Mini Review Article

Emerging Pathogenic Methicillin-Resistant *Staphylococcus aureus* (MRSA) Strains in Veterinary Medicine (Narrative Review)

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Abstract | Methicillin-resistant *Staphylococcus aureus* (MRSA) is a burden bacterium of considerable concern in veterinary medicine, presenting substantial problems to both animal and human health. *Staphylococcus aureus* is a primary etiological agent of healthcare- and community-associated infections globally and has been increasingly identified in veterinary environments. Infected animals act as reservoirs for zoonotic transmission, posing human health implications. The worldwide burden of MRSA in veterinary settings varies significantly, with incidence rates differing by region and species, posing zoonotic risks and complicating infection control strategies in both affluent and developing countries. Contaminated meat products may promote the transmission of *S. aureus*, especially multidrug-resistant (MDR) strains, among meat handlers, slaughterhouse workers, and consumers. MRSA infections continue to provide management challenges owing to pervasive antibiotic resistance. Alarmingly, several MRSA strains have shown diminished sensitivity or resistance to vancomycin, a last-resort antibiotic. Comprehending the transmission dynamics and resistance mechanisms of MRSA is essential for formulating effective management measures and alleviating its effects on both animal and human health. This review examines various topics, including the prevalence of methicillin-resistant *Staphylococcus aureus* (MRSA) in veterinary environments, the incidence of multidrug-resistant *S. aureus* among meat handlers and abattoir personnel, the aetiology and manifestations of MRSA infections in animals, diagnostic difficulties, treatment and management approaches, public health ramifications, and preventive strategies.

Received | 23 January 2025; **Accepted** | 24 March 2025; **Published** | 10 April 2025
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Citation | Olanipekun, T.A., F.D. Ojeniyi, O.I. Celestina, A.D. Ayanyinka, O.H. Abiona, O.R. Ayanbolade, O. Ojurongbe, O.O. Opaleye and O.A. Olowe. 2025. Emerging pathogenic methicillin-resistant *Staphylococcus aureus* (MRSA) strains in veterinary medicine (Narrative review). *Advanced Analytical Pathology*, 1: 39-51.
DOI | https://dx.doi.org/10.17582/journal.aap/2025/1.39.51
Keywords | MRSA, LA-MRSA, Antimicrobial resistance, MDR

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Introduction

Methicillin-resistant *Staphylococcus aureus* (MRSA) is a drug-resistant bacteria accountable for a wide variety of infections worldwide (Figure 1), from mild cutaneous disorders to severe, life-threatening illnesses. MRSA was first identified in hospital settings and mostly restricted to healthcare areas until the 1990s. Nonetheless, it has broadened its influence due to its adaptability and is now prevalent in the society, commonly colonising animals, especially cattle. Methicillin-resistant *Staphylococcus aureus* (MRSA) poses a considerable risk, especially in healthcare environments like hospitals and nursing homes. Colonisation by MRSA strains may lead to significant consequences, such as purulent skin and soft tissue infections, severe pneumonia, surgical site infections, bloodstream infections, sepsis, and death, under appropriate circumstances (Lee *et al*., 2018). MRSA reservoirs were mostly identified in animals (Neradova *et al*., 2020). The widespread use of antibiotics in veterinary medicine, especially in livestock management, may lead to MRSA developing antibiotic resistance (Mehndiratta and Bhalla, 2014).

The livestock-associated variations (LA-MRSA) are acknowledged for their adaptation to animal hosts. Humans may be colonised by MRSA-positive bacteria after frequent and close contact with an infected animal, however they seldom develop an infection (Dong *et al*., 2021). Both farmers and animal breeders, as well as veterinary staff, are at an increased risk of developing MRSA, as previously proven (Neradova *et al*., 2020).

Emerging pathogenic genotypes of Methicillin-resistant *Staphylococcus aureus* (MRSA) have been shown to pose considerable challenges in veterinary medicine. This bacterial illness is considered a worldwide health threat owing to the fast spread and emergence of multidrug-resistant bacteria in the environment, animals, and people. Epidemiological study on MRSA from human and animal lineages indicates that some strains have a propensity for cross-infection between animals and people (Gulani *et al*., 2016). MRSA ST398, first discovered in pigs, has since been found in people, other animals, and veterinary environments (Aires-de-Sousa, 2017). MRSA infections in humans may be harboured by animals (Crespo-Piazuelo and Lawlor, 2021). The main locus of LA-MRSA transmission is humans, due to occupational contact to animals (Chen and Wu, 2020). The scientific community has raised great concerns about the occurrence of *S. aureus* and MRSA on animals, farms and slaughterhouses, along with the possibility for their transmission to meat and workers in these environments (Dimitrios Komodromos *et al*., 2022).

