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ORIGINAL RESEARCH

Surgical site infection and antibiogram within 90 days of elective intramedullary nail fixation of femoral and tibial diaphyseal fractures: A prospective case series of adult patients at a tertiary hospital in Lusaka, Zambia

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Abstract

Background

Surgical site infections (SSIs) represent frequent complications in orthopaedic surgery. These challenging and typically protracted conditions can lead to deep bone and implant infections. Notwithstanding the reported delays in fracture repair associated with open reduction and internal fixation, a dearth of information exists regarding SSI rates and antibiograms following intramedullary nailing for femoral and tibia diaphyseal fractures.

Methods

This prospective case series, conducted from September 2019 through August 2020, enrolled adults undergoing elective intramedullary nailing for femoral and tibial fractures at a tertiary care centre in Lusaka, Zambia. Skeletally mature patients with closed diaphyseal fractures of the femur or tibia were eligible for inclusion, and we excluded patients with pathological fractures and established spine injuries, as well as those who missed any planned clinic visits within the 90-day active postoperative surveillance period. Recruitment was affected by implant availability and COVID-19–related shutdowns. Information was gathered from participant interviews, medical records, and laboratory investigations, with a 90-day postoperative surveillance period. SSIs were assessed according to NHSN (National Healthcare Safety Network, US Centers for Disease Control and Prevention) criteria. Significance set at a P value < 0.05. Continuous variables were tested for normality, with skewed data presented as medians and interquartile ranges, while categorical variables were analysed to generate frequencies and percentages. Multivariate analysis was employed to evaluate potential risk factors for SSI.

Results

Of the 132 participants, the median age was 30 years (interquartile range, 25-42). The study identified an SSI rate of 15.9%. Among the participants with SSI, 23.8% subsequently developed deep bone infections necessitating explantation. Multivariate analysis indicated that—compared with tibial fractures—femoral diaphyseal fractures were associated with lower odds of developing SSI (adjusted odds ratio, 0.08; 95% confidence interval, 0.02-0.35; P=0.001). *Staphylococcus aureus*, predominantly methicillin-resistant *S. aureus*, was the most commonly isolated pathogen.

Conclusions

Both the SSI rate and the prevalence of methicillin-resistant *S. aureus* were higher than globally accepted standards. This information is crucial for the development of locally relevant strategies for SSI case management.

Keywords: surgical site infection, sensitivity patterns, antibiogram, femur, tibia, fracture, open reduction and internal fixation, intramedullary nailing, Zambia

Introduction

Low- and middle-income countries (LMICs) are experiencing a substantial escalation in vehicular accidents, and this has been associated with an upsurge in musculoskeletal injuries that necessitate operative fixation.[1]-[4] Gerhard Kuntscher's introduction of intramedullary nailing (IMN) for long bone fractures in 1939 notably improved patient care in resource-limited settings.[5] Essentially, IMN facilitates an early return to preinjury activities for affected individuals.[6] However, this fracture fixation method faces significant risks, with surgical site infections (SSIs) potentially yielding devastating outcomes if mismanaged.[7]-[11]

There have been varied reports of SSI rates across several studies involving early closed fracture repair (within 1 week).[12]-[14] Informal data from our institution indicate that most femur and tibia fractures are subjected to delayed repair (beyond 2 weeks), often necessitating open reduction and internal fixation (ORIF). Both delayed repair and ORIF could potentially escalate the risk of SSI,[15] thereby warranting investigations into early vs delayed fracture repair–associated SSI rates and causative organisms. Information gleaned from such research would be crucial for formulating locally relevant targeted management approaches to SSIs.

SSIs and their prevalence

An SSI is a postsurgical complication that ranges from superficial incisional SSI, deep incisional SSI, to organ/space infection, as outlined by the US Centers for Disease Control and Prevention's National Healthcare Safety Network (NHSN) criteria for SSI diagnosis.[13],[16]-[18]

In relation to IMN of diaphyseal fractures of the femur and tibia, the prevalence of SSIs, as documented in numerous publications (primarily from middle- and high-income countries), ranges from 2.4% to 11.8%, with the tibia often affected more commonly.[16],[19],[20] However, there is a scarcity of such data from LMICs.

