
REVIEWS

One Health approach, a solution to reducing the menace of multidrug-resistant bacteria and zoonoses from domesticated animals in Nigeria – A review

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Abstract

Antibiotic resistance and zoonoses are leading public health challenges the world is currently battling. However, the continuous use of antibiotics for veterinary care in companion animals, including fish and dogs among others, has increased the prevalence of multidrug-resistant (MDR) bacteria of zoonotic potential. Domesticated animals are tamed animals that are kept by humans as companion animals, food sources or work animals, and live in close proximity to humans. They have been documented as potential sources of MDR pathogens. The establishment of a national surveillance database for MDR bacteria in humans, animals and the environment will help understand the true burden of MDR pathogens in developing countries, like Nigeria. It will also help identify possible ways to curb them and fill the knowledge gap in the global epidemiological map. The One Health approach to curbing the spread of MDR and zoonotic pathogens by determining the human-animal-environment transmission holds a great advantage in tackling and reducing the prevalence of these pathogens in Nigeria. The regulation of antibiotic use in animals and the implementation of good hygiene are possible ways to reduce the incidence and spread of MDR bacteria and zoonoses.

Keywords: Zoonoses, Domesticated animals, Multidrug-resistant Pathogens, Antibiotic Resistance, One Health, Nigeria

Introduction

Domesticated animals are tamed animals kept by humans as companion animals, food sources or work animals. They include cattle, chickens, pigs, dogs, cats, horses and camels [1]. The domestication of animals by humans over the years have had significant effects on humans and the biosphere in its entirety [2]. Due to the proximity of domestic animals to humans, they are likely to transmit pathogens to humans, which could also include multidrug-resistant (MDR) bacteria [3]. The human-animal-environment interface of disease transmission in developing countries, like Nigeria, pose a great threat to the welfare of the populace, leading to higher emergence of infections that are challenging to manage [4], and ultimately affect the country's economy [5].

Bacterial strains have become resistant to almost every available antibiotic. A notable example of a typical MDR bacteria is methicillin-resistant *Staphylococcus aureus* (MRSA). It is usually resistant to aminoglycosides, chloramphenicol, tetracycline, lincosamides, and macrolides, in addition to methicillin [6]. Increase in the use of antimicrobials in veterinary medicine and as growth promoters in animal husbandry has resulted in a rise in MDR zoonotic bacteria transferred to humans through interactions with domesticated animals [7]. Domesticated animals have been documented as reservoirs of MDR zoonotic bacteria, such as MRSA, methicillin-resistant *Staphylococcus pseudointermedius* (MRSP) and extended-spectrum beta-lactamase (ESBL)-producing *Escherichia coli* [8-9].

A One Health approach brings together human, animal and environmental perspectives to curb the spread of multidrug resistance. The One Health

Commission [39] defines One Health as “a collaborative, multi-sectoral, and trans-disciplinary approach - working at local, regional, national, and global levels - to achieve optimal health and well-being outcomes recognizing the interconnections between people, animals, plants and their shared environment”. Also, the World Health Organization (WHO) [40] defines the concept as “an approach to designing and implementing programmes, policies, legislation and research in which multiple sectors communicate and work together to achieve better public health outcomes.

Increasing the interdisciplinary coordination to curbing MDR bacteria can help promote science-based decision making; reduce unnecessary duplication among the sectors responsible for the health of humans, animals and the environment; and effectively address factors influencing MDR zoonotic infection burdens [12]. The ultimate aim of this approach is to address global public health issues that are intricately interconnected and interdependent on the growing human population and their actions on the environment, as well as their interaction with animals.

The scarcity of scientific data on MDR zoonoses from some parts of Nigeria makes it difficult to measure the true burden of MDR zoonotic diseases in the country. However, research identifies Nigeria, alongside other African countries, as countries with the greatest burden of neglected zoonoses worldwide [13;14]. Nigeria is considered to have one of the highest burdens of endemic diseases globally and also a major contributor to 44% of the world's poorest livestock keepers [15;16]. Diseases like anthrax, zoonotic tuberculosis and rabies are widespread among livestock keepers, but their neglected nature provides an inaccurate view of their public health significance. Despite the huge burden of endemic zoonoses and increased risks of the emergence of novel zoonotic diseases, there is little awareness about zoonoses, even among health professionals in Nigeria. There is no single intervention that can address all zoonoses. It is now increasingly recognized that the establishment of a One Health approach is the most efficient strategy to address existing and emerging MDR bacterial zoonoses.

