Examining Major Sources of Bacterial Contaminants, Distribution and Their Susceptibility to Antibiotics in Kitui County Referral Hospital

Charity Mutave Kimwele[1*], Stanley Kinge Waithaka[1], Jonathan Chome Ngala[2]

[1]Department of Medical Laboratory Sciences, Mount Kenya University, Kenya
[2]Department of Medical Microbiology, Mount Kenya University, Kenya

Abstract

Background: Bacterial contaminants are the major sources of nosocomial infections which causes hospital acquired infections among health care workers patients and visitors in health facilities. Nosocomial infections are acquired during provision of health care services. The buildings provide the space used to provide hospital care while the equipment entails the tools and machines used to run the operations of the hospital. The people could be patients, healthcare workers or visitors. Thus, patient environment in surgical and medical wards has a huge impact on health safety of patients. The study sought to determine antimicrobial susceptibility patterns of bacteria isolated in Kitui County Referral Hospital.

Methods: This study was done by collection of 195 swabs samples in the patient care and treatment environment which involved the floors, beds, drugs trolleys, infusion stands, sinks, door handles, chairs, tables and bedside lockers of the medical and surgical wards.
A total of 177 bacteria isolates contaminants were identified from both surgical and medical wards. The study was done through culturing of specimen in MacConkey, Sheep blood agar and chocolate blood agar media. The identification was done by gram staining technique and biochemical tests which included citrate utilization test, catalase, coagulase, indole, Methyl Red, Voges Proskauer and oxidase test.

Results: The study found that the primary types of bacteria in hospital setting being *Staphylococci aureus, Escherichia coli, Klebsiella oxytoca, and Pseudomonas aeruginosa*. *S. aureus* had the highest prevalence at 43% while the least was *Pseudomonas aeruginosa* at 13%. Lockers were the major source of contaminants (28%) whereas the least contaminants' source was infusion stand (5.5%). Antimicrobial susceptibility test showed that all the isolated bacteria were sensitive to Meropenem. *P. aeruginosa* showed high sensitivity to Meropenem (100%) but averaged 33.3 % against Piperacillin Tazobactam, Ampicillin -clavulanic acid, and Ciprofloxacin and no sensitivity (0%) on other drugs. *E. coli* was only susceptible to Tazobactam, Ciprofloxacin, and Ceftazidime (20%), Augmentin (40%), and Meropenem (80%). Similarly, *K. oxytoca* was (100%) susceptible to Meropenem and ranked second with the most sensitivity to drugs tested: Tazobactam, Cefixime, Gentamicin, Ciprofloxacin, Ceftazidime (50%), and Augmentin, Ampicillin (25%). Vancomycin, Oxacillin, Penicillin, and Levofloxacin had no activity on bacteria isolates. *S. aureus* showed sensitivity to most of the drugs tested: Clindamycin (5.55%), Tazobactam, Ciprofloxacin, Ampicillin (38.88%), Augmentin (66.66%), and Meropenem, Linezolid and Gentamicin (88.8%).

Conclusion: Hospital surfaces, including doors, were the primary source of contaminants. *S. aureus* was distributed mainly on doors, while lockers, beds, sinks, and drug trolleys were contaminated with all bacteria isolates.

Keywords: Bacteria, Contaminants, Nosocomial Infections

* Corresponding author: charitykimwele@gmail.com

1. Introduction

Bacteria are unicellular prokaryotic micro-organisms and have no nucleus. Many bacteria have a peptidoglycan cell wall and divides asexually by binary fission. In addition, they have flagella for locomotion. Bacteria come in various forms, which include Bacillus, Coccus, Spirilla (Goyal et al., 2019). Gupta, (2021) categorizes bacteria into Gram-positive or Gram-negative using the gram staining technique. The prevalence of high bacteria contaminants in the hospital environment has become a menace to the health system (Gola et al., 2021). The threat is attributed to poor decontamination and sterilization, poor disinfection and inefficient antimicrobial management strategies. The threat has also become a menace because of continued hospital visits, high rates of antibiotic resistance and inadequate healthcare safety information (Ling et al., 2015). In Africa, HAIs among the inpatients are frequent with a prevalence rate of 3%-15%. The Gram-negative bacteria are the most widespread in surgical site infections and ventilator-associated pneumonia, however, disproportionate in sub-Saharan region as it is estimated to have a range of 2.5%-14.8%. HAIs rates in Kenya are 4.4 per 100 admissions of patients (Ndegwa, 2015). They are linked to hospital environment and high transmission rates through contact (Odoyo et al., 2021). Most common HAIs from surface contamination in Kenyan hospitals are caused by *Clostridium defficile, Acinetobacter baumannii*, *oxacillin-resistant Staphylococcus aureus*, *Carbapenem-Resistant Enterobacteriaceae* (CRE) and *vancomycin-resistant enterococci* (VRE).

Sources of Bacteria for Nosocomial Infections

According to Onifade et al. (2020) key sources of bacteria include surfaces, table tops, door handles, and hands of healthcare staff, among others, act as catchments for contaminants in the hospital setting. Onifade *et al.* (2020) assert that most HAIs are acquired from contact with hospital surfaces or interaction with contaminated equipment. Onifade et al. (2020) research shows that the ward surfaces have the highest number of isolates at 58.7% (n=27).