Responsible organisms and antibiotic sensitivity patterns

Notably, in some instances, the patient's bacterial flora has been identified as a source of surgical wound infections.[21] Commonly isolated organisms following orthopaedic implant surgery include *Staphylococcus* species, *Escherichia coli, Proteus mirabilis, Pseudomonas* species, and *Enterococcus* species.[19],[20],[22]-[26]

Medical treatment of SSIs after orthopaedic implant insertion is often complicated by deep bone and implant infections, leading to biofilm formation around the implant that is resistant to commonly prescribed antibiotics.[27]-[29] Some studies have shown that the administration of a single dose of a locally guided broad-spectrum antibiotic during closed fracture fixation can mitigate the severity of deep-wound and surface-wound infections.[25],[30]-[32] The emergence of methicillin-resistant and vancomycin-resistant *Staphylococcus aureus* represents a concerning trend over recent years, necessitating immediate intervention to prevent further morbidity and mortality.[19],[25]

Understanding the locally relevant antibiogram is pivotal for determining both empirical and intraoperative antibiotic treatments during revision surgery.

Methods

Study design, site, and setting

We conducted a prospective case series comprising participants who underwent elective IMN between September 2019 and August 2020, for diaphyseal fractures of the femur and tibia, at a tertiary care centre in Lusaka, Zambia. We used Kuntscher nails and interlocking nails (Nebula Surgical, Rajkot, India) for femur and tibia fractures, respectively.

Study population and selection criteria

We included all adult patients with diaphyseal fractures of the femur and tibia planned for IMN. Eligible participants were skeletally mature individuals who presented with closed diaphyseal fractures of the femur or tibia and who consented to both undergoing surgery and participating in the study. We excluded patients with pathological fractures, established spine injuries, and those who missed any planned clinic visits during the active surveillance period after surgery.

Sampling method

We consecutively recruited eligible participants. Due to the COVID-19 pandemic and limited implant availability, we added a limited number of patients to the elective surgery list, leading to fewer elective procedures than typically expected. These factors significantly influenced our sampling frame.

Data collection plan and tools

We collected data from participant interviews, theatre findings, medical record reviews, participant examinations, and laboratory investigations. We implemented SSI active surveillance using modified data collection forms validated by the NHSN and piloted prior to use in this study. We assessed trauma severity using the Kampala Trauma Score, a simplified composite of the RTS (Revised Trauma Score) and the ISS (Injury Severity Score, validated for use in LMICs).[33]

Preoperative, perioperative, and postoperative procedures

All participants received preoperative antibiotics at least 30 minutes before surgery, typically ceftriaxone or cefotaxime. We observed the World Health Organization's global guidelines on the prevention of SSIs during the perioperative period. The IMN procedure adhered to the current practice at the study site, as guided by the AO Foundation and Orthopaedics Trauma Association.[34],[35] Participants underwent delayed (beyond 2 weeks) ORIF with reaming due to lengthy waiting lists and implant unavailability. Notably, our hospital did not have a fracture traction table during the study period. Patients were responsible for purchasing implants. ORIF was chosen because of the need—before IMN fixation—to clear fibrous tissue from the site of delayed fracture repair.

Table 1. Sociodemographic and clinical characteristics of study participants (N=132)

Variable	All participants	No SSI	SSI	*P* value
Age, median (IQR), years	30 (25-42)	30 (25-32)	30 (26-44)	0.990^{a}
Sex				
Male	102 (77.3)	88 (86.3)	14 (13.7)	0.206^{b}
Female	30 (22.7)	23 (76.7)	7 (23.3)	
Smoking				
Yes	27 (20.5)	22 (81.5)	5 (18.5)	0.678^{b}
No	105 (79.6)	89 (84.7)	16 (15.2)	
Alcohol consumption				
Yes	67 (50.8)	56 (83.6)	11 (16.4)	0.871^{b}
No	65 (49.2)	55 (84.6)	10 (15.4)	
HIV status				
Positive	15 (11.4)	15 (100)	0	0.074^{c}
Negative	117 (88.6)	96 (82.1)	21 (18)	
Injury scenario				
Road traffic crash	99 (75)	82 (82.8)	17 (17.2)	0.410^{c}
Fall	21 (15.9)	20 (95.2)	1 (4.8)	
Assault	5 (3.8)	3 (60)	2 (40)	
Sport related	4 (3.0)	3 (75)	1 (25)	
Other	2 (1.5)	2 (100)	0	
Gunshot	1 (0.8)	1 (100)	0	
Bone involved				
Tibia	23 (17.4)	15 (65.2)	8 (34.8)	0.006^{b}
Femur	109 (82.6)	96 (88.1)	13(11.9)	
KTS, mean (IQR)	15 (14-15)	15 (14-15)	14 (14-15)	0.228^{a}
Preoperative immobilisation				
None	6 (4.6)	4 (66.7)	2 (33.3)	0.077^{c}
Plaster of Paris	23 (17.4)	16 (69.6)	7 (30.4)	
Skin traction	25 (18.9)	21 (84)	4 (16)	
Skeletal traction	78 (59.1)	70 (89.7)	8 (10.3)	
Explantation for deep SSI				
Yes	5 (23.8)	NA	5 (23.8)	NA
No	16 (76.2)	NA	16 (76.2)	
Total	132 (100)	111 (84.1)	21 (15.9)	<0.001