Most studies on multidrug-resistant bacterial zoonoses in Nigeria have always focused on food-producing animals, and have neglected other domesticated animals that can also be potential carriers of MDR bacteria [17;18]. This article reviews the epidemiology and possible solutions to reducing the spread of MDR bacterial zoonoses in Nigeria using a One Health approach. Understanding the true burden of MDR bacterial zoonoses in humans, animals and the environment will help curb the spread, direct public health decisions and policies, and add to existing information on the spread of MDR in Nigeria.

Methods

Databases (PubMed and Google scholar) were searched for articles using the One Health approach to

curb antibiotic resistance, MDR bacteria in Nigeria, the spread of antibiotic resistance in the environment, and domesticated animals as carriers of MDR zoonotic bacteria. A combination of keywords including “multidrug-resistant”, “zoonoses”, “household animals”, “domestic animals”, “one health”, “bacteria”, and “Nigeria” were used during the search. The last search date was 25 August 2020. Abstracts and full texts of the articles were screened based on relevance to this literature review. Articles with prevalence data on MDR in zoonotic pathogens in Nigeria and reviews with relevant information on the spread and prevalence of MDR zoonoses and/or one health perspectives of MDR zoonoses were included in this review.

Domesticated animals as vectors of multidrug-resistant and zoonotic pathogens

Today, companion animals such as cats, dogs, rodents, rabbits, birds, geckos ferret and ornamental fishes are commonly found in many homes across the world and thus in close proximity with humans. Companion pets are believed to be innocuous. The bacterial zoonoses associated with them is neglected when compared to foodborne zoonoses. As these animals are in close proximity with people, the potential for spreading large numbers of pathogenic bacteria, including MDR bacteria, between them and their owners is high [19; 20]. This transmission could occur by direct contact (such as petting, licking and physical injury) or indirectly via contamination of food and household environments [8]. Indeed, the regular exchange of skin microbiota between owners and their pets has been shown, hence putting emphasis on the impact of contact in the spread of zoonoses [21].

The WHO has identified antibiotic-resistant pathogens as one of the biggest challenges and threats to human health [22]. Wieler *et al.* [19] reported that household animals are reservoirs of MDR bacteria of zoonotic potential such as ESBL- producing *Escherichia coli*, MRSA, and MRSP. A recent report showed household animals to be the source of many zoonotic diseases including bite wound infections, cat scratch disease, leptospirosis, salmonellosis, psittacosis, brucellosis, Q-fever, and mycobacterial-infections [8].

A report has shown that kittens can be colonized with *Bartonella henselae*, which they eventually transmit to humans by biting and scratching, leading to bartonellosis [23]. *B. henselae* has also been found in fleas, obtained from cats, dogs, sheep and goats, leading to bartonellosis [25]. *Mycobacterium marinum*, the causative agent of aquarium fish tank granuloma, has also been reported as a MDR pathogen with zoonotic potential [26]. Epidemiological studies have shown that *Brucella* spp. are present in different species of domestic livestock and pet animals in Nigeria, including cattle, sheeps, goats, camels, horses and dogs [27-30]. There are no laws aimed at controlling this disease, but they can negatively impact the economy and human health. Contact with pets and livestock in northern Nigeria increases the danger of leptospirosis infection, which

may occur through skin contact when handling infected animals and their tissues [31-32]. Non-typhoidal salmonellosis is one of the most important enteric zoonoses globally [33]. Salmonellosis has been implicated in dogs in some parts of Nigeria, including Aba [34] and Maiduguri [35]. Reports have shown that dogs generally remain resistant to *Salmonella* infections. Infected animals may remain carriers and through their faecal shedding, they may serve as source of infection to people and other animals [36]. Several studies have linked parrots and ornamental birds as the source of many human psittacosis infections [37-38].