In the hospital set-up, access to the surrounding environment may pose as a risk of bacterial contamination. Table tops can be contaminated by patients, healthcare workers and family members during a patient's hospital stay (Magill et al., 2018). Patients can be sharing tables in cases where the hospital set-up has limited resources and this can lead to contamination of the table tops hence transmission of pathogens from one patient to another. Also, healthcare workers can cause contamination when the table tops come into contamination with already used patient equipment like intravenous infusion sets, branulas, used needles, swabs and strappings among others (Magill et al., 2018).

The disease-causing micro-organisms tend to colonize and multiply on the surface. When a patient comes into contact with the pathogens, then the disease transmission cycle ensues and the patient acquires another disease while in the hospital set-up. However, in this case, the disease to be acquired will depend on the organism that the patient acquires. The same principle applies toother objects that pose as sources of bacteria contaminants (Magill et al., 2018).

The employees, hospital facility surfaces, instruments and devices are prone to colonization with different microbial contaminants (Goyal et al., 2019). Bacteria are known to survive on devices, instruments and tools such as dustcoats, computer devices, communication devices, furniture, clothes, stethoscopes, and elevator buttons among others. This makes patients, healthcare staff, and the environment form the main sources of contaminants in healthcare facilities (Artika & Ma'roef, 2017). The healthcare facilities are a major reservoir for potential microorganisms. Due to their repeated interaction with patients or through infected inanimate objects (Ling & Mandriaga, 2015). The hospital facilities could contain gram positive and gram-negative bacteria which are able to survive for many days on inanimate surfaces of the hospital facility. Some of the bacteria that are table on dry hospital environment include methicillin *resistant Staphylococcus aureus* (MRSA), *Pseudomonas spp., Acinetobacter spp*. and *Vancomycin Resistant Enterococci* (VRE) Wang et al., 2020).

Sources of bacteria are either exogenous from the environment or endogenous from the patient (Graves et al., 1990). The endogenous flora of the patient could also be a source of microbes. Nosocomial infections can also originate from patient food in healthcare facilities, medical devices, and equipment (Ken et al., 2005)**.** Microbes could be passed through direct contact *(Escherichia coli and Staphylococci*) and droplets from infections surfaces or people. Indirect contact is a frequent way illness is spread in hospitals. The healthcare workers can spread microorganisms through their hands. Infected patients disseminate microorganisms in the hospital surfaces through expectorate drops, fluids from the body or infected wounds, blood and excrements. Clothes could also be a source of pathogens from infected patients (Tantray et al., 2022).

Visitors to the hospital and health care providers could also be carriers when colonized by pathogens. It is common for asymptomatic carriers to be sources of bacteria such as *Neisseria meningitidis, Staphylococcus aureus, Streptococcus pyogenes,* and *Corynebacterium diphtheria* (Goyal et al., 2019). Water distribution points and aerosols released from water cooling machines could also be a source of pathogens (Feng et al., 2019). Bacterial contamination can occur when pharmaceuticals are undergoing distribution, or when food and beverages are served to the patients. Moreover, poor handling of hospital waste could be a contamination source. Water from the tap could also contaminate the medical equipment (Kramer et al. (2006); Silhavy et al., 2010). Alternatively, Bhatta et al. (2021) argues that the high distribution of bacteria on surfaces and equipment observed may be due to overcrowded wards, high bed occupancy for surgical areas, patients admitted with different clinical conditions from other health facilities, and lack of compliance to infection control practices (ICP). Bhatta *et al*. assert that patients, visitors, health professionals, and workers could contaminate the hospital environment and equipment, thus leading to microbial colonization.

Contaminated Medical Equipment

Medical equipment plays a vital role in patient care, but it can also become a breeding ground for bacteria if not properly cleaned and disinfected. Studies have shown that a wide range of equipment, from stethoscopes and blood pressure cuffs to ventilators and ultrasound machines, can be contaminated with bacteria, including multidrug-resistant (MDR) pathogens (Simões et al., 2013; Dancer, 2014). The contamination can occur in several ways were patients themselves can shed bacteria onto equipment during procedures or examinations. Additionally, healthcare workers' hands can inadvertently transfer bacteria from one patient to another through contaminated equipment. Furthermore, some bacteria can survive on dry surfaces for extended periods, further increasing the risk of transmission (Rutala et al., 2006). The consequences of contaminated medical equipment can be severe. HAIs are a significant burden on healthcare systems, leading to increased morbidity, mortality, and healthcare costs (Allegranzi et al., 2011). Bacteria on medical equipment can contribute to the spread of these infections, particularly in vulnerable patient populations with weakened immune systems.

Contaminated Surfaces

Beyond medical equipment, hospital surfaces are another major source of bacterial contamination. Frequently touched surfaces like bed rails, doorknobs, light switches, and keyboards can harbor a variety of bacteria (Cardo et al., 2018). Similar to equipment, these surfaces can become contaminated through patient shedding or contact with contaminated hands. The risk associated with contaminated surfaces is particularly concerning in areas with high patient turnover, such as waiting rooms and patient care areas. Bacteria can persist on surfaces for extended periods, creating a potential source of transmission for patients and healthcare workers alike. For instance, a study by Otter et al. (2011) found that Clostridium difficile (C. Diff), a bacterium known for causing severe diarrhea, could survive on surfaces for weeks. This highlights the importance of thorough and regular cleaning and disinfection of all hospital surfaces.

