30%	26%	6%	31%	0.250[b]
Poor hand washing practice by healthcare/veterinary workers	8%	8%	5%	5%	6%	23%	0.467[a]
Inadequate farm biosecurity and animal vaccination	8%	12%	10%	0%	11%	8%	0.624[a]
Using/prescribing antibiotics by non-veterinarians/non-professionals	29%	32%	40%	21%	28%	23%	0.741[b]
Administering inadequate antibiotic doses for inappropriate frequency	23%	48%	20%	16%	6%	15%	0.017[a]
Prescribing and using substandard quality of antibiotics to treat animals	15%	16%	20%	21%	11%	0%	0.465[a]
Antibiotic use attitudes in veterinary settings							
Prescribing and use of antibiotics in veterinary hospitals in Nigeria are not appropriate	65%	64%	60%	89%	50%	62%	0.133[b]
I have prescribed or have been allowed to prescribe antibiotic in my institutional Veterinary Teaching Hospital where I have rotated	35%	32%	20%	47%	28%	54%	0.219[b]
Antibiograms are rarely used during prescription in my institutional Veterinary Teaching Hospital where I have rotated	97%	96%	100%	89%	100%	100%	0.362[a]
Antibiotics are overused in my institutional Veterinary Teaching Hospital where I have rotated	28%	40%	35%	37%	11%	8%	0.087[b]
Better use of antibiotic will reduce problems with antibiotic resistance	78%	76%	80%	74%	67%	100%	0.206[a]
I would like more education on antibiotic resistance	73%	84%	70%	89%	61%	77%	0.258[a]
Factors that could influence my decision to prescribe antibiotic							
Client pressure/push	18%	8%	45%	11%	17%	8%	0.020[a]
Health status/condition of the patient	37%	20%	50%	21%	56%	46%	0.043[b]
Peers (other students)	8%	8%	5%	11%	11%	8%	0.964[a]
Senior colleague	11%	8%	20%	5%	6%	15%	0.541[a]
Antibiogram of isolates	52%	68%	10%	68%	50%	62%	<0.001
Cost of antibiotic	37%	52%	10%	63%	28%	23%	0.002[b]
Profit to be made	15%	16%	25%	5%	17%	8%	0.487[a]
Ensure therapeutic success	40%	32%	50%	42%	44%	31%	0.716[b]
Troublesome resistant zoonotic bacteria of public health concern							
Staphylococcus aureus	39%	44%	65%	11%	33%	38%	0.013[b]
Pseudomonas aeruginosa	17%	24%	35%	0%	11%	8%	0.024[a]
Klebsiella pneumoniae	6%	16%	5%	5%	0%	0%	0.278[a]
Enterococcus faecium	4%	4%	5%	5%	6%	0%	1.000[a]
Clostridium difficile	13%	16%	10%	0%	33%	0%	0.017[a]

[a]Fischer's exact test
[b]χ^2 test

that they would like more education on ABR.

Regarding factors that could influence the respondent's prescription of AB, 18% (range across institutions, 8%-45%; $P = 0.020$) agreed that their client could influence them, 37% reported that the health status/condition of the animal (range across institutions, 20%-56%; $P = 0.043$) and cost of AB (range across institution, 10%-63%; $P = 0.002$) could influence their prescription, slightly above half of the respondents (52%) (range across institutions, 10%-68%; $P < 0.001$) reported that antibiogram of the isolate could influence them, while 8%, 10%, 14% and 40% agreed that peers, senior colleague(s), profit to be made, and ensuring therapeutic success, are factors that could influence their prescription of AB (Table 3).

With regards to perceptions/knowledge about zoonotic resistant bacteria of public health concern, 39% (range across institutions, 11%-44%; $P = 0.013$) of the respondents recognized *Staphylococcus aureus*, *Pseudomonas aeruginosa* 17% (range across institutions, 0%-35%; $P = 0.024$), and *Clostridium difficile* 13% (range across institutions, 0%-33%; $P = 0.017$) (Table 3). Far less minority of the respondents agreed that *Klebsiella pneumoniae* (6%) and *Enterococcus faecium* (4%) are also problematic zoonotic resistant bacteria.

Perceptions and knowledge about goals and development strategies of antibiotic stewardship

The respondents' perceptions about goals and development strategies of ABS are summarized in Table 4. Concerning the goals of ABS, minority of the respondents knew that ABS seek to reduce hospital stay (2%), reduce ABR (17%), and minimize toxicity and other adverse effects (6%). Very minimal proportion of the respondents agreed that ABS seek to increase the use of broad-spectrum AB (1%) and increase duration of therapy to ensure therapeutic success (2%) whereas none of the respondent agreed that increasing the use of AB is among the goals of ABS.

Regarding the development strategies of ABS, minority of the respondents (19%) agreed that assembling and leading of the core ABS team is one of the responsibilities of the veterinarians in ASPs. None of the respondent agreed that ASP exist for veterinary hospitals in Nigeria. For the formation of ABS team, low proportion of the respondents agreed that veterinarians (19%), veterinary assistants (5%), physicians (9%), veterinary hospital pharmacists (13%) and infection control staffs (8%), are members of ABS team. There was also agreement by a minority of the respondents (13%) that hospital cleaning staffs are members of ABS team but with significant variation ($P < 0.001$; range across institutions, 0%-50%) in responses of the respondents. Pertaining to the role of veterinarians in ABS, prescribing AB over-the-counter was thought to be the major role of veterinarians (69%) whereas promoting optimal use of antibiotic (15%), educating veterinary allied healthcare professionals (13%) and working with therapeutic committees to develop policies (7%), were regarded as the minor roles of veterinarians in ASPs.

Regarding interventions that could help in curbing ABR, majority of the respondents (92%) agreed that the establishment and implementation of ASPs in veterinary hospitals are essential in Nigeria while less than half of the respondents agreed that education on AB therapy (44%) and development of AB usage policies (35%) are useful interventions to contain ABR (Table 4). Less than one-third of the respondents agreed that reduction of AB use (14%), establishment of national AB resistance surveillance (28%) and development of institutional guidelines for AB use (29%), are interventions to curb ABR. Majority of the respondents (84%) agreed that inappropriate use of AB can harm patients although with significant difference in responses between the schools (range across institutions, 70%-96%; $P = 0.047$). Only half of the respondents (51%) agreed that avoidance of treating self-limiting infections reduces ABR. High proportion of the respondents (88%) agreed that strong knowledge of AB is important for their future veterinary career and teaching about ABR and ABS at all levels of veterinary education will enhance appropriate use of AB by veterinarians. Majority of the respondents (71%) agreed that new AB will be developed in the future that will keep up with the problem of ABR.

Perceptions about education on appropriate antibiotic use and stewardship preparedness

Respondents' perception about the quality and quantity of their ABS education and ABS preparedness is summarized in Table 5. Overall, minority of the respondents (12%) agreed they have had formal lecture on ABS for 1-4 hours whereas most of them (88%) reported that they have never had any formal training on ABS. None of the respondents agreed to have ever had ABS training for 5 hours. A low proportion of the respondents (17%) were confident that what they were taught on ABR resistance is enough for their veterinary career while most of them (84%) indicated that they would like more training on ABS.

Regarding topics on AB and AB therapy, 68 out of 95 (72%) of the students recalled that spectrum of therapy for different AB have been taught very well with significant variation in responses between the schools (range across institutions, 56%-96%; $P = 0.020$). Most of the respondents agreed that their education about the basic mechanisms of ABR (74%) and how to select the best AB for specific infection was good/very good. Less than two-third (59%) of the respondents also believed that their education about how to find reliable information to treat patients, when to start AB therapy (57%), and how to interpret antibiograms (60%) was good/very good while less than one-third lacked confidence about their education on transitioning from intravenous to oral ABs (27%), streamlining/de-escalating AB therapy (19%) and handling clients demanding unnecessary AB for their animals (41%).