Given this evidence that illustrates companion animals as potential vectors of zoonotic pathogens, and in most cases MDR strains, it is of utmost necessity that effective policy control is put in place. This includes good hygiene practiced by animal owners, and most importantly, embracing the One Health approach.

One Health of animals, humans and our shared environment

The One Health approach started as a result of the interconnection between human, animal and environmental health [39-40]. The aim of this approach is to address global public health issues that are intricately interconnected and interdependent on the growing population of humans and their actions on the environment, as well as their interaction with animals.

The increasing human population, as described by [41], has led to rapid urbanisation, an increase in livestock production, globalization and intensive exploitation of the ecosystem. Thus, environmental changes such as climate change, deforestation, pollution and habitat encroachment have led to the rapid proliferation of infectious diseases including antimicrobial resistance pathogens. Therefore, there is a need for cross-collaboration among public health professionals and veterinarians, with the inclusion of bioscientists and environmentalists working holistically together for optimal health outcomes. As observed by Bidaisee *et al.* [2014], the pioneers of microbial sciences, Louis Pasteur and Robert Koch, and physicians including William Osler and Rudolph Virchow, established the theory of interdependent links between human and animal health. In recent times, Calvin Schawabe (a veterinary epidemiologist) called for an integrated approach between veterinarians and physicians to tackle zoonotic diseases [43]. In 2007, the American Veterinary Medical Association (AMVA), the American Medical Association (AMA), and the American Public Health Association, in a bid to achieve effective collaborations between human and animal health professionals, formed the One Health Initiative Task Force [43]. This led to the creation of 12 recommendations for advancing and attaining One Health Practices. One Health has therefore evolved to become a framework to tackle global public health challenges.

Recognizing the importance of the One Health approach in tackling the burden of zoonotic diseases, antimicrobial resistance and environmental health

issues in Nigeria, the Nigeria Centre for Disease Control (NCDC) launched a 5-year Strategic Plan for One Health in Nigeria in 2019 [44]. The plan is aimed at building intersectoral collaboration between stakeholders of human, animal and environmental health in order to improve on the One Health strategy developed by the WHO and the World Organisation for Animal Health (OIE). The plan fostered the creation of a national technical working group (AMR-TWG), comprising stakeholders from human health, animal health, food animal production and environmental sectors. This AMR-TWG group had the responsibility of carrying out a situation analysis of AMR in Nigeria. Several gaps were identified from the analysis. These included poor public awareness and weak coordination of AMR activities by government and partners such as vertical disease control programs, poor One Health coordination of animal and human national surveillance systems, the non-existence of a national AMR laboratory surveillance system, the lack of dedicated funding for AMR control activities, and an absence of antimicrobial stewardship in the private and public sectors [44]. Following this gap analysis, strategic interventions have been set up, including: increasing the awareness of AMR amongst Nigerians and improving the knowledge of AMR and related topics, building AMR surveillance through strengthening institutional capacities for AMR detection, ensuring rational antimicrobial use by improving access to quality antimicrobial agents, re-enacting laws related to the overuse of antibiotics, promoting One Health antimicrobial stewardship, strengthening regulatory agencies across all sectors in Nigeria, and investing in One Health AMR research and encouraging the development of antibiotic alternatives and new AMR diagnostics [44]. These activities are pivotal to reducing the menace of MDR zoonoses in Nigeria.

The microbial connectedness between humans, animals, and the environment has been established by several studies on infectious diseases and antimicrobial resistance [45-47]. Over 70% of infectious diseases are zoonotic, and a high percentage of zoonotic transfer are transmitted by companion animals, also transferring drug-resistant pathogens in the process. It has also been reported that genes that confer antimicrobial resistance in pathogens can be transferred within the environment and shared among these disease-causing organisms. Therefore, the need to re-enforce a One Health approach in combating emerging and re-emerging zoonotic diseases, especially those implicated by household animals such as Lassa fever, which is endemic in Nigeria [48].

