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Prevalence and determinants of orthopedic surgical site infections in rural northern Ghana: a retrospective cohort study

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Abstract
Background The annual incidence of orthopedic surgeries has been steadily rising globally. The rise in orthopedic surgeries is associated with increased surgical site infection, which is linked with high mortality, extended hospital stays, and decreased quality of patient life. There is a dearth of knowledge on the magnitude and risk factors of orthopedic surgical site infections in Ghana.
Objective To investigate the prevalence and determinants of orthopedic surgical site infections in St. Theresa's Hospital, Nandom.
Method A retrospective cohort design among 1032 patients who underwent orthopedic surgeries between January 2014 and December 2018. Admission and patient record books constituted the data sources. The data were initially extracted into a Microsoft Excel spreadsheet, cleaned, and exported to SPSS version 27 and R for coding and analysis.
Results The prevalence of orthopedic surgical site infection was 9.3%. The determinants of orthopedic surgical site infections were: male sex (OR = 2.33, 95%CI 1.04, 5.51) p = 0.04; self-employed (OR = 3.25, 95%CI 1.2, 10.29) p = 0.030; unemployed/retired (OR = 4.61, 95%CI 1.35, 17.72) p = 0.019; duration of admission (OR = 1.03, 95%CI 1.01, 1.05) p = 0.002; number of days on postoperative medications (OR = 1.21, 95%CI 1, 1.46) p = 0.045; white blood cell count (OR = 1.04, 95%CI 0.98, 1.08) p = 0.050; and revised surgery (OR = 9.89, 95%CI 5.32, 18.79) p = 0.001.
Conclusion This study's prevalence of orthopedic surgical site infection was 9.3%. Surgical site infections are the most surveyed and common types of healthcare-associated infections that occur in low and middle-income countries. Several factors may contribute to these infections. Standardized guidelines are needed to consolidate the prevention of these infections globally.

Keywords Orthopedic · Surgical site infection · Prevalence · Risk factors · Determinants · Ghana

1 Introduction

In recent decades, there has been a progressive global increase in the yearly incidence of orthopedic surgeries [1]. Among patients undergoing orthopedic surgical procedures, closely, 14.4% experience adverse events during perioperative care, with 5.2% of these occurrences deemed avoidable [2]. Notably, infections are the most prevalent perioperative complications

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after surgeries, with 1.3% of surgeries leading to surgical site infection (SSI) [3]. The rising prevalence of orthopedic surgeries is associated with increased SSI. These SSIs are identified as significant contributors to healthcare-associated infections (HAIs) and are linked with high mortality, extended hospital stays, decreased quality of patient life, and increased demand for healthcare resources [4, 5]. These negative consequences are noted despite improvements in interventions to control infectious diseases such as improved air-conditioning in operating rooms, sterilization techniques, surgical procedures, and availability of disinfectants [6, 7]. Consequently, SSI has emerged as the major focus for clinical infection surveillance [8].

Surgical site infections as defined based on the criteria proposed by the Center for Disease Control (CDC) is an infection occurring within 30 days after a surgical operation if no metal plate or an implant is left in place or within 90 days if an implant or metal plate is left in place. The SSIs are categorized as either deep or superficial; deep SSIs represent infections that impact the profound layers of soft tissues, encompassing bones, muscles, tendons, and related structures [6]. These infections exhibit distinctive clinical features, including but not limited to persistent discharge or dehiscence emanating from the deep surgical incision, the presence of a visually discernible abscess or gangrenous tissue necessitating surgical intervention for debridement and potential removal or replacement of implanted devices, as well as the manifestation of culture-confirmed exudates originating from the depth of the surgical incision site [6].