Educational resources used for learning about antibiotic use and resistance

Sources of information about AB use and resistance used by the respondents are summarized in Table 6. The sources of information used by the respondents were, in rank of decreasing frequency: iPhone/Smart phone applications (36%), lecturers/resident doctors (25%) (range across schools, 0%-40%; $P=0.014$), textbooks /Merck's/Black's veterinary manual (17%), class lecture notes (16%) (range across schools, 0%-35%; $P = 0.010$), Nigerian veterinary formulary (14%), medical/veterinary journals (12%) (range across schools, 0%-24%; $P = 0.023$), Wikipedia (8%), peers (other students) (5%), veterinary hospital pharmacists (3%) and veterinary assistants (2%).

Table 4. Veterinary medical students' perceptions and knowledge about goals and development strategies of antibiotic stewardship

Goals and development strategies of antibiotic stewardship	Percentage (rounded) of students per university who strongly agree/agree						*P* Value
	School						
	All (n = 95)	A (n = 25)	B(n=20)	C (n = 19)	D (n = 18)	E (n = 13)	
Goals of antibiotic stewardship							
Increasing the use of antibiotics	0%	0%	0%	0%	0%	0%	N[c]
Reducing hospital stay	2%	0%	10%	0%	0%	0%	0.133[a]
Increasing duration of therapy to ensure therapeutic success	2%	0%	5%	0%	0%	8%	0.299[a]
Increasing use of broad-spectrum antibiotics	1%	4%	0%	0%	0%	0%	1.000[a]
Reducing antibiotic resistance	17%	20%	15%	21%	6%	23%	0.630[a]
Minimizing toxicity and other adverse effects	6%	4%	5%	11%	6%	8%	0.945[a]
Members of the antibiotic stewardship team							
Physicians	9%	20%	5%	11%	6%	0%	0.351[a]
Veterinary assistants	5%	12%	5%	0%	6%	0%	0.534[a]
Veterinary hospital pharmacists	13%	24%	5%	16%	11%	0%	0.221[a]
Infection control staff	8%	12%	5%	11%	11%	0%	0.775[a]
Veterinary clinical microbiologist	5%	12%	5%	0%	6%	0%	0.534[a]
Veterinary hospital cleaning staff	13%	12%	0%	0%	50%	0%	<0.001
Veterinarians	19%	24%	5%	16%	28%	23%	0.340[a]
Roles of veterinarians in antibiotic stewardship							
Assembling and leading of the core antibiotic stewardship team	19%	16%	5%	21%	33%	23%	0.234[a]
Promoting optimal use of antimicrobials	15%	12%	10%	21%	17%	15%	0.871[a]
Educating veterinary allied healthcare professionals/public	13%	12%	5%	21%	11%	15%	0.650[a]
Working with therapeutic committees to develop policies	7%	8%	10%	5%	11%	0%	0.852[a]
Prescribing antibiotics over-the-counter	69%	48%	85%	79%	67%	77%	0.062[b]
Interventions that can help in combating antibiotic resistance							
Development of antibiotic usage policies	35%	40%	50%	26%	33%	15%	0.283[b]
Reduction of antibiotic use	14%	16%	25%	11%	11%	0%	0.373[a]
Establishment of national antibiotic resistance surveillance	28%	36%	40%	11%	28%	23%	0.274[b]
Development of institutional guidelines for antibiotic use	29%	32%	40%	16%	17%	46%	0.201[b]
Education on antibiotic therapy	44%	56%	40%	37%	44%	38%	0.723[b]
Antibiotic stewardship programme exist for veterinary clinics/hospitals in Nigeria	0%	0%	0%	0%	0%	0%	N[c]
Establishment and implementation of antibiotic stewardship programmes in veterinary hospitals are essential in Nigeria	92%	92%	90%	89%	89%	100%	0.863[a]
Avoidance of treating self-limiting infections in animals reduces antibiotic resistance	51%	40%	50%	74%	56%	23%	0.055[b]
Teaching about antibiotic resistance and stewardship at all levels of veterinary education will enhance appropriate use of antibiotics by veterinarians	88%	96%	75%	84%	78%	92%	0.242[a]
Strong knowledge of antibiotics is important for my future veterinary career	88%	92%	80%	84%	78%	92%	0.645[a]
New antibiotics will be developed in the future that will keep up with the problem of antibiotic resistance	71%	68%	70%	68%	72%	77%	0.984[b]

[a]Fischer's exact test
[b]χ^2 test; N[c]: Not calculable

Table 5. Veterinary medical students' perceptions of their antibiotic stewardship education and preparedness

Perceptions	Percentage (rounded) of students per university who strongly agree/agree						*P* Value
	School						
	All (n = 95)	A (n = 25)	B (n = 20)	C (n = 19)	D (n = 18)	E (n = 13)	
I have attended a formal lecture on antibiotic stewardship	12%	16%	20%	5%	6%	8%	0.573[a]
I have attended a 1-4 hour antibiotic stewardship lecture or training	12%	16%	20%	5%	6%	8%	0.573[a]
I have attended antimicrobial stewardship lecture/training that lasted more than 5 hours	0%	0%	0%	0%	0%	0%	N[c]
I have had no formal antibiotic stewardship lecture/training	88%	84%	80%	95%	94%	92%	0.573[a]
What I have been taught on antibiotic resistance in the veterinary school is enough for my future veterinary career	17%	16%	20%	5%	28%	15%	0.481[a]
I would like to be trained/more training on antibiotic stewardship	87%	96%	75%	89%	78%	100%	0.093[a]
Antibiotic stewardship activity understood very well and considered useful for my career							
Finding reliable information to treat my patients	59%	64%	55%	79%	56%	31%	0.097[b]
Basic mechanisms of antibiotic resistance	74%	88%	70%	68%	61%	77%	0.337[a]
Handling clients demanding unnecessary antibiotics for their animals	41%	36%	55%	47%	39%	23%	0.424[a]
When to start antibiotic therapy in sick animals	57%	60%	70%	42%	61%	46%	0.423[b]
Selecting appropriate antibiotic for specific infection	79%	92%	70%	84%	78%	62%	0.166[a]
Identifying spectrum of therapy for different antibiotics	72%	96%	70%	58%	56%	69%	0.020[b]
Interpreting antibiograms	60%	76%	60%	47%	50%	62%	0.330[b]
Transitioning from intravenous to oral antibiotics	27%	28%	45%	21%	28%	8%	0.209[b]
Streamlining/de-escalating antibiotic therapy	19%	20%	35%	21%	11%	0%	0.126[a]

[a]Fischer's exact test
[b]χ^2 test; N[c]: Not calculable

Table 6. Resources used for learning about antibiotic use/prescribing and resistance