Epidemiology of MDR bacteria in Nigeria

The increase in the use of antibiotics as growth promoters in animal husbandry has been regarded as one of the major reasons for the rise in the prevalence of MDR strains [51]. The increase in antibiotics use in livestock was evidenced in a survey that reported the total antibiotics consumption in 228 countries to be about 63, 000 tons in 2010 and projected a 67% increase

by 2030 [52]. This estimated increase poses a great risk as it might lead to an increase in the spread of MDR zoonoses globally. The rate of consumption of antibiotics in livestock and other domesticated animals in Nigeria is not well known. A three-year epidemiological study of the consumption of antibiotics in livestock farming in the south-western part of Nigeria showed that tetracycline, fluoroquinolones, beta-lactams, and aminoglycosides are the most used antibiotics in livestock [53]. Also, the misuse of antimicrobials in companion animals such as dogs, cats, and birds has been reported in Nigeria [34].

The actual epidemiology of MDR bacteria pathogens in Nigeria is also not well known due to the absence of a national antimicrobial resistance (AMR) surveillance system. There are only studies from different parts of the country reporting different MDR prevalence rates in humans, animals, and the environment. Thus, the establishment of an interdisciplinary surveillance plan for research and disease diagnosis in hospitals and veterinary clinics will help determine the true burden of MDR pathogens in Nigeria. Some frequently studied MDR bacteria in Nigeria include MRSA, multidrug-resistant *Pseudomonas aeruginosa*, Vancomycin-resistant *Enterococcus* (VRE) and carbapenem-resistant *Enterobacteriaceae* (CRE), with varying prevalence in humans, animals and the environment [49-50].

Studies have been conducted on the incidence of MDR bacteria in animals in Nigeria, with a focus on food-producing animals, such as cattle, chickens, turkeys, and pigs [54]. Antibiotic-resistant zoonotic bacteria have been reported from healthy and sick domesticated animals in Southern and Northern parts of Nigeria [55-56]. Most studies on drug-resistant bacteria in pets in Nigeria have been on dogs, the most common pet in Nigeria [58-59]. Direct and indirect contacts with pets have been regarded as one of the means of MDR bacterial transmission to humans [60]. The poultry environment has for a long period been known as a reservoir of MDR bacteria, which is supported by several Nigerian studies [61-63]. Most poultry in Nigeria are close to residential buildings. Thus, this makes it easy for MDR bacteria to transfer between humans and other animals. The detection of MDR bacteria (prevalence rates of above 30%) in poultry feeds from Nigerian poultry farms can be attributed to the misuse of antibiotics in poultry [64-65]. In a study from the Federal Capital Territory, Abuja reported a 39.7% prevalence of MDR *E. coli* among poultry workers in Nigeria [71]. Other studies [72-73] have also reported similar transmission routes, and this is evidence of occupational exposure of poultry workers to MDR bacteria.

Many clinical studies have reported MDR zoonotic pathogens in humans from different parts of Nigeria with prevalence rates above 90%, and MDR bacteria (such as *E. coli* and *Klebsiella* spp.) top the list [66-68]. MDR zoonotic pathogens have been transmitted to humans through different associations with companion animals and shared environments, and also through their consumption [69].

A One Health approach to curbing zoonoses in Nigeria

Globally, zoonotic diseases are a burden on the healthcare systems of developing nations like Nigeria. Zoonoses represent 60% of infectious diseases and 75% of novel or emerging infectious diseases, according to the United States Centers for Disease Control and Prevention [74]. Despite recent interventions, Gbemisola et al [2018] argues that there has been an upsurge in zoonotic disease infection. However, there has been continued support for interdisciplinary approaches that aid in the management and implementation of new interventions including curbing detrimental management strategies. According to Bidaisee and Macpherson [2014], the concept of One Health, which dates back to the late twentieth century, has continually been promoted by researchers and physicians. One Health has been described by Rabozzi et al [2012] as a comprehensive and global approach that seeks to highlight the importance of interdisciplinary interaction between all sections of healthcare for the effective management of humans, animal welfare and proper environmental management and conservation.

In the last 3 decades, there has been a promotion of strategies by the WHO to foster a closer interdisciplinary approach between medical and veterinary sectors in the development of public health (PH) [75]. PH has a multidisciplinary scope and is not limited to veterinarians. It extends to professionals such as physicians, nurses, microbiologists, environmentalists, and food technologists, among others who contribute to the treatment, control and prevention of zoonoses [76]. This indicates the importance of collaborative efforts among professionals of varying sectors and stakeholders.

