MEDITERRANEAN JOURNALS
Infectious Diseases Reviews

DOI: 10.55085/idr.2022.662

REVIEW

Bacteriology of Wound Infections in Nigeria and its Effect on Antibiotics Selection during Management

Chukwu E E.[1*], Fadunsin, F A.[1], Nwaokorie F O.[2]

[1]Centre for Infectious Diseases Research, Microbiology Department, Nigerian Institute of Medical Research Yaba, Lagos, Nigeria.

[2]Department of Medical Laboratory Sciences, College of Medicine, University of Lagos, Nigeria

Correspondence: Dr. Emelda Chukwu; Email: emeldachukwu123@gmail.com

ABSTRACT

A wound is a rupture in the skin exposing the underlying subcutaneous tissue. It creates a moist, warm, and nutritive environment conducive to microbial colonization and proliferation. Depending on the time it takes for the wound to heal, it can be categorized as either acute or chronic. Infection in a wound elongates the healing period and results in longer hospital stays and higher treatment costs. Most open wound infections are polymicrobial containing both aerobic and anaerobic microorganisms, which should be considered when choosing antimicrobials. Controlling wound infections has become more difficult as the prevalence of antibiotic resistance has increased. This problem is exacerbated in Nigeria by a lack of epidemiological data on the microbial agents that cause wound infections. Thus, it is necessary to understand the microbes prevalent in infected wounds to encourage proper antimicrobial selection for the offending microbe and enhance better treatment and management outcomes. The bacteriology of wound infections, susceptibilities to routinely prescribed antibiotics, and the effects of the presence of these bacterial species in wound management are all discussed in this review.

Keywords: Wound infection; Microbial colonization; Polymicrobial infection; Antibiotic resistance; Aerobes; Anaerobes

1. INTRODUCTION

Wound infections continue to be a source of concern in clinical practice as they cause delayed or poor wound healing. In 2010, the World Health Organization (WHO) reported that the prevalence of healthcare-associated wound infections in low-income and middle-income countries (LMICs) was 2 to 20 times higher than in high-income countries [1,2]. Surgical site infection (SSI) was the most frequently reported and surveyed infection affecting up to one-third of patients who underwent surgery. SSI is the second leading cause of healthcare-associated infection in Europe and the United States [1,3]. According to data from the USA, up to 60% of the microorganisms isolated from infected surgical wounds are antibiotic-resistant [4]. In Nigeria, the incidence of SSI has been documented in parts of the country [5,6,7]. Olowo-okere et al. [7] have reported an incidence of 27.6% in a Tertiary Healthcare Facility in Abuja, Nigeria. Prolonged postoperative hospital stays, wound type, and several comorbidity conditions were all shown to be associated with a higher SSI rate.

Infected wounds are home to various microorganisms, including Gram-positive cocci such as *Staphylococcus aureus* and *Streptococcus* spp.*;* Gram-negative bacilli, mostly *Acinetobacter*, *Enterobacter*, *E. coli*, *Proteus* spp., and *P. aeruginosa;* anaerobic bacteria, especially *Clostridium* spp., *Propionibacterium* spp., and *Bacteroides* spp. [8,9]. These wound pathogens produce several virulence factors that mediate adhesion, nutrient acquisition, immune system evasion, leukocyte killing, tissue destruction, and bloodstream invasion [10].

Despite significant technological breakthroughs in the management of wound infections, it remains the most prevalent nosocomial infection in patients undergoing surgery [11,12]. Lifestyle diseases, such as diabetes, obesity, and cardiovascular diseases, contribute significantly to the yearly proportion of chronic wound infections [13]. In 2011, 366 million individuals worldwide were diagnosed with diabetes, which is projected to rise to 552 million by 2030 [14]. In addition, nearly 80% of people with diabetes reside in low- and middle-income countries, including Nigeria. Polymicrobial infections make up the majority of wound infections, and microbial synergy increases the severity of infection in several ways. Oxygen consumption by aerobic bacteria induces tissue hypoxia and reduces the redox potential, which promotes anaerobic bacteria growth. Specific nutrients produced by one bacterium may encourage the growth of fastidious and potentially pathogenic cohabiting microorganisms, and some anaerobes can interfere with the operations of the host's immune cell function. As a result, they gain a competitive advantage for themselves and other cohabiting microorganisms [15,16].

Bacterial resistance to medications has made controlling wound infections more difficult, particularly in infections caused by methicillin-resistant *Staphylococcus aureus* (MRSA) and

polymicrobial flora [12,17]. In addition to the direct care of patients, diagnostic microbiology findings are utilized to inform local, regional, and national surveillance systems. As a result, WHO recommends laboratory-based antibiotic resistance surveillance [18]. The scarcity of quality-assured microbiology laboratories in low-resource settings and the minimal attention given to persistent bacterial surveillance have resulted in a shortage of resistance data, particularly in sub-Saharan Africa and rural Asia [19]. This review aims to explore current views on diverse wound infections, compare their etiology, and assess the microbiologist and the microbiology laboratory's role in diagnosing and treating microbial colonization and infection in wounds.

2. WOUND INFECTIONS

The fundamental role of healthy, undamaged skin is to keep microbial populations that live on the skin surface under control and to prevent possible pathogens from colonizing and invading underlying tissue [15,20]. A wound causes a breach in the skin, exposing subcutaneous tissue and causing skin integrity to be compromised. This creates a moist, warm, and nutrient-rich environment that encourages microbial colonization and proliferation [16]. Depending on how long it takes for a wound to heal, it can be classified as acute or chronic [17,21]. Infected wounds take longer to heal and lengthen hospital stays. Furthermore, the overall cost of wound management rises significantly when infected [9,15].

Infection occurs when virulence factors expressed by microorganisms in a wound overcome the host’s natural immune system and subsequently invade and disseminate viable microorganisms into the tissues, thereby triggering a cascade of local and systemic host responses [15,22]. A variety of microbial and host factors contribute to the wound being infected. The wound's type, location, size, and depth all play a role in these reactions. Other factors include the degree of blood perfusion to the wound, the host's overall health and immunological condition, the microbial load, and the combined level of virulence displayed by the types of bacteria [15]. Most acute and chronic wound infections are caused by a combination of aerobic and anaerobic bacteria [23]. In numerous investigations, the most prevalent wound isolates were *Staphylococcus aureus* and *Pseudomonas aeruginosa*, which may be found in both healing and nonhealing wounds [24,25].

Burn wounds, surgical sites, bite wounds, acute soft tissue infections, diabetic foot ulcers, and leg and pressure ulcer infections are all examples of wound infections. However, SSIs are the most common type of healthcare-associated infections, leading to increased patient morbidity and death, particularly in low-resource countries [1]. As a result, the WHO guideline

development group was formed and charged with the responsibility of developing a guideline for the prevention of SSI. They came up with 29 recommendations and key measures for SSI prevention to be implemented in the preoperative, intraoperative, and postoperative periods [26,27]. These recommendations were developed from a global perspective, taking into account the balance of benefits and risks, the quality of evidence, cost and resource implications, and patient values and preferences. Similarly, in 1999, the Centers for Disease Control and Prevention (CDC) issued broad recommendations for preventing surgical infections, which were reviewed and revised in 2017 [28]. If these guidelines are followed consistently, the risk of surgical infections may be significantly reduced.