Recent study has shown that LA-MRSA may colonise many animals and related persons (Chen and Wu, 2020). The public health community is apprehensive over the rising incidence of LA-MRSA. The occurrence of MRSA across various countries differs, as shown in (Figure 1), with rates ranging from 0% to 7.0%, highlighting a significant public health risk (Wong *et al*., 2018). Interactions between humans and livestock are common due to the domestication of animals, which exceeds 90% in Nigeria (Klous *et al*., 2016). It is essential to assess the pathogenic potential of *S. aureus* strains linked to livestock to ascertain if they are zoonotic agents or whether the cattle are responsible and act as reservoirs (Relangi *et al*., 2023). The wellness of the environment, animals, and people is interconnected, a concept referred to as One Health. The effectual ways for alleviating the increased apprehension surrounding MRSA in veterinary research encompass the following: the establishment of stewardship programs within veterinary practices, the diminution of antibiotic administration in animals, especially for prophylactic reasons, the rigorous compliance with controlling infection protocols in veterinary clinics to avert the proliferation and dissemination of resistant bacteria, the cultivation of awareness among pet owners, far It is essential to create a collaborative initiative across the human and animal health, and environmental sectors to understand the dynamics of MRSA and tackle antibiotic resistance comprehensively.

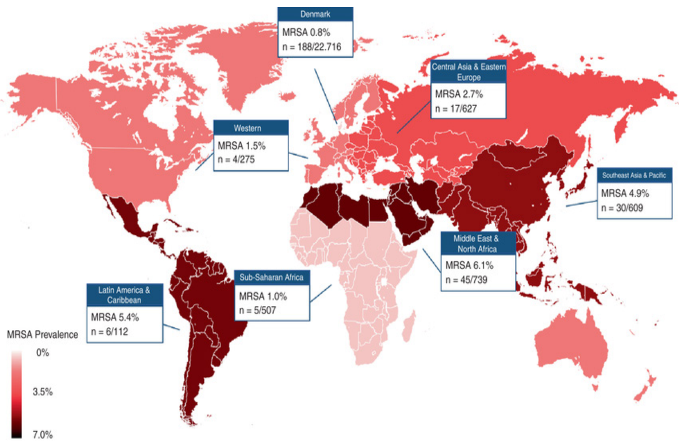

Figure 1: *Global prevalence and transmission patterns of MRSA (Rikke et al., 2022).*

The preface of methicillin resistant *Staphylococcus aureus* (MRSA) into veterinary medicine, its epidemiology, pathophysiology, and clinical manifestations, and its diagnostic methods and difficulties, treatment and management of MRSA infections in animals, public health consequences, and preventive controls and measures, are the main topics of this review.

Epidemiology of MRSA in veterinary settings

Resistant to methicillin in both human and animal medicine, *Staphylococcus aureus* (MRSA) antibiotic resistance is a serious problem. Pet owners, doctors, and animals are at danger due to the prevalence rate of MRSA at veterinary facilities (Khairullah *et al*., 2023). Numerous factors, such as the antimicrobial misuse, the kind of animal, husbandry practices, and geographic location, affect the global dissemination of MRSA in veterinary settings (Ahmed *et al*., 2024). The earliest reports of methicillin-resistant *Staphylococcus aureus* infections in cattle date back to the early 1970s in Belgium, (Figure 2) (Khairullah *et al*., 2023). The importance of this zoonotic and veterinary disease is shown by the following rise in publications showing MRSA infection and colonization in companion and food-chain animals (Roy *et al*., 2024). After being transferred from vertebrates, MRSA may infect humans. Similarly, persons may spread *S. aureus* to vertebrates. Even though the isolates were close to usual bovine strains, given the antimicrobial qualities, it is likely that the farmer acquired a unique strain of MRSA from a human source (Roy *et al*., 2024; Aires-de-Sousa, 2017). Since then, *S. aureus* has been found on the skin, lesions, and nasal specimens of dogs, cats, horses, cattle, pigs, rabbits, and poultry, making the US the country with the highest recorded rate of MRSA colonization in these species (Crespo-Piazuelo and Lawlor, 2021). In Canada and several European countries, such as the United Kingdom, Germany, the Netherlands, and France, studies show that methicillin-resistant *Staphylococcus aureus* (MRSA) is common in both household and wild animals, particularly in pigs (Martyna *et al*., 2023). Methicillin-resistant *Staphylococcus aureus* has been found in cattle by African researchers, particularly in areas where cows are closely grouped.

