

Bacterial Pathogens And Antibiotic Resistance In Orthopaedic Implant-Related Infections: Challenges And Strategies For Effective Management

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Keywords:	ABSTRACT
Orthopaedic Implant-Related Infection, MRSA, ESBL, Risk Factors, Microbial Profile, Antibiotic Prophylaxis.	Background: Orthopaedic implant-related infections (OIRI) cause significant clinical and therapeutic challenges, coupled with high morbidity and costs to patients as well as to healthcare systems. This study looked into the prevalence, risk factors, and the microbial profile of OIRI by identifying resistant strains and their associated clinical implications. Methods: This was a one-year study conducted from July 2016 to June 2017 at Coimbatore Medical College, in which 137 clinically suspected OIRI cases were included. Culture positivity was assessed, and microbiological isolates were identified through phenotypic and molecular methods, including PCR for MRSA strains and ESBL testing for Gram-negative bacilli. Results: Of 137 OIRI cases, 116 were culture-positive (85%). The commonest pathogens isolated were Staphylococcus aureus (77.2%) and Klebsiella spp. (34.4%). MRSA was isolated in 32.3% of Staphylococcus aureus isolates, while 22 Gram-negative isolates produced ESBL. The study also found diabetes mellitus, smoking, and alcoholism as major risk factors, with early onset of infection being predominant (76.6%). Emergency surgeries were also found to be associated with higher rates of infection. Conclusion: OIRI is still a significant concern in orthopaedic practice, with some shifts in the patterns of microbial resistance, especially the emergence of MRSA and ESBL-producing strains. Preventive strategies, such as perioperative glycemic control and antibiotic prophylaxis, are essential in reducing infection rates. Accurate microbial surveillance and tailored antibiotic regimens based on local resistance trends are vital for improving patient outcomes.

I. INTRODUCTION

Orthopaedic implants have revolutionized the treatment options for musculoskeletal conditions, offering critical advancements in the care of bone fractures and degenerative joint diseases. Designed to restore the structural and functional integrity of bones and joints, these implants result in relief of

pain, improved mobility, and enhanced quality-of-life measures in millions of patients all over the world. Orthopaedic devices range from screws and plates to internal fixation devices and, finally, joint replacement implants, which have made them an indispensable part of modern surgical practice due to their versatility [1-2].

However, as the use of orthopaedic implants increases, so does the problem of serious complications, most notably orthopaedic implant-related infections (OIRI). These are rare but pose considerable challenges to both the patient and healthcare providers. They are especially worrying as they can lead to implant failure, prolonged hospital stays, multiple surgical interventions, and, in extreme cases, limb amputation or even death. Of course, the incidence of OIRI in elective surgeries ranges from 0.7% to 4.2%, but can escalate to over 30% in trauma cases involving open fractures, thereby showing how dependent the risks that are found are on the type of procedure [3-4].

OIRI is most commonly noted due to contamination of the implant with microbes at the time of surgery or from haematogenous or contiguous spread post-surgery. Formation of biofilms by bacteria on the implant surfaces complicates further the pathogenesis of such infections because the bacteria develop significant resistance to both antibiotics and host immune responses. Common pathogens involved in OIRI include *Staphylococcus aureus* and Coagulase-negative staphylococci as well as some Gram-negative pathogens like *Klebsiella* spp. and *Pseudomonas aeruginosa*. The exact timing of infection onset is, however, unpredictable and may develop from early, postoperative infection within weeks or months of intervention to late after many years [5-6].

The added layer of complexity in the management of OIRI is the specter of antibiotic resistance. Multidrug-resistant pathogens have increased their prevalence, and most first-line antibiotics are now ineffective, complicating the strategy for treatment and raising the risk of poor clinical outcomes. Development of resistance ultimately constrains therapeutic options and further increases the financial burden of healthcare systems and patients [7].

The management of OIRI, therefore, involves early detection and prevention as well as effective management of these challenges. Such an approach necessitates multi-layered infection control practices, routine surveillance for bacterial pathogens and their antibiotic susceptibility profiles, and implementation of strong antibiotic stewardship programs. Proper management of these critical factors can ensure reduction of risks associated with implant-related infections, improved patient outcomes, and restriction of the spread of antibiotic-resistant organisms [8].