2.1 Bacteriological profile of wound infections in Nigeria

Most wound pathogens are bacteria, and the etiology of wound infection in Nigeria follows a similar trend as in other countries [22]. In Nigeria, wound infection analysis has revealed various findings across different areas and states, emphasizing the need for local prevalence and susceptibility investigations. Despite this, studies have repeatedly shown that *S. aureus, P. aeruginosa,* and *Proteus* species are the most common bacteria found in wound infections in Nigeria [21,22,29]. There has also been evidence of polymicrobial infection involving both aerobic and anaerobic bacteria [30,31]. Unfortunately, most studies in Nigeria on the microbial profile of wound infections focus on aerobic species, leaving data on anaerobic organisms capable of causing severe infections leading to sepsis, lacking. Regardless of the types and nature of wounds, *Staphylococcus aureus* is the most commonly identified Gram-positive bacterium from diverse wound infections in Nigeria [23,29,31,32]. *Staphylococcus aureus* was found to be most susceptible to amikacin (83%) and erythromycin (79 %) and least sensitive to amoxicillin (53 %), clindamycin (55 %), and cefuroxime (55 %) in research by Iroegbu et al. [22]. However, Saini and workers [23] have reported that the most effective antibiotics for *S. aureus* were clindamycin, amikacin, and cefuroxime. Nasal carriage of *S. aureus* has been established as a significant risk factor for infection [20,33]. The proposed sequence of events comprises nasal carriage, which is subsequently spread to other body regions via hand carriage, where infection can develop through cracks in the dermal surfaces [33]. On the other hand, concurrent studies have identified *Pseudomonas aeruginosa* [30], *Proteus* spp. [34], *and Klebsiella* [35] as the most common Gram-negative organisms in various wound infections. Recent studies have also reported this trend in other West African countries [36,37]. Analysis of chronically infected wounds in a rural district hospital in Ghana revealed a predominance of *Enterobacteriaceae* (41%), mainly *P. aeruginosa*, and *Staphylococcus aureus* (14%) as predominant Gram-positive bacteria [36].

Pseudomonas aeruginosa is notorious for its antibiotic resistance due to the permeability barrier afforded by its Gram-negative outer membrane. Also, its tendency to colonize surfaces in a biofilm form makes the cells impervious to therapeutic concentrations of antibiotics. Thus, *P. aeruginosa* was resistant to six antibiotics (amoxicillin, erythromycin, cotrimoxazole, gentamycin, streptomycin, and Zinacef) out of 10 employed in research on diabetic wound infection [29]. Similarly, Iroegbu and colleagues stated that *Pseudomonas aeruginosa* was most responsive to imipenem and amikacin and least sensitive to gentamicin, ceftazidime, and ofloxacin in a research on wound infections in Abuja, Nigeria. [22] (see Table 1). This tendency is not unique to Nigeria; a similar trend has been recorded in the United States [38], Europe [9], and Asia [16]. A comprehensive review and meta-analysis in the UK identified *P. aeruginosa*, *K. pneumoniae*, *E. coli*, *Enterobacter* spp., and *Proteus* spp. as the most prevalent Gram-negative organisms isolated from infected burn wounds [9]. Using microarray and next-generation sequencing, numerous *Pseudomonas* species were discovered in tissue biopsies from combat wound samples in US service members [38]. Furthermore, *P. aeruginosa*, *P. entomophilia*, *P. putida*, and *P. stutzeri* were among the isolates.

Proteus mirabilis is the species most commonly recovered from the urinary tract and wound infections. It is responsible for 90% of all illnesses caused by the *Proteus* genus [39]. Mordi and Momoh [32] conducted a two-year prospective investigation at the University of Benin Teaching Hospital and found that 390 (97.5%) of the 400 wound samples from diverse areas of the body showed growth of *Proteus* species accounting for 150 (26.8%) of the isolates. *Proteus mirabilis* was the most often isolated *Proteus species* (97.3%), followed by *Proteus vulgaris* (40.7%), *Proteus rettgeri* (8.40%), and *Proteus morgagni* (5%). Amikacin (100%) and imipenem (78%) were the most effective antibiotics against *Proteus species*, whereas amoxicillin/clavulanate and cefuroxime were the least effective [22]. Unfortunately, isolation and identification of anaerobes are time-consuming and expensive, particularly in developing countries, and only a few laboratories routinely or even periodically test for clinical anaerobic species [40]. Bacteroides were found to be the most common anaerobe species [30]. A summary of the bacteria species found in wound infections in Nigeria is shown in Table 1.

2.2 Risk factors of wound infections

Wound infections remain a major clinical challenge for hospitals, especially in developing countries where limited resources weigh down adequate healthcare delivery. Studies have implicated several risk factors for acute and chronic wound infections, including older age, diabetes, immune system disorders, cancer, HIV infection, malnutrition, paralysis (limited mobility), and hospitalization, which increases the risk of infection by organisms that are

resistant to antibiotics [44,45]. Several studies have attested that various risk factors come into play in wound infection and reiterate the need for doctors to adhere to aseptic procedures when dealing with surgical wounds [44-46]**.** Power and colleagues [45] used multivariate logistical regression to reveal that obese patients and those having open surgery had the highest risk of infections in patients who had colorectal surgery. Similarly, a systematic review of risk factors associated with SSI by Korol et al. [47] identified comorbidities, advanced age, risk indices, patient frailty, and surgery complexity as risk factors consistently associated with SSI. Nonetheless, a recent study has reported that surgical treatment, prolonged hospitalization, tracheostomy, pressure ulcer, and previous hospitalization are significant risk factors for MRSA infection in a tertiary care hospital in India [46].

On the other hand, sub-Saharan Africa has shown a peculiar trend, with a study reporting lack of constant water supply and breakdown of sterilization equipment as risk factors for the high rate of wound infection in healthcare facilities in Buea, Cameroon [48]. According to this study, age, gender, and wound type were not significant risk factors for wound infection [48]. On the contrary, a meta-analysis of postoperative wound infections returned that male gender and immunosuppression were significantly associated with higher infection rates in patients [49]. A study in Northwestern Nigeria has reported age, anemia, obesity, number in operating rooms, and duration of surgery to be significantly associated with SSI levels [50]. This finding agrees with other authors across the globe; however, risk factors appear to differ slightly based on wound type. In another study in Southwestern Nigeria, the authors concluded that patients with HIV infection, diabetes mellitus, preoperative anemia, and chorioamnionitis have an increased risk of postcesarean wound infection [51]. This emphasizes the importance of effective infection control measures and adopting good regular surveillance to reduce the risk of SSI. Although several reports have implicated diverse risk factors for different wound infections, most of these reports have pointed to the fact that people who are less fit (immunosuppressed) with prolonged hospital exposure are at greater risk of wound infection.

