RESEARCH ARTICLE

Post-surgical wound infection; bacteria isolated and antibiotic susceptibility. A retrospective study from Al-Nu'man General Hospital in Baghdad

Ruqaya Khaleel Muhammed,[a] Muhammed Hazim Muhammed ,[b] Mustafa Salman Hamid[c]

ABSTRACT

Introduction: Post-surgical wound infections pose a significant global challenge in surgical practice, leading to prolonged hospital stays, increased healthcare costs, and heightened morbidity and mortality rates. Inadequately managed, these infections can escalate medical expenses, trigger secondary complications, and even result in severe outcomes such as limb loss or fatality.

Objective: This study aims to identify the micro-organisms causing surgical site infection and their susceptibility patterns towards the common antibiotics in surgical words at Al-Nu'man General Hospital.

Methods: In this retrospective cross-sectional study, the data were collected from microbiology laboratory records of patients with post-surgical infected wounds. Sixty-one patients were included in the study, and wound swabs were cultured to identify microbial isolates. The antimicrobial susceptibility of the isolated bacteria was analysed using SPSS software.

Results: Out of the 61 wound swabs analysed, 44 (72.1%) were culture-positive, yielding 59 microbial isolates. The most prevalent bacterial isolates were Staphylococcus aureus (17.1%) followed by Escherichia coli (13.2%). Linezolid, vancomycin, and teicoplanin exhibited the highest activity against gram-positive bacteria, while amikacin and meropenem demonstrated the most effectiveness against gram-negative bacteria.

Conclusion: Staphylococcus aureus and Escherichia coli were the predominant bacterial isolates in post-surgical wound infections. Linezolid, vancomycin, and teicoplanin were the most effective drugs against gram-positive bacteria, while amikacin and meropenem showed optimal efficacy against gram-negative bacteria.

Key words: Post-surgical wound infection, Antimicrobial susceptibility, Retrospective study.

INTRODUCTION

Surgical site infection (SSI) is an infection in the surgical site's wounds within 30 days after surgery.[1] The epidemiology of SSIs varies depending on the type of surgery and the country.[2] It is influenced by patient-related, preoperative, intraoperative, and post-operative risk factors.[2] The CDC classifies wounds into four categories: clean, clean/contaminated, contaminated, and dirty/infected.[3] Clean operations exclude those involving the gastrointestinal, genital, urinary, or respiratory tracts.[4] Clean-contaminated operations occur when respiratory, alimentary, genital, or urinary tracts are entered under controlled conditions and without unusual contamination; no evidence of infection or major break in technique is encountered.[5] Contaminated operations include those where there is acute inflammation, infected bile or urine, gross spillage from the gastrointestinal tract, and fresh traumatic wounds.[6] Dirty operations usually result from inadequate treatment of traumatic wounds, gross

a: B pharm, Practitioner pharmacist. Al-Nu'man General Hospital. Al-Russafa Health Directorate, Baghdad, Iraq. b: FICMS, Orthopedic surgery specialist. Al-Nu'man general hospital. Al-Russafa Health Directorate, Baghdad, Iraq. c: FIBMS, Otolaryngology surgery Specialist, Al-Nu'man general hospital. Al-Russafa Health Directorate, Baghdad, Iraq.

*Corresponding Author: **Ruqaya Khaleel Muhammed**, E mail: **Ruqayasuadad136@gmail.com.***

purulence, and evident infections such as perforated diverticulitis and necrotising soft tissue infections.[7,8] Surgical site infections range from minor wound discharge to osteomyelitis.[9] Carelessness may occur from surgical prophylaxis to patient discharge. Factors such as extended surgical prophylaxis, underestimation of signs and symptoms, omission of source control, inappropriate collection of wound swabs, improper use of clinical microbiology and pharmacology, lack of hygiene measures, and delay in discharge may lead to poor outcomes.[10]

The risk for SSIs in gastroduodenal surgery increases with conditions such as obstruction, haemorrhage, or malignancy.[11] Bile contamination in hepatobiliary surgery can increase the frequency of SSIs and is present in many patients, such as those with acute cholecystitis or biliary obstruction and those of advanced age.[11] Laparoscopic rectal surgery carries a greater risk of wound infection than colonic surgery.[12] Laparoscopic rectal surgery involving abdominoperineal resection, patients with higher BMI, and chemoradiotherapy require careful observation in wound care and countermeasures against wound infection.[12] The second most frequent cause of maternal mortality in obstetrics and gynaecology after postpartum haemorrhage is infection.[13] Emergency cesarean section is a significant risk factor for surgical site infection.[14] Pregestational obesity, preexisting psychiatric conditions, and blood transfusion during or following delivery are independent risk factors for surgical site infection.[14] Orthopaedic surgical sites mainly include spinal, joint, and trauma surgeries.[15] SSIs can be categorised as superficial, deep, periprosthetic joint infections or severe complications after joint surgery.[15]

The data analysis revealed that the mean weekly counts of the top 3 most frequently reported organisms from 2011 to 2015 in England, Wales and Northern Ireland were *Chlamydia trachomatis*, *Escherichia coli* and *Staphylococcus aureus*.[16] An annual epidemiological report for surgical site infections from the European Centre for Disease Prevention and Control showed that the most common micro-organisms identified in SSIs from 13 European Union/European Economic Area (EU/EEA) countries from 2013 to 2014 were *Staphylococcus aureus*, *Escherichia coli*, Acinetobacter species, Bacteroides species and Candida species.[17]