Values are n (%) unless indicated otherwise. ^{a}Mann-Whitney *U* test; ^{b}chi-square test; ^{c}Fisher exact test

ASA, American Society of Anaesthesiologists; IQR, interquartile range; KTS, Kampala Trauma Score; NA, not applicable; SSI, surgical site infection

Postoperatively, we followed participants for 90 days (active surveillance period), which is recommended for monitoring implant-related infections.[16] Postoperative wound cleaning adhered to the current practice at the study site, typically using clean water and a carbolic soap (such as the Lifebuoy-branded bar soap commonly used in Zambia). If clinical features suggested an infection, as defined by the NHSN criteria,[13],[16]-[18] we sought laboratory confirmation as per procedures described elsewhere.[36] The involved surgical site was first cleaned with saline-soaked gauze before a deep swab was collected via the open, discharging wound in a sterile environment (operating theatre).

Laboratory procedures

The collected specimen was placed in Amies transport medium (Oxoid, Basingstoke, UK) and transported to the microbiology laboratory for culture within 2 hours. Over the subsequent days, we performed culture and subculture techniques, identified organisms, and conducted antimicrobial susceptibility testing as per laboratory protocol. We were guided in the selection of antibiotics and interpretation of susceptibility by the 2019 CLSI (Clinical and Laboratory Standards Institute) guidelines.[36]

Day 1

The specimen was inoculated and subcultured on blood, chocolate, and MacConkey media (all from Oxoid, Basingstoke, UK), which were incubated at

Table 2. Multivariate analysis of factors associated with surgical site infection following intramedullary nailing of femoral or tibial fractures

Variable	aOR	95% CI	*P* value
Sex – male	0.30	0.08-1.17	0.08
Head injury present[a]	3.06	0.71-13.21	0.13
Prolonged surgery (>138 min)	2.31	0.74-7.22	0.15
Bone involved – femur	0.08	0.02-0.35	0.001
Bone involved – tibia	Omitted due to collinearity[b]		

[a] Clinically significant finding

[b] There was perfect prediction of the development of surgical site infection for middle- and distal-third fractures.

aOR, adjusted odds ratio; CI, confidence interval

35 to 37 °C in a carbon dioxide (blood and chocolate) or oxygen (MacConkey) incubator for 18 to 24 hours.

Day 2

We examined the plates for growth. For pure growths, we performed Gram staining and biochemical tests (Oxoid, Basingstoke, UK), such as catalase, coagulase, mannitol salt, bile esculin, oxidase, Simmons citrate, urease, TSI (triple sugar iron agar), and SIM (sulphide indole motility) tests. For mixed growths, purity plates were set and incubated. Antimicrobial susceptibility testing was carried out on pure growths using a 0.5 McFarland standard suspension (Oxoid, Basingstoke, UK) prepared with pure isolates and normal saline. The suspension was inoculated on Mueller–Hinton agar plates, and antibiotic discs (Oxoid, Basingstoke, UK) were placed as per standard disc diffusion procedures. The plates were then incubated in an oxygen incubator at 35 to 37 °C for 18 to 24 hours.

Day 3

We identified organisms by interpreting the biochemical test results. The selection of antibiotics and interpretation of susceptibility were guided by the 2019 CLSI guidelines.[36] Participants received broad-spectrum antibiotics and underwent serial debridement while awaiting sensitivity results, which guided medical treatment when they were available.