3. ANTIBIOTIC SELECTION IN WOUND INFECTION MANAGEMENT

Early detection and fast implementation of antimicrobial treatments are essential for the early clearance of infected wounds. Systemic antibiotics are the treatment of choice for infected spreading wounds [9,52]; however, therapeutic dosages may not be obtained in the wound bed in wounds with inadequate blood supply, such as pressure and leg ulcers [9]. In suspected or established wound infection, WHO recommends intravenous penicillin G and metronidazole to be administered every 6 hours and 8 hours, respectively, for 5–7 days [53]. In polymicrobial

illnesses, this combination treatment is intended to address both aerobic and anaerobic microorganisms. In contaminated operations, prophylactic antibiotics are also recommended. Unfortunately, in Nigeria, most studies on the microbial profile of wound infections and their antibiotic sensitivity focus on aerobic species; thus, data on critical anaerobic players are severely lacking. Saini and workers [23] recommended using metronidazole, chloramphenicol, or clindamycin to treat anaerobic infections and third-generation cephalosporins, amikacin, and ciprofloxacin for Gram-negative aerobes (*K. pneumonia, E. coli*, and *Proteus* spp.) and clindamycin or cefuroxime for *S. aureus*. Newer antibiotic families, such as ureidopenicillin, carbapenems, and b-lactam/b-lactamase inhibitor combinations, have broadened the treatment options for both preventive and therapeutic purposes [23]. Mordi and Momoh [32] have recommended using fluoroquinolones and gentamycin as the antibiotics of choice in wound infections since they are effective and provide the most coverage. Furthermore, Akinjogunla and colleagues [21] have discovered that isolates from car accident wounds were highly susceptible to ofloxacin (81.6%), ciprofloxacin (75.8%), and pefloxacin (81%) but resistant to penicillin, streptomycin, and gentamycin (Table 2). Mupirocin was found to be successful in eradicating *S. aureus* nasal carriage and decreasing SSIs in certain trials [20,54].

Most isolates from four general hospitals in Niger State's Bida, Kontagora, Minna, and Suleja districts were susceptible to ciprofloxacin, pefloxacin, and Tarivid, with *S. aureus* displaying a greater resistance profile to most antibiotics utilized than *Streptococcus pyogenes* [55]. However, a later examination of infected surgical wounds from patients at Ibrahim Badamasi Babangida specialist hospital in Minna, Niger state, showed a varied report [6]. Among the Gram-negative bacteria isolates, *Klebsiella ozaenae* had the greatest susceptibility to the antibiotics used, whereas *Clostridium perfringens* had the highest sensitivity to the antibiotics used among the Gram-positive bacteria isolates.

Despite this, Iroegbu and colleagues discovered an intriguing susceptibility pattern of *S. aureus* to chloramphenicol (100%), a drug seldom used due to its toxicity in the bone marrow and newborns [22]. They concluded that this medicine might be beneficial again in the context of rising multidrug resistance. Even though chloramphenicol has recognized side effects, it has been used increasingly in recent years due to the rise of antibiotic resistance [56]. Most of these ancient antibiotic compounds, such as chloramphenicol, have remained active against many currently widespread bacterial isolates due to low usage levels. Application of a single dose of topical chloramphenicol to high-risk sutured wounds after minor surgery resulted in a significant reduction in infection rate [57] in a prospective randomized placebo-controlled double-blind, multicenter trial. Using topical antibiotics as prophylaxis in preventing SSIs,

rather than systemic antibiotics, has been shown to be effective. Various surgical procedures, including joint arthroplasty, cataract surgery, and even breast augmentation [58], have been found to benefit from perioperative topical prophylaxis to reduce postoperative SSI. Cephalosporins, aminoglycosides, glycopeptides, chloramphenicol, and bacitracin [58] are among the most commonly used topical antibiotics. However, the evidence for using topical antibiotics in surgery is still debatable, with no clear randomized controlled studies. As a result, WHO does not recommend their usage.

In light of the rising frequency of antibiotic resistance, the WHO advisory committee has recommended a new therapeutic intervention approach [59] instead of antibiotic therapy. Several in vitro investigations have shown that bacteriophages can lyse specific bacterial pathogens [60]. Bacteriophages are bacteria-infecting viruses that are obligate intracellular parasites that replicate within the host via the host's enzymatic machinery. Bacteriophages have a high level of host specificity, infecting only certain strains even within a single bacterial species, whereas some bacteriophages may infect many species [61]. According to a recent study, these bacteriophages may be useful in healing septic wounds caused by *P. aeruginosa*, *S. aureus*, *K. pneumoniae*, and *E. coli* [12]. When utilized in a bacteriophage cocktail, these phages could be a promising first-line treatment for wound sepsis, with the added benefit of not enhancing multidrug resistance in bacteria and being able to function concurrently on a wide variety of MDR bacteria. Before this approach may be used therapeutically, additional regular standardization is still required.

3.1 Treatment failure and antimicrobial resistance

The widespread use of antibiotics both for human consumption and animal production has fostered the development of resistance in various pathogenic bacteria [63]. The rise of bacterial strains resistant to several medicines, or multidrug-resistant strains, is becoming a significant cause of infection treatment failure worldwide [12]. Drug-resistant germs kill 25,000 people in Europe per year, whereas MDR-bacterial infections kill 23,000 people in the United States every year [64]. According to WHO reports, drug resistance in bacteria has been detected in all parts of the world [59]. A survey of wound infections in Mayamar, South East Asia, revealed a high level of resistance with *Staphylococcus aureus* isolates resistant to penicillin (98%), oxacillin (70%), and tetracycline (66%), while *Escherichia coli* showed resistance to ampicillin (98%) [65]. Similarly, high resistance rates were documented in chronically infected wounds in rural Ghana, comprising 29% methicillin resistance in *S. aureus* and resistance to third-generation cephalosporins and fluoroquinolones in 33% and 58% of *Enterobacteriaceae*, respectively [36]. The authors stressed the need for microbiological diagnostic approaches,

including antimicrobial resistance testing, to guide the management of patients with chronic wounds in Ghana.