Multidrug resistant S. aureus among handlers and slaughterhouse workers

Recent years have seen a significant increase in public health attention to *Staphylococcus aureus* due to antimicrobial resistance (AMR) (Salam *et al*., 2023).

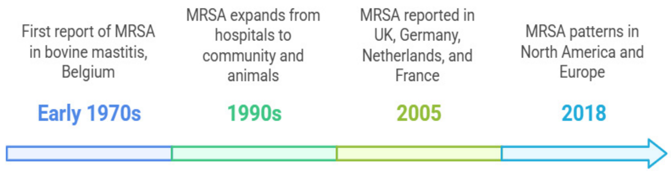

Figure 2: *The rise in occurrence of MRSA in veterinary medicine.*

This particular type of bacterium is common in people who have close contact with cattle and may cause zoonotic illnesses. Due to the animals near proximity to their bodies, farmers and veterinarians who often work with livestock are at an increased likelihood of contracting *S. aureus*, especially MRSA (Roy *et al*., 2024). According to research, exposure often results in higher colonisation rates than the general population. Cattle producers and their families are much more likely to get methicillin-resistant *Staphylococcus aureus* infections when there is environmental pollution present (Fetsch *et al*., 2021). Human nasal carriage seems to be significantly influenced by the duration of animal contact and exposure to CC398 MRSA in barn air, particularly in highly exposed cattle producers (Dong *et al*., 2021). According to (Crespo-Piazuelo and Lawlor, 2021), the prevalence of methicillin-resistant *Staphylococcus aureus* carriage in the general population ranges from 0.8% to 1.3%. *Staphylococcus aureus* colonization rates in humans who have come into touch with animals may vary greatly, often surpassing 50%. As shown in Figure 3, the occurrence rates are higher for staff members who touch live animals at the start of the slaughter process than for those who only handle corpses. According to Effelsberg *et al*. (2019), nasal LA-MRSA colonization is frequent in people who sometimes come into contact with animals and is probably just transient. According to research, methicillin-resistant about 25% of agricultural environments have a high prevalence of *Staphylococcus aureus* (Nene *et al*., 2023). The duration and kind of animal interaction determine the probability of MRSA colonization (Matuszewska *et al*., 2021). The menace of MRSA infection is higher for abattoir employees who have frequent animal interaction and veterinary personnel who have little animal contact, such as administering medication or maybe conducting autopsies (Ivbule *et al*., 2017). An extra danger is posed by the animals' ages. Crespo-Piazuelo and Lawlor (2021) found that MRSA colonization is more prevalent in animals, especially in pigs and cattle. A potential transmission connection to persons is implied by strains like ST398 that are often seen in cattle. Factors that can contribute to the expansion of MRSA infection from animals to humans include the antimicrobial misuse in livestock management, a lack of biosecurity measures to prevent the introduction, establishment, persistence, or spread of possible pathogens on or from a farm or geographic area, and the frequent handling of animals, which can cause discomfort and reduce animal welfare (Zhang *et al*., 2024). Because of persistence and recolonization, it is becoming more challenging to develop effective preventative techniques to lower the risk of MRSA infections among persons who relate with cattle in the workplace.