The risk of infection resulting from orthopedic surgeries is higher than other procedures. This is largely due to the complex nature of the surgeries, the patient's characteristics, the underlying conditions they present with, and the risk of concomitant soft tissue injury [9]. Regarded as one of the most common types of nosocomial infections in healthcare settings in low-and-middle-income countries (LMICs), [10, 11] the incidence of surgical site infection globally stood at 10 to 20% [12, 13]. Globally, there are variations in the incidence of SSIs, however, the distribution is uneven with increased rates reported in LMICs. The World Health Organization (WHO) reported that the prevalence of HAI ranges between 5.7% in developed countries and 11.2% in LMICs [7, 14]. For instance, in a LMIC, Mosleh et al. reported an incidence rate of SSI at 18.2% in Iran [15]. Additionally, in sub-Saharan Africa, a study in Rwanda reported the incidence of SSI to be 10.9%, [16] while in the Eastern Mediterranean region, the overall prevalence was estimated at 9.7% [17]. Similarly, in Asia, the study by Zhang et al. reported the incidence of SSI among orthopedic surgical cases at 1.3% in China [18] while in India, it was reported at 7.6% [19]. Compared to some high-income countries such as the USA and Germany, SSI incidence following orthopedic surgeries were 3.4% and 5.1% respectively [20, 21].

Several factors have been identified to be associated with orthopedic surgical site infections globally. Notably, the study of [22, 23] identified low serum albumin levels (ALB < 36.7–41.6 g/L) and a high body mass index (BMI ≥ 28). Furthermore, smoking, [24] open fracture, [25] multiple fractures (more than two), contaminated wounds, presence of surgical drains, [26] diabetes, and surgeries in areas of deep-seated infections [23, 25] contributed to infections. More so, the level of experience of the surgeon, reoperation, prolonged duration of surgery, male sex, and prolonged postoperative stay in the ward were also reported [20, 21, 27].

Though SSIs are preventable and avoidable through time-tested interventions, evidence indicates that the incidence is high, especially in LMICs including sub-Saharan Africa. Ghana as a LMIC has limited data on orthopedic SSI. This study is crucial for two purposes; firstly, to ascertain the magnitude of SSI related to orthopedic surgeries, secondly, to identify the risk factors associated with orthopedic surgical site infections. Having a better understanding of the factors that may predispose a patient to orthopedic SSI may help to prevent or eliminate it thereby decreasing SSI rates. However, without knowing the prevalence and the factors influencing SSI, evidence-based strategies may not be formulated and implemented adequately to tackle infection prevention. In light of the aforementioned, the current study was conducted to determine the prevalence and to identify the risk factors of orthopedic surgical site infections.

2 Methods and materials

2.1 Study design

This was a retrospective cohort study involving patients who underwent orthopedic surgery at St. Theresa's Hospital in Nandom.

2.2 Study setting

This current study was conducted in Nandom in the Upper West region at St. Theresa's Hospital. The hospital is under the ownership of the Christian Health Association of Ghana (CHAG) and operates as a private non-profit healthcare facility. Nandom district is one of the six administrative districts in the Upper West region which has a total population according to the 2021 national housing and population census of 51,328 comprising 50.2% (25,751 females) and 48.8% (25,577 males) [28]. St. Theresa Hospital has a bed capacity of 218 and is a referral facility for other primary-level health facilities in the district including neighboring Burkina Faso. The hospital has one operating theatre where all operations including orthopedic and other surgeries are conducted. All surgical cases including orthopedic surgeries are managed in general surgical wards (male and female). The hospital also provides a wide range of services including but not limited to general medical and surgical care, and other specialized services such as ear, nose, and throat (ENT), obstetrics and gynecology, eye and public health. The hospital is also a referral center for orthopedic surgeries from the region and other parts of the country usually performed by visiting orthopedic surgeons. Between 2014 and 2018, there were two resident orthopedic surgeons and one visiting general surgeon. Currently, the hospital has four (4) specialist medical doctors, which include an orthopedic and a general surgeon. There are also 130 nurses of all cadres, four (4) medical officers, and a host of house officers (junior medical officers) (hospital records: unpublished).