Data management, storage, and analysis

We stored de-identified data on a password-protected server, accessible only by the research team. Data were tabulated in an Excel (Microsoft Corp., Redmond, WA, USA) spreadsheet, managed, coded, and then exported into Stata 15 (StataCorp, College Station, TX, USA) for analysis.

For the analysis of continuous variables, like age and Kampala Trauma Score, we employed the Shapiro–Wilk test to evaluate their distribution. Finding that the distributions of these variables were skewed, we chose to present them using medians and interquartile ranges (IQRs). For categorical variables, we adopted frequencies and percentages as the primary descriptive statistics.

In the comparative analysis, we used the Mann–Whitney *U* test to compare continuous variables among participants with and without SSIs. For categorical variables, we carried out chi-square tests to determine independent associations. However, when we had less than 5 observations in any category (which violates chi-square test assumptions), we used the Fisher exact test as an alternative.

To identify variables for multivariate analysis, we set a *P* value cut-off of ≤0.25. We subsequently performed a final analysis to ascertain whether specific bones were associated with increased risk of SSI, expressing the results in terms of odds ratios with their corresponding 95% confidence intervals.

P values <0.05 were considered statistically significant.

Ethical considerations

We conducted this study involving human participants in accordance with the principles of research ethics stipulated by Zambia's National Health Research Authority (NHRA). Ethical approval for this study was obtained from the University of Zambia Biomedical Research Ethics Committee (UNZABREC, IRB00001131 of IORG0000774; No. 199-2019).

Results

Baseline characteristics and comparisons

Table 1 presents the critical sociodemographic and clinical data. The median age of the participants was 30 years, with a majority being male (n=102, 77.3%) and alcohol consumers (n=67, 50.8%). A small subset (n=27, 20.5%) of the participants smoked (median pack-years, 0.25; IQR, 0.1-1). The median Kampala Trauma Score was 15 (IQR, 14-15). A small proportion of the participants (n=15, 11.4%) was HIV positive. Skeletal traction was predominantly employed for preoperative fracture immobilization. The most frequent mechanism of injury was road traffic accidents (n=100, 75.8%), followed by falls (n=20, 15.1%). The femur was the most frequently fractured bone (n=109, 82.6%).

Twenty-one participants (15.9%) developed SSIs, and out of these, tibia fractures (n=8, 34%) were more commonly involved than femur fractures (n=13, 11.9%). Of the participants with SSIs, 5 (23.8%) subsequently developed deep bone infections, resulting in the removal of the respective IMNs (explantation).

Multiple adjusted logistic regression between SSI and variables most predictive of SSI

Table 2 displays the results of the multivariate analysis of long-bone fractures most predictive of SSI. The multivariate analysis revealed that femur diaphyseal fractures (odds ratio, 0.08; 95% confidence interval, 0.02-0.35; P=0.001) were associated with lower odds of developing SSI compared with tibial diaphyseal fractures.

Table 3. Antibiogram: Isolates from surgical site infections following intramedullary nailing for femoral and tibial fracture fixation

Organism	Resistant to	Sensitive to
Staphylococcus aureus	Penicillin, erythromycin, gentamicin, oxacillin, cotrimoxazole, ciprofloxacin	Ciprofloxacin, clindamycin, chloramphenicol, linezolid, gentamicin
Escherichia coli	Ampicillin, ciprofloxacin, gentamicin, cefotaxime	Cefotaxime, piperacillin–tazobactam, chloramphenicol, tobramycin, ampicillin–sulbactam, ciprofloxacin

Antibiogram

Table 3 shows that the most frequently isolated organism was *S. aureus* (n=4 of 15, 26.7%), followed by *E. coli* (n=3, 12%). The least commonly isolated organisms were *Enterobacter aerogenes* and *Proteus vulgaris*, each occurring at a frequency of 6.7% (n=1). *E. coli* was commonly associated with femoral fractures, while *Klebsiella pneumoniae* was frequently associated with tibial fractures. No *K. pneumoniae* was grown from cultures from the femoral SSIs, and neither *E. aerogenes* nor *P. vulgaris* was found in swabs from infection sites that arose after tibial repairs.

All *S. aureus* isolates from the femoral SSIs were resistant to penicillins, macrolides, and aminoglycosides, while all *S. aureus* isolates from the tibial SSIs were resistant to macrolides but sensitive to aminoglycosides and cotrimoxazole. Three-quarters (75%) of the *S. aureus* isolates were identified as methicillin-resistant *S. aureus* (MRSA).