Hands of Healthcare Personnel

Healthcare workers' hands are often the final link in the chain of bacterial transmission in hospitals. During routine patient care, healthcare workers frequently come into contact with patients, their bodily fluids, and contaminated surfaces. This constant contact can readily transfer bacteria onto their hands, making them a potential vector for spreading infections (World Health Organization, 2015). Research indicates that even with proper hand hygiene practices, some level of bacterial contamination can remain on healthcare workers' hands (Boyce & Pittet, 2002). This underscores the critical role of hand hygiene in preventing HAIs. The World Health Organization (WHO) recommends a five-moment hand hygiene strategy, which outlines specific times when healthcare workers should clean or disinfect their hands (World Health Organization, 2015). Following these guidelines is essential for minimizing the risk of bacterial transmission via hands.

2. Materials and methods

2.1 Study site

The study was carried out in Kitui County Referral Hospital, Kitui County. The hospital has a bed capacity of 239 beds with outpatient visits per month is approximately 800 and 500 patients respectively and health care workers population is 650 staffs. The facility approximate number of visitors per day is 100 visitors for both patients and offices. 195 samples were collected using purposive sampling technique.

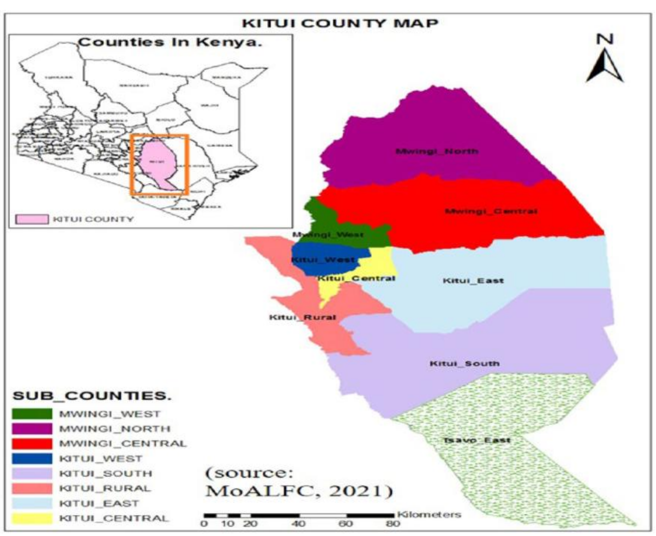

Figure 1: Map of Kitui County

2.2 Study design and sample collection

Study design was experimental and observational -cross sectional via purposive sampling technique. It was observational because the research sites were not manipulated. Purposive was chosen because the researcher identified specific sites for the purpose of the study. A total of 195 swabs were collected for the study from medical wards and surgical wards in the hospital. Sample collection was done on beds, bedside lockers, door handles, tables, chairs, sinks, drugs trolleys, infusion stands and floors.

The selected sources were targeted because they are frequently touched by patients like beds, bedside lockers and sinks. Health care providers frequently touched the door handles, tables, chairs drugs trolleys and infusion stand. The visitors as some of them stay with the patient in the hospital wards, they frequently touch the beds, bedside lockers, sinks and door handles. Before sample collection the swabs were properly labelled with location of collection where in the study samples were collected from medical wards and surgical wards, source of the samples and date of collection. Sterile swabs with amies transport media moistened with normal saline at a concentration of 0.9% were used to collect the samples.

2.3 Isolation and identification

Bacterial contaminants samples were cultured and isolated in Sheep Blood agar media and MacConkey media. Identification was done using gram staining technique and biochemical tests (citrate utilization test, catalase, coagulase, indole, Methyl Red, Voges Proskauer and oxidase test)

2.4 Antimicrobial susceptibility testing

Disc diffusion sensitivity technique using Muller Hinton Agar (MHA) was used to test antimicrobial susceptibility of the isolates. Following an overnight incubation, the culture media were examined for zones of inhibition around the antibiotic disk. The antibiotics resistance was confirmed by growth of microorganisms up to the edge of the antibiotic discs. The zones of inhibition diameter breakpoints were measured in millimeters and compared to the reference guideline of Clinical Laboratory Standard Institute (CLSI M100). Inoculum standardization was done by use of MacFarland standards adjusted to 0.5 turbidity.

2.5 Quality control

Quality control procedures were done and followed for validity which showed the accuracy and meaningfulness on inferences based on research and reliability as the measure of the degree unto which research instrument produces consistent results after repeated trials analysis. Standard organisms which were used in the study were; E. coli ATCC-25922, Pseudomonas aeruginosa ATCC-27853, Staphylococci aureus ATCC-25923, Klebsiella Oxytoca ATCC-70060 from Kenya Medical Research Institute (KEMRI). Antimicrobial susceptibility patterns zone of inhibition diameter breakpoints were measured in millimeters. The zone diameter breakpoints were in reference to Clinical and Laboratory Standards Institute (CLSI M100). Standard Operating Procedures, manufactures instructions were adhered to in pre-analytical, analytical and post -analytical phases. Media were adequately sterilized and positive and negative control organisms tested on the reagents. Proper storage and sterilization conditions were followed. Autoclaved samples were sub cultured to ascertain degree of sterility.

2.6 Management of data, analysis and presentation

Raw data was entered into Microsoft excel sheets. It was cleaned and exported to Statistical Package for Social Sciences (SPSS) version 29 for analysis. Data was presented in the form of frequency tables, bar graphs and pie charts.

3. Results

3.1 Bacteria isolates

The prevalence of different types of bacteria isolated from surgical and medical wards in Kitui County Referral Hospital was determined as shown in figure 2. Out of a total of 177 isolates identified from both surgical and medical wards, 76 were *Staphylococci aureus*, 21 were *Pseudomonas* aeruginosa, 54 were *Escherichia coli*, and 24 were *Klebsiella oxytoca*; *Staphylococci aureus* had the highest prevalence at 43%; *Escherichia coli* was second highest with 30% followed by *Klebsiella oxytoca* with 14%. The isolate with the lowest prevalence was *Pseudomonas aeruginosa* with 13% just use percentages in this section. However, the prevalence of the bacteria isolates was not significantly different across the wards, $F_{15}=0.09$, $p=0.96$, $\alpha=0.05$.