2.3 Study population and sampling method

The study population was all patients admitted to the hospital for orthopedic conditions and underwent orthopedic surgery at the health facility. A total sampling strategy was used to sample patients between January 2014 and December 2018.

2.4 Inclusion and exclusion criteria

Patients who underwent orthopedic surgeries due to a fracture, deformity, or osteopathology from 1st January 2014 to 31st December 2018 with more than 50% completed admission, clinical and perioperative information were included. A total of 1520 orthopedic cases were identified and extracted within the stated period of the study. However, due to poor patient data entry, 488 cases were removed due to missing information more than the 50% mark. In all, 1032 cases were included in the initial analysis. The study, however, excluded surgeries performed in other hospitals that were later referred to the St. Theresa's hospital due to complications. It also excluded other surgeries that were not orthopedically related such as abdominal and neurosurgeries.

2.5 Data extraction tool and data collection procedure

The authors designed an Excel spreadsheet for the extraction of relevant patient information. The information aimed to achieve the study's objective to assess the prevalence and identify risk factors of orthopedic surgical site infection. Independent variables made up of demographic and surgical-related information were included. This information was consistent with previous studies [9, 15, 19, 21, 22]. The main sources of data were the admission and discharge books and the patients' folders in the possession of the hospital records. Data extractors included all the authors in this study. In addition, two research assistants (RAs) were recruited to help extract data. During the initial stages of data extraction, authors and RAs began the extraction. This was done to effectively usher the RAs into the extraction process to reduce and prevent errors in data extraction. Later, the RAs were constantly monitored and supervised by the authors to ensure that the data extracted reflected the correct and exact information in the folders and admission and discharge books. The Authors and RAs had frequently scheduled meetings to discuss and resolve all data conflicts and ensure clarity before the final data were obtained to avoid ambiguity and conflicting information.

2.6 Definition and identification of SSI

The definition of SSI was obtained from the criteria proposed by the Center for Disease Control (CDC) and other relevant sources. The patients' folders and medical record books were examined to identify patients with orthopedic SSI. That is, readmission diagnosis of infection within 1 year after discharge from the hospital if an implant was used or within 30 days after an orthopedic surgical intervention was carried out. The researchers were responsible for identifying orthopedic SSI based on CDC criteria such as; persistent wound discharge or dehiscence from the deep incision; visible abscess or gangrenosis requiring surgical debridement and implant removal or exchange; and culture-positive excretions from the deep incision site [6]. It also includes the type and dose of prescribed antibiotics and or definitive diagnosis of SSI by the attending surgeon [24].

2.7 Study variables

There are two (2) main variables in this study; dependent and independent. The main dependent variable was the presence of orthopedic surgical site infection among patients who were admitted on account of orthopedic problem. The independent variables were either categorical or quantitative. The quantitative independent variables were age, hemoglobin level, white blood cell count, duration of admission, duration of post-operative antibiotic administration, duration of preoperative stay, and duration of surgical procedure. The categorical variables were (i) sex (male and female); (ii) marital status (married and unmarried); (iii) ethnicity (Dagaare, Dagomba, Waala and others); (iv) religion (Christianity and Islam); (v) occupation (unemployed/retired, housewife, self-employed and employed); (vi) national health insurance scheme (Yes and No); (vii) type of fracture (none, close and open); (viii) urethral catheterization (yes and no); (ix) presence of intravenous catheters (yes and no); (x) presence of surgical drains (yes and no); (xi) wound infection on admission (yes and no); (xii) obesity (yes and no); (xiii) intraoperative blood transfusion (yes and no); (xiv) revise surgeon (yes and no) and (xv) site for surgery (below elbow, above elbow, below knee, above knee and others).

2.8 Sampling and sampling technique

A total sampling strategy was used in this study which included all patients who underwent orthopedic surgeries from January 2014 to December 2018. All folders of patients that were available to the authors within the stated period at the time of data extraction constituted the database for extraction of information as well as information from the admission and discharge record books.