Resource	Percentage (rounded) of students per university who agree to have often/sometimes/occasionally used the resource						*P* Value
	School						
	All (n = 95)	A (n = 25)	B (n = 20)	C (n = 19)	D (n = 18)	E (n = 13)	
iPhone/Smartphone applications	36%	28%	35%	42%	50%	23%	0.490[b]
Nigerian veterinary formulary	14%	8%	15%	32%	6%	8%	0.177[a]
Veterinary hospital pharmacists	3%	4%	5%	0%	0%	8%	0.755[a]
Veterinary assistants	2%	0%	5%	5%	0%	0%	0.681[a]
Lecturers/Resident doctors	25%	36%	40%	0%	22%	23%	0.014[a]
Medical/Veterinary journals	12%	24%	5%	0%	22%	0%	0.023[a]
Textbook/Merck's Veterinary Manual/Black's Veterinary Manual	17%	16%	30%	11%	17%	8%	0.507[a]
Peers (other students)	5%	4%	10%	0%	11%	0%	0.439[a]
Class lecture notes	16%	16%	35%	0%	22%	0%	0.010[a]
Wikipedia	8%	4%	20%	0%	11%	8%	0.191[a]

[a]Fischer's exact test
[b]χ^2 test

Students' mean correct knowledge score for the clinical vignettes was 29% with no statistical significance in responses between the study sites. The concepts assessed and scores are shown in Table 7. Respondents scored fairly highly on questions dealing with identification of scenarios with potential for unnecessary use of AB in animals (68%), recognizing the possible risks associated with unnecessary use of AB in animals (62%) and recognition of spectrum of activity of selected AB (56%), but poorly on questions regarding recognition of critically-important AB for human use (9%), treating ESBL-resistant infections in companion animals (11%), recognition of *Clostridium difficile* infection (25%), determination of antibiogram of colistin-resistant enterobacterial isolates (2%), treating complicated urinary tract infection in companion animals (19%), and mechanisms of resistance of bacteria of zoonotic public health importance (13-23%). Suboptimal scores were recorded for *Escherichia coli*/β-lactam resistance (23%), *Staphylococcus aureus*/methicillin resistance (28%) and *Enterococcus*/cephalosporin (13%).

Table 7. Summary of knowledge vignettes with corresponding proportion of correct responses by veterinary schools

Clinical vignettes	Percentage (rounded) of students per university who showed correct competency						*P* Value
	School						
	All (n = 95)	A (n=25)	B (n =20)	C (n = 19)	D (n = 18)	E (n = 13)	
Identify scenarios with potential for unnecessary use of antibiotics in animals	68%	72%	80%	74%	44%	69%	0.173[b]
Recognize the possible risks associated with unnecessary use of antibiotics in animals	62%	64%	50%	58%	67%	77%	0.603[b]
Recognize *Clostridium difficile* infection in humans/animals secondary to the use of antibiotics	25%	20%	25%	37%	17%	31%	0.637[b]
Recognize the spectrum of activity of selected antibiotic	56%	40%	55%	58%	67%	77%	0.222[b]
Colistin-resistant enterobacterial diarrhoea: appropriate antibiotic susceptibility test	2%	4%	0%	0%	6%	0%	0.782[a]
Recognize critically-important antibiotics for human use	9%	8%	10%	5%	17%	8%	0.845[a]
Extended-spectrum β-lactamases-producing *Escherichia coli* bacteraemia in companion animals: antibiotic selection	11%	8%	15%	11%	11%	8%	0.985[a]
Complicated urinary tract infection in companion animals: appropriate antibiotic selection and duration of treatment	19%	20%	25%	21%	11%	15%	0.878[a]
Match the antibiotic/organism with the most likely mechanism of resistance							
E. coli/β-lactam resistance	23%	24%	20%	21%	22%	23%	1.000[a]
Staphylococcus aureus/methicillin resistance	28%	32%	40%	32%	17%	15%	0.436[b]
Enterococcus/cephalosporin	13%	12%	15%	16%	11%	8%	0.722[a]
Overall for all questions	29%	28%	30%	30%	26%	30%	0.232[a]

[a]Fischer's exact test
[b]χ^2 test

Discussion

This is the first assessment of Nigerian veterinary medical students' perception about ABR and ABS and their preparedness for appropriate use of ABs, and to our knowledge it is the first of such report in Africa. In Nigeria, a fresh VM graduate is expected to start prescribing drugs from inception of a compulsory one year national youth service, thus every Nigerian veterinarian is a potential prescriber and dispenser of AB (Fairles, 2013; Anyanwu and Kolade, 2017), and there are limited opportunities (if there is any) for postgraduate training in ABS, particularly outside the academic setting (Wasserman *et al*., 2017). Further, there is no residency (house job/internship) programme for fresh VM graduates, and veterinarians (most of which have no experience/skill on graduation) are allowed to start prescribing (with or without supervision by senior veterinarians) and dispensing AB immediately on graduation from veterinary schools (Anyanwu and Kolade, 2017). Given the importance of veterinarians as key partners in ABS efforts, VMS should therefore be knowledgeable about ABR and ABS (Brink *et al*., 2017). In this study, 3 major findings which are similar with those of multicentre studies (Minen *et al*., 2010; Abbo *et al*., 2013; Dyar *et al*., 2014; Justo *et al*., 2014; Burger *et al*., 2016; Ferdoush *et al*., 2016; Yang *et al*., 2016; Wasserman *et al*., 2017) conducted among medical/pharmacy students in developed and developing countries were made: (i) low level of knowledge about ABR and ABS, (ii) perceived lack of preparedness to practice ABS and lead in ASPs, and (iii) desire for more education about ABR and ABS.

The result of this study revealed that a very minimal proportion (7%) of Nigerian veterinary students may know the meaning of ABS. Burger *et al*. (2015) reported that 83.5% among 260 final-year pharmacy students in 3 South African Universities knew the meaning of antimicrobial stewardship (AMS). The low level of knowledge about ABS in this study is attributed to the fact that very few (17%) of the respondents in this study have heard of ABS. Ferdoush *et al*. (2016) reported that 6% among 171 4th-year students in 3 Bangladeshi medical schools were familiar with the term AMS while less than two-third of 289 final-year students in 3 South African medical schools reported familiarity with the term ABS (Wasserman *et al*., 2017). Anyanwu and Kolade (2017) reported that 17.1% among 280 practicing/teaching veterinarians in Enugu State Nigeria have heard of ABS. The disparities in these studies may be due to differences in ABS awareness education that has been conducted in the various health profession institutions, degree of integration in the curricula and teaching of AMS education in the institutions, and/or the degree of AMS education awareness that has been conducted via sources such as mass media, journals, peers, etc in the study area (Lee *et al*., 2015; Anyanwu and Kolade, 2017). Among the NVS that reported familiarity with the term ABS, highest number reported that they heard about ABS from their lecturer while a very minority of them heard/learnt of ABS from their peers, senior colleagues, mass media and/or scientific journals (Lee *et al*., 2015). The low awareness about ABS observed in this study, suggested that there is little or no effort in Nigeria to educate veterinary students about ABS and there is also little or no ABS education awareness in form of seminars, symposium, radio jingles, etc in Nigeria (Lee *et al*., 2015). It also suggested that the curricula of Nigerian veterinary medical schools might be deficient on issues of ABS (Anyanwu and Kolade, 2017).

Regarding background knowledge and perceptions of ABS, it is very worrisome that very minimal proportion of NVS (7%) knew that ABS involves therapeutic monitoring of AB use, timely collection of appropriate specimens for microscopy, culture and sensitivity, choosing the proper AB, timely administration of AB at the appropriate dose and route, administering AB for appropriate duration in every case, using AB only when needed, improving hygiene and infection control, and the study of AB (O'Donnell and Guarascio, 2017). This finding contrasts Burger *et al*. (2016) that 50.4%-95% (range for the principles) among pharmacy students in South Africa, knew that ABS involved the above principles. Variation in the perceptions of students in these studies may be attributed to differences in exposure to ABS in the various institutions and/or study area (Thriemer *et al*., 2016; Anyanwu and Kolade, 2017). The low level of knowledge about ABS principles in the present study, further suggested that veterinary students in Nigeria may not be well exposed to the basic principles of ABS.