A study carried out to determine the prevalence of bacterial pathogens causing wound infection in surgical wards and to determine the antimicrobial sensitivity patterns of the isolated bacteria in tertiary care hospitals of Peshawar, Pakistan, concluded that *E. coli* and *S. aureus* were the most commonly isolated pathogens, followed by *Pseudomonas aeruginosa* and *Klebsiella pneumoniae*. linezolid, vancomycin, amoxicillin, cefoperazone, and meropenem are the most effective antibiotics for treating post-surgical wound infections.[18] The Clinical and Laboratory Standards Institute (CLSI) Subcommittee on Antimicrobial Susceptibility Testing (AST SC) develops and publishes standards and guidelines, among other products, for antimicrobial susceptibility testing (AST) methods and results interpretation in the United States and internationally.[19] The rationale for choosing this topic is to make healthcare professionals dealing with wound management aware of the importance of wound infection and help them choose adequate treatment options to control microbial infection in wounds. This study aims to identify the micro-organisms causing surgical site infection and their susceptibility patterns towards the common antibiotics in surgical wards at Al-Nu'man General Hospital.

METHODS

Setting and study design: A hospital-based retrospective analytic cross-sectional study was conducted at Al-Nu'man General Hospital in Baghdad, Iraq, from the 1st of July 2023 to the 1st of January 2024.

Ethical consideration: Preliminary approval was obtained from Al-Nu'man General Hospital to use the data recorded. The research protocol was approved by the research committee in

Baghdad/Al-Russafa Health Directorate.

Definition of the enrollment criteria: We included the records of all patients with post-operative infected wounds who had undergone surgical procedures in general surgery, obstetrics and gynaecology, and orthopaedic departments of Al-Nu'man General Hospital during 2022. Data from Patients with traumatic wounds, diabetic foot ulcers, and pressure ulcers were excluded. Data were retrieved from the bacteriological records of the microbiology laboratory of the hospital.

Sampling: We used all recorded patients who fulfil the inclusion criteria.

Data collection; variables, outcomes and procedures: Data were collected by reviewing the records of the bacteriology laboratory during 2022. Data retrieved from the records included demographic characteristics of the patients, like patient's name, age, sex, and ward of admission, and bacteriological results like Gram stain results, results of bacterial wound culture and the susceptibility results to antibiotics. Our laboratory depends on CLSI and United Kingdom Standard Operating Procedures (UK SOPs) protocols.

Accordingly, a fresh swab is collected from the infected surgical wound. Next, it is evenly spreads the most purulent portion of the specimen onto a clean slide using a bacteriological loop. Then, the smear is fixed with heat and stained with Gram stain. The slide is then examined using the oil immersion technique to detect polymorphonuclear granulocytes, gram-positive cocci, and gram-negative rods. When fungal infection is suspected, a wet preparation is examined. Candida or other yeast calls, which are seen as Gram-positive budding spheres, often form branched pseudomycelia under microscopic examination. Anaerobes studies are not routinely conducted, especially during the study period. If the pus is thick, it is thinned with a drop of saline.

Specimens are inoculated onto a blood agar plate to isolate staphylococci, a MacConkey agar plate to isolate Gram-negative rods, and Sabouraud agar for yeast or fungal organisms. Plates were incubated at 37 ^{o}C for 24-48 hours for aerobic and facultative organisms. Identifying specific micro-organisms was done using a biochemical test and VITEK 2 system. The antibiotic susceptibility pattern for each bacterial isolate is determined using the disc diffusion method and Vitek 2 susceptibility testing cards and interpretation was done according to Clinical Laboratory Standards Institute (CLSI) guidelines.

Penicillin G (Pen G) (10 units), tetracycline (TET) (30µg), erythromycin (ERY) (15µg), clindamycin (CLI) (2µg), gentamicin (GEN) (10µg), levofloxacin (LVX) (5µg), vancomycin (VAN) (5µg), teicoplanin (TEC) (30µg), linezolid (LZD) (30µg) were used for Gram-positive isolates. Piperacillin-tazobactam (PTZ) (100/10µg) , ceftazidime (CAZ) (30µg), cefepime (FEP) (30 µg), Imipenem (IPM) (10µg), meropenem (MEM) (10 µg), gentamicin (GEN) (10 µg), amikacin (AMK) (30 µg), ciprofloxacin (CIP) (5 µg), levofloxacin (LVX) (5µg) were used for Gram-negative isolates. We depend on Minimum inhibitory concentration (MIC) to identify the presence of sensitivity and resistance according to CLSI. Isolation of normal flora is considered no growth or negative results according to our laboratory protocol.

Statistical Analysis: We used Statistical Packages for Social Sciences (SPSS) 23.0

Table 1 | Characteristics of patients, n(%)

Patients characteristics	No. of patients	(%)
Age (years)	Mean± SD (41.786±18.812)	
17-30	21	34.4
31-40	12	19.8
41-59	14	22.9
≥60	14	22.9
Gender		
Male	31	50.8
Female	30	49.2
Ward		
Orthopedics	19	31.1
General Surgery	27	44.3
Obstetrics and gynaecology	15	24.6
The total	61	100.0

Table 2 | Microbiological examination result based on characteristics of the patient