2.9 Statistical analysis

The initial data were entered into Microsoft Excel for cleaning and coding. The data were exported to SPSS version 27.0 for descriptive and bivariate analyses. R statistical package was used for Mann Whitney U test, logistic regression modeling, and visualizations. Descriptive results were presented as frequencies and percentages within tables. Boxplots with the Whitney test were used to compare median values of quantitative data among those with and without the presence of infection. Pearson chi-square test was used to assess the association between the dependent and independent variables. Logistic regression analysis was used to model the predictors of the presence of infection. Cases with missing values were deleted before applying the logistic regression model. Some candidate predictors were also eliminated from the final model, due to high correlations with other predictors. All tests were undertaken at a 5% level of significance. The McFadden, Cox & Snell, and Nagelkerke Pseudo R-squared values and receiver operating characteristic (ROC) curve based on the logistic regression model were used to assess the model data fit. All the independent variables of interest were tested for multicollinearity with values less than the threshold of 2.24 [29]. These factors were, therefore, included in the final analysis for the logistic model.

2.10 Ethical consideration

Ethical approval for this study was obtained from the Research Ethics Committee under the research coordinating unit, regional health directorate, Upper West Region approved and waived the need for informed consent with a reference number (UWR/RHD/ADM/TP-51). Further approval was obtained from the Institutional Review Board (IRB) of St. Therasa's hospital and from the ward in charge of the surgical ward where the data was extracted. The authors did not have access to any identifying information about the participants during the retrospective data extraction process. Therefore, consent from the participants was not needed at this point. However, in this study, all the necessary procedures were performed in accordance with relevant guidelines and regulations. Finally, confidentiality, privacy, and anonymity of the participants' admission information were maintained throughout the data extraction process.

3 Results

From the overall study population of 1032 participants, 96/1032 (9.3%) developed orthopedic surgical site infections. Most of the participants were males (55.1%), the majority were married (74.9%), Christians (56.9%), self-employed (57.7%), and 92% had national health insurance. Sex ($p < 0.001$), Waala ethnic group ($p = 0.001$), and Unemployed/retired ($p = 0.034$) were significantly associated with SSI. Marital status ($p = 0.122$), religion ($p = 0.153$), and NHIS ($p = 0.092$) had no associations with SSI. The minimum number of participants included in the initial analysis in Table 1 was 98.2% of 1032 (1013/1032). The demographic characteristics are shown in Table 1.

Table 1 Unadjusted demographic factors of infection: bivariate analysis

	Presence of infection		Total (%)	p-value	COR (95% CI)
	Yes (%)	No (%)			
Sex (N = 1032)					
Male	78 (13.7)	491 (86.3)	569 (55.1)	< 0.001	3.93 (2.32, 6.66)
Female	18 (3.9)	445 (96.1)	463 (44.9)		
Marital status (N = 1030)					
Married	65 (8.5)	700 (91.5)	765 (74.3)	0.122	0.70 (0.45, 1.10)
Unmarried	31 (11.7)	234 (88.3)	265 (25.7)		
Ethnicity (N = 1017)					
Dagaare	44 (7.9)	516 (92.1)	560 (55.1)		
Dagomba	5 (4.6)	104 (95.4)	109 (10.7)	0.231	0.56 (0.22, 1.46)
Waala	43 (15.1)	242 (84.9)	285 (28)	0.001	2.08 (1.33, 3.26)
Others	4 (6.3)	59 (93.7)	63 (6.2)	0.807	0.80 (0.28, 2.29)
Religion (N = 1032)					
Christianity	48 (8.2)	539 (91.8)	587 (56.9)	0.153	0.74 (0.48, 1.12)
Islam	48 (10.8)	397 (89.2)	445 (43.1)		
Occupation (N = 1013)					
Unemployed/retired	25 (13.3)	163 (86.7)	188 (18.6)	0.034	2.40 (1.05, 5.49)
Housewife	3 (2.8)	104 (97.2)	107 (10.6)	0.354	0.45 (0.12, 1.74)
Self-employed	58 (9.9)	527 (90.1)	585 (57.7)	0.160	1.72 (0.80, 3.69)
Employed	8 (6)	125 (94)	133 (13.1)		
NHIS (N = 1032)					
Yes	84 (8.9)	865 (91.1)	949 (92)	0.092	0.57 (0.30, 1.10)
No	12 (14.5)	71 (85.5)	83 (8)		