Over 98% of the isolates from SSIs were resistant to β-lactam antibiotics in a Nigerian hospital, according to Akunkunmi and colleagues [31], while more than 70% of the isolates from SSIs were resistant to erythromycin, fusidic acid, and tobramycin. *P. aeruginosa* was resistant to six antibiotics (amoxicillin, erythromycin, cotrimoxazole, gentamycin, streptomycin, and Zinacef) out of 10 employed in a study of diabetic wound infection in a rural community in Nigeria [29]. Vancomycin is used as a last option to treat methicillin-resistant *Staphylococcus aureus* (MRSA), and enterococcal strains that no longer react to vancomycin have also been identified [66]. Etok and colleagues [34] found 100% methicillin resistance in *Staphylococcus aureus* isolated from surgical wound infections and extended-spectrum beta-lactamase (ESBL) production in 50% of Gram-negative isolates (*Proteus* spp., *E. coli,* and *Klebsiella* spp.) that were most sensitive to imipenem. Similarly, Iroegbu et al. [22] discovered that, except for *E. coli*, which showed significant sensitivity to amoxicillin/clavulanate (83%) and *S. aureus* to erythromycin (79%) and chloramphenicol (100%), all common isolates were more than 30% resistant to all commonly used first-line drugs, particularly third-generation cephalosporins and gentamycin. Mechanisms of bacteria resistance to antibiotics fall into three main categories: antibiotic deactivation by modification of its active chemical moiety; the specific modification of the macromolecular target by mutagenesis of key residues; the prevention of antibiotics from reaching their targets through decreased uptake [67]. The growth and spread of ESBL among Gram-negative bacteria is a major challenge when trying to control wound infections and hospital costs. In Gram-negative bacteria isolated from orthopedic wound infections in Ile-Ife, Nigeria, Idowu et al. [68] found a 35% ESBL incidence. Of the 102 Gram-negative bacteria isolated, 36 were positive for ESBL, mainly of the Enterobacteriaceae family. They also discovered that the ESBL gene was horizontally transmitted, as were the genes for tetracycline, cotrimoxazole, nitrofurantoin, gentamicin, and aztreonam resistance. Almost all of the bacteria identified from SSIs were resistant to routinely administered antibiotics such as ampicillin, cotrimoxazole, streptomycin, and tetracycline, according to a study by Mofikoya and colleagues [30]. In nearly 80% of the infected individuals, the cultured aerobes showed less than 50% sensitivity to the cephalosporins examined (ceftazidime, cefuroxime, and ceftriaxone). With this level of antibiotic resistance, choosing an empirical treatment becomes extremely difficult.

3.2 Effects of Biofilm formation on wound management

One of the most critical components of wound care is identifying and treating biofilms. Biofilms are formed when single-cell bacteria attach to the exposed extracellular matrix proteins on the wound surface [69,70]. Wound biofilms are bound together by extracellular polymeric substrates attached to the surface, making them resistant to external forces that might otherwise overwhelm a single bacterium [69]. Biofilms can contribute to bacterial infection, inflammation, and delayed wound healing [71], which can considerably influence wound healing. Because of these concerns, reduced biofilm presence is an important component of good wound care. Biofilms were discovered in 60% of chronic wounds and just 6% of acute wounds, according to James and workers [72], who examined materials from 50 chronic wounds and 16 acute wounds. According to this study, chronic wounds have more substantial evidence of biofilms than acute wounds. Kirketerp-Moller and colleagues [73] examined wound samples from 22 individuals who were suspected of having *P. aeruginosa* infection. They discovered that *P. aeruginosa* was present in these wounds as biofilms rather than single cells using PNA FISH and anti-alginate antibodies. Although it may be tempting for the physician to begin antibiotic therapy, in the event of an established, mature biofilm, this treatment will most likely only have a transient effect on both inflammation and healing. Furthermore, the doctor must rely on swab or biopsy data, which rarely accurately represent all bacteria species present in the wound. Antibiotics have a lower efficacy against bacteria in biofilms [74,75]. According to Neopane et al., the Minimum Inhibitory Concentration (MIC) is not achieved in chronic wound fluid. Biofilm development was found in 30 (69.8%) and 28 (65.1%) isolates of *S. aureus* from wounds of hospitalized patients, respectively, using tissue culture plates and tube adherence methods [75]. In this study, biofilm-producing *S. aureus* had a greater rate of antimicrobial resistance than biofilm nonproducers, with 86.7% of biofilm-producing *S. aureus* being multidrug-resistant. In light of this, the practitioner should use caution when prescribing antibiotics. Antibiotic administration favors microorganisms that may form biofilms and promote antibiotic resistance. Mechanical removal of wound waste, including granulation tissue, is an effective method for reducing bacterial load.

4. ROLE OF THE MICROBIOLOGY LABORATORY IN GUIDING ANTIBIOTIC TREATMENT

Due to the complex etiology of wound infections, empirical therapy is not usually advisable. Microbiological data are critical in validating the appropriateness of a treatment plan in a quickly spreading soft tissue illness. Most doctors give broad-spectrum antimicrobial medicines before evaluating a microbiology report in chronic wounds that have failed to heal.

In many cases, the therapy is incorrect or unnecessary, resulting in a more extended stay in the hospital and the emergence of resistant strains. Furthermore, broad-spectrum antibiotics might disrupt normal gut microbiota, potentially putting patients at risk for *Clostridium difficile* colitis and other opportunistic infections (e.g., vancomycin-resistant *Enterococcus*) [76]. It is crucial to identify the clinically relevant isolates, undertake antibiotic susceptibility testing, and then provide guidance on the most appropriate treatment based on information acquired about the location of wound infection and clinical symptoms [77,78]. This support will aid in not only good wound treatment but also the control of antibiotic usage, reducing the spread of antibiotic-resistant germs.

In addition, the microbiology laboratory is critical in monitoring antibiotic resistance in wound infections. Laboratory-based surveillance is recommended as a preliminary step toward monitoring resistance trends to prevent further development and spread of drug resistance, according to the WHO global action plan to combat the growing problem of resistance to antibiotics and other antimicrobial medicines [18].

5.0 CONCLUSION

Although the microbiology of wounds has received much attention in recent years, there is still a lot to learn about the microbial pathways that cause infection and hinder wound healing. Clinical microbiology laboratories should create local reproducible, standardized methodologies to evaluate wound bacterial isolates for antimicrobial susceptibility regularly. Uniform adherence to the existing WHO recommendations for wound infection prevention and care will also help to reduce wound infections significantly. According to research, most open wounds are polymicrobial, with anaerobic bacteria accounting for one-third of all microbial species in colonized wounds. As a result, antimicrobial therapy of clinically infected wounds should cover potentially synergistic aerobic, facultative, and anaerobic microbes rather than focusing on a few pathogens that are frequently thought to be the cause. The use of metronidazole for the treatment of anaerobic infections is recommended.

Authors' contributions

The participation of each author corresponds to the criteria of authorship and contributorship emphasized in the Recommendations for the Conduct, Reporting, Editing, and Publication of Scholarly work in Medical Journals of the International Committee of Medical Journal Editors. Indeed, all the authors have actively participated in the redaction, the revision of the manuscript, and provided approval for this final revised version.

Acknowledgements

None.

Funding

None

Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this article.