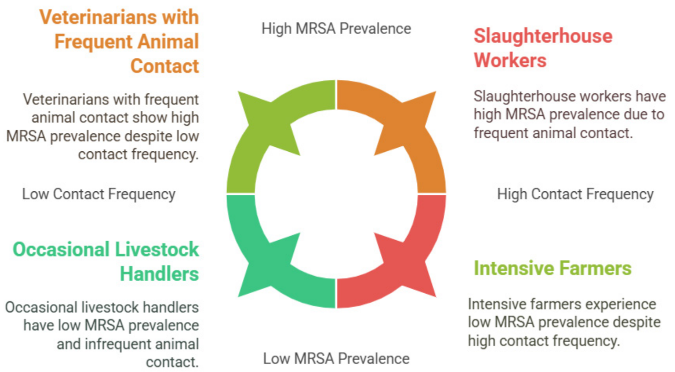

Figure 3: *MRSA risk and prevalence in livestock workers.*

Reservoirs and transmission routes

MRSA can infect both animals and human, potentially causing cross-species transmission (Dong *et al*., 2021). They can colonize the nasal passages of animals, mucosal surfaces, skin and other physiological sites. Methicillin-resistant *Staphylococcus aureus* (MRSA) may be found in people, particularly among animal handlers, veterinarians, and agricultural workers who have direct interactions with infected animals during tasks such as operating in slaughterhouses or overseeing livestock. Faecal matter, skin sores, and environments such as animal housing and veterinary clinics (including cages, bedding, and medical equipment) may act as reservoirs for methicillin-resistant *Staphylococcus aureus* (MRSA) (Traverse and Aceto, 2015). The principal means of disseminating MRSA to a farm include the transfer of animals, including household pets (such as cats and dogs), livestock (including cattle, pigs, sheep, goats, poultry, and horses), and other MRSA reservoirs, from one farm to another (see to Figure 4). The introduction of MRSA may occur by physical contact with colonized individuals and via contaminated transport vehicles that interact with animals (Khairullah *et al*., 2023; Crespo-Piazuelo and Lawlor, 2021). MRSA that colonizes cattle may serve as a significant reservoir for drug-resistant genes, similar to companion animals. The transfer of these genes is a critical issue in epidemiology, since they may facilitate the acquisition of MRSA colonization in people. Wild animals, such as bats, birds, and rodents, may release nasal and buccal (saliva) secretions, as shown by the studies of (Martyna *et al*., 2023; Abdullahi *et al*., 2021). These secretions may function as important transitory or permanent vectors, facilitating the spread of MRSA to humans and other animal species. This depends on the degree of contact and closeness between urban or agricultural settings and wild animals. Antibiotics are essential in the treatment of bacterial illnesses that impact the health, productivity, and wellbeing of cattle, according to Van *et al*. (2019). Additionally, antibiotics are used for prophylactic and metaphylactic applications to maintain animal health and enhance productivity. Antimicrobials are crucial for the treatment of skin, wound, respiratory, and urinary tract infections in companion animals, also for mitigating peritonitis and surgical site infections (Pomba *et al*., 2017). Antimicrobials are essential for preventing the spread of infections at the surgical site. Recent studies indicate that antibiotics are becoming ineffective in controlling harmful bacteria (Huemer *et al*., 2020). This is despite the established efficacy of antibiotics against bacteria. Antibiotics are used in several ways, including topical, systemic, broad-spectrum, and narrow-spectrum. The selection of antibiotics is dictated by the specificity of the bacteria and the types of illnesses present.

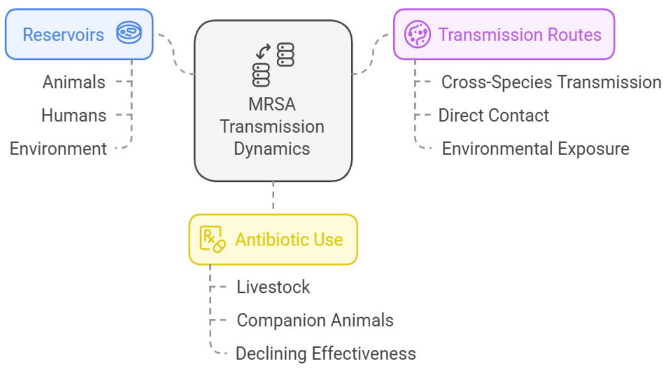

Figure 4: *MRSA transmission dynamics.*

Pathogenesis and clinical manifestations of MRSA in animals

Beta-lactam antibiotics are the most often recommended agents for the treatment of bacterial infections. Methicillin, amoxicillin, and penicillin G are all classified under this category by definition (Bush and Bradford, 2016). The antibiotic's beta-lactam ring specifically targets penicillin-binding proteins (PBP) inside bacterial cell membranes, which are crucial for cell wall synthesis. The bacterial cell succumbs when the antibiotic attaches to the PBPs, inhibiting their essential function. PBP2a is a protein that facilitates beta-lactam resistance in gram-positive bacteria (Nauta *et al.*, 2021). Their antibiotic resistance arises from this protein's capacity to evade their inhibitory effects. This mechanism enables methicillin-resistant *Staphylococcus aureus* to persist after treatment with several beta-lactam drugs.

The study's results indicated that the BLIP-II protein may exhibit poor binding and inhibition of PBP2a, rendering it susceptible to beta-lactam antibiotics. MRSA, a kind of bacterium, may lead to skin and soft tissue infections, including pyoderma. Additional symptoms include erythema, pruritus, and exudate from the integument; respiratory infections in animals with preexisting conditions like feline asthma or porcine species; and, in chronic cases, septicaemia, toxic shock syndrome, scalded skin syndrome, and endocarditis, especially in canines. Immunocompromised animals have a heightened susceptibility to septicaemia and other clinical manifestation (Figure 5).