COR: Crude Odd Ratio; CI: Confidence Interval; NHIS: National Health Insurance Scheme

3.1 Bivariate analysis of surgery-related factors associated with orthopedic SSIs

Surgical-related factors such as type of fracture ($p < 0.001$), urethral catheterization ($p < 0.001$), presence of surgical drain ($p < 0.001$), wound infection on admission ($p < 0.001$), blood transfusion ($p < 0.001$) and revise surgery ($p < 0.001$) were strongly associated with the development of orthopedic SSI. These findings are presented in Table 2. The minimum number of participants included in the results for Table 2 was 99.7% of 1032 (1029/1032).

3.2 Boxplots showing different factors that determined the presence of infection

Admission-related factors such as duration of admission in days ($p < 0.001$); Duration of operative antibiotics usage ($p < 0.001$); Surgical-related factors like duration of surgical procedure in minutes ($p < 0.001$); and Biomarkers such as number of WBC count ($p < 0.001$) and hemoglobin level ($p < 0.001$) varied with the development of infection. However, demographic factors such as age ($p = 0.066$) and admission-related factors such as duration of pre-operative stay in days ($p = 0.118$) did not determine infections.

However, those who developed SSI reported lower HB values than those without infection (Fig. 1).

3.3 Multiple logistic regression analysis on the determinants of orthopedic SSIs

Multivariate analyses after controlling for co-variates revealed that demographic characteristics, admission-related factors, surgical-related factors and postoperative antibiotic usage were associated with orthopedic SSI. Specifically, demographic factors such as male gender (AOR = 2.33, 95% CI 1.04, 5.61, $p = 0.048$); self-employed (AOR = 3.25, 95% CI 1.2, 10.29, $p = 0.030$); unemployed/retired (AOR = 4.61, 95% CI 1.35, 17.72, $p = 0.019$); surgical-related factors such as revised

Table 2 Bivariate analysis on surgical-related factors associated with orthopedic SSIS

	Presence of infection		Total (%)	p-value	COR (95% CI)
	Yes (%)	No (%)			
Type of fracture (N = 1032)					
None	10 (3)	318 (97)	328 (31.8)	< 0.001	0.07 (0.03, 0.15)
Closed	47 (8.1)	530 (91.9)	577 (55.9)	< 0.001	0.20 (0.12, 0.32)
Open	39 (30.7)	88 (69.3)	127 (12.3)		
Urethral catheterization (N = 1031)					
Yes	69 (17.8)	318 (82.2)	387 (37.5)	< 0.001	4.96 (3.11, 7.89)
No	27 (4.2)	617 (95.8)	644 (62.5)		
Presence of IV lines (N = 1031)					
Yes	96 (9.4)	920 (90.6)	1016 (98.5)	0.385	
No	0 (0)	15 (100)	15 (1.5)		
Presence of surgical drain (N = 1032)					
Yes	20 (60.6)	13 (39.4)	33 (3.2)	< 0.001	18.68 (8.95, 39.02)
No	76 (7.6)	923 (92.4)	999 (96.8)		
Wound infection on admission (N = 1032)					
Yes	24 (80)	6 (20)	30 (2.9)	< 0.001	51.67 (20.46, 130.45)
No	72 (7.2)	930 (92.8)	1002 (97.1)		
Obesity (N = 1032)					
Yes	14 (38.9)	22 (61.1)	36 (3.5)	< 0.001	7.09 (3.50, 14.39)
No	82 (8.2)	914 (91.8)	996 (96.5)		
Blood transfusion (N = 1032)					
Yes	27 (22)	96 (78)	123 (11.9)	< 0.001	3.42 (2.09, 5.60)
No	69 (7.6)	840 (92.4)	909 (88.1)		
Revision surgery (N = 1029)					
Yes	51 (38.9)	80 (61.1)	131 (12.7)	< 0.001	12.37 (7.78, 19.68)
No	44 (4.9)	854 (95.1)	898 (87.3)		