In this study, respondents shared common perceptions and attitudes about AB use/prescribing and resistance across the veterinary schools. Inappropriate AB use may result from inadequate preparation at undergraduate level and an under-appreciation of the extent and implications of ABR (O'Donnell and Guarascio; 2017; Wasserman *et al*., 2017). About two-third (65%) of the respondents in this study perceived that AB prescribing and use in most Nigerian veterinary hospitals are inappropriate. This finding is higher than 53.9% reported by Anyanwu and Kolade (2017) among practicing/teaching veterinarians in Enugu State Nigeria, who also agreed that AB prescribing and use in most Nigerian veterinary hospitals are inappropriate. But it is lower than 94% among 311 final-year students in 3 American medical schools (Abbo *et al*., 2013), 84.8% among 611 4th-year students in 3 Chinese medical schools (Yang *et al*., 2016) and 87.5% among medical doctors/students in the Democratic Republic (DR) of Congo (Thriemer *et al*., 2013), respectively, who agreed that antimicrobials (AMs) are overused nationally in healthcare. It has been severally reported that > 50% of AB prescription in hospitals could be adjudged inappropriate (Cotta *et al*., 2014; Cisneros *et al*., 2014); the case of veterinary hospitals in Nigeria may not be different as almost all the students in this study reported that antibiograms are rarely used during empiric treatment in their institutional VTH where they have rotated and about half of the students do not know that treating self-limiting infections with ABs promotes ABR. It is disconcerting that despite the fact that all the participants in this study agreed that ASP does not exist in any veterinary clinic/hospital in Nigeria, less than one-third (28%) perceived that ABs are overused in their institutional VTH where they have rotated. Sixty nine percent among 579 graduating students in 12 American pharmacy schools (Justo *et al*., 2014) and 63% among medical students in South Africa (Wasserman *et al*., 2017), respectively, perceived that AMs are overused in hospitals where they have rotated/are working.

The lower perception on AB overuse in local settings observed in this study, further suggested that NVS may not be well grounded on the issues of ABR and ABS, this is because arbitrary AB prescription not based on culture and sensitivity as observed in the hereby study, is a major cause of ABR (Coyne *et al*., 2016; O'Donnell and Guarascio, 2017). It equally suggested that these students may also not be well grounded on how to detect cases associated with resistance in animals (Afzal Khan *et al*., 2013; O'Donnell and Guarascio, 2017). Many drivers are associated with overuse of drugs in Nigerian veterinary settings, including the use of AB to counterbalance poor hygiene, lack of knowledge/awareness about appropriate AB for specific infections, etc (Thriemer *et al*., 2013; Anyanwu and Kolade, 2017; O'Donnell and Guarascio, 2017). However, AB overuse could result from the intention to fulfill the responsibility of offering optimal therapy to the individual patient under a veterinary clinician's care while neglecting/overlooking the responsibility of preserving the efficacy of AB and minimizing the development of resistance in the same patient and other patients in the future and to public health (Scaioli *et al*., 2015; Gharbi *et al*., 2016; Anyanwu and Kolade, 2017).

Concerning the impact and scope of ABR, majority of the respondents (74%) in this study believed that ABR is a global problem, but there was significant variation (P = 0.009) in responses between the schools. The global problem of ABR was perceived stronger (85.4%-97.7%) among medical/pharmacy students in other countries (Afzal Khan *et al*., 2013; Thriemer *et al*., 2013; Burger *et al*.,

2016; Padmanabha *et al*., 2016). It is a matter of serious concern that most students (73%) in this study believed that ABR is not a significant problem in their institutional VTH where they have rotated whereas a minority of them (9%; $P = 0.030$) felt that ABR is not a significant problem in Nigeria. These results suggested that NVS perceived AB overuse and resistance as being of greater concern nationally than at their local institutions. Medical/pharmacy students in other studies (Thriemer *et al*., 2013; Afzal Khan *et al*., 2013; Justo *et al*., 2014; Burger *et al*., 2016; Ferdoush *et al*., 2016; Padmanabha *et al*., 2016; Wasserman *et al*., 2017) similarly perceived AB overuse and resistance as being of greater concern nationally than at local institutions; but in China, Yang *et al*. (2016) reported 15% among medical students who believed that antimicrobial resistance (AMR) is not a significant problem in hospitals where they have rotated and 8.4% who perceived that AMR is not a significant problem nationally. Variations in perceptions of the impact and scope of the problem of ABR in these studies may be related to the differences in exposure to the concept of ABR and/or level of knowledge about ABS possessed by the respondents in the various studies (Afzal Khan *et al*., 2013). The perceptions of NVS that ABR is of lesser problem in their institutional VTHs (local settings) may result in behaviours that are untoward ABS as Brink *et al*. (2017) rightly remarked "this view of 'not in my backyard' which suggests that others overprescribe ABs and drive resistance may contribute to inappropriate prescribing behaviour."

To effectively sustain behavioural change around AB use/prescribing, an insight into, and an appreciation of, the factors leading to ABR is required (O'Donnell and Guarascio, 2017; Wasserman *et al*., 2017). The perception by most NVS that poor hand hygiene and poor infection control practices such as inadequate biosecurity and vaccination of animals against preventable diseases, are not important contributors to the spread of ABR, is very worrisome. Only 8% of participants in this study knew the importance of these practices in the spread of ABR. This finding is significantly lesser than the result (33.8%-83.3%) of previous studies (Afzal Khan *et al*., 2013; Burger *et al*., 2016; Ferdoush *et al*., 2016; Yang *et al*., 2016; Wasserman *et al*., 2017) among medical/pharmacy students. Apart from improving farm biosecurity and routine animal vaccination against preventable diseases, improved personal hygiene, quarantine, herd test and isolation, are important infection control practices that can potentially reduce the use of ABs and hence development of ABR (Cotta *et al*., 2014; Llor and Bjerrum, 2014; Guardabassi and Prescott, 2015; Schwartz *et al*., 2016). The teaching of these practices in Nigerian veterinary schools should be endorsed and it should begin at early stages of veterinary education so that students would be able to practice them and educate their clients/the public how to curb ABR by these means, even before they qualify as veterinarians (Afzal Khan *et al*., 2013). Clear connection of AB prescribing in Pharmacology with infection control in Microbiology is crucial to enhance understanding of these practices by veterinary students (Afzal Khan *et al*., 2013).

Equally worrisome is that minority of students (15%) in this study did not regard using substandard AB as a prominent cause of ABR. Substandard drugs do not exert optimal therapeutic effect in animals thereby stimulating the development of ABR in both targeted and commensal bacteria (Garcia *et al*., 2011; Afzal Khan *et al*., 2013). The finding (15%) of this survey is lower than 48.8% and 71.2% reported by Burger *et al*. (2016) among pharmacy students in South Africa and Thriemer *et al*. (2013) among medical students in DR Congo, respectively. The use of substandard drugs is particularly important in Nigeria where there are no enforced regulations guiding the marketing and usage of AB (Essack *et al*., 2017; Anyanwu and Kolade, 2017). The issue of substandard and counterfeit AB is associated with counterfeit/suboptimal active ingredient, poor production, shipping, storage and handling conditions (Essack *et al*., 2017). Maximization of profit, ignorance, client pressure, availability and affordability are enablers for consumption of substandard AB in Nigerian veterinary settings (Guardabassi and Prescott, 2015; Anyanwu and Kolade, 2017).