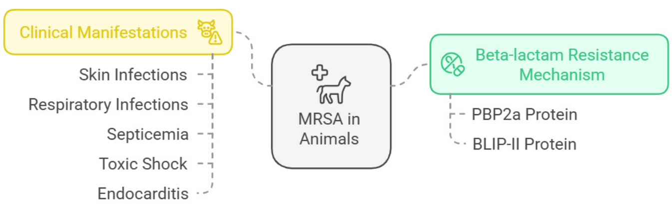

Figure 5: *MRSA in animals.*

Slaughtering environment and AMR contamination

The significant degree of human-animal contact at slaughterhouses exacerbates the rising incidence of diseases. Methicillin-resistant *Staphylococcus aureus* (MRSA), a bacterium endemic to cattle, has contaminated several areas of slaughterhouses, as seen in Figure 6. This presents a risk to slaughterhouse employees, particularly those handling animals such as chickens, piglets, and calves (Chen and Wu, 2020; Sadiq *et al.*, 2020; Cook *et al.*, 2017). Human illnesses may develop resistance to standard antibiotics if they result from consuming meat contaminated with bacteria from an infected surface or environment. Prioritizing personal and occupational hygiene is essential for effective resistance management (Arbin *et al.*, 2021). The abattoir requires safety equipment for workers; yet, some employees may be unable to afford it owing to insufficient wages and significant instability. To mitigate the danger of infection, slaughterhouse personnel must adhere to stringent hygiene protocols, which including frequent application of hand sanitizer and thorough hand cleansing. Employees who fail to maintain personal hygiene Biosecurity principles, including bio-exclusion, bio-management, and biocontainment, are used to avert disease transmission inside a facility by immunizations and to prevent the dissemination of sickness to the external environment once it is established. To minimize the danger of contamination, it is recommended that all animals undergo vital sign assessments prior to and during slaughter. The misuse of drugs is a contributing factor to drug resistance in both humans and animals. Inappropriate usage entails the administration of medication to animals without the consultation of physicians or veterinarians, as well as the practices of overdosing or underdosing. Butchers must receive education and training on fundamental meat handling safety protocols to identify and mitigate the risk of bacterial antimicrobial resistance in the slaughterhouse.

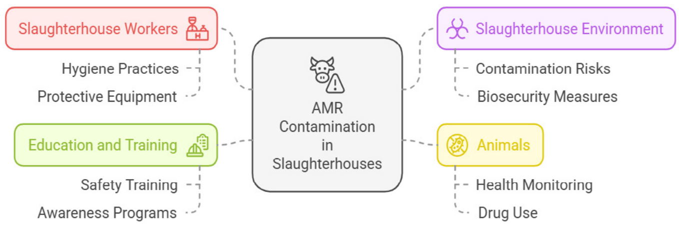

Figure 6: *AMR contamination in slaughterhouses.*

Diagnostic challenges and strategies

Diagnostic methods in veterinary settings focus on isolating pathogens, identifying species, and determining resistance profiles, which inform treatment decisions and infection control measures. The methods depicted in Figure 7 are widely utilized:

Collection of samples: Clinical samples are obtained from the skin, wounds, blood, urine, respiratory secretions, or body fluids. Swabs and aspirates are collected from farm workers, veterinarians, and animals using sterile techniques and are transported appropriately.

Culture and isolation: Samples collected are cultured on selective media, including mannitol salt agar

(MSA), chromogenic agar, and chocolate agar, which promote the growth of staphylococci while inhibiting other bacterial species. These media facilitate the identification of *Staphylococcus* species through their distinct growth patterns or colour changes. Incubation typically takes place at 37 ˚C for a duration of 24-48 hours to facilitate bacterial growth, during which colonies of Staphylococcus species manifest as large, round, and either golden or white in colour. To distinguish *S. aureus* from other staphylococcal species, additional testing is necessary.

Biochemical testing: Tests such as catalase and coagulase are utilised to differentiate and assist in the initial identification. Additionally, various biochemical assays, including fermentation patterns and sugar utilisation tests, can be employed for further identification (Nepali *et al.*, 2018).

Antibiotic susceptibility testing: The susceptibility of microorganisms to different antibiotics can be evaluated through the Disc Diffusion Method (Kirby-Bauer Test). A minimum inhibitory concentration (MIC) quantifies the lowest antibiotic concentration required to inhibit bacterial growth. The Oxacillin Screening assists in the identification of MRSA.