References

1. World Health Organisation (2011). Report on the burden of endemic health care-associated infection worldwide. Geneva: World Health Organization, 2011. http://apps.who.int/iris/bitstream/10665/80135/1/9789241501507_eng.pdf (accessed Oct 9, 2016).
2. Allegranzi, B., Bagheri, N. S., Combescure, C., *et al.*(2011). Burden of endemic health-care-associated infection in developing countries: systematic review and meta-analysis. *Lancet*; 377: 228–41.
3. European Center for Disease Control (2013). Point prevalence survey of healthcare-associated infections and antimicrobial use in European acute care hospitals. Stockholm: European Centre for Disease Prevention and Control, 2013. http://ecdc.europa.eu/en/publications/Publications/ healthcare-associated-infections-antimicrobial-use-PPS.pdf
4. Magill, S.S., Edwards, J.R., Bamberg, W., et al. (2014). Multistate point-prevalence survey of health care-associated infections. *N Engl J Med*; 370: 1198–208.
5. Amoran, O.E., Sogebi, A.O., Fatugase, O.M. (2013). Rates and Risk Factors Associated with Surgical Site Infection in a Tertiary Care Center in South-West Nigeria. *International Journal of Tropical Disease and Health*. 3(1): 25-36.
6. Abubakar, I., Maikaje, D.B., Orukotan, A.A., Gana, E.N., and Ibrahim, H.A. (2018). Characterization and Antibiogram of Bacteria Isolated from Surgical Wounds of Patients Attending Ibrahim Badamasi Babangida Specialist Hospital Minna, Niger State, Nigeria. Journal of Advances in Microbiology 9(1): 1-9.
7. Olowo-okere, A., Ibrahim, Y. K. E., Sani, A. S. and Olayinka, B. O. (2018). Occurrence of Surgical Site Infections at a Tertiary Healthcare Facility in Abuja, Nigeria: A Prospective Observational Study. Med. Sci. 6, 60
8. Taiwo, S.S., Okesina, A.B., Onile, B.A. (2002). Invitro antimicrobial susceptibility pattern of bacterial isolates from wound infection in university of Ilorin Teaching Hospital *Afr J Clin Exp Microbiol.* 3(1): 6-10.
9. Azzopardi, E.A., Azzopardi, E., Camilleri, L., Villapalos, J., Boyce, D.E., et al. (2014) Gram Negative Wound Infection in Hospitalised Adult Burn Patients- Systematic Review and Metanalysis-. PLoS ONE 9(4): e95042. doi:10.1371/journal.pone.0095042
10. Van Delden, C., Iglewski, B.H. (1998). Cell-to-cell signaling and Pseudomonas aeruginosa infections. *Emerg. Infect. Dis*. 4:551–560.
11. Dionigi, R., Rovera, F., Dionigi, G., Imperatori, A., Ferrari, A., Dionigi, P., Dominion, I. (2001).Risk factors in Surgery. *J. Chemother*. 13: 6-11.
12. Pallavali, R.R., Degati, V.L., Lomada, D., Reddy, M.C., Durbaka, V.R.P. (2017) Isolation and *in vitro* evaluation of bacteriophages against MDR- bacterial isolates from septic wound infections. PLoS ONE 12(7): e0179245. https://doi.org/10.1371/journal.pone.0179245
13. Gottrup, F. (2004). A specialized wound-healing center concept: importance of a multidisciplinary department structure and surgical treatment facilities in the treatment of chronic wounds. *Am J Surg*. 187(5A):38S–43S.
14. Diabetes Atlas (2012). International Diabetes Federation. The IDF Diabetes Atlas. 5th edition. A summary of the figures and key findings. www.idf.org/diabetesatlas/papers.
15. Bowler, P., Duerden, B., Armstrong, D. (2001). Wound microbiology and associated approaches to wound management. *Clin Microbiol Rev.* 14: 2, 244-269.
16. Sawdekar, H., Sawdekar, R., Wasnik, V.R. (2015). Antimicrobial susceptibility pattern of bacterial isolates from wound infection and their sensitivity to antibiotic agents at super specialty hospital, Amravati city, India Int J Res Med Sci*;* 3(2):433-439
17. Shittu, A.O., Kolawole, D.O., Oyedepo, E.R. (2002). A study of wound infections in two health institutions in Ile-Ife, Nigeria. *Afr. J. Biomed. Res*. 5: 97-10.
18. World Health Organization. Surveillance standards for antimicrobial resistance (2016). Available from: http:// www.who.int/csr/resources/publications/drugresist/whocdscsrdrs20015.
19. Nasir, I.A., Babyo, A., Emeribe, A.U., and Sani, N.O. (2015). Surveillance for Antibiotic Resistance in Nigeria: Challenges and Possible Solutions. Trends in Medical Research 10 (4): 106-113, 2015