The 3 leading potential drivers of AB prescription identified by participants in this study were: antibiogram of isolates (52%) ($P < 0.001$), health status of the patient (37%) ($P = 0.043$) and cost of AB (37%) ($P = 0.002$). This finding is troubling because only half of the students recognized the need for using antibiogram during prescription for empiric treatment of animals, which is a core strategy in ABS (O'Donnell and Guarascio, 2017). It is crucial that NVS are exposed to methods utilized in rapid identification and susceptibility testing of bacteria (Okeke *et al*., 2011; Maurer *et al*., 2017). Although in the minority (11%) in this study, reliance on senior colleagues to make AM prescribing decisions has been identified as a barrier to appropriate AB prescribing (Chaves *et al*., 2014). Thriemer *et al*. (2013) reported 79.4% among medical students in DR Congo who agreed they sometimes consult senior colleagues on AB prescribing. Less than 10% of NVS reported that their peers (other students) could have influence on their decision to prescribe an AB.

Although in the minority, it is concerning that client pressure/push (18%) ($P = 0.020$) and profit to be made (15%), were mentioned as factors that could influence AB prescription by NVS. In previous surveys among practicing medical doctors (Garcia *et al*., 2011; Abera *et al*., 2014; Shanuga Vadivoo *et al*., 2015), patient push/demand, patient's health status and profit of hospitals were perceived even stronger as thriving factors/drivers for unnecessary AB prescribing. The high expectation of AB use by clients is often a consequence of their lack of knowledge about these drugs and their side effects; therefore, veterinary students should be well educated and knowledgeable about these concepts in order to take the leading role as educators of their clients/the public (Garcia *et al*., 2011; Bowater, 2015). Good enough, although with significant difference in responses between the schools, a vast majority (84%, $P = 0.047$) of NVS agreed that inappropriate use of AB can directly harm patient (O'Donnel and Guarascio, 2017). This finding is consistent with that of previous studies (Abbo *et al*., 2013; Justo *et al*., 2014; Burger *et al*., 2016; Ferdoush *et al*., 2016; Padmanabha *et al*., 2016; Yang *et al*., 2016; Wasserman *et al*., 2017) among medical/pharmacy students in other countries. It is however unfortunate that

less than half (41%) of the students in this study, were confident that they can handle clients demanding unnecessary AB therapy for their animals. In Bangladesh (Ferdoush *et al*., 2016), China (Yang *et al*., 2016) and America (Abbo *et al*., 2013), 13%, 25.6% and 54% among medical students, respectively, were confident they can handle patients demanding unnecessary AB therapy. However, prescribing decision of a veterinarian is made after consideration of intrinsic and extrinsic factors (such as type of husbandry practice in food-producing animals) (Coyne *et al*., 2014; Speksnijder *et al*., 2015). A sense of responsibility should be nutured in NVS, that as prescribers, they are not only responsible for the benefit/welfare of their patients and satisfaction of their clients, but also for the society at large (Afzal Khan *et al*., 2013). These skills should be targeted in future ABS educational interventions in Nigerian veterinary schools. Teaching of the principles of protocol development in VTHs and small group exercises facilitating client education skills (such as educating clients about the need and proper use of AB in animals), should form an integral part of the veterinary undergraduate studies (Steiner *et al*., 2004; Afzal Khan *et al*., 2013). The findings in this survey showed that there is need for urgent intervention by ABS education in NVS in order to change perceptions and attitude of these future veterinarians regarding AB use. Apart from improving knowledge, a key objective of ABS education is to shift attitudes, perceptions and prescribing behaviours (Ohl and Luther, 2014; Wasserman *et al*., 2017).

The 3 leading causes of ABR identified in this study were: widespread/overuse of AB in humans and animals (55%), use/prescription of AB by non-veterinarians/professionals (29%) and unnecessary use of broad-spectrum AB for treating animals when narrower-spectrum antibiotic is available (26%). Pharmacy students in South Africa (Burger *et al*., 2016) and practicing physicians in other countries (Pulcini *et al*., 2011; San Fransisco *et al*., 2013; Abera *et al*., 2014), also observed these 3 factors and others, as leading causes of ABR. The 26% respondents in this study who agreed that unnecessary use of broad-spectrum AB promotes ABR, is lower than the result (32.5%-95%) of previous studies (Abbo *et al*., 2013; Justo *et al*., 2014; Burger *et al*., 2016; Ferdoush *et al*., 2016; Yang *et al*., 2016; Wasserman *et al*., 2017) among medical/pharmacy students. Administration of inappropriate doses of AB for inadequate frequency was perceived by less than one-third (29%) of respondents in this study as cause of ABR; this attitude/factor was perceived stronger (30.9%-90%) as a cause of ABR by medical/pharmacy students in other studies (Thriemer *et al*., 2013; Burger *et al*., 2016; Weier *et al*., 2017). But a weaker perception (27.54%) of this attitude as a cause of ABR was observed among 162 2nd-year medical students in India (Padmanabha *et al*., 2016). In future educational interventions in Nigerian veterinary schools, emphasis should be placed on teaching ABS which involves avoiding selection pressure in the patient, both on the pathogen and commensal by avoiding unnecessary use, choosing the least broad-spectrum AB, adequate doses, a good timing and the shortest possible duration (Pulcini and Gyssens, 2013; Ohl and Luther, 2014; Nori *et al*., 2017).

It calls for serious concern that most NVS do not know that *Staphylococcus aureus* (39%), *Pseudomonas aeruginosa* (17%) and *Clostridium difficile* (13%), *Enterococcus faecium* (4%) and *Klebsiella pneumoniae* (6%), are troublesome zoonotic antibiotic-resistant bacteria of global public health concern (WHO, 2017). Burger *et al*. (2016) reported that 45%-81.9% (range for the pathogens) among final year pharmacy students in South Africa, knew that these resistant bacteria are of zoonotic and public health importance. The knowledge gaps observed in this study on zoonotic troublesome pathogens, suggested that there is unavailability and/or lack of bacteriological culture and sensitivity testing in most (if not all) the VTHs in Nigeria (Pulcini *et al*., 2011; Abera *et al*., 2014). It also suggested that there may be need for the Microbiology curricula of veterinary schools in Nigeria to be improved, especially on the issues of medically-important pathogens and ABR with these topics taught from a 'One Health' perspective (O'Donnell and Guarascio, 2017).

Regarding interventions to combat ABR, majority of students (78%) in this survey agreed that better use of AB will reduce problems with ABR, but medical/pharmacy students (86.1%-98.5%) in other countries (Abbo *et al*., 2013; Justo *et al*., 2014; Burger *et al*., 2016; Wasserman *et al*., 2017) were better convinced that this attitude will help to contain ABR. Encouragingly, most NVS recognized that establishment and implementation of ASPs in veterinary hospitals in Nigeria are essential to ensure better use of AB. The findings that most students in this study do not know that education on AB therapy (44%), development of antibiotic usage policies (35%), reduction of AB use (14%), establishment of national AB resistance surveillance (28%) and development of institutional guidelines for antibiotic use (29%), are critical interventions to curb ABR (Schwartz *et al*., 2016) is very worrisome. These results are lower than 65.8%-92.3% (range for all the interventions) recorded by Burger *et al*. (2016) among pharmacy students in South Africa. The poor knowledge exhibited by students in this current survey suggested that veterinary students in Nigeria have poor knowledge about ABS interventions to contain ABR. The misperception by majority of NVS (71%) that new AB will be developed in the future to keep up with the problem of ABR calls for concern. Medical students in China (Yang *et al*., 2016) had a stronger misperception (76.9%) that new AB will be developed in the future to keep up with the problem of ABR whereas medical/pharmacy students elsewhere (Abbo *et al*., 2013; Justo *et al*., 2014; Wasserman *et al*., 2017) had a better perception/understanding (15%-27%) in terms of difficulties associated with the development/manufacturing of new AB in the future (Theuretzbacher *et al*., 2017).