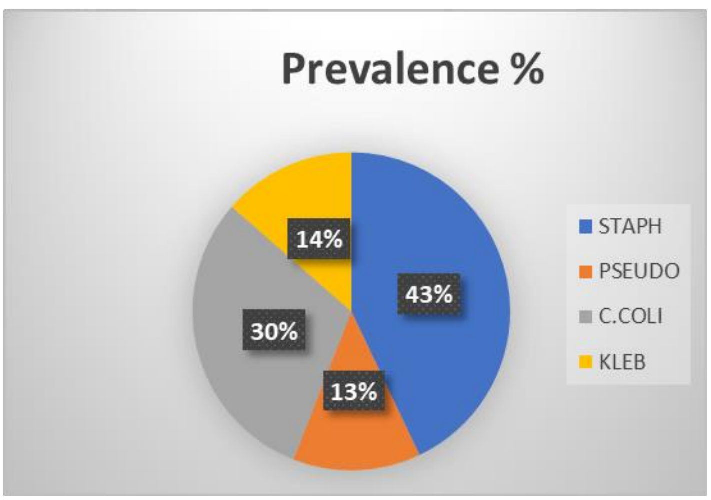

Figure 2: The prevalence of different types of bacteria isolated from surgical and medical wards in Kitui County Referral Hospital

3.2 Comparison between Surgical Wards

The prevalence of different types of bacteria in two surgical wards (W2 & W4) in Kitui County Referral Hospital was determined, as shown in figure 3. In ward 2, *S. aureus* had the highest prevalence, at 51.3%. However, the prevalence of the bacteria isolates was not significantly different in the surgical wards, $t_2<4.30$, $p>0.05$.

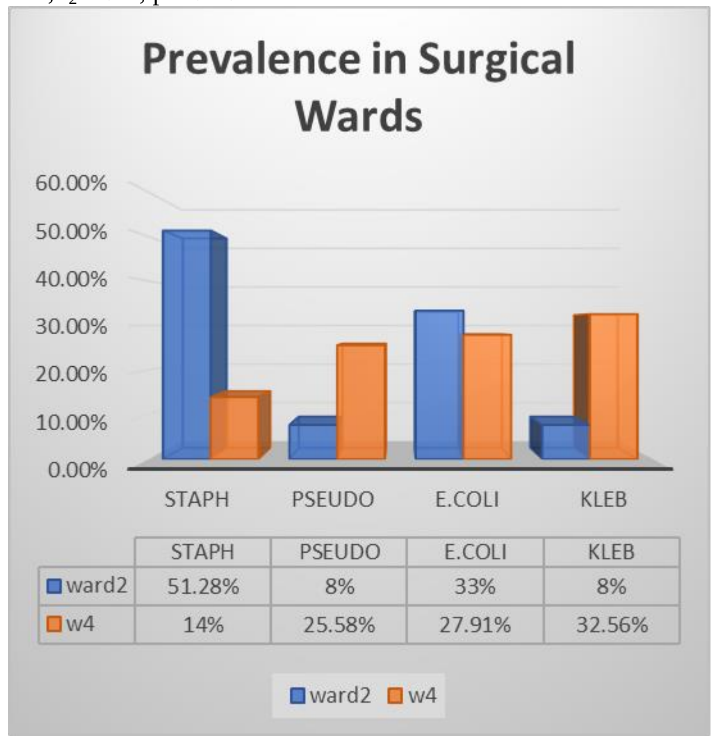

Figure 3: Comparison of prevalence between surgical wards

3.3 Comparison between Medical Wards

The prevalence of different types of bacteria in two medical wards (W3 & W6) in Kitui County Referral Hospital was determined, as shown in figure 4. *S. aureus* had the highest prevalence in wards 6 and 3, at 60% and 44%, respectively. *P. aeruginosa* had 18 % in Ward 3 and 2 % in Ward 6, whereas *E-coli* and *K. oxytoca* had 31% in Ward 3 and 30% in Ward 6; 7 % in Ward 3 and 8% in Ward 6, respectively. However, the prevalence of the bacteria isolates was not significantly different in the medical wards, $t_2=0.99$, $p>0.05$.

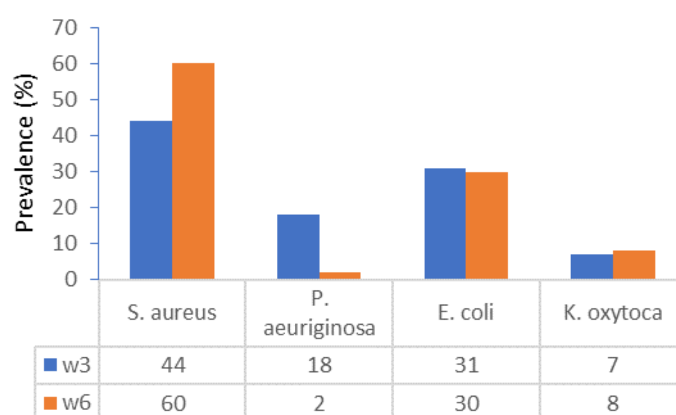

Figure 4: Comparison of prevalence between medical wards

3.4 Major sources of bacterial contaminants

The sources of 177 different bacteria contaminants in Kitui County Referral Hospital were determined as shown in figure 5. Locker had the highest bacteria contamination, at 28%. The infusion stand had the lowest contaminations, at 5.5%. Doors were only contaminated with *S. aureus*. More so, the sources of bacteria contaminants (isolates) differed significantly in terms of their prevalence of infection, $F_{35}=2.73$, CI=95%, $p<0.05$.