20. Kooistra-Smid, M., Nieuwenhuis, M., van Belkum, A., Verbrugh, H. (2009). The role of nasal carriage in Staphylococcus aureus burn wound colonization. *FEMS Immunol Med Microbiol*. 57: 1-3.
21. Akinjogunla, O.J., Adegoke, A.A., Mboto, C.I., Chukwudebelu, I.C., Udokang, I.P. (2009), Bacteriology of automobile accident wounds infection. *International Journal of Medicine and Medical Sciences.* 1(2): 023-027.
22. Iregbu, K.C., Uwaezuoke, N.S., Nwajiobi-Princewell, I.P., Eze, S.O., Medugu, N., Shettima, S., Modibbo, Z. (2013). A profile of wound infections in National Hospital Abuja. *Afr J Clin Exp Microbiol*. 4(3): 160-163.
23. Saini S., Gupta N., Lokveer A., Griwan M.S. (2004). Surgical Infections: A Microbiological Study. *The Brazilian J Infect Dis*. 8(2): 118-125.Bowler and Davies, 1999.
24. Bowler, P.G., Davies, B.J. (1999) The microbiology of infected and noninfected leg ulcers. *Int J Dermatol*. 38: 573-578.
25. Gethin, G., Cowman, P.S. (2008). Bacteriological changes in sloughy venous leg ulcers treated with manuka honey or hydrogel: an RCT. *J Wound Care*. 17: 241-247.
26. Allegranzi, B., Bischoff, P., de Jonge, S., Kubilay, N. Z., Zayed, B., Gomes, S. M., Abbas, M., Atema, J. J., Gans, S., van Rijen, M., Boermeester, M. A., Egger, M., Kluytmans, J., Pittet, D., Solomkin, J. S. and the WHO Guidelines Development Group (2016). New WHO recommendations on preoperative measures for surgical site infection prevention: an evidence-based global perspective. *Lancet Infect Dis* http://dx.doi.org/10.1016/S1473-3099(16)30398-X
27. Allegranzi, B., Bischoff, P., de Jonge, S., Kubilay, N. Z., Zayed, B., Gomes, S. M., Abbas, M., Atema, J. J., Gans, S., van Rijen, M., Boermeester, M. A., Egger, M., Kluytmans, J., Pittet, D., Solomkin, J. S. and the WHO Guidelines Development Group (2016b) New WHO recommendations on intraoperative and postoperative measures for surgical site infection prevention: an evidence-based global perspective. *Lancet Infect Dis* 2016 http://dx.doi.org/10.1016/S1473-3099(16)30398-X
28. Berríos-Torres, S. I., Umscheid, C. A., Bratzler, D.W., Leas, B., Stone, E. C., Kelz, R. R., Reinke, C. E., et al. (2017).. Guideline for the Prevention of Surgical Site Infection, Centers for Disease Control and Prevention for the Healthcare Infection Control Practices Advisory Committee. *JAMA Surg*. 2017;152(8):784-791.
29. Osariemen, I.J., Olowu, S.S., Adevbo, E., Omon, E.E., Victoria, O., Imuetinyan, E.J., Adesuwa, E. (2013). Aerobic Bacteria Associated With Diabetic Wounds In Patients Attending Clinic In A Rural Community In Nigeria. *Global Res J Microbiol*. 3(1): 8 – 12.
30. Mofikoya, B.O., Neimogha, M.I., Ogunsola, F.T., Atoyebi, O.A. (2009). Bacterial Agent of Abdominal Site Infections in Lagos, Nigeria. *European Journal of Scientific Research*. 38(3): 509-513.
31. Akinkunmi, E. O., Adesunkanmi, A, Lamikanra, A. (2014). Pattern of pathogens from surgical wound infections in a Nigerian hospital and their antimicrobial susceptibility profiles. African Health Sciences; 14(4): 802-809.
32. Mordi, R.M., Momoh, M.I. (2009). Incidence of *Proteus* species in wound infections and their sensitivity pattern in the University of Benin Teaching Hospital. *Afr J Biotech*. 8(5): 725-730.
33. Mahdi, S.E.I., Ahmed, A.O.A., Boelens, H., Ott, A., Abugroun, E.S., van Belkum, A., Zijlstra, E, Verbrugh, H, Fahal, A (2000). An epidemiological study of the occurrence of Staphylococcus aureus in superficial abscesses of patients presenting for surgery in a teaching hospital in Khartoum, Sudan. *FEMS Immunology and Medical Microbiology*. 29: 155-162.
34. Etok, C.A., Edem, E.N., Ochang, E. (2012). Aetiology and antimicrobial studies of surgical wound infections in University of Uyo Teaching Hospital (UUTH) Uyo, Akwa Ibom State, Nigeria. *Open Access Scientific Reports*. 1(7): 341.
35. Kehinde, A.O., Ademola, S.A., Okesola, A.O., Oluwatosin, O.M., Bakare, R.A. (2004). Pattern of bacterial pathogens in burn wound infections in Ibadan Nigeria. *Ann. Burns Fire Disasters*. 17(1): 12-15.
36. Krumkamp, R., Oppong, K., Hogan, B., Strauss, R., Frickmann, H., Wiafe-Akenten, C., et al. (2020) Spectrum of antibiotic resistant bacteria and fungi isolated from chronically infected wounds in a rural district hospital in Ghana. PLoS ONE 15(8): e0237263. https://doi.org/10.1371/journal.pone.0237263
37. Vicar, E.K., Acquah, S.E.K., Williams, W., Kuugbee, E.D., Saba, C.K.S., and Mensah, G.I. (2021). Antibiotic Resistant Bacteria Infecting Wounds of Rural Community Dwellers in Northern Ghana. European Journal of Medical and Health Sciences. 3 : 112-117; DOI: http://dx.doi.org/10.24018/ejmed.2021.3.1.678

38. Be, N. A., Allen, J. E., Brown, T. S., Gardner, S. N., McLoughlin, K. S., Forsberg, J. A., Kirkup, B. C., Chromy, B. A., Luciw, P. A., Elster, E. A., Jainga, C. J. (2014). Microbial Profiling of Combat Wound Infection through Detection Microarray and Next-Generation Sequencing. Journal of Clinical Microbiology; 52(7): 2583–2594
39. Auwaerter, P. (2008). Antibiotic guide. Johns Hopkins ABX (antibiotic) Guide, Baltimore, MD.
40. Nwaokorie, F.O, Nwokoye, N.N., Yisau, J.A. (2011). Survey of Anaerobic Infection Diagnostic Facilities in Laboratories in Nigeria. . Nig J Clin Biomed Res. 12 (2)49-52.
41. Makanjuola, O. B., Olowe, O. A., Adeyankinnu, A. F. (2013). Bacterial Agents of Surgical Site Infections in South-Western Nigeria. Am. J. Biomed. Sci. 2013, 5(4), 217-225
42. Abdu A.B., Egbagba J., Fente B.G. (2018). Identification and antimicrobial susceptibility profile of bacterial pathogens isolated from wound infections in a tertiary hospital, Bayelsa South southern, Nigeria. Tropical Journal of Pathology & Microbiology. Volume 06 – Issue 04, August 2018
43. Moro, D. D., Bello, H. O. and Akano, S. O. (2018). Incidence and Antibiotic Resistance Pattern of Bacteria Associated with Wound infection in some Hospitals in Lagos, Nigeria. Asian Journal of Applied Sciences (ISSN: 2321 – 0893) Volume 06 – Issue 04, August 2018
44. Torpy, J.M., Burke, A., Glass, R.M. (2005). Wound Infections. *JAMA.* 2005;294(16):2122. doi:10.1001/jama.294.16.2122
45. Power, K., Davies, M,M,.Hargest, R., Phillips, S., Torkington, J., Morris, C. (2014). A case-control study of risk factors for wound infection in a colorectal unit. Ann R Coll Surg Engl; 96: 37–40 doi 10.1308/003588414X13824511650137
46. Thimmappa, L., Bhat, A., Hande, M., Mukhopadhyay, C., Devi, E., Nayak, B., et al. (2021). Risk factors for wound infection caused by Methicillin Resistant Staphylococcus aureus among hospitalized patients: a case control study from a tertiary care hospital in India. Afri Health Sci. 2021;21(1):286-94. https://dx.doi.org/10.4314/ahs.v21i1.37
47. Korol, E., Johnston, K., Waser, N., Sifakis, F., Jafri, H.S., et al. (2013) A Systematic Review of Risk Factors Associated with Surgical Site Infections among Surgical Patients. PLoS ONE 8(12): e83743. doi:10.1371/journal.pone.0083743
48. Kihla, A.J., Ngunde, P.J., Evelyn, M.S., Gerard,0 N., Ndip, R.N. (2014). Risk factors for wound infection in health care facilities in Buea, Cameroon: aerobic bacterial pathogens and antibiogram of isolates. Pan Afr Med J. 2;18:6. doi: 10.11604/pamj.2014.18.6.2304.
49. Schlager, J.G., Hartmann, D., Wallmichrath, J., et al. (2022). Patient dependent risk factors for wound infection after skin surgery: A systematic review and meta-analysis. Int Wound J. 2022;1-10. doi:10.1111/iwj.13780
50. Nwankwo, E.O., Ibeh, I.N., Enabulele, O.I. (2012). Incidence and risk factors of surgical site infection in a tertiary health institution in Kano, Northwestern Nigeria. Int J Infect Control, v8:i4 doi
51. Rabiu, K.A., Akinlusi, F.M., Adewunmi, A.A., Alausa, T.G., Durojaiye, I.A. (2020). Risk factors for postcesarean wound infection in a tertiary hospital in Lagos, Nigeria. Niger Med J; 61:262-8.
52. White, R., Cooper, R., Kingsley, A. (2001). Wound colonization and infection. *B J Nurs.* 10: 563-578.
53. World Health Organization (2013). Prevention and management of wound infection. Guidance from WHO's Department of Violence and Injury Prevention and Disability and the Department of Essential Health. Technologies. https://www.who.int/hac/techguidance/tools/guidelines_prevention_and_management_wound_infection.pdf
54. Kalmeijer, M.D., Coertjens, H., van Nieuwland-Bollen, P.M., Bogaers-Hofman, D., de Baere, G.A., Stuurman, A., *et al* (2002). Surgical site infections in orthopedic surgery: the effect of mupirocin nasal ointment in a double-blind, randomized, placebo-controlled study. *Clin Infect Dis.* 35:353–358.
55. Sani R. A., Garba S. A., Oyewole O. A., Ibrahim A. (2012). Antibiotic Resistance Profile of Gram-Positive Bacteria Isolated from Wound Infections in Minna, Bida, Kontagora and Suleja Area of Niger State. Journal of Health Sciences, 2(3): 19-22
56. Kalita, S., Devi, B., Kandimalla, R., Sharma, K. K., Sharma, A., Kalita, K., Kataki, A. C., Kotoky, J. (2015). Chloramphenicol encapsulated in poly-ε- caprolactone–pluronic composite: nanoparticles for treatment of MRSA-infected burn wounds. International Journal of Nanomedicine; 10 2971–2984
57. Heal, C F., Buettner, P. G., Cruickshank, R., Graham, D., Browning, S., Pendergast, J., Drobetz, H., Gluer, R., Lisec C. (2009). Does single application of topical chloramphenicol to high risk sutured wounds reduce