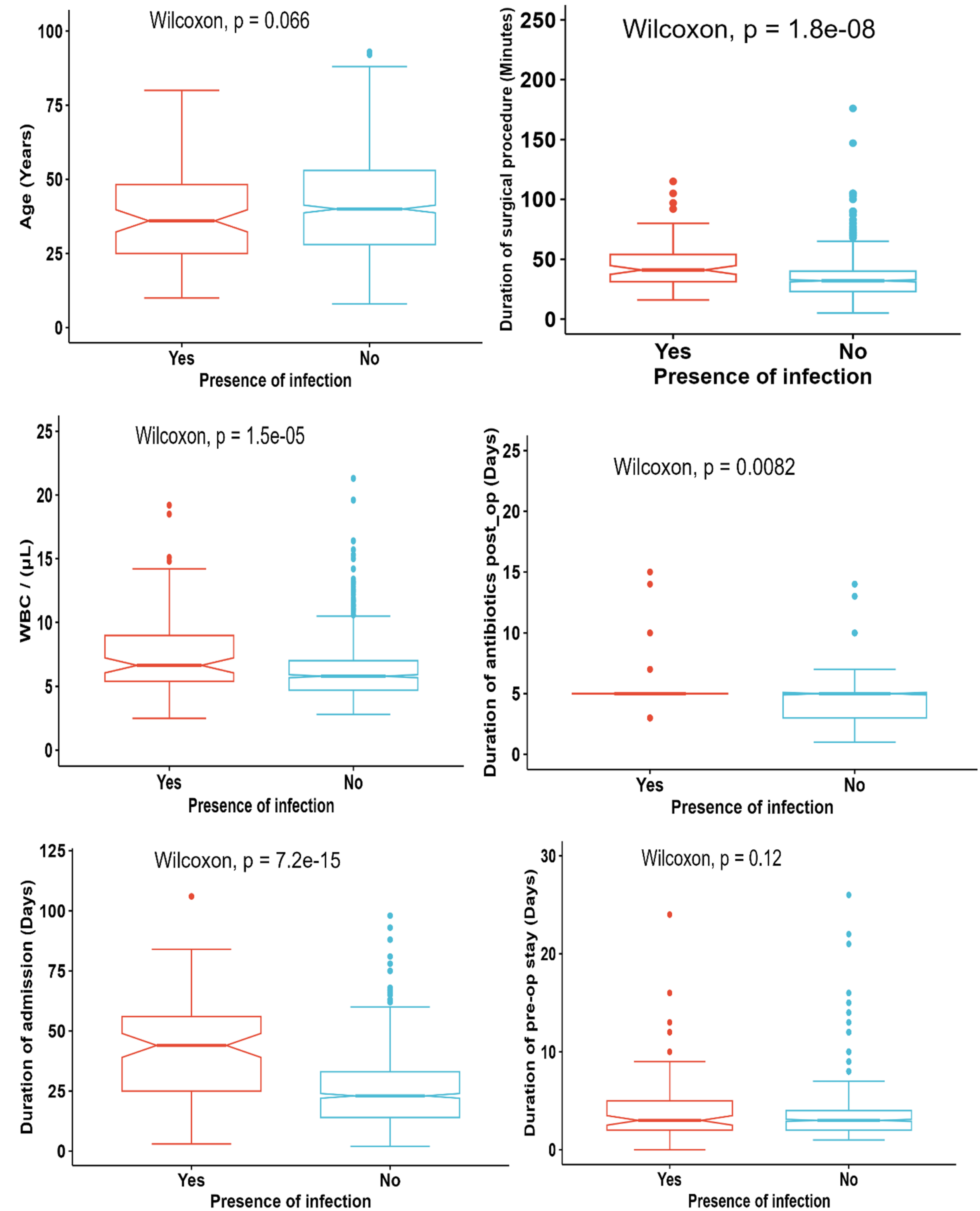

Fig. 1 Boxplots showing differences in biomarkers by the presence of infection. WBC: White Blood Cell (µL)

surgery (AOR = 9.89, 95% CI 5.32, 18.79, p < 0.001); prolong hospital admission (AOR = 1.03, 95% CI 1.01, 1.05, p = 0.002); prolong number of days on postoperative antibiotics (AOR = 1.21, 95% CI 1.00, 1.46, p = 0.045) were associated with SSI. The number of participants included in the logistic regression model (Table 3) was 87.4% of 1032 (902/1032).

Table 3 Multiple logistic regression analysis on the determinants of orthopedic SSI

Predictors (N = 902)	AOR (95% CI)	p-value	GVIF	Df	$GVIF^{(1/(2*Df))}$
Age	0.99 (0.97, 1.01)	0.400	1.98	1	1.41
Sex [Male]	2.33 (1.04, 5.61)	0.048	1.50	1	1.23
Marital status [Married]	0.88 (0.36, 2.19)	0.778	2.22	1	1.49
Religions [Christian]	1.57 (0.62, 4.08)	0.348	2.84	1	1.68
Occupation [Housewife]	1.54 (0.22, 9.09)	0.643	2.47	3	1.16
Occupation [Self-employed]	3.25 (1.2, 10.29)	0.030			
Occupation [Unemployed/Retired]	4.61 (1.35, 17.72)	0.019			
Duration of pre-op stay days	1.06 (0.97, 1.16)	0.182	1.11	1	1.05
Duration of admission days	1.03 (1.01, 1.05)	0.002	1.27	1	1.13
Number of days on postoperative antibiotics	1.21 (1.00, 1.46)	0.045	1.20	1	1.10
Type of fracture [Closed]	0.41 (0.19, 0.87)	0.020	2.05	2	1.20
Type of fracture [None]	0.44 (0.13, 1.35)	0.159			