Patients' characteristics	Microbiological examination result, n (%)					
	Gram-positive bacteria (n=20)	Gram-negative bacteria (n=38)	No growth (n=17)	Fungi (n=1)	Total (n=76)	P value
Age						
17-30	5(25.0%)	13(34.2%)	6(35.3%)	0(0.0%)	24(31.6%)	0.380
31-40	6(30.0%)	6(15.8%)	3(17.6%)	1(100.0%)	16(21.1%)	
41-59	7(35.0%)	7(18.4%)	4(23.5%)	0(0.0%)	18(23.7%)	
≥60	2(10.0%)	12(31.6%)	4(23.5%)	0(0.0%)	18(23.7%)	
Gender						
Male	12(60.0%)	15(39.5%)	11(64.7%)	0(0.0%)	38(50.0%)	0.175
Female	8(40.0%)	23(60.5%)	6(35.3%)	1(100.0%)	38(50.0%)	
Ward Type						
Orthopedics	5(25.0%)	13(34.2%)	5(29.4%)	1(100.0%)	24(31.6%)	0.394
General Surgery	10(50.0%)	13(34.2%)	10(58.8%)	0(0.0%)	33(43.4%)	
Obstetrics and gynecology	5(25.0%)	12(31.6%)	2(11.8%)	0(0.0%)	19(25.0%)	
Overall	**20(100.0%)**	**38(100.0%)**	**17(100.0%)**	**1(100.0%)**	**76(100.0%)**	

software to introduce and analyse the data. Results were presented as frequency and percentage, and the chi-square test was used to test the statistical significance. A p-value less than 0.05% was considered significant.

RESULTS

Characteristics of patients: Of 61 wound swabs taken, 44 (72.1%) were cultured positively, yielding 59 microbial isolates; 31 (50.8%) were male and 30 (49.2%) were female. The mean age of the patients was (41.786±18.812) years, ranging from 17–80 years. Twenty seven patients (44.3%) were in general surgery wards, 19(31.1%) in orthopaedic wards. For other characteristics of the patients, see Table 1.

Table 3 | Various organisms isolated from the wound swabs collected from surgical wounds.

Microbial species isolated	No.	Percentage (%)
S. aureus	13	17.1
Enterococcus faecalis	6	7.9
E. coli	10	13.2
Klebsiella pneumonia	8	10.5
Proteus mirabilis	6	7.9
P. aeruginosa	7	9.2
Enterobacter cloacae	3	3.9
Acinetobacter baumannii	3	3.9
S. aglactiae	1	1.3
M. morganii	1	1.3
Candida	1	1.3
No growth	17	22.4
Overall	**76**	**100.0%**

Microbiological examination result based on characteristics of the patients: Out of 61 swabs, 17 (27.9%) yielded no growth, while the other 44 swabs yielded 59 cultures, as some patients yielded more than one growth. Those 59 positive growths were Gram-positive 20 (33.9%), Gram-negative 38 (64.3%) and Candida spp. only in 1(1.7%). Table 2 shows the association of growth with age groups, gender, and wards. There is no statistically significant association among these variables.

Types of micro-organisms isolated from surgical wounds: *Staphylococcus aureus* (*S. aureus*) 13 (17.1%) and *Enterococcus faecalis* (*E. faecalis*) 6 (7.9%) and *Streptococcus agalactiae* (*Str. agalactiae*), 1(1.3%) were the most common gram-positive species detected. On the other hand, the most common bacterial gram-negative species detected were *Escherichia coli* (*E. coli*) 10 (13.2%), *Klebsiella pneumonia* (*K. pneumonia*) 8 (10.5%), *Pseudomonas aeruginosa* (*P. aeruginosa*) 7 (9.2%), *Proteus mirabilis* (*P. mirabilis*) 6 (7.9%), *Enterobacter cloacae* (*E. cloacae*) and *Acinetobacter baumannii* (*A. baumannii*) each

Table 4 | Characteristics of the poly microbial growth of our sample

Type of growth	Main microbial species	No. of isolates (%)	Co-existent pathogen	No. of isolates (%)	Total (%)
Polymicrobial	*S. aureus*	2(3.3%)	*E. faecalis*	2(13.3%)	4(5.3%)
Polymicrobial	*S. aureus*	1(1.6%)	*E. coli*	1(6.7%)	2(2.6%)
Monobacterial	*S. aureus*	10(16.4%)	Nil	-----	10(13.2%)
Polymicrobial	*E. coli*	3(4.9%)	*E.faecalis*	3(20.0%)	6(7.9%)
Polymicrobial	*E. coli*	1(1.6%)	*A.baumannii*	1(6.7%)	2(2.6%)
Monobacterial	*E. coli*	5(8.2%)	Nil	-----	5(6.6%)
Polymicrobial	*P. aeruginosa*	2(3.3%)	*K. pneumonia*	2(13.3%)	4(5.3%)
Polymicrobial	*P. aeruginosa*	1(1.6%)	*E. cloacae*	1(6.7%)	2(2.6%)
Monobacterial	*P. aeruginosa*	4(6.6)	Nil	-----	4(5.3%)
Polymicrobial	*K. pneumonia*	3(4.9%)	*P. mirabilis*	3(20.0%)	6(7.9%)
Monobacterial	*K. pneumonia*	2(3.3%)	Nil	-----	2(2.6%)
Polymicrobial	Candida species	1(1.6%)	*M. morganii* *K. pneumonia*	1(6.7%) 1(6.7%)	3(3.9%)
Monobacterial	*E. cloacae*	2(3.3%)	Nil	-----	2(2.6%)
Monobacterial	*A.baumannii*	2(3.3%)	Nil	-----	2(2.6%)
Monobacterial	*E. faecalis*	1(1.6%)	Nil	-----	1(1.3%)
Monobacterial	*Str. agalac-tiae*	1(1.6%)	Nil	-----	1(1.3%)
Monobacterial	*P. mirabilis*	3(4.9%)	Nil	-----	3(3.9%)
No growth	-----	17(27.9)	-----	-----	17(22.4%)
Overall	-----	61(80.3%)	-----	15(19.7%)	76(100.0%)

have three isolates representing 3.9 %, *Morganella morganii* (*M. morganii*), and Candida spp., 1(1.3%) for each. See table 3

Types of microbial growth: The presence of only one species isolated from each sample was the most frequent 30 (39.5%). Polymicrobial infection was found in 29(38.2%) of the infected wounds. In our study, no growth was found in 17(27.9%) of swabs. The species most frequently identified in a co-infection condition were *E. coli* and *E. faecalis* (7.9%), as do *K. pneumoniae* and *P. mirabilis*, followed by *S. aureus* and *E. faecalis* (5.3%), *P. aeruginosa* and *K. pneumonia* also hold the same percentage. Only a triple co-infection was identified and involves Candida species, *M. morganii* and *K. pneumonia* with a percentage of 3.9%, Table 4.