Insights into the socio-economic relevance of human and animal interactions could also be provided using One Health. There is an increasing risk of realization of emergent zoonotic diseases via knowledge of influences of urbanization, migration of people, animals and pathogens between surrounding rural settlements and urban areas [42]. Some zoonotic diseases have a varying pattern of transmission in urban and rural areas, which could further facilitate the spread of pathogens as in the case of water-borne diseases in rural areas with existing poor hygienic conditions or densely inhabited urban areas. The spread of zoonotic diseases could be facilitated through extremely contagious human-human interactions [76]. Collaborative efforts provided by the One Health approach would help in thoroughly understanding the transmission patterns of these zoonoses, which can help reduce their spread and make better policies in curbing these infections

Challenges and future directions

Due to emergence and wide increase in spread of diseases from animals to people (zoonoses) through the environment, there has been a need for a better and efficient approach to curbing zoonotic diseases. One Health is a promising approach, in this regard, because it is important to meet the challenges of the twenty-first

century, such as climate change, population growth and globalisation.

There is a major challenge in achieving the goals of One Health in developing countries (like Nigeria) where little or less is known about zoonoses due to the lack of surveillance systems. There are some diseases such as rabies, anthrax, brucellosis, zoonotic trypanosomiasis and leishmaniasis, among many others, which are neglected zoonotic diseases [77] escaping the One Health scope.

Many of these diseases receive little consideration in some parts of Europe, but they still are endemic in the developing world. These diseases pose risks on animals and people leading to new strains of these causative agents in countries depending majorly on livestock as a source of livelihood [78]. A close study between animals, humans and the environment should be done. Cooperation is therefore required between disciplines such as veterinary, medical and ecological personnel to further improve the diagnosis, epidemiology and control of zoonotic infections [79-80].

To improve this One Health approach, there is a need for interdisciplinary levels of collaboration which includes professionals from different fields and beyond academia [81-82]. Although there can be collaborative conflicts, which may include problems such as imbalance in powers, and conflicts of interest resulting in the non-release of results. There should be guidance on how to better handle the collaboration between different professions. Also, the enactment of laws will help guide the use of antibiotics in animals and reduce the prevalence of antibiotic resistance in domestic animals and the environment.

Furthermore, in the 21st century, there is no one approach sufficient to curb zoonotic infections, but One Health stands out as it integrates various fields in its unique approach. Therefore, to achieve this goal, it requires more practical implementation, research and evidence beyond theory and paperwork.

Current status of knowledge

This review has shown that the epidemiology of MDR bacteria with zoonotic potential from Nigerian households is still not known due to the absence of a national antibiotic resistance surveillance system and few studies on companion animals, such as dogs, cats, rabbits and birds. This review was also able to emphasize the importance of a One Health approach involving multiple disciplines in the bid to reduce the spread of MDR bacterial zoonoses. There is the need for more epidemiological studies on the spread of MDR bacterial zoonoses between pets and their owners. This review has also emphasised the need for enactment of laws that will curb the inappropriate use of antibiotics in Nigeria.

Conclusion

Domesticated animals have been living and interacting with humans for centuries. Thus, they have been a source of the spread of pathogens, including MDR bacteria to humans. The absence of a national surveillance system

has been one of the major problems encountered in the fight against MDR pathogens in Nigeria. The use of the One Health approach in determining the epidemiology of MDR bacteria in Nigeria and in tackling its spread is a potential solution to reducing the burden of MDR zoonoses globally. There is a need for collaborative efforts among health professionals and environmentalists in Nigeria, in order to improve the health status of Nigerians by curbing the spread of MDR bacterial zoonoses.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

All authors contributed equally to this review.

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How to cite this article: Akinsuyi OS, Orababa OQ, Juwon OM, Oladunjoye IO, Akande ET, Ekpueke MM & Emmanuel HE. One Health approach, a solution to reducing the menace of multidrug-resistant bacteria and zoonoses from domesticated animals in Nigeria – A review. *Global Biosecurity*, 2021; 3(1).

Published: June 2021

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