The general goal of ABS is to ensure appropriate use of ABs, this entails cost effective use of AB which maximizes therapeutic effect while minimizing both drug related toxicity and ABR (WHO, 2011; Oberje *et al*., 2017). Among the goals of ABS asked in this survey, it is only increasing the use of AB that was rightly perceived by all the respondents not to be a goal of ABS. Nevertheless, it gives concern that minority of students in this study knew that reducing hospital stay (2%), reducing ABR (17%) and minimizing toxicity and other adverse effects (6%) are goals

of ABS (WHO, 2011). These results are lower than the findings (72.5%-98.5%) of Burger *et al*. (2016) among pharmacy students in South Africa. This further suggested that respondents in this study have poor knowledge about the concept of ABS. It is also of concern that although in the minority, some students in this survey thought that increasing the use of broad-spectrum ABs (1%) and increasing the duration of therapy to ensure therapeutic success (2%), were also among the goals of ABS. In South Africa, Burger *et al*. (2016) reported 7.7% and 10.4% among pharmacy students, who thought that ABS seek to increase the use of broad-spectrum ABs and increase the duration of therapy to ensure therapeutic success, respectively. Poor knowledge about goals of ABS exhibited by respondents in this study may be attributed to lack of awareness/exposure to the basic concepts of ABS in the veterinary schools. It is imperative that these veterinary students understand that the goal of ABS is not only to reduce total AB use but also to ensure that ABs are prescribed only when indicated, at the correct dose, route, and for proper duration for each infection (Ohl and Luther, 2014; Nori *et al*., 2017).

It is unfortunate that less than 20% of students in this study knew that veterinarians are responsible for leading ABS team especially in veterinary settings (Brink *et al*., 2017; Espinosa-Gongora *et al*., 2017) and also a vast majority of them do not know the members to constitute an ABS team (MacDougall and Polk, 2005). ABS is a team effort that must involve the whole continuum of healthcare workers (Pereira *et al*., 2017). Veterinarians (19%), Veterinary hospital cleaning staffs (13%) and Veterinary pharmacists (13%), were the members of ABS team mostly identified in this study whereas Veterinary clinical microbiologist and Veterinary assistants were the least mentioned (5%). However, there was significant variation ($P < 0.001$) in responses between the schools regarding hospital cleaning staffs being members of ABS team. Final year pharmacy students in South Africa exhibited higher level of knowledge (range for listed members, 20.8%-95%) about members of an ABS team (Burger *et al*., 2016). The professionals, including veterinarians, have the responsibility of forming ABS team and developing effective ASPs in their settings (MacDougall and Polk, 2005; Brink *et al*., 2017). Veterinarians are prescribers and in private veterinary clinics in Nigeria, they also double as dispensers; thus, serving as the 'nucleus' of ABS team in veterinary settings (Khan *et al*., 2017). Veterinarians play a crucial role in the surveillance of and feedback on ABS practices as they prescribe and dispense AB (Fairles, 2013; Khan *et al*., 2017). The role of Veterinary clinical microbiologist in ASPs is critical because laboratory diagnosis (isolation and identification of bacteria) and conduct of AB sensitivity, is the only way to avoid blind AB prescription and therapy and hence unnecessary use (overuse) of ABs (MacDougall and Polk, 2005; O'Donnell and Guarascio, 2017). Collaboration with Microbiology laboratory is a major requirement for ASP and to achieve ABS (Coyne *et al*., 2016; Gharbi *et al*., 2016). ABS education intervention in Nigerian veterinary schools should emphasize the importance of a multidisciplinary ABS team in which veterinarians and other professionals combine to achieve the 'One Health' goals (O'Donnell and Guarascio, 2017). The poor knowledge exhibited by NVS about ABS team formation, further suggested the need for integration of ABS education into the curricula of veterinary schools in Nigeria. These students need to understand their role (and that of other healthcare workers) as future leaders (steward champions) in the fight against ABR (Espinosa-Gongora *et al*., 2017; MacDougall *et al*., 2017; Wasserman *et al*., 2017).

Concerning the roles of veterinarians in ASPs, more than one-third of students (69%) in this study thought that prescribing AB over-the counter is the major role of veterinarians in ASPs whereas a minimal number perceived that promoting the optimal use of AB (15%), educating veterinary allied healthcare professionals (13%) and working with therapeutic committees to develop policies (7%), were the minor roles of veterinarians in ASPs. This further suggested that these students possessed abysmal knowledge about their roles (as future veterinarians) in ensuring appropriate use of AB. A higher level of knowledge (7.3% for prescribing over-the-counter and 88.5%-92.3% for the other roles) was exhibited by final year pharmacy students in South Africa regarding their roles (as future pharmacists) in ASPs (Burger *et al*., 2016). Differences in exposure to ABS education may account for the variations in perceptions among the students in the various studies.

The availability of unbiased information about AB is a prerequisite for appropriate AB prescribing (Threimer *et al*., 2013; WHO, 2012). In this survey, although in the minority, more students (36%) referred to iPhone/Smart phone applications and lecturers/resident doctors (25%) than textbooks (17%) or formally peer-reviewed sources of information, including the Nigerian veterinary formulary (14%), Merck's/Black's veterinary manual (17%) and medical/veterinary journals (12%), and very minor proportion of respondents in this study referred to Wikipedia (8%), Veterinary hospital pharmacists (3%) and Veterinary assistants (2%). In previous multicentre studies (Minen *et al*., 2010; Abbo *et al*., 2013; Justo *et al*., 2014; Ferdoush *et al*., 2016; Yang *et al*., 2016) among medical/pharmacy students, significantly higher proportion of students referred to iPhone/Smart phone applications (50.5%-72%), textbooks (46%-80.2%), Wikipedia (36%-52.1%) and medical/veterinary journals (19.7%-82%), respectively. Unlike these previous multicentre studies among medical/pharmacy students, this present survey did not assess whether there was association between knowledge scores and the sources of educational information. However, some studies (Minen *et al*., 2010; Justo *et al*., 2014) showed that students who referred to peer-reviewed sources of information performed significantly higher in knowledge questions than those who referred to non-peer-reviewed sources such as Wikipedia. Nevertheless, the differences in knowledge was not actually attributed to the educational resources utilized but rather to several other reasons, including, personal experiences, motivations, availability of educational resources, instructional initiatives, influence of senior colleagues during clinical trainings and teaching methodology at each site (Minen *et al*., 2010; Justo *et al*., 2014). In any case, NVS should be encouraged to refer to peer-reviewed resources for information about AB use and resistance because these materials contain more reliable and accurate information than the non-peer reviewed

resources (Minen *et al*., 2010). A balanced approach in the utilization of peer reviewed and non-peered reviewed resources like Wikipedia has been suggested (Minen *et al*., 2010). Economic constraint on the part of the students and limited internet access in Nigeria, are factors that may limit access of NVS to internet-based educational resources (Thriemer *et al*., 2013). As such, interactive classic face-to-face trainings may be more effective and feasible than e-learning tools in future ABS interventions in Nigerian veterinary schools (Afzal Khan *et al*., 2013; Threimer *et al*., 2013).