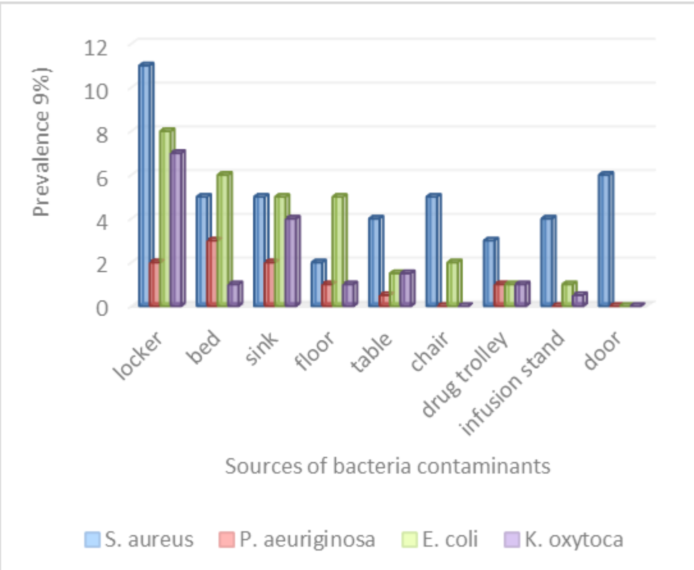

Figure 5: Sources of bacteria contaminants in Kitui County Referral Hospital

3.5 Sources of bacteria contaminants in surgical wards

Figure 6 shows the determined sources of different types of bacteria in surgical wards in Kitui County Referral Hospital. Doors were the major source of *S. aureus*. The lockers, bed, sink, floors, and tables were contaminated with all bacteria isolates, with chairs, drug trolley, and infusion stand having two bacteria isolates each: drug trolley had *Klebsiella oxytoca and Staphylococci aureus*, chairs had *S. aureus* and *E-coli*. The prevalence of the bacteria isolates from different sources in the surgical wards was not significantly different, $F_{35}<2.30$, CI=95%, $p>0.05$.just point out the significant results.

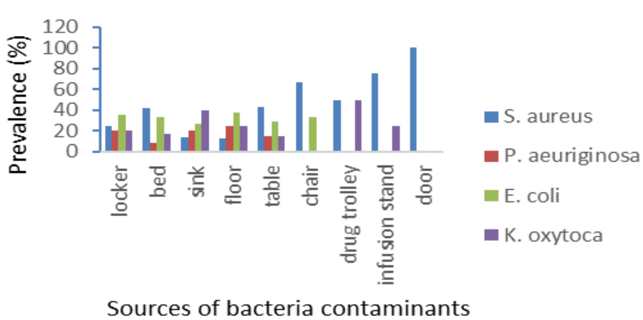

Figure 6: Sources of bacteria contaminants in surgical wards

3.6 Sources of bacteria contaminants in medical wards as above

The sources of different types of bacteria in medical wards in Kitui County Referral Hospital were determined as shown in figure 7. As in surgical wards, doors were the major source of *S. aureus*. Locker, bed, sink, and drug trolleys were contaminated with all bacteria isolates. Floors were contaminated with *S. aureus, P. aeruginosa, and E. coli.* Chairs and infusion stands were contaminated with *S. aureus and E. coli.* Alternatively, tables had *S. aureus, E. coli, and K. oxytoca* contaminants. However, the prevalence of the bacteria isolates from different sources in the medical wards was also not significantly different, CI=95%, $p>0.05$.

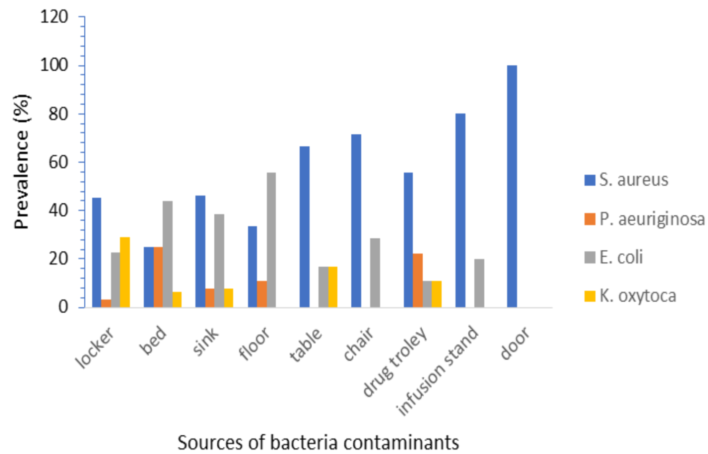

Figure 7: Sources of Bacteria Contaminants in Medical Wards

3.7 Antimicrobial Susceptibility Patterns

In the figure 8, *Pseudomonas aeruginosa* showed high sensitivity to Meropenem (100%) *E. coli* was only susceptible to Tazobactam, Similarly, *K. oxytoca* was 100% susceptible to Meropenem *S. aureus* showed sensitivity to most of the drugs tested: Clindamycin (CD) (5.55%), Tazobactam, Ciprofloxacin, Ampicillin (38.88%), Augmentin (66.66%), and Meropenem, Linezolid and Gentamicin (88.8%). Vancomycin, Oxacillin, Penicillin, and Levofloxacin had no activity on all bacteria isolates. The susceptibility of bacteria contaminants to the antibiotics differed significantly, $F_{55}=5.86$, CI=95%, $p<0.05$.