Molecular technique: The mecA gene, which causes methicillin resistance, may be found using molecular techniques like Polymerase Chain Reaction (PCR), which is quick and precise for MRSA confirmation. Additionally, mecA and other associated genes that provide particular information on the resistance mechanism may be sequenced using gene sequencing. There are classic diagnostic techniques that are quicker than others, such laparotomies and biopsies. After the MRSA has been isolated and verified, further identification may be done to identify the strain type (either by spa tying or field gel electrophoresis) in order to get a better knowledge of how MRSA spreads in the veterinary environment. Worldwide, veterinary microbiology diagnostic labs are crucial for maintaining the health and welfare of animals as well as halting the spread of zoonotic diseases, which cause 60% of human illnesses (Schlundt *et al.*, 2004).

Nevertheless, there are a number of drawbacks to using traditional diagnostic methods in veterinary settings to identify illnesses and ailments, including the inability to get sophisticated diagnostic methods like laboratory testing or specialised imaging in veterinary clinics, which may cause delays; restricted laboratory equipment for certain species, which might result in incorrect animal diagnoses; time-consuming procedures may impede prompt diagnosis and treatment, especially during crises; errors in the lab and by the operator might result in incorrect diagnoses and compromise the accuracy of the test.

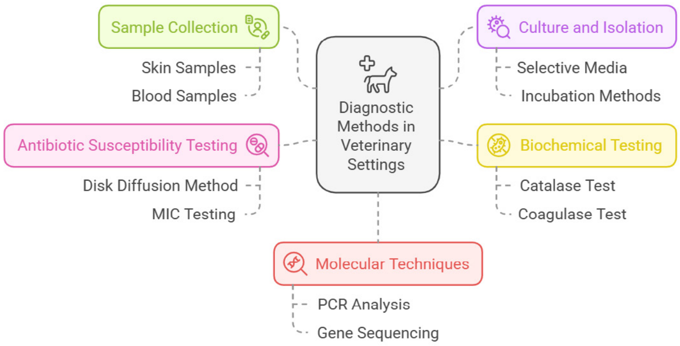

Figure 7: *Diagnostic methods in veterinary settings.*

Treatment and management of MRSA infections in animals

Animal antimicrobial medications are often identical to those used to treat human illnesses (Lynch and Zhanel, 2022). The main medications used to treat staphylococcal infections in people and animals include beta-lactams, macrolides, aminoglycosides, fluoroquinolones, sulfonamides, rifamycins, and tetracyclines (Xu *et al.*, 2022). The severity of each instance determines the treatment. To stop continuous exchange, animals that test positive should be segregated or temporarily taken out of the house for three to four weeks. Since MRSA colonization is temporary and usually goes away in three weeks, positive animals or humans may not need treatment. On the other hand, animals who have purulent skin infections could have their skin cut and drained. Depending on the results of culture-based antimicrobial susceptibility testing, more severe infections may need antibiotic therapy. Clindamycin, doxycycline, trimethoprim-sulfamethoxazole, rifampin (frequently used in conjunction with other antibiotics), tetracyclines (for some strains), and vancomycin are common antibiotics that may be used for MRSA infections in animals. Because MRSA is resistant to beta-lactam antibiotics, it is not recommended to use beta-lactam antibiotics like penicillin or methicillin. Many factors make it difficult to choose the right antimicrobial therapy, such as the broad variety of agents accessible, the existence of resistant organisms, practitioners general desire to use the most targeted therapy available, and the patient's medical history, which includes factors like weight, age, comorbidities, allergies, and immune status, as well as the identification of the specific pathogen causing the disease.

Public health implications

The global health community is increasingly alarmed by *Staphylococcus aureus* (MRSA), a systemic, multi-sectoral illness that endangers the health of people and animals worldwide. Staphylococcus aureus, a widespread infection capable of developing resistance to several treatments, is one of the most serious instances of bovine illness. An example is methicillin-resistant *Staphylococcus asureus*. Antimicrobial resistance (AMR) may increase healthcare expenses, health complications, and mortality rates worldwide, irrespective of socioeconomic position (Sharma *et al*., 2024; Ahmad *et al*., 2021). LA-MRSA is a public health risk owing to its capacity for zoonotic transmission (Pawarut *et al*., 2023). The likelihood of LA-MRSA colonization increases with direct contact with animals, especially on farms affected by MRSA (Avberšek *et al*., 2020). Methicillin-resistant infected animals or animal products may convey *Staphylococcus aureus* to humans. Inadequate hygiene standards may facilitate the transmission of MRSA in the food chain (Lienen *et al*., 2021).