The use of local prescribing guidelines (in this case the Nigerian veterinary formulary) should be promoted (Chaves *et al*., 2014; Wasserman *et al*., 2017). Medical practitioners elsewhere rated local guidelines on AMs and AM prescribing better than international guidelines (Garcia *et al*., 2011; Chaves *et al*., 2014) and medical students in South Africa who referred to local prescribing guidelines, exhibited higher knowledge scores and better confidence in AB prescribing (Wasserman *et al*., 2017). Information provided by pharmaceutical industries and the WHO (Threimer *et al*., 2013) are also important resources whose usefulness to veterinary students' education on AB use and resistance, may be assessed in future studies.

Very few (5%) of the students in this survey indicated that they consulted their peers on AB use and resistance. Previous studies (Minen *et al*., 2010; Abbo *et al*., 2013; Justo *et al*., 2014; Ferdoush *et al*., 2016; Yang *et al*., 2016) among medical/pharmacy students, reported a significantly higher proportion of students (25.4-74%), who agreed that they consulted their colleagues on AB prescribing. Lack of self-confidence has been suggested as causes why health profession students do want the inputs of their colleagues during AB use/prescribing (Thriemer *et al*., 2013). Therefore, the lower propensity of students to consult peers observed in this study, might be related to the fact that very few participants in this survey have prescribed or have been allowed to prescribe ABs in their institutional VTHs; thus, most NVS have not faced challenges in which the need for consulting their peers arise. Interaction of undergraduates with lecturers/resident doctors (learning resource) was reported in this study but with significant variation (P = 0.014) in responses between the schools. Student-lecturer/resident doctors' interaction usually takes place during class lectures/clinical rotations in VTHs; therefore, it could be considered an active form of teaching/learning (Wasserman *et al*., 2017). The levels of competence of the lecturer(s)/resident doctor(s) about ABS, degree of engagement with undergraduate students and the content and design of these interactions, will determine the effect of these human resources on the knowledge and modification of behaviour of veterinary students regarding AB use (Pulcini and Gyssens, 2013; Wasserman *et al*., 2017). In medical settings, prescribing advice from a multidisciplinary management team resulted in more appropriate AB prescribing than input from residents alone (Gross *et al*., 2001; Wasserman *et al*., 2017). Thus, in future ABS education interventions in NVS, emphasis should be laid on multidisciplinary approach to AB prescribing (Friedman *et al*., 2016; Schellack *et al*., 2016; Roca *et al*., 2015; Wasserman *et al*., 2017). Class lecture notes was referred to by 16% (P = 0.010) of students in this study; this highlights the potential role of class lectures in veterinary schools as a forum for interventions on ABS (Thriemer *et al*., 2015). These veterinary students who are the future lecturers should therefore be well educated and equipped about issues of ABR and ABS (MacDougall *et al*., 2017; Weier *et al*., 2017).

Less than 20% of students in this survey believed that their education on specific ABS activities was good and useful. Majority of NVS had a comfortable understanding of basic mechanisms of ABR, selecting the best AB for specific infection, spectra of therapy for different AB (P = 0.020), and less than two-third of them felt comfortable with when to start AB therapy, finding reliable information to treat patients and interpretation of antibiograms. The students exhibited suboptimal knowledge and preparedness regarding transitioning from intravenous to oral AB, and performance of de-escalation. These findings further suggested that there are deficiencies in Microbiology and Pharmacology training at undergraduate level in Nigerian veterinary schools (Afzal Khan *et al*., 2013; O'Donnell and Guarascio, 2017; Wasserman *et al*., 2017). Moreover, most of the students (88%) have never had any formal training on ABS, with the only knowledge they had on stewardship being from class lectures. In addition, the minor proportion of NVS who reported to have had a formal lecture on ABS did so within a short duration which may not have been enough to have a good grasp/understanding of these ABS skills. The gap in stewardship knowledge observed in this study suggested that there is need for more clinic practical training than class lectures in Nigerian veterinary schools (Yang *et al*., 2016). This study did not assess various teaching modalities that could be employed in delivering ABS trainings to NVS. However, passive education such as class lectures has been reported to have limited impact on improving AB use on its own (Pulcini and Gyssens, 2013; Ohl and Luther, 2014; Wasserman *et al*., 2017); however, it is an important method to teach fundamental stewardship principles (Khan *et al*., 2017; Wasserman *et al*., 2017). In South Africa, medical students rated the usefulness of formal lectures in AB prescribing very low (Wasserman *et al*., 2017). It has been reported that there is often a failure in translating classroom knowledge into clinical prescribing practice, and there is discordance between knowledge and practice (Eyal and Cohen, 2006; Scaioli *et al*., 2015; Wasserman *et al*., 2017). More active educational approaches such as clinical case discussions and interactive e-learning are generally considered to be more effective for influencing prescribing behaviours (Ohl and Luther, 2014; Broom *et al*., 2016; Wasserman *et al*., 2017).

Two key stewardship concepts that were mostly misunderstood by NVS are transitioning from intravenous to oral AB (27%) and de-escalation of AB therapy (19%). These concepts/strategies are utilized internationally (Shrahtey *et al*. 2015; Broom *et al*., 2016; O'Donnell and Guarascio, 2017) and every veterinary undergraduate should be knowledgeable about them for obvious reasons: early switch from intravenous to oral AB reduces duration of AB therapy, length of hospital stay, intravenous-associated morbidity and improve cost effectiveness (Broom *et al*., 2016). De-escalation is a critical strategy in reducing

overuse of broad-spectrum AB, in practice, it entails daily review of broad-spectrum prescriptions (where it is imperative to use broad-spectrum therapy) and de-escalation to narrow-spectrum where possible (Abbo *et al*., 2013; Roca *et al*. 2015; Wickens *et al*., 2013). Medical/pharmacy students in other countries (Abbo *et al*., 2013; Justo *et al*., 2014; Ferdoush *et al*., 2016; Haque *et al*., 2016; Yang *et al*., 2016) were more confident with their education (32%-51% and 25.6%-54%, respectively) than NVS (27% and 19%, respectively) on transitioning and de-escalation, respectively, but NVS felt more confident on transitioning than medical students (18%) in Bangladesh (Ferdoush *et al*., 2016). Regarding basic mechanisms of ABR, selecting AB and interpreting antibiograms, NVS felt more comfortable (74%, 79% and 60%, respectively) than medical/pharmacy students elsewhere (54.1%-59%, 36.9%-67% and 35.2%-59%, respectively) (Abbo *et al*., 2013; Justo *et al*., 2014; Haque *et al*., 2016; Yang *et al*., 2016). The differences in these responses may be due to variation in the method of teaching in the schools, extent of trainings the students have received on those topics, individual experiences, and differences in knowledge about stewardship skills acquired by individuals from other means/sources and/or degree of casual answers that were correct. This survey did not evaluate the usefulness of modalities that could be employed in Nigerian veterinary schools to deliver trainings on ABR/ABS to the students.

Gaps in knowledge about AB were identified among veterinary students at all the study sites, without significant differences ($P > 0.05$) between the 5 schools in all the areas. Majority of the students did not know the appropriate management of complicated urinary tract infection in companion animals (19%) (Wesse *et al*., 2011) and ESBL-resistant infections in companion animals (11%) (Spohr *et al*., 2012), recognition of critically-important AB for human use (9%) (WHO, 2016) and *Clostridium difficile* infection (25%) (Keesen *et al*., 2011) and determination of antibiogram of colistin-resistant enterobacterial isolates (2%) (Nordmann *et al*., 2017), only about one-third of the respondents appropriately recognized risks associated with unnecessary use of AB in animals (62%) (Llor and Bjerrum, 2014) and scenarios with potential for unnecessary use of AB in animals (Llor and Bjerrum, 2014), and slightly above half (56%) appropriately recognized the spectrum of activity of certain selected AB (Coates *et al*., 2011). Students in this study performed sub-optimally in matching specific bacteria/AB and resistance mechanism. This finding creates a doubt regarding the report by majority of them that their education about selecting the best AB for specific infection and basic mechanism of ABR was good. It is crucial that veterinary students understand the concept of the 'bug drug' coverage, where the selection of appropriate AB therapy is selected based on the likely pathogens involved in a given condition (O'Donnell and Guarascio, 2017).