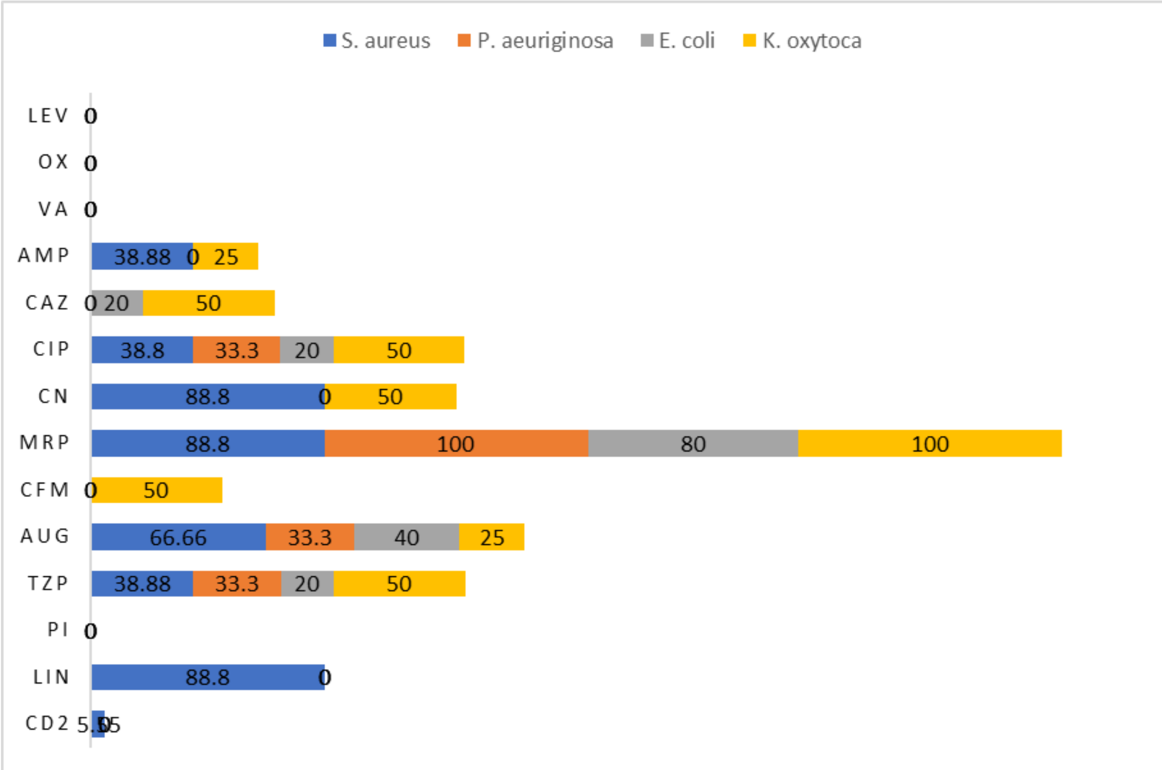

Figure 8: Antimicrobial Susceptibility Patterns

4 Discussions

The present study found *Staphylococcal aureus, Pseudomonas aeruginosa, Escherichia coli,* and *Klebsiella oxytoca* in medical and surgical wards. *S. aureus* had the highest prevalence at 43%; *E. coli* was second highest at 30%, followed by K. oxytoca at 14%. The isolate with the lowest prevalence was *Pseudomonas, with 13%.* The prevalence varied in surgical wards (2 and 4), showing that *S. aureus* had the highest prevalence at 51.3% in Ward 2. In contrast, *Pseudomonas aeruginosa, E. coli,* and *K. Oxytoca* had a close prevalence in Ward 4 (25.6%, 33% and 28%).

The observation was analogous to other research work findings as it agrees with Ratemo's (2014) study, which found that *S. aureus* was the predominant isolate (29.9%), followed by *Pseudomonas* (13.7%).

The sources had the following distribution: locker 28%, bed 15 %, sink 16%, floor 9%, table 7.5 %, chair 7%, drug trolley 6%, infusion stand 5.5%, and door 6%. Locker had the highest bacteria contamination at an average of 28%. The infusion stand had the lowest average contaminations at 5.5%. Doors were only contaminated with *S. aureus*. Lockers emerged as the most frequent harborage for bacteria, with an average contamination rate of 28%. This highlights the potential risk posed by personal belongings stored in close proximity to patients. Beds (15%), sinks (16%), floors (9%), and tables (7.5%) also exhibited significant bacterial presence, underlining the importance of thorough cleaning and disinfection of these surfaces between patient use. They align with Otter et al. (2011) which found that Clostridium difficile (C. Diff), a bacterium known for causing severe diarrhea, could survive on surfaces like doors, tables and lockers. Surgical wards displayed a wider range of bacterial contamination compared to medical wards. Lockers, beds, sinks, floors, and tables were susceptible to all four bacteria identified (S. aureus, E. coli, Klebsiella spp., Pseudomonas aeruginosa). Chairs, drug trolleys, and infusion stands in surgical wards harbored a limited number of bacterial isolates. Notably, drug trolleys specifically contained Klebsiella and S. aureus, while chairs had S. aureus and E. coli, and infusion stands primarily yielded S. aureus.