The article concerns bacterial pathogens and resistance mechanisms to antibiotics involved in orthopaedic implant-related infections, discusses issues in the management of this condition, and explores various strategies which may make treatment more effective. A greater understanding of the pathophysiology, diagnostic techniques, and newer concepts in therapy is the attempt of this review to contribute towards the ongoing fight against this devastating complication of orthopaedic surgery.

II. METHODS

Study Design and Setting

This study, titled “Epidemiological Study of Implant-Related Infection in Orthopaedic Surgery and Its Management Outcome by Use of Biodegradable Antibiotic Delivery System – A Prospective Analysis,” was conducted in the Department of Orthopaedics, SCB Medical College Hospital, Cuttack. This was a two-year, hospital-based prospective study conducted from July 2018 to August 2020. The ethical approval was given by the Institutional Ethics Committee, and all patients provided their consent before their entry into the study.

Sample Size and Study Population

In total, 136 patients with implant-related infections were admitted to the orthopaedic and plastic surgery wards. Both sexes, all ages, and open or closed fractures cases that applied for emergency or elective surgical interventions were included.

Data Collection

Data collected included patient demographics, such as name, age, and address, date of admission, diagnosis at admission, duration of hospital stay, physical examination findings, nutritional status, type of implant, and duration of the procedure. Comorbid conditions, including diabetes mellitus, and underlying illnesses, such as urinary tract and respiratory tract infections, were documented. Drug history, including steroid or immunosuppressive therapy, and lifestyle factors, such as smoking and alcohol consumption, were also documented.

Inclusion and Exclusion Criteria

Patients who were diagnosed with implant-related infections were included, whereas those who were implanted through pre-existing infected wounds, on prolonged steroids or immunosuppressive therapy, or having chronic diseases such as tuberculosis or malignancy were excluded.

Aseptically, pus samples were obtained from patients who manifested clinical signs of infection, like purulent drainage at the site of incision, drain, or implant. The area adjacent to the site of sample collection was prepared with sterile saline to ensure that skin commensals did not contaminate the sample. Deep abscesses were aspirated using a sterile syringe in strict aseptic technique. Anaerobic cultures were obtained from fragments of infected tissues and periprosthetic membranes during wound debridement, and transported in thioglycollate broth for maintenance of an oxygen-free environment.

Microbiological Processing

Samples were directly microscopically examined using Gram staining to identify bacteria, pus cells, and debris. For aerobic organisms, inoculations were done on nutrient agar, blood agar, and MacConkey agar, while thioglycollate broth was used for anaerobic cultures. Culture plates were incubated at 37°C for 24 to 48 hours, with anaerobic samples maintained in a gas-free environment for a minimum of seven days. Colony morphology, culture characteristics, and biochemical tests were used to identify organisms.

Biochemical and Phenotypic Testing Various biochemical tests, that involve catalase, oxidase, urease, and coagulase testing, were conducted to obtain the identification of the isolates. The isolates that had a Gram-negative staining pattern required additional testing including motility, oxidation-fermentation, and nitrate reduction tests. Specific enterococcal identification tests performed include bile esculin, PYR, and sugar fermentation.

Susceptibility Test

The Kirby-Bauer disc diffusion method on Mueller-Hinton agar, according to CLSI, was used to conduct antimicrobial susceptibility testing. The bacterial inoculum was standardized to a 0.5 McFarland standard. Antibiotic sensitivity was checked against a panel of drugs for both Gram-positive and Gram-negative isolates by using zone diameters interpreted according to CLSI M100-S24 standards.

Statistical Analysis

Data was input into Microsoft Excel and subsequently analyzed with the aid of SPSS (version 24). Categorical variables were represented through frequencies and percentages, whereas continuous variables were illustrated as means accompanied by standard deviations. Statistical relationships were assessed employing chi-square tests and independent sample t-tests, with a p-value of less than 0.05 deemed statistically significant.