In this survey, the overall knowledge score was 29% which is considered poor with similar scores across the schools. This finding suggested that NVS have low level of knowledge about the clinical vignettes and thus may be inadequately prepared to practice ABS (Brink *et al*., 2017; O'Donnell and Guarascio, 2017; MacDougall *et al*., 2017). The finding further suggested that however well-meaning, stewardship-related diagnostic or therapeutic teaching, lectures, does not translate into clinical practice (Brink *et al*., 2017). This present survey did not assess whether there was an association between the respondents' knowledge scores and their perceptions about the quality of their AB-related education. Moreover, evaluation of the formal curricula of veterinary schools regarding education about ABs is not the focus of this study. However, the respondents' perception and clinical vignette knowledge scores further suggested that there are deficiencies in the Nigerian veterinary schools' curricula, including fundamental concepts of AB use (Abbo *et al*., 2013). These deficiencies could be addressed by standardization of Nigerian veterinary schools' curricula about AB use and resistance, providing easy access to accurate information and emphasizing the importance of clinical rotations in the VTHs (Abbo *et al*., 2013; Brink *et al*., 2017). The use of standardized educational electronic tools with clinical scenarios has been recognized as effective means of improving AB use in undergraduate veterinarians (Pulcini *et al*., 2011; Abbo *et al*., 2013).

Most students (88%) in this survey agreed that strong knowledge of AB is important for their future veterinary career but the proportion is lower than that (91.8%-98.5%) of previous studies (Abbo *et al*., 2013; Justo *et al*., 2014; Burger *et al*., 2016; Ferdoush *et al*., 2016; Yang *et al*., 2016; Wasserman *et al*., 2017) among medical/pharmacy students. This finding showed that NVS had a lower understanding about the potential impact of ABR on their future career than the students in the previous surveys; this could be attributed to inadequate understanding of the implications of ABR by NVS. Low level of awareness/knowledge about ABR and ABS in the various institutions and/or study area may account for the differences in the perceptions of impact of ABR on future career. In this study, students recognized the importance of appropriate AB use and majority indicated they would like more education on ABR (73%) and ABS (87%). This receptive attitude to ABS education by NVS is consistent with the findings of previous studies (Abbo *et al*., 2013; Burger *et al*., 2016; Yang *et al*., 2016; Wasserman *et al*., 2017). Majority of NVS opined that ABS education should occur at all levels in the veterinary school. By taking advantage of the receptive view of these students to improve their knowledge about ABR and ABS, the Veterinary Council of Nigeria, veterinarians in the academic setting and other stakeholders, should consider forming an expert group comprising of competent individuals from VM, Veterinary Public Health, Veterinary Microbiology and Pharmacology, who would assess the curricula of veterinary schools with the intention of developing a standardized, structured and practical ABR and ABS curricula (Brink *et al*., 2017; Espinosa-Gongora *et al*., 2017; Khan *et al*., 2017). This would address the disparate education that Nigerian VM undergraduates are receiving (Brink *et al*., 2017).

It has been suggested that ABS should be taught concurrently with foundational learning of bacteria and AB rather than waiting until habits are already established at later stages of the veterinarian's career (Schwartz *et al*., 2017). Changing behaviour is a lot harder than shaping it and once veterinarians become qualified and gained experience, their views and behaviours become very hard to

change (Lee *et al*., 2015; Pereira *et al*., 2017; Nori *et al*., 2017). In medical settings, students in previous surveys suggested that education on AB should occur at a later stage/level of their education (Abbo *et al*., 2013; Ferdoush *et al*., 2016). But the qualifications for entry into these health profession institutions vary in different countries, and this should be considered if the need for modification of the curricula of veterinary schools in Nigeria arises; this is because most students are admitted into Nigerian veterinary schools with basic secondary school qualifications. There may also be need for integration of an inter-professional ABS education in the curricula of Nigerian universities; this may help in exposing students to the concepts of ABS from the early stages of their university education (Schellack *et al*., 2016; MacDougall *et al*., 2017; Pereira *et al*., 2017; Shwartz and Chin-Hong, 2017). Early education integrates stewardship into students' core understanding of ABS principles and this will likely lead to long term incorporation of these principles into future AB use/prescribing practices (Brink *et al*., 2017; Schwartz *et al*., 2017).

Strengths of this study were that it highlighted an area where there is little or no availability of literature. A relatively high response rate (53.4%) compared with previous multicentre surveys in medical/pharmacy settings (51% (Wasserman *et al*., 2017), 61% (Abbo *et al*., 2013), 26.6% (Burger *et al*., 2016), 30% (Minen *et al*., 2010), 35% (Dyar *et al*., 2014), 40% (Justo *et al*., 2014), 82% (Ferdoush *et al*., 2016)) was obtained and the survey was anonymous and voluntary; this likely reduced the tendency of the students to produce "socially desirable" response (Abbo *et al*., 2013; Thriemer *et al*., 2013; Burger *et al*., 2016). The study was conducted in the final-year of veterinary undergraduate study when students have almost completed their formal academic curriculum, thus providing a good estimate of their education about ABR and ABS upon graduation (Abbo *et al*., 2013; Burger *et al*., 2016). All the participants responded to all the survey questions so there was no need for adjusting using the series means (Abbo *et al*., 2013; Yang *et al*., 2016). The external validity of this study is supported by the fairly consistent responses between the veterinary schools in this survey, and those from multicentre studies (Minen *et al*., 2010; Abbo *et al*., 2013; Justo *et al*., 2014; Burger *et al*., 2016; Ferdoush *et al*., 2016; Yang *et al*., 2016) in non-veterinary settings from other countries. This survey addressed most of the topic cited by WHO as influencing AB, development of ABR and ABS strategies to contain escalating ABR from a 'One Health' approach (Thriemer *et al*., 2013; WHO, 2012). Because of the inclusion of 5 diverse and geographically distant veterinary schools (although 2 were in the same geopolitical region), the findings of this study are likely to be generalizable to other Nigerian veterinary schools. Any difference in responses or knowledge scores may be related to difference in pedagogies which was not assessed.

Potential for recall bias is possible since all measures were based on self-report (Abbo *et al*., 2013; Ferdoush *et al*., 2016). However because only final-year students were surveyed in the 5 sites, it is likely that the respondents and non-respondents had similar demographic characteristics, perhaps minimizing the selection bias (Johnson and Wislar, 2012; Abbo *et al*., 2013). Nonetheless, the relatively low response rate in some of the veterinary schools in this study may imply that interpretation of the results should be done with caution.

Conclusions

In conclusion, the final-year VMS in Nigeria have poor knowledge/awareness about ABR and ABS; thus they may not be adequately prepared to practice ABS. Intervention by ABS education in Nigerian veterinary schools are urgently needed. NVS desired so much to be more educated about ABR and ABS. Despite the identified limitations, the findings of this study could be useful in improving the undergraduate curricula of Nigerian veterinary medical schools in order to produce veterinarians who are adequately knowledgeable about AB and ABR, and can confidently stand on the front line of the fight against ABR.

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