incidence of wound infection after minor surgery? Prospective randomised placebo controlled double blind trial. BMJ 2009;338:a2812 doi:10.1136/bmj.a2812
58. McHugh1, S. M., Collins, C. J., Corrigan, M. A., Hill, A. D. K., and Humphreys, H. (2011). The role of topical antibiotics used as prophylaxis in surgical site infection prevention. J Antimicrob Chemother; 66: 693–701
59. WH Organization (2014) Antimicrobial resistance global report on surveillance: 2014 summary.
60. Wang Z, Zheng P, Ji W, Fu Q, Wang H (2016) SLPW: A Virulent Bacteriophage Targeting Methicillin-Resistant Staphylococcus aureus In Vitro and In Vivo. Frontiers in Microbiology 7: 934. https://doi.org/10.3389/fmicb.2016.00934
61. Haq IU, Chaudhry WN, Akhtar MN, Andleeb S, Qadri I (2012) Bacteriophages and their implications on future biotechnology: a review. Virology Journal 9: 1.
62. Jido, TA, Garba, ID (2013). Surgical-site Infection Following Cesarean Section in Kano, Nigeria. *Annals of Medical and Health Sciences Research*. 2(1): 33-36.
63. Dessen, A, Mouz, N, Gordon, E, Hopkins, J, Dideberg, O (2001). Crystal structure of PBP2x from a highly penicillin-resistant *Streptococcus pneumonia* clinical isolate. *Journal of Biological Chemistry*. 45 (2): 106-121.
64. World Health Organization. Surveillance standards for antimicrobial resistance (2016). Available from: http:// www.who.int/csr/resources/publications/drugresist/whocdscsrdrs20015.
65. Sandar, W.P.; Saw, S.; Kumar, A.M.V.; Camara, B.S.; Sein, M.-M. (2021). Wounds, Antimicrobial Resistance and Challenges of Implementing a Surveillance System in Myanmar: A Mixed-Methods Study. Trop. Med. Infect. Dis. 2021, 6, 80. https://doi.org/10.3390/tropicalmed6020080
66. Novak, R, Henriques, B, Charpentier, E, Normark, S, Tuomanen, E (1999). Emergence of Vancomycin tolerance in *Streptococcus pneumonia*, *Nature*. 399 (6736): 590-593.
67. Walsh, C (2000). Molecular mechanisms that confer antibacterial drug resistance. *Nature*. 406(23): 775-781.
68. Idowu, O.J., Onipede, A. O., Orimolade, A. E., Akinyoola, L. A., and Babalola, G. O. (2011). Extended-spectrum Beta-lactamase Orthopedic Wound Infections in Nigeria. J Glob Infect Dis. 3(3): 211–215.
69. Wolcott, R, Rhoads, D, Dowd, S (2008). Biofilms and chronic wound inflammation. *J Wound Care*. 17: (8) 333-341.
70. Clinton, A., Carter, T. (2015). Chronic Wound Biofilms: Pathogenesis and Potential Therapies; Lab Medicine 46 (4): 277-284.
71. Phillips, P.L., Wolcott, R.D., Fletcher, J., Schultz, G.S. (2010). Biofilms made easy. *Wounds Int*.;1(3).
72. James, GA, Swogger, E, Wolcott, R, Pulcini, E, Secor, P, Sestrich, J, Costerton, JW, Stewart, PS (2008). Biofilms in chronic wounds. *Wound Repair Regen*. 16(1):37–44.
73. Kirketerp-Moller, K, Jensen, PO, Fazli, M, Madsen, KG, Pedersen, J, Moser, C, Tolker-Nielsen, T, Hoiby, N, Givskov, M, Bjarnsholt, T (2008). Distribution, organization, and ecology of bacteria in chronic wounds. *J Clin Microbiol*. 46(8):2717–2722.
74. Bjarnsholt T, Kirketerp-Moller K, Jensen PO, Madsen KG, Phipps R, Krogfelt K, Hoiby N, GivskovM (2008). Why chronic wounds will not heal: a novel hypothesis. *Wound Repair Regen.* 16(1):2–10.
75. Neopane, P., Nepal, H. P., Shrestha, R., Uehara, O., Abiko, Y. (2018). In vitro biofilm formation by *Staphylococcus aureus* isolated from wounds of hospital-admitted patients and their association with antimicrobial resistance. International Journal of General Medicine 2018:11 25–32
76. Papasian, C.J., Kragel, PJ (1997). The microbiology laboratory's role in life-threatening infections. *Crit. Care Nurs. Q*. 20:44–59.
77. Washington, J.A. (1999). The role of the microbiology laboratory in antimicrobial susceptibility testing. *Infect. Med*. 16:531–532.
78. Clinical and Laboratory Standards Institute (2018). Performance Standards for Antimicrobial Susceptibility Testing. 28th ed. CLSI supplement M100 (ISBN 1-56238-838-X [Print]; ISBN 1-56238-839-8 [Electronic]). Clinical and Laboratory Standards Institute, 950 West Valley Road, Suite 2500, Wayne, Pennsylvania 19087 USA, 2018