Duration surgical procedure	1.01 (0.99, 1.02)	0.421	1.36	1	1.17
NHIS [Yes]	1.14 (0.46, 3.08)	0.791	1.13	1	1.06
Blood transfusion [Yes]	1.49 (0.73, 2.99)	0.268	1.21	1	1.10
WBC Count	1.04 (0.98, 1.08)	0.050	1.15	1	1.07
Haemoglobin level	1.00 (0.97, 1.03)	0.811	1.09	1	1.04
Revision Surgery [Yes]	9.89 (5.32, 18.79)	< 0.001	1.23	1	1.11
Urethral catheterization [Yes]	1.65 (0.83, 3.30)	0.154	1.37	1	1.17
Ethnic Group [Dagomba]	1.62 (0.39, 6.27)	0.493	3.91	3	1.26
Ethnic Group [Others]	0.50 (0.08, 2.09)	0.392			
Ethnic Group [Waala]	1.40 (0.51, 3.86)	0.514			
Site [Below Elbow]	0.80 (0.13, 4.52)	0.796	1.67	4	1.07
Site [Below Knee]	1.97 (0.60, 7.93)	0.295			
Site [Knee/Above Knee]	1.52 (0.46, 6.15)	0.525			
Site [Others]	1.01 (0.04, 9.72)	0.995			

$GVIF^{(1/(2*Df))}$: Generalized variance inflation factors for predictors of infection; AOR: adjusted odds ratio

3.4 ROC curve for the logistic regression model

The logistic regression model was accurately fitted (286.17, p < 0.001), with McFadden, Cox and Snell, and Nagelkerk Pseudo R-squared values of 0.45, 0.27, and 0.54, respectively. The model also showed an appropriate ROC curve implying a good model data fit (Fig. 2). The values of the generalized variance inflation factor for the independent variables were less than the threshold of 2.24, hence these independent variables were maintained in the model since there is no collinearity among them.