Drug susceptibility testing for gram-positive bacteria: Table 5 shows that all *S. aureus* isolates 13 (100.0%) were resistant to penicillin G. Also, all *Enterococcus faecalis* isolates 6 (100.0%) were resistant to tetracycline and erythromycin. Vancomycin, teicoplanin and linezolid have been shown to be active against all Gram-positive species tested.

Drug susceptibility testing for gram-negative bacteria: E.coli showed 100% resistance to ceftazidime, ciprofloxacin, levofloxacin. *Enterobacter cloacae* showed 100% resistance to ceftazidime. All *Acinetobacter baumannii* isolates 3 (100.0%) were non-susceptible to all antimicrobial agents listed or pandrug-

Table 5 | Antibiotic resistance pattern of gram-positive bacteria isolated from patients with infected surgical wounds.

Organisms isolated	Resistant Isolate for each antibiotics used, No. (%)								
	Pen G	TET	ERY	CLI	GEN	LVX	VAN	TEC	LZD
S.aureus (n=13)	13(100.0)	11(84.6)	8(61.5)	5(38.5)	2(15.4)	3(23.1)	0(0.0)	0(0.0)	0(0.0)
E.faecalis (n=6)	2(33.3)	6(100.0)	6(100.0)	Not Tested	Not Tested	2(33.3)	0(0.0)	0(0.0)	0(0.0)
Str. Agalactiae (n=1)	0(0.0)	1(100.0)	1(100.0)	1(100.0)	Not Tested	0(0.0)	0(0.0)	0(0.0)	0(0.0)
overall (n=20)	15(75.0)	18(90.0)	15(75.0)	5(25.0)	2(10.0)	5(25.0)	0(0.0)	0(0.0)	0(0.0)

Table 6 | Antibiotic resistance pattern of gram-negative bacteria isolated from patients with infected surgical wounds.

Organisms isolated	Resistant Isolate for each antibiotics used, No. (%)								
	PTZ	CAZ	FEP	IPM	MEM	GEN	AMK	CIP	LVX
P. aeruginosa (n=7)	2 (28.6)	3(42.9)	2(28.6)	3(42.9)	3(42.9)	3 (42.9)	2(28.6)	2 (28.6)	3 (42.9)
E. coli (n=10)	5(50.0)	10(100)	2 (20.0)	3(30.0)	1 (10.0)	5(50.0)	0(0.0)	10(100)	10(100)
K. pneumonia (n=8)	4(50.0)	6(75.0)	5(62.5)	4(50.0)	3(37.5)	2(37.5)	2 (25.0)	4(50.0)	5(62.5)
P. mirabilis (n=6)	2(33.3)	4(66.7)	2(33.3)	3(50.0)	1(16.7)	4(66.7)	0(0.0)	3(50.0)	5(83.3)
E. cloacae (n=3)	1 (33.3)	3(100)	2(66.7)	2(66.7)	1 (33.3)	2(66.7)	0(0.0)	2(66.7)	2(66.7)
A. baumannii (n=3)	3(100)	3(100)	3(100)	3(100)	3(100)	3(100)	3(100)	3(100)	3(100)
M. morganii (n=1)	0(0.0)	0(0.0)	0(0.0)	1(100.0)	0(0.0)	1(100.0)	0(0.0)	0(0.0)	0(0.0)
Overall (n=38)	17(44.7)	29(76.3)	16(42.1)	19(50.0)	12(31.6)	20(52.6)	7(18.4)	24(63.2)	28(73.7)

resistant (PDR). Drug resistance of overall Gram-negative bacilli irrespective of species was 17(45.9%) to piperacillin-tazobactam, 16(43.2%) cefepime 29(78.4%), to ceftazidime, 29.6% to cefoperazone, 18(48.6%) to imipenem, 18(48.6%) to meropenem, 19(51.4%) to gentamicin; 7(18.9%) to amikacin, 49.6% to tetracycline, 24(64.9%) to ciprofloxacin and 28(75.7%) to levofloxacin. Amikacin and meropenem have been shown to be active against all Gram-positive species tested. See table 6.

DISCUSSION

Nosocomial infections (NIs) are infections among patients admitted to hospitals and are associated with different toxins or infectious agents.[20] Infectious agents that cause NIs are prone to resistance to some antibiotics. The main mechanisms of resistance include limiting the uptake of a drug, modification of a drug target, inactivation of a drug, and active efflux of a drug.[21]

In our study, the most common isolates were *S. aureus*, followed by *E. coli*, *Klebsiella pneumoniae*, and Pseudomonas spp., accounting for 13 (17.1%), 10 (13.2%), 8 (10.5%), and 7 (9.2%) cases, respectively. These results are consistent with those reported in a study conducted at Nil Ratan Sircar Medical College, Kolkata, West Bengal.[22] and Jordan.[23] on the contrary, Ioannou et al., [24] in a study from a tertiary hospital in Greece have reported that Enterococcus is the most common Gram-positive bacteria. Our study found *Escherichia coli*, the predominant Gram-negative bacteria involved in SSI, 10 (13.2%). Meanwhile, Giacometti [25] from Italy found Pseudomonas spp. to be the most prominent bacteria.