III. RESULTS

General Overview

A total of 137 cases of Orthopaedic Implant-Related Infections (OIRI) were analyzed over a one-year period (July 2016 to June 2017). Among these, 116 cases (85%) were culture-positive, while 21 cases (15%) were culture-negative. The findings shed light on the nature of injuries, onset of infections, associated risk factors, and microbial etiology, along with antimicrobial susceptibility patterns.

Nature and Onset of Infections

The most common causes of infection following injury were road traffic accidents (72%, n=84), followed by self-falls (21%, n=24). The timing of infections was predominantly early or acute, at 79% (n=91), while delayed and chronic infections were reported in 13% (n=16) and 8% (n=9) of cases, respectively.

Type of Fractures and Surgical Interventions

Open fractures were significantly more related to culture-positive infections, accounting for 71% (n=82) compared to 29% (n=34) for closed fractures. Emergency surgical procedures were also significantly associated with infections at 64% (n=74) while elective surgical procedures accounted for the remaining 36% (n=42).

Demographic Characteristics and Risk Factors

The incidence of implant-related infections was highest in the age group of 36–45 years at 31%, n=35; followed by the age group of 46–55 years at 20%, n=23. Males were predominantly affected with a proportion of 75% (n=87), as compared to females with 25% (n=29). Among the risk factors, diabetes mellitus was the most common, found in 36% (n=42), followed by smoking 23% (n=26) and alcoholism 21% (n=25).

Microbial Isolates

The study revealed *Staphylococcus aureus* to be the most frequently isolated organism at 29% (n=34). Other Gram-negative organisms such as *Klebsiella* spp at 18% (n=21) and *Pseudomonas aeruginosa* at 13% (n=15) were also seen commonly. However, of all *Staphylococcus aureus* isolates, 32.3% were MRSA.

Antibiotic Sensitivity and Resistance Patterns

Linezolid and Vancomycin gave 100% of Sensitivity. Gram Negative bacteria, especially *Klebsiella* spp., demonstrated 100% sensitivity to the drug Amikacin, although *Pseudomonas aeruginosa* was still sensitive to another drug, which is Meropenem. Total of 62.5 percent ESBL in the isolates of *Escherichia coli*, n = 8;.

The prevalence of ESBL production was high at 47.6% (n=10) for *Klebsiella* spp and 50% (n=7) for *Proteus* spp, and 62.5% (n=5) for *Escherichia coli* isolates were confirmed as ESBL producers.

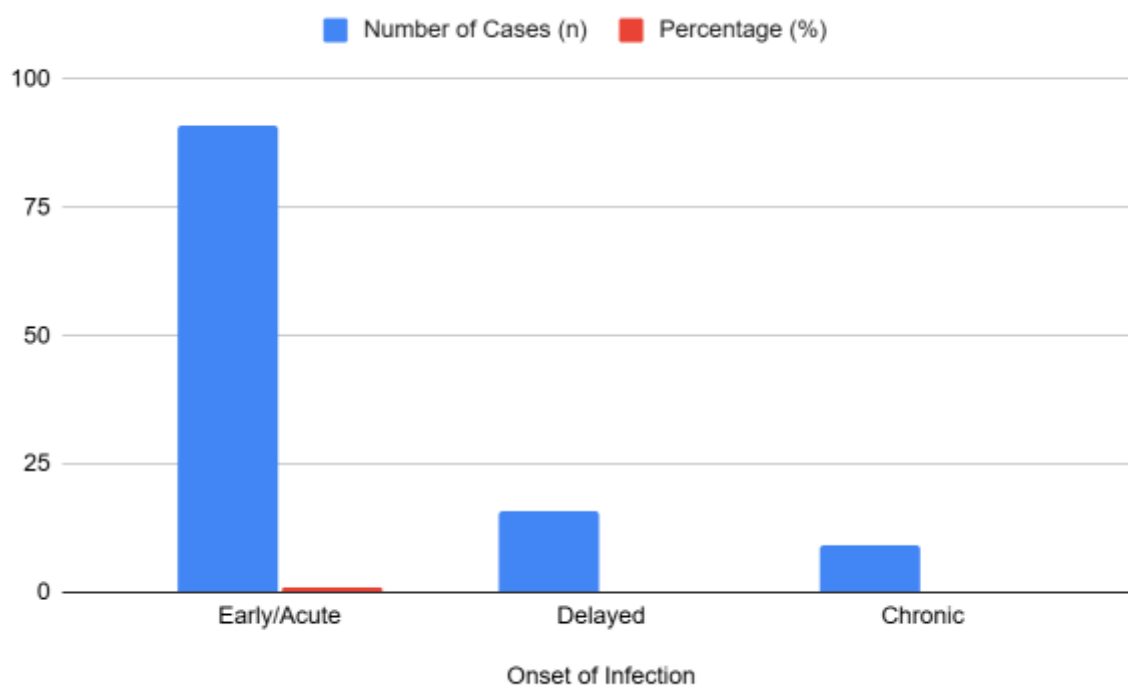
Table 1: Demographic Distribution of Patients with OIRI