Medical wards exhibited a similar pattern, with lockers, beds, sinks, and drug trolleys susceptible to all bacteria. Floors differed slightly, harboring S. aureus, P. aeruginosa, and E. coli. Chairs and infusion stand in medical wards shared contamination with S. aureus and E. coli, while tables uniquely presented a combination of S. aureus, E. coli, and K. oxytoca.

The current study's findings regarding bacterial distribution on hospital surfaces align with the observations of Ken et al. (2019). Their research emphasizes how nosocomial infections can originate from various sources within healthcare facilities, including patient food, medical devices, and equipment. Ken et al. (2019) highlights the crucial role of direct and indirect contact in spreading pathogens. Direct contact involving bacteria like *E. coli* and *S. aureus* can occur through contaminated surfaces or infected individuals. Indirect contact, often through the hands of healthcare workers, is another frequent mode of transmission within hospitals.

Bhatta et al. (2021) offer explanations for the observed high bacterial distribution on surfaces and equipment. Factors such as overcrowded wards, high bed occupancy, admission of patients with diverse medical conditions, and inadequate adherence to infection control practices (ICP) likely contribute to this phenomenon. Their research emphasizes how patients, visitors, healthcare professionals, and even cleaning staff can unwittingly contaminate the hospital environment and equipment, facilitating microbial colonization.

The current study's findings resonate with Onifade et al. (2020), who identify surfaces, tabletops, door handles, and healthcare worker hands as key reservoirs for contaminants in hospitals. Their research suggests that most hospital-acquired infections (HAIs) stem from contact with contaminated surfaces or equipment. Notably, Onifade et al. (2020) found that ward surfaces harbored the highest number of bacterial isolates (58.7%), potentially due to weak disinfection protocols. As frequently touched surfaces, doors are particularly likely to harbor high bacterial loads.

Gram-positive isolates showed sensitivity to several drugs tested, whereas *S. aureus* showed sensitivity to most of the medicines tested: Clindamycin (5.55%), Tazobactam, Ciprofloxacin, Ampicillin (38.88%), Augmentin (66.66%), and Meropenem, Linezolid and Gentamicin (88.8%). These findings are analogous to Ratemo (2014) findings, where S. aureus *P. aeruginosa* and *K. oxytica* showed high sensitivity to Meropenem (100%). This study's findings agree with Goyal et al. (2019) and Ratemo's study, which found that Pseudomonas spp was highly sensitive to meropenem (81.1%), amikacin (86.7%), piperacillin (80%), ciprofloxacin (83.3%) and levofloxacin (77.4%).

Vancomycin, Oxacillin, Penicillin, and Levofloxacin had no activity on the four bacteria isolates. *S. aureus* showed sensitivity to most drugs tested: Clindamycin (5.55%), Tazobactam, Ciprofloxacin, and Ampicillin resistance was 38.88%. *E. coli* was lowly sensitive to Tazobactam, Ciprofloxacin, and Ceftazidime (20%), In this study, only *Klebsiella*, of all the gram-negative isolates, was more sensitive, with 50% or more sensitivity to Tazobactam, Cefixime, Ciprofloxacin, and Ceftazidime. Other gram-negative isolates were susceptible to Meropenem, whereas *P. aeruginosa, E. Coli,* and *K. oxytoca* had 100%, 80%, and 100% sensitivity to MRP, respectively. This agrees with the Ratemo (2014) study that gram-negative isolates were most susceptible to levofloxacin, imipenem, amikacin, and piperacillin/tazobactam.

Conclusion

The study found that hospital surfaces, including doors, were the primary source of contaminants. *S. aureus* was distributed mainly on doors, while lockers, beds, sinks, and drug trolleys were contaminated with all bacteria isolates. S. *aureus, P. aeruginosa, E. Coli,* and *K. oxytoca* were the predominant bacteria isolated from the surgical and medical wards surfaces and equipment. All the isolated bacteria were sensitive to meropenem, while S. *aureus* showed relatively high resistance to Linezolid, Ampicillin -Clavulanic Acid, and Gentamicin. *Klebsiella* was reasonably prudent to Piperacillin Tazobactam, Cefixime, Gentamicin, Ciprofloxacin, and Ceftazidime (50%), with the remaining isolates showing low sensitivity to the antibiotics.

Recommendation

This study recommends that the hospital management in support from the ministry to have a multidisciplinary team of infection prevention and control to counter hospital acquired infections. Ensure compliance with infection prevention practices by increasing the frequency and effective cleaning of all patient items during hospital stay and surfaces.

Acknowledgements

We acknowledge Mount Kenya University, Department of Medical Laboratory Sciences and Microbiology for the unwavering support during sample analysis. Thanks to the administration and employees of Kitui County Referral Hospital for their assistance and for providing the chance to collect samples in the medical and surgical wards.

Conflicts of interest

The authors declare that there are no competing interests.

References

Allegranzi, B., Nejad, S. B., Combescure, C., Graafmans, W., Attar, H., Donaldson, L., & Pittet, D. (2011). Burden of endemic health-care-associated infection in developing countries: systematic review and meta-analysis. *The Lancet*, *377*(9761), 228-241.

Artika, I. M., & Ma'roef, C. N. (2017). Laboratory biosafety for handling emerging viruses. *Asian Pacific Journal of Tropical Biomedicine*, *7*(5), 483–491. https://doi.org/10.1016/j.apjtb.2017.01.020

Bhatt, D. L., Szarek, M., Steg, P. G., Cannon, C. P., Leiter, L. A., McGuire, D. K., ... & Pitt, B. (2021). Sotagliflozin in patients with diabetes and recent worsening heart failure. *New England journal of medicine*, *384*(2), 117-128.