Veterinary clinics, slaughterhouses, and farms are especially vulnerable to MRSA epidemics because to the significant level of human-animal interaction. The transmission of methicillin-resistant *Staphylococcus aureus* (MRSA) from animals to humans poses a substantial risk in industrial farming regions due to antibiotic overuse and overcrowding (Crespo-Piazuelo and Lawlor, 2021).

Prevention and control measures

Some important approaches address the crisis caused by methicillin resistance *staphylococcus aureus* are:

Routine screening and surveillance of animals for MRSA carriage and infection

To manage the risk of MRSA transmission between animals and humans, particularly in veterinary and agricultural settings, routine screening and surveillance of animals for MRSA carriage (Figure 8) and infection are important area to look into by early identification of animal that are MRSA carriers before the appearance of any sign of infection; surveillance should help to reduce the spread of MRSA between humans, animals and environment; protects public health by avoiding zoonotic transmission through the spread of MRSA to human especially in hospitals, veterinary clinics and farms. Screening methods should be carefully carried out on animals and workers either annually, semi-annually or more frequently; managing colonized or infected animals by receiving appropriate antimicrobial treatment and proper control of the infection with strict hygiene protocol.

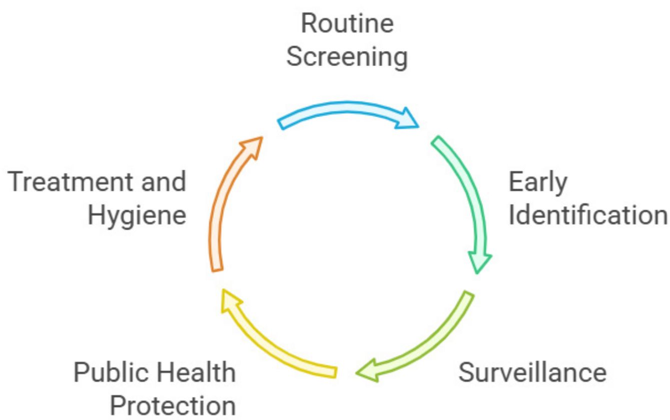

Figure 8: *MRSA screening and management cycle.*

Reduce the incidence of infection through effective sanitation, hygiene, and infection prevention measures

Enhancing infection control protocols in environments such as hospitals and farms is a recognised and efficacious strategy for mitigating the dissemination of antibiotic-resistant bacteria and other illnesses (Aslam *et al*., 2021). Nonetheless, established infection control measures in veterinary clinics are not comprehensively implemented (Feyes *et al*., 2021). To prevent pathogen transmission to humans, farms must implement infection control measures, including biosecurity and disease management programs. This is particularly applicable to intensive production within the hog and poultry sectors (Royden *et al*., 2021). Vaccination initiatives, hygiene of animals and handlers, and sanitation in slaughterhouses may mitigate antibiotic resistance and diminish disease transmission.

Optimize the use of antimicrobial medicines in human and animal health

To sustain the effectiveness of antibiotics in all areas, including agriculture, animal health, and human health, a One Health approach for better antimicrobial stewardship consists of a number of voluntary and regulatory actions (Chinemerem *et al*., 2022). This strategy must include antimicrobial use surveillance, prescription and utilisation optimisation technologies, and antibiotic stewardship initiatives (Neo *et al*., 2020). McCubbin *et al*. (2023) assert that the efficacy of antimicrobials for humans and animals must be preserved via a one health stewardship strategy, requiring the coordination of efforts across several sectors, including agriculture, human health, and veterinary medicine. Animal welfare and health are equally significant considerations, despite the tendency to concentrate human health issues. O'Rourke *et al*. (2020) suggest that the categorization of medications might be an effective approach to address antibiotic resistance. From a one health perspective, the paramount categorization systems are those that categorize antimicrobials based on their significance to human and animal health. The categorization aims to facilitate risk management in the food industry's battle against antimicrobial resistance.

Role of vaccination

Animal vaccination is the method used for the immunization of domestic livestock and wild animals. More studies are ongoing as to the development of vaccines to prevent MRSA infections in animals to reduce the transmission of MRSA between animals and humans (Das-Mitra *et al*., 2023). There are some researches on MRSA vaccines in animal such as; vaccine strategies for immunization to generate an immune response against surface proteins involved in MRSA infection, to help the bacteria cling to cells or evade the immune system; vaccines involving inactivated MRSA bacteria or components of the bacteria to trigger immunity without causing disease; also, vaccines that are live attenuated are used; vaccines that are clinically tried are carried out to evaluate the safety and effectiveness of these vaccines in different animal populations and to prevent MRSA colonization in animals, especially those that are at high risk of developing infections, such as animals in veterinary clinics or farms.