Parameter	n (%)
Age Group (Years)	
18–25	14 (10.2%)
26–35	22 (16.1%)
36–45	35 (31%)

46–55	23 (20%)
56 and above	43 (22.7%)
Gender Distribution	
Male	87 (75%)
Female	29 (25%)

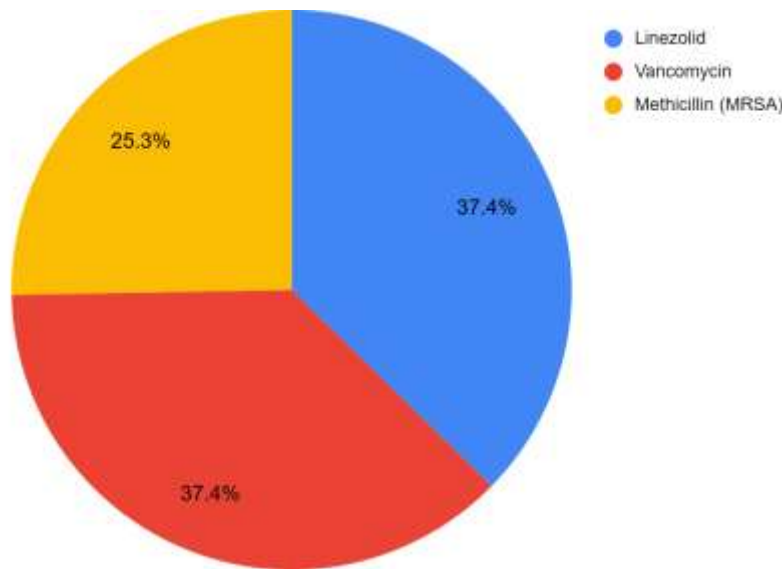
Table 2: Microbial Isolates and Antibiotic Sensitivity Patterns

Microorganism	Isolated (n)	Most Sensitive Antibiotic(s)	Notable Resistance Patterns
Staphylococcus aureus	34	Linezolid, Vancomycin	MRSA (32.3%)
Klebsiella spp	21	Amikacin	ESBL (47.6%)
Pseudomonas aeruginosa	15	Amikacin, Meropenem	-
Escherichia coli	8	Amikacin	ESBL (62.5%)



Graph 1: Distribution of Cases by Onset of Infection

The bar graph illustrates the distribution of cases based on the timing of infection onset (early/acute, delayed, or chronic).



Graph 2: Antibiotic Sensitivity Pattern of Staphylococcus aureus

The pie chart depicts the sensitivity profile of *Staphylococcus aureus* to Linezolid, Vancomycin, and resistance to Methicillin.

The result highlights the burden of implant-related infections, emphasizing the importance of early intervention, robust infection control measures, and vigilant monitoring of antibiotic resistance patterns.

IV. DISCUSSION

With advancements in surgical techniques and infection control, orthopedic implant-related infections remain a challenge in modern medical practice. The present study aimed at analyzing the bacterial pathogens responsible for OIRIs, their resistance patterns, and also risk factors associated in the admissions of the orthopedic and plastic surgery wards in Coimbatore Medical College Hospital. In all, 137 of the 1987 patients who received orthopedic implant surgeries were found to develop infections, and this translated to an incidence rate of 6.8%. This is more than the widely accepted standard rate of <1–2% as noted in several studies. The infection rate was thus seen to be relatively high in this study due to the preponderance of emergency surgeries, soft-tissue damage before surgery, and the complexity of trauma cases [9].