Discussion

The aims of this study were to ascertain the rate of SSI and elucidate the antibiogram of common organisms following elective IMN of femoral and tibial diaphyseal fractures. These insights could offer a basis for strategic management actions aimed at reducing resource use and enhancing postoperative results. The study involved 132 participants in need of surgical intervention at a large tertiary hospital over approximately 1 year. The majority of participants were young males with femur fractures resulting from road traffic accidents who received preoperative traction immobilization (most commonly skeletal traction). Most participants were nonsmokers, relatively healthy, and with a low risk profile for SSI.

In this study, 15.9% of participants (11.9% of femur IMN recipients and 34.8% of tibia IMN recipients) developed SSIs, a higher rate than previously reported.[12],[13],[15],[19],[23],[24],[37] The widely accepted SSI prevalence following IMN of femur fractures is generally less than 2%.[20] Several factors may have contributed to the high prevalence of SSI observed here, including the low socioeconomic status of the study population[15] and inconsistent or improper antimicrobial prophylaxis. Perioperative antibiotics were administered based on what was available at the time of the surgery, and there was an inconsistent supply of antibiotics from the pharmacy.

Nearly a quarter (23.8%) of participants with SSI developed deep bone infections. This outcome led to the removal of IMNs before fracture healing due to poorly controlled, multidrug-resistant infections that responded poorly to available antibiotics.

S. aureus was the most commonly isolated organism, in line with numerous other studies.[19],[24],[25] There were notable findings in cultures from femur and tibia SSIs that warrant further investigation. *S. aureus* originating from the normal skin and nasal flora has been implicated in certain cases as the source of infection.[38] The detection of *S. aureus* and *E. coli*, among other commensals, in specimen cultures also sometimes reflects nonpathogenic (false-positive) contamination by handlers during specimen collection and processing, particularly if samples are exposed to an operating theatre environment.[39]-[41] These observations support the usefulness of preoperative swabbing of the nasal passages of both patients and surgical teams, with subsequent implementation of appropriate interventions, such as the application of mupirocin nasal ointment, when such organisms are cultured.[42] Notably, preoperative swabbing is not routinely performed at the study site. Surprisingly, viridans streptococci were not cultured from femur SSIs, nor were *E. aerogenes* or *P. vulgaris* from tibia SSIs, warranting further investigation. *E. coli* was commonly present in femur SSIs, suggesting the possibility of faecal contamination due to its proximity to the anorectal region. Notably, *S. aureus* isolates were generally resistant to penicillins, macrolides, and aminoglycosides, and three-quarters were determined to be MRSA.

Limitations

This study had several limitations, including its single-centre design at a tertiary care hospital, which may limit the generalizability of results. Although the patient diversity associated with the nationwide referrals received by our hospital lends to this study's generalizability, it should be noted that part of the study period coincided with a high-transmission period during the COVID-19 pandemic. Our hospital was not a designated COVID-19 management centre, but we experienced a surge in coinfected surgical patients, resulting in the temporary closure of elective clinics and operating rooms. Other limitations include the aforementioned possibility of specimen contamination, the lack of standardized perioperative antibiotics, potential underrepresentation of the SSI rate (considering that other SSIs might have occurred after 90 postoperative days), the lack of a comparison group with early fracture fixation, the potential introduction of bias because of the lack of a sample processing control, potential selection bias from consecutive sampling, and limited analysis due to the relatively small number of infections and organisms cultured.

Considering the high SSI rate and the prevalence of MRSA, a longer-term multicentre study with standardized perioperative antibiotics is warranted to facilitate an improved understanding of the SSI rate and its prognostic factors. Also, a study comparing early closed reduction and delayed ORIF may provide valuable insights. Community (and hospital) surveillance for MRSA and urgent intervention are also suggested.

Conclusions

The study site had a high SSI associated with delayed femoral and tibial IMN. Femur diaphyseal fractures were associated with lower odds of developing SSI compared with tibia fractures following elective IMN, and MRSA was commonly isolated. This research offers a locally relevant SSI rate and antibiogram for SSIs of femoral and tibial diaphyseal fractures following IMN. Knowledge of locally relevant antibiograms is crucial for determining both empirical and intraoperative antibiotic treatment during revision surgery.

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