We detected one culture of Group B Streptococcus (GBS) strain, which was sensitive to penicillin, vancomycin and linezolid but resistant to erythromycin, tetracycline, and clindamycin. This matches what Heelan found, where GBS strains were also susceptible to penicillin and vancomycin, with some susceptibility to tetracycline. However, unlike their study, our strain showed complete resistance to tetracycline.[26]

In our study, Staphylococcal isolates were completely resistant to penicillin and showed low resistance to gentamicin. Similar findings were found in a retrospective study of bacteriology and antibiotic sensitivity patterns of post-operative surgical site infections in orthopaedics.[27] Additionally, *S. aureus* in our series was highly resistant to tetracycline, similar to that reported by Mengesha R et al.[28] In general, we found that all Gram-positive isolates were susceptible to vancomycin and linezolid, consistent with that reported by Bessa et al.[29] However, a study from Rizgary Teaching Hospital in Erbil, in the Kurdistan Region of Iraq, has shown that Gram-positive bacteria were resistant to vancomycin in 60% and teicoplanin in 20%, but sensitive to linezolid.[30]

Staphylococcus aureus is naturally susceptible to virtually every antibiotic that has ever been developed. Resistance is often acquired by horizontal transfer to genes from outside sources, although chromosomal mutation and antibiotic selection are also important.[31] Resistance to penicillin, the first antibiotic determined to be effective against S. aureus, was reported only one year after the introduction of the drug into clinical practice.[32] Equally rapid was the development of resistance to other antibiotics that were progressively entering clinical use, such as erythromycin, streptomycin, and tetracyclines.[32]

The development of semisynthetic penicillins, such as methicillin, oxacillin, cloxacillin, dicloxacillin, and nafcillin, stable to degradation by the *S. aureus* penicillinase enzyme, seemed to solve the problem.[33] However, increased use of methicillin and related antimicrobials has resulted in *S. aureus*, resistant to several ß-lactam antibiotics, such as methicillin and oxacillin.[34] These strains are known as methicillin-resistant *S. aureus* (MRSA). Vancomycin has been the agent of choice for empiric treatment of life-threatening MRSA infections for decades.[34,35] However, the clinical isolates of *S. aureus* with intermediate and complete resistance to vancomycin have emerged within the past two decades and have become a serious public health concern.[35] Linezolid, the first oxazolidinone used clinically, effectively treats infections caused by Gram-positive pathogens, including multidrug-resistant enterococci and methicillin-resistant *Staphylococcus aureus*.[36]

We found that Enterococcus isolates showed complete resistance to tetracycline. A study of the bacteriological profile of surgical site infections and their antibiotic resistance in Sangli District, Maharashtra, India, demonstrated a high degree of resistance among enterococcus isolates to tetracycline.[37] Additionally, our enterococcal isolates were resistant to erythromycin. Similar to that reported by Stefania from Italy.[38] In our study, all enterococcus isolates were highly sensitive to vancomycin and linezolid. These results are consistent with that reported by a study from India about the microbiology and antibiotic sensitivity patterns of surgical site infection following caesarean section in a tertiary-care centre in Chhattisgarh.[39]

Ampicillin and penicillin are the most active ß-lactams against enterococci, preventing peptidoglycan synthesis.[40] Monotherapy with aminopenicillins is imperfect.[41] Synergistic antibiotics that act in conjunction with ampicillin have been studied in depth to help combat enterococcal infections.[41] Many strains of enterococci are inhibited and rapidly killed by low concentrations of penicillin when combined with an aminoglycoside.[42] Increased antimicrobial resistance among Enterococcus spp. is a serious health problem universally.[43] Multi-drug resistant (MDR) enterococci are major nosocomial pathogens causing serious problems frequently in hospitalised patients.[44]

Enterococcus faecalis isolates are resistant to clindamycin (CLI), which is thought to be a species feature.[45] Disarrangement of a gene abc-23, now designated lsa, for lincosamide and streptogramin A resistance of *E. faecalis* was related to resistance to clindamycin.[45] According to Clinical and Laboratory Standards Institute (CLSI) guidance, aminoglycosides, except for high-level resistance testing and clindamycin, may appear active in vitro. Still, they are ineffective clinically and should not be reported as susceptible.[46] High resistance among Enterococcus to erythromycin and tetracycline was documented.[47] Changes at the ribosomal level were more frequently detected in erythromycin and tetracycline resistance than in efflux systems.[47]

The evolution of nosocomial (hospital-acquired) strains of Gram-negative bacilli like Pseudomonas and Klebsiella spp., *Escherichia coli*, and others are often resistant to several antibiotics, and it has become a serious medical problem.[48] In our study, we found high resistance to ceftazidime, which is consistent with the findings of a study about the antibiotic resistance of gram-negative bacteria that cause surgical site infections in tertiary hospitals.[49] Amikacin was the drug of choice for gram-negative bacterial isolates, as shown by a study to determine antibiotic susceptibility patterns of bacterial pathogens of surgical site infection.[50]

In our study, amikacin demonstrated greater efficacy compared to meropenem. In contrast, a study conducted by Negi V et al. reported that meropenem was more effective than amikacin.[51] Moreover, our study found that meropenem was more effective than imipenem against Gram-negative bacteria. This finding is consistent with a study conducted by Worku S et al.[52]

Our study showed that gram-negative bacteria were highly resistant to cephalosporins and fluoroquinolones. In contrast to our findings, a study conducted by Njoku CO et al reported that Gram-negative isolates were moderately resistant to fluoroquinolones.[53] at the same time, another study in southwest Nigeria observed that they were highly sensitive to cephalosporins and fluoroquinolones.[54]