The majority of cases were related to RTAs. These constituted 72% culture-positive cases, and RTA is often followed by extensive tissue damage, soil contamination, and devascularization of the periosteum predisposing the patients to infections. Open fractures alone accounted for 71% cases, which establishes the vulnerability open wounds have against endogenous cutaneous flora besides environmental pathogens on the outside of the wound itself. Emergency surgeries, performed in 64% of the cases, further contributed to the higher incidence of infections due to inadequate preparation time, suboptimal optimization of patient comorbidities, and challenges in maintaining strict aseptic conditions [10].

The onset of infection in this study revealed a predominance of acute or early infections (<3 months post-surgery) in 79% of cases, followed by delayed (13%) and chronic infections (8%). Early infections were associated with contamination during surgery and inadequate disinfection practices. The study also emphasized the role of trauma-related immune impairment, which lowers the local host tissue's resistance to microbial colonization.

There was a marked gender difference, with 75% of the infected cases belonging to males. This is consistent with the fact that men are more exposed to risky work environments like construction sites

and industries. The age group 36–45 years showed the highest infection rates, as this group was more actively involved in risky behavior such as rash driving, leading to higher RTA incidence [11-12].

Diabetes mellitus (36% of cases), smoking, and alcoholism were significant risk factors that predisposed patients to OIRIs. Diabetes, for instance, compromises neutrophil function and wound healing by the effect of hyperglycemia, thereby increasing susceptibility to infections. Long surgical times and inadequate perioperative glycemic control increased the risk further.

The most common isolate was *Staphylococcus aureus* at 29%, followed by *Klebsiella* spp. (18%), *Pseudomonas aeruginosa* (13%), and *Proteus* spp. (12%). Gram-positive cocci like *S. aureus* were reported to be sensitive to Linezolid and Vancomycin at a 100% rate, but Gram-negative bacilli were entirely sensitive to Meropenem as well. Some resistance patterns exhibited that Methicillin-resistant *S. aureus* (MRSA) was obtained in 32.3% of *S. aureus* cases. Molecular diagnostic techniques revealed the *mecA* gene among 90.9% strains of MRSA, which thus emphasizes the high utility of high-tech diagnostic methodology like PCR-based detection of resistance pathogens [13].

Polymicrobial infections occurred in 9.5% of the patients, generally including mixtures of Gram-positive and Gram-negative bacilli, among whom *S. aureus* and *Klebsiella* spp. were the most common pair. The presence of biofilm-producing microorganisms significantly contributed to persistent infection, challenging the treatment [14].

The study mainly focused on antibiotic prophylaxis, which decreased the infection rates. Patients with prophylaxis had a lesser rate of infections (32%) compared to those without (62%). On the other hand, the report also showed the importance of frequent surveillance in cases of changing resistance patterns. It recommended local methods of antibiotic delivery, such as antibiotic-loaded bone cement, for adjunctive therapy in controlling infection, especially in trauma cases where vascularization was compromised.

Emerging strategies include vaccines, silver-coated implants, and quorum-sensing inhibitors, all of which may hold future promise. They can prevent biofilm formation, enhance local antimicrobial activity, and reduce systemic toxicity. Biofilm-degrading enzymes and antimicrobial peptides also hold promise for treating persistent infections [15].

V. CONCLUSION

OIRI remains a challenging area of clinical practice. High morbidity and financial burden remained attached to patients and healthcare systems due to such factors. This study reports the prevalence, risk factors, and microbial profile of OIRI, in which diabetes mellitus emerged as the most common comorbidity, followed by smoking and alcoholism. Predominant pathogens were *Staphylococcus aureus* and *Klebsiella* species. Emergence of MRSA and ESBL strains emphasized the need for vigilant antimicrobial stewardship. Prevention by appropriate infection control measures, optimization of comorbid conditions preoperatively, and adherence to antibiotic prophylaxis protocols is critical in reducing the infection rates. The primary management strategies include tailored antibiotic regimens based on susceptibility patterns, ultimately proven to really improve outcome and minimize complications such as prolonged treatment or amputation.

VI. REFERENCES

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