592 **Table 1:** Bacteriological profile of infected wounds in Nigeria
593

Location	Study description and no. of wounds	No. of microbial isolates	Predominant isolates in descending order of frequency	References
Uyo	Analysis of purulent materials from 40 patients with automobile accident wounds	74	*Staphylococcus aureus* (37.8%), *Pseudomonas aeruginosa* (27.0%), *Escherichia coli* (14.9%), *Streptococcus pyogenes* (12.2%), and *Klebsiella pneumoniae* (8.11%)	21
Abeokuta	200 samples from surgical sites	160	*Staphylococcus aureus* (28.75%), *Pseudomonas aeruginosa* (16.25%); *Proteus species* (11.25%), *Klebsiella species* (8.75%), *Enterococcus species* (1.25%), and α-hemolytic streptococci (1.25%)	41
Minna	50 swab samples of infected surgical wound	30	*Staphylococcus aureus* (46.67%), *Pseudomonas aeruginosa* (20%), *Streptococcus agalactiae* (10%), *Streptococcus pyogenes* (10%), *Escherichia coli* (6.67%), *Clostridium perfringens* (3.33%), and *Klebsiella ozaenae* (3.33%)	6
Bayelsa	130 wound samples were using Sterile Swab Sticks	164	**Aerobes***: Pseudomonas aeruginosa* (28, 17.07%), *followed by E. coli* (19, 11.58%), *Klebsiella pneumoniae* (17, 10.37%), *Staphylococcus aureus* (10, 6.10%) **Anaerobes:** *Bacteroides fragilis (16, 9.75%), Peptostreptococcus* spp. *(2.44%),* and *Prevotella* spp. *(2.44%)*	42
Benin City	Analysis of 400 wound swab samples from many sites	560	*Staphylococcus aureus* (30%), *Proteus* spp. (26.8%), *Pseudomonas species* (23.6%), *E. coli* (11.6%), *Klebsiella species* (6.61%), *Streptococcus species* (0.8%), *Providence species* (0.5%), and *Enterobacter species* (0.36%)	32
Ile-Ife	102 swab samples from many wound sites	162	*Staphylococcus aureus* (25%), *Escherichia coli* (12%), *Pseudomonas aeruginosa* (9%), and *Staphylococcus epidermidis* (9%)	17
Lagos	144 swab samples of surgical wounds were analyzed	14	**Aerobes**: *P. aeruginosa, Enterobacter* spp.*, Proteus* spp., and *Klebsiella spp.* **Anaerobes**: *Bacteroides* spp., *Eubacterium* spp., and *Actinomyces* spp.	30
Lagos	202 wound samples consisting of surgical, burn, and accident/cut	320	*Pseudomonas aeruginosa*, (128, 40%), *Enterobacter spp*., (60, 19%), *Proteus mirabilis* (56, 18%), *Escherichia coli*, (20, 6%) and *Staphylococcus aureus* (16, 5%)	43

Edo	150 wound swabs from diabetic patients were analyzed	50	*Staphylococcus aureus* (38%), *Escherichia coli* (24%), *Proteus* spp. (20%), *Klebsiella spp* (10%), and *Pseudomonas aeruginosa* (8%)	29
Uyo	Analysis of 120 infected surgical wounds	150	*Proteus* spp. (33.3%), *Staphylococcus aureus* (20.0%), *Escherichia coli* (20.0%), *Coagulase-negative Staphylococcus*(13.3%), *Klebsiella* spp. (6.7%), and *Pseudomonas* spp. (6.7%)	34
Sagamu	50 surgical site infections were analyzed	49	*E. coli* (34.7), *S. aureus* (32.7%), *Proteus mirabilis* (14.3), *and Klebsiella* spp. (18.4%)	5
Abuja	380 wound specimens from various sites	314	S. *aureus* (27%), *P. aeruginosa* (19%), *E. coli* (14%), *K. pneumoniae* (13%), *Proteus* spp. (18%)	22
Ile-Ife	89 surgical site wound samples	126	*S. aureus* (18.3%) *P. aeruginosa* and *Bacillus* spp. (11.1% each), *E. coli* (10.3%), *Coagulase-negative Staphylococci* (8.7%), *Pseudomonas* spp. (6.3%), *Serratia odorifera* (4.7%), *Bacteroides* (4.0%), and *Enterococcus* spp. (3.2%)	31

594

595 **Table 2:** Bacterial isolates from wound infections in Nigeria and their susceptibility pattern
596 to commonly used antibiotics.
597

Site	Bacterial isolates	Susceptibility	References
Diabetic wounds	*S. aureus, E.coli, Proteus* spp., *Klebsiella* spp., *P. aeruginosa*	**Sensitive** to Pefloxacin, Augmentin, Rocephin/ Zinacef, Ciprofloxacin, and Gentamycin **Resistant** to Erythromycin and Cotrimoxazole	29
Multiple sites (trauma, pathological, and postoperative wound)	*S.aureus, Proteus* spp., *Pseudomonas* spp., *E.coli, Klebsiella* spp., *Streptococcus* spp.	**Sensitive** to Ofloxacin, Ciprofloxacin and Gentamycin **Resistant** to Erythromycin and Tetracycline	32
Surgical site infection following Cesarean section	*S. aureus, E. coli, Pseudomonas* spp., *Salmonella* spp., *Morganella morganii*	**Sensitive** to second and third-generation Cephalosporins, Quinolones, Amoxicillin-clavulanate, and Macrolides	62
Automobile accident wound	*S. aureus, Pseudomonas aeruginosa, E.coli, Streptococcus pyogenes, Klebsiella pneumonia*	**Sensitive** to Ofloxacin, Ciprofloxacin and Pefloxacin **Moderately sensitive** to Augmentin and Nalidixic acid **Resistant** to Penicillin, Streptomycin, and Gentamycin	21
Surgical wounds	*Proteus* spp., *S.aureus, E. coli,* Coagulase-negative *Staphylococcus, Klebsiella* spp., *Pseudomonas* spp.	**Gram-negative isolates**: **Sensitive** to Imipenem and Gentamycin **Resistant** to Cefotaxime, Cefpodoxime, and Levofloxacin **Gram-positive isolates**: **Sensitive** to Clindamycin, Erythromycin, and Ceftriaxone **Resistant** to Methicillin	34

598