Multi-drug resistance in *Escherichia coli* has become a worrying problem that is increasingly shown in humans worldwide.[55] The most important mechanism for resistance is the acquisition of genes coding for extended-spectrum ß-lactamases.[55] In our series, the most effective antibiotics against *Escherichia coli* were amikacin and meropenem; a study conducted by Ali MJ and Ali LA revealed a different pattern. In their investigation of antibiotic sensitivity among bacteria causing surgical site infections in various hospitals in Kirkuk, Iraq, they found that the most effective antibiotic against *Escherichia coli* was ciprofloxacin, followed by amikacin.[56]

Acinetobacter species and *Pseudomonas aeruginosa* are emerging as pathogens that frequently cause infections in patients in intensive care units.[57] Foremost among the mechanisms of resistance in both of these pathogens is the production of ß-lactamases and aminoglycoside-modifying enzymes.[58] Additionally, diminished expression of outer membrane proteins, mutations in topoisomerases, and up-regulation of efflux pumps play an important role in antibiotic resistance.[58] *Enterobacter cloacae* exhibits a high frequency of enzymatic resistance to broad-spectrum cephalosporins.[59] Resistance of Enterobacter spp. to third-generation cephalosporins is most typically caused by overproduction of AmpC ß-lactamases.[59]

Limitations: Due to a lack of data regarding the risk factors and details of surgical operations that may affect the development of SSI, we could not include them in the analysis. Anaerobic bacterial cultures were also not included because they were not routinely performed at our hospital during the study period due to a lack of resources. The overall sample size was relatively small, making statistical analysis for some parameters difficult.

CONCLUSION

S. aureus was the most common bacteria isolated from SSI, followed by *E.coli*. Linezolid, vancomycin and teicoplanin were the most active drugs against gram-positive bacteria. On the other hand, amikacin and meropenem were the most active drugs against gram-negative bacteria. Knowledge of the successful treatment of bacterial wound infection is of great importance. Bacteriological and antibiotic susceptibility studies are significant tools for treating infections promptly and effectively to reduce undesirable long-term sequelae of surgical site infections.

REFERENCES

1. Alemayehu MA, Azene AG, Mihretie KM. Time to development of surgical site infection and its predictors among general surgery patients admitted at specialised hospitals in Amhara region, northwest Ethiopia: a prospective follow-up study. *BMC Infect Dis*. 2023 May 17;23(1):334.
2. Ekanem EE, Oniya O, Saleh H, et al. Surgical site infection in obstetrics and gynaecology: Prevention and management. *Obstet Gynaecol*. 2021 Feb 23;23(2):124-137.
3. Yin V, Cobb JP, Wightman SC, et al. Centers for Disease Control (CDC) Wound Classification is Prognostic of 30-Day Readmission Following Surgery. *World J Surg*. 2023 Oct;47(10):2392-2400.
4. Sweetman SC. Martindale: The Complete Drug Reference. 38th edition. London: Pharmaceutical Press; 2014.
5. O'Connell PR, McCaskie AW, Sayers RD, et al. Bailey & Love's Short Practice of Surgery. 28th edition. Kent: CRC Press Taylor & Francis Group; 2023.