Boyce, J. M., & Pittet, D. (2002). Guideline for hand hygiene in health-care settings: recommendations of the Healthcare Infection Control Practices Advisory Committee and the HICPAC/SHEA/APIC/IDSA Hand Hygiene Task Force. *Infection Control & Hospital Epidemiology*, *23*(S12), S3-S40.

Cardo, L., Nawroth, I., Cail, P. J., McKeating, J. A., & Hannon, M. J. (2018). Metallo supramolecular cylinders inhibit HIV-1 TAR-TAT complex formation and viral replication in cellulo. *Scientific Reports*, *8*(1), 13342.

Dancer, S. J. (2008a). Importance of the environment in meticillin-resistant Staphylococcus aureus acquisition: The case for hospital cleaning. *The Lancet Infectious Diseases*, *8*(2), 101–113. https://doi.org/10.1016/S1473-3099(07)70241-4

Feng, X., Zhang, Y., Xu, Z., Song, D., Cao, G., & Liang, L. (2019). Aerosol containment by airflow in biosafety laboratories. *Journal of Biosafety and Biosecurity*, *1*(1), 63–67. https://doi.org/10.1016/j.jobb.2018.12.009

French, G., Otter, J., Shannon, K., Adams, N., Watling, D., & Parks, M. (2004). *Tackling contamination of the hospital environment by methicillin-resistant Staphylococcus aureus (MRSA): A comparison between conventional terminal cleaning and hydrogen peroxide vapour decontamination*. *57*, 21–43.

Gola, D., Tyagi, P. K., Arya, A., Chauhan, N., Agarwal, M., Singh, S. K., & Gola, S. (2021). The impact of microplastics on marine environment: A review. *Environmental Nanotechnology, Monitoring & Management*, *16*, 100552.

Goyal, S., Khot, S., Ramachandran V, Shah, K., & Musher, D. M. (2019). *Bacterial contamination of medical providers' white coats and surgical scrubs*. *47*(8), 994–1001.

Graves, J. E., Pollock, M. L., Carpenter, D. M., LEGGETT, S. H., JONES, A., MacMILLAN, M. I. C. H. A. E. L., & FULTON, M. (1990). Quantitative assessment of full range-of-motion isometric lumbar extension strength. *Spine*, *15*(4), 289-294.

Gupta, S. (2021). *Nosocomial Infection: Cause, Prevention and Control* (1st ed.). LAP LAMBERT Academic Publishing.

Ken, I., Jayshree, D., & Allison, P. (2005). *Nosocomial infections*. *5*(1), 14–17. https://doi.org/10.1093/bjaceaccp/mki006 .bibtex (BibTex)

Kramer, A., Schwebke, I., & Kampf, G. (2006). How long do nosocomial pathogens persist on inanimate surfaces? A systematic review. *BMC infectious diseases*, *6*, 1-8.

Ling, M. L., Apisarnthanarak, A., & Madriaga, G. (2015). The burden of healthcare-associated infections in Southeast Asia: a systematic literature review and meta-analysis. *Clinical Infectious Diseases*, *60*(11), 1690-1699.

Magill, S. S., O'Leary, E., Janelle, S. J., Thompson, D. L., Dumyati, G., & Edwards, J. (2018). *Changes in prevalence of health care–associated infections in US hospitals."*. *379*(18), 1732-1744. https://doi.org/10.1056/NEJMoa1801550

Ndegwa, L. K. (2016). *Surveillance of Respiratory Viral Healthcare associated infections (rHAI) amongst inpatients in selected Hospitals in Kenya* (Doctoral dissertation).

Odoyo, E., Matano, D., Tiria, F., Georges, M., Kyanya, C., Wahome, S., ... & Musila, L. (2023). Environmental contamination across multiple hospital departments with multidrug-resistant bacteria pose an elevated risk of healthcare-associated infections in Kenyan hospitals. *Antimicrobial Resistance & Infection Control*, *12*(1), 22.

Rutala, W. A., White, M. S., Gergen, M. F., & Weber, D. J. (2006). Bacterial contamination of keyboards: efficacy and functional impact of disinfectants. *Infection Control & Hospital Epidemiology*, *27*(4), 372-377.

Tantray, J. A., Mansoor, S., Wani, R. F. C., & Nissa, N. U. (2023). Chapter 44—Gram staining of bacteria. In J. A. Tantray, S. Mansoor, R. F. C. Wani, & N. U. Nissa (Eds.), *Basic Life Science Methods* (pp. 181–183). Academic Press. https://doi.org/10.1016/B978-0-443-19174-9.00043-X

Wang, C., Huttner, B. D., Magrini, N., Cheng, Y., Tong, J., Li, S., Wan, C., Zhu, Q., Zhao, S., Zhuo, Z., Lin, D., Yi, B., Shan, Q., Long, M., Jia, C., Zhao, D., Sun, X., Liu, J., Zhou, Y., … Hu, H. (2020). Pediatric Antibiotic Prescribing in China According to the 2019 World Health Organization Access, Watch, and Reserve (AWaRe) Antibiotic Categories. *The Journal of Pediatrics*, *220*, 125-131.e5. https://doi.org/10.1016/j.jpeds.2020.01.044

WHO. (2023). *Antimicrobial resistance*. https://www.who.int/news-room/fact-sheets/detail/antimicrobial-resistance