Enhancing awareness and comprehension of antimicrobial resistance through effective communication, education, and training

Antimicrobial resistance is an aspect that is quick evolving and highly detailed and difficult, especially its one health dimensions, which feature various forms of antimicrobial use within human, animal, and environmental sectors, accompanied by selection of antimicrobial resistance among bacteria in a wide variety of niches and with serious consequences to the health of humans and animals. Principles of basic hygiene to prevent the spread of infections, adhering to the antimicrobial instructions for treatment, and basic appreciation of the risks to themselves and others associated with antimicrobial use, in addition to the benefits are all essential for controlling antimicrobial resistance (Musoke *et al*., 2021; Essack, 2021). This applies to antimicrobial use in humans as well as animals. While all can benefit from a more in-depth understanding of the one health dimensions of antimicrobial resistance, those with particular need include companion animal owners, farmers, veterinarians, and others involved in food production and the wider food industry. Raising awareness about antimicrobial resistance among the general public, healthcare professionals, and farmers is vital as well as educational campaigns can inform about the risks of misuse of antibiotics and the importance of compliance with treatment protocols.

Challenges and knowledge gaps

Antimicrobial resistance (AMR) is an escalating public health issue in Nigeria, particularly in the natural environment and among animal populations. The deficiency of data and surveillance systems for AMR in Nigeria arises from several factors, including inadequate surveillance frameworks, insufficient data on livestock antimicrobial utilization, ineffective sector-wide coordination for monitoring and controlling AMR, and challenges related to waste management and environmental concerns.

Nigeria can enhance its surveillance infrastructure, fortify regulatory frameworks, augment research capacity, and promote cross-sector collaboration to rectify the deficiencies in data collection and monitoring systems for methicillin-resistant *Staphylococcus aureus* (MRSA) in cattle and the environment. To comprehend and combat MRSA nationally, it is essential to collect comprehensive data from several sectors, including agriculture, healthcare, and the environment.

Conclusion

The focus on the emergence of dangerous MRSA strains in veterinary care raises substantial concern about the transmission of Methicillin-Resistant *Staphylococcus aureus* (MRSA) in both animals and people. Researchers have identified these strains in companion animals, cattle, and pets, and their

Links Researchers

occurrences in veterinary environments are becoming more frequent. The existence of methicillin-resistant *Staphylococcus aureus* (MRSA) in animals is a considerable concern due to its ability to transfer and induce zoonotic diseases from animals to people.

Research indicates that the use of antibiotics in veterinary clinics correlates with a rise in the incidence of MRSA and other antibiotic-resistant bacteria. Furthermore, the issue may escalate significantly in some veterinary institutions due to insufficient infection control measures used inside these facilities. A holistic strategy is necessary to effectively prevent and manage MRSA infections in animals. The administration of medications necessitates vigilance, enhancement of hygiene procedures is essential, veterinary professionals need better information, and monitoring must be intensified.

Collaboration among public health authorities, healthcare providers, and veterinarians is frequently necessary to mitigate the risks associated with resistant strains, lessen their impact on the health of humans and animals, and enhance the veterinary community's understanding of methicillin-resistant *Staphylococcus aureus* (MRSA).

Acknowledgement

We would like to express our gratitude to all the staff members of the Department of Medical Microbiology and Parasitology for their invaluable support and cooperation.

Novelty Statement

This review article, *Emerging Pathogenic Methicillin-Resistant Staphylococcus aureus, (MRSA) Strains in Veterinary Medicine*, delves into the intricate zoonotic dynamics between animals and humans, in veterinary environments, the incidence of multidrug-resistant S. aureus among meat handlers and abattoir personnel, the aetiology and manifestations of MRSA infections in animals, diagnostic difficulties, treatment and management approaches, public health ramifications, and preventive strategies.

Author's Contribution

TAO and FDO collected and analyzed the data. OIC and ADA collected the data online and did further comparative analysis. AOH and ORA designed the review and wrote the manuscript. OO, OOO and OAO edited the manuscript and supervised activities. All authors read and approved the final version of the manuscript.

Conflict of interest

The authors have declared no conflict of interest.

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