6. Whittlesea C, Hodson K. Clinical Pharmacy and Therapeutics. 6th edition. London: Elsevier; 2019.
7. Onyekwelu I, Yakkanti R, Protzer L, et al. Surgical Wound Classification and Surgical Site Infections in the Orthopaedic Patient. *J Am Acad Orthop Surg Glob Res Rev*. 2017 Jun;1(3):e022.
8. Brunicardi F, Andersen DK, Billiar TR. Schwartz's Principles of Surgery. 11th edition. New York: McGraw-Hill Education; 2019.
9. Torok ME, Moran ED, Cooke FJ. Oxford Handbook of Infectious Diseases and Microbiology. 2nd edition. London: Oxford University Press; 2017.
10. Sganga G, Pea F, Aloj D, et al. Acute wound infections management: the 'Don'ts' from a multidisciplinary expert panel. *Expert Rev Anti Infect Ther*. 2020 Mar;18(3):231-240.
11. DiPiro JT, Yee GC, Posey LM, et al. DiPiro's Pharmacotherapy: A Pathophysiologic Approach. 12th edition. New York: McGraw Hill; 2023.
12. Ikeda A, Fukunaga Y, Akiyoshi T, et al. Wound infection in colorectal cancer resections through a laparoscopic approach: a single-center prospective observational study of over 3000 cases. *Discov Oncol*. 2021;12(1):2.
13. Kulkarni SP, Kothari O. Surgical Site Infection in Obstetric and Gynecological Surgeries: A Prospective Observational Study. *Cureus*. 2023 Feb 11;15(2):e34855.
14. Kvalvik SA, Rasmussen S, Thornhill HF, et al. Risk factors for surgical site infection following cesarean delivery: A hospital-based case-control study. *Acta Obstet Gynecol Scand*. 2021 Dec;100(12):2167-2175.
15. Feng Y, Feng Q, Guo P, et al. Independent risk factor for surgical site infection after orthopedic surgery. *Medicine*. 2022 Dec 30;101(52):e32429.
16. Enki DG, Noufaily A, Garthwaite PH, et al. Automated biosurveillance data from England and Wales, 1991–2011. *Emerging Infectious Diseases*. 2013 Jan;19(1):35.
17. European Centre for Disease Prevention and Control. Annual Epidemiological Report 2016 – Surgical site infections. Stockholm: ECDC; 2016.
18. Hubab M, Ullah O, Hayat A, et al. Antibiotic susceptibility profile of bacterial isolates from post-surgical wounds of patients in tertiary care hospitals of Peshawar, Pakistan. *J Pak Med Assoc*. 2018 Oct;68(10):1517-1521.
19. Weinstein MP, Lewis JS. The Clinical and Laboratory Standards Institute Subcommittee on Antimicrobial Susceptibility Testing: Background, Organisation, Functions, and Processes. *J Clin Microbiol*. 2020 Feb 24;58(3):e01864-19.
20. Nimer NA. Nosocomial Infection and Antibiotic-Resistant Threat in the Middle East. *Infect Drug Resist*. 2022 Feb 25;15:631-639.
21. Reygaert WC. An overview of the antimicrobial resistance mechanisms of bacteria. *AIMS Microbiol*. 2018 Jun 26;4(3):482-501.
22. Bhattacharya S, Pal K, Jain S, et al. Surgical Site Infection by Methicillin Resistant Staphylococcus aureus - on Decline? *J Clin Diagn Res*. 2016 Sep;10(9):DC32-DC36.
23. Raed Ennab, Waleed Al-Momani, Rama Al-Titi, et al. Antibiotic Profile of Pathogenic Bacteria Isolated from Post-surgical Site Infections in Public Hospitals in Northern Jordan. *Infection and Drug Resistance*. 2022 Sep 17:359-366.
24. Ioannou P, Maraki S, Koumaki D, et al. A Six-Year Retrospective Study of Microbiological Characteristics and Antimicrobial Resistance in Specimens from a Tertiary Hospital's SurgicalWard. *Antibiotics*. 2023;12:490.
25. Giacometti A, Cirioni O, Schimizzi AM, et al. Epidemiology and microbiology of surgical wound infections. *J Clin Microbiol*. 2000 Feb;38(2):918-22.
26. Heelan JS, Hasenbein ME, McAdam AJ. Resistance of group B streptococcus to selected antibiotics, including erythromycin and clindamycin. *J Clin Microbiol*. 2004 Mar;42(3):1263-4.
27. Rajani R, Veerabhadra J. A Retrospective Study of Bacteriology and Antibiotic Sensitivity Pattern of Post Operative Surgical Site Infections in Orthopedics. *J Pure Appl Microbiol*. 2021 Sep;15(3):1379-1383.
28. Mengesha R, Kasa B, Saravanan M, et al. Aerobic bacteria in post surgical wound infections and pattern of their antimicrobial susceptibility in Ayder Teaching and Referral Hospital, Mekelle, Ethiopia. *BMC Research Notes*. 2014 Aug;7:575.
29. Bessa LJ, Fazii P, Di Giulio M, et al. Bacterial isolates from infected wounds and their antibiotic susceptibility pattern: some remarks about wound infection. *Int Wound J*. 2015;12:47–52.
30. Abdulqader HH, Saadi AT. The distribution of pathogens, risk factors, and their antimicrobial susceptibility patterns among post-surgical site infection in Rizgari Teaching Hospital in Erbil/Kurdistan Region/Iraq. *JUD*. 2019 Apr;15(22):1-10.
31. Chambers HF, Deleo FR. Waves of resistance: Staphylococcus aureus in the antibiotic era. *Nat Rev Microbiol*. 2009 Sep;7(9):629-41.
32. Esposito S, Blasi F, Curtis N, et al. New Antibiotics for Staphylococcus aureus Infection: An Update from the World Association of Infectious Diseases and Immunological Disorders (WAidid) and the Italian Society of Anti-Infective Therapy (SITA). *Antibiotics* (Basel). 2023 Apr 12;12(4):742.
33. Enright MC, Robinson DA, Randle G, et al. The evolutionary history of methicillin-resistant Staphylococcus aureus (MRSA). *Proc Natl Acad Sci USA*. 2002;99:7687–7692.
34. Harvey RA, Fisher BD, Cornelissen CN. Lippincott's Illustrated Reviews: Microbiology. 3rd edition. Philadelphia: Lippincott Williams & Wilkins. 2013.
35. Cong Y, Yang S, Rao X. Vancomycin resistant Staphylococcus aureus infections: A review of case updating and clinical features. *J Adv Res*. 2019 Oct 12;21:169-176.
36. Stefani S, Bongiorno D, Mongelli G, et al. Linezolid Resistance in Staphylococci. *Pharmaceuticals* (Basel). 2010 Jun 24;3(7):1988-2006.
37. Sharnathe GS, Gadgil SA. Bacteriological Profile of Surgical Site Infections and its Resistogram in Sangli District, Maharashtra. *Med J DY Patil Vidyapeeth*. 2020 Sep;13(5):441-446.
38. Bajaj A, Kukanur S, Kotigadde A, et al. Gram Positive Cocci Causing Surgical Site Infection: Identification and Antibiotic Susceptibility Pattern. *IOSR-JDMS*. 2015 Aug;14(8):62-67.
39. Thakur N, Kujur A. Microbiological and antibiotic sensitivity pattern of surgical site infection following caesarean section in a tertiary care center of Chhattisgarh. *Int J Reprod Contracept Obstet Gynecol*. 2021 Jul;10(7):2638-2646.
40. Miller WR, Munita JM, Arias CA. Mechanisms of antibiotic resistance in enterococci. *Expert Rev Anti Infect Ther*. 2014 Oct;12(10):1221-1236.
41. Farsi S, Salama I, Escalante-Alderete E, et al. Multidrug-Resistant Enterococcal Infection in Surgical Patients, What Surgeons Need to Know. *Microorganisms*. 2023 Jan 17;11(2):238.
42. Ryan KJ, Ahmad N, Alspaujh JA, et al. Sherris Medical Microbiology. 7th edition. New York: McGraw-Hill; 2018.
43. Labibzadeh M, Kaydani GA, Savari M, Ekrami A. Emergence of High-level Gentamicin Resistance among Enterococci Clinical

Isolates from Burn Patients in South-west of Iran: Vancomycin Still Working. *Pol J Microbiol*. 2018;67(4):401-406.

44. Haghi F, Lohrasbi V, Zeighami H. High incidence of virulence determinants, aminoglycoside and vancomycin resistance in enterococci isolated from hospitalised patients in Northwest Iran. *BMC Infect Dis*. 2019 Aug 27;19(1):744.

45. Singh KV, Weinstock GM, Murray BE. An Enterococcus faecalis ABC homologue (Lsa) is required for the resistance of this species to clindamycin and quinupristin-dalfopristin. *Antimicrob Agents Chemother*. 2002 Jun;46(6):1845-1850.

46. CLSI. Performance Standards for Antimicrobial Susceptibility Testing. 33rd ed. CLSI supplement M100. Clinical and Laboratory Standards Institute; 2023.

47. Ahmadpoor N, Ahmadrajabi R, Esfahani S, et al. High-Level Resistance to Erythromycin and Tetracycline and Dissemination of Resistance Determinants among Clinical Enterococci in Iran. *Med Princ Pract*. 2021;30(3):272-276.

48. Beale JM, Block JH. Wilson and Gisvold's Textbook of Organic Medicinal and Pharmaceutical Chemistry. 12th edition. Philadelphia: Lippincott Williams & Wilkins; 2011.

49. Deka S, Kalita D, Mahanta P, et al. High Prevalence of Antibiotic-Resistant Gram-Negative Bacteria Causing Surgical Site Infection in a Tertiary Care Hospital of Northeast India. *Cureus*. 2020 Dec 21;12(12):e12208.

50. Bhatt CP, Baidya R, Karki P, et al. Multi Drug Resistance Bacterial Isolates of Surgical Site Infection. *Open J Med Microbiol*. 2014 Dec;4:203-209.

51. Negi V, Pal S, Juyal D, et al. Bacteriological Profile of Surgical Site Infections and Their Antibiogram: A Study From Resource Constrained Rural Setting of Uttarakhand State, India. *J Clin Diagn Res*. 2015 Oct;9(10):DC17-DC20.

52. Worku S, Abebe T, Alemu A, et al. Bacterial profile of surgical site infection and antimicrobial resistance patterns in Ethiopia: a multicentre prospective cross-sectional study. *Ann Clin Microbiol Antimicrob*. 2023 Nov 7;22(1):96.

53. Njoku CO, Njoku AN. Microbiological Pattern of Surgical Site Infection Following Caesarean Section at the University of Calabar Teaching Hospital. *Open Access Maced J Med Sci*. 2019 May 14;7(9):1430-1435.

54. Olufunmiola BM, Olugbenga AO, Adeyankinnu AF. Bacterial agents of surgical site infection in south-west Nigeria. *Am J Biomed Sci*. 2013;5(4):217–225.

55. Poirel L, Madec JY, Lupo A, Schink AK, Kieffer N, Nordmann P, Schwarz S. Antimicrobial Resistance in Escherichia coli. *Microbiol Spectr*. 2018 Jul;6(4). doi: 10.1128/microbiolspec.ARBA-0026-2017. PMID: 30003866.

56. Ali MJ, Ali LH. Pattern of antibiotics sensitivity of bacteria causing surgical site infections in several hospitals in Kirkuk- Iraq. EAI. 2020 Sep 3. http://dx.doi.org/10.4108/eai.28-6-2020.2297968.

57. Wisplinghoff H, Bischoff T, Tallent SM, et al. Nosocomial bloodstream infections in US hospitals: analysis of 24,179 cases from a prospective nationwide surveillance study. *Clin Infect Dis*. 2004 Aug 1;39(3):309-317.

58. Bonomo RA, Szabo D. Mechanisms of multidrug resistance in Acinetobacter species and Pseudomonas aeruginosa. *Clin Infect Dis*. 2006 Sep 1;43(2):49-56.

59. Davin-Regli A, Pagès JM. Enterobacter aerogenes and Enterobacter cloacae; versatile bacterial pathogens confronting antibiotic treatment. *Front Microbiol*. 2015 May 18;6:392.

Abbreviations list: Acinetobacter baumannii (A. baumannii), Amikacin (AMK), Antimicrobial susceptibility testing (AST), Body Mass Index (BMI), Cefepime (FEP), Ceftazidime (CAZ), Centers for Disease Control and Prevention (CDC), Ciprofloxacin (CIP), Clindamycin (CLI), Clinical and laboratory standards institute (CLSI), Enterobacter cloacae (E. cloacae), Enterococcus faecalis (E. faecalis), Erythromycin (ERY), Escherichia coli (E. coli), European Union/European Economic Area (EU/EEA), Gentamicin (GEN), Group B Streptococcus (GBS), Imipenem (IPM), Klebsiella pneumonia (K. pneumonia), Levofloxacin (LVX), Linezolid (LZD), Meropenem (MEM), Methicillin-resistant S. aureus (MRSA), Microgram (µg), Minimum inhibitory concentration (MIC), Morganella morganii (M. morganii), Multi-drug resistant (MDR), Nosocomial infections (NIs), pandrug-resistant (PDR), Penicillin G (Pen G), Piperacillin-tazobactam (PTZ), Proteus mirabilis (P. mirabilis), Pseudomonas aeruginosa (P. aeruginosa), Staphylococcus aureus (S. aureus), Statistical Packages for Social Sciences (SPSS), Streptococcus agalactiae (Str. agalactiae), Subcommittee on Antimicrobial Susceptibility Testing (AST SC), Surgical site infection (SSI), Teicoplanin (TEC), Tetracycline (TET), United Kingdom Standard Operating Procedures (UK SOPs), Vancomycin (VAN).

Conflict of interest: Authors have nothing to declare.

Funding: Nothing apart from personal fund.