4 Discussions

This study provides comprehensive evidence on the prevalence and risk factors of SSI among patients who underwent orthopedic surgery in rural Ghana. SSI is a ubiquitous complication after orthopedic surgery and a significant contributor to morbidity and mortality in persons undertaking orthopedic surgery [30].

The overall prevalence of SSI among orthopedic patients was 9.3% in the current study. Our finding is lower compared to a similar study in Iran, a LMIC which reported a prevalence of 18.2% of infections after orthopedic surgeries [15]. In a similar study in Tanzania, the prevalence was 25.0% [31] was reported. In contrast, the current finding is higher when compared to other findings in India 7.6% [19], and in Malaysia. However, in USA, the SSI rates were 1.2% and 3.4% respectively [3, 20]. It is reported that orthopedic procedures generally present with relatively lower SSI rates than other procedures in both high and some low and middle-income countries [19]. Previous studies have revealed

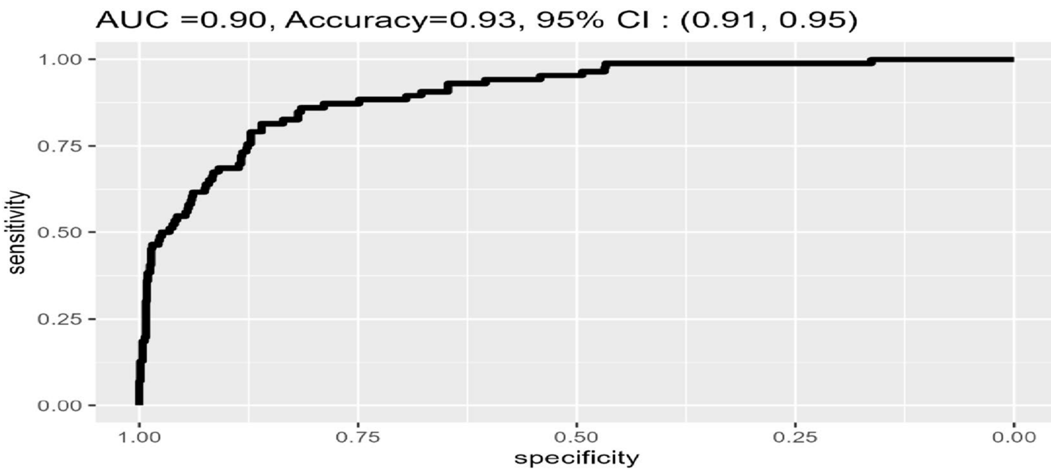

Fig. 2 ROC curve for the logistic regression model

that SSI incidence following orthopedic surgery ranges between 3.4% [20] in developed countries to over 7.6% [19] in developing countries. The explanation for the variations could be somewhat due to the implementation of aseptic measures and strict policies for managing surgical cases in advanced countries compared to some developing [19]. Infections following orthopedic surgeries remain a challenging dilemma for healthcare professionals. Several factors could prove useful in mitigating the development of SSI. Improvement in air-conditioning in operating rooms, appropriate sterilization of surgical equipment, and availability of disinfectants [6, 7] are crucial in this fight. Furthermore, encouraging preoperative bathing before surgery on the night before it, [7] and using electric clippers to shave the surgical site on the day of surgery [8] have proven to reduce the incidence of SSI among orthopedic patients.

The risk for developing SSI related to orthopedic surgeries is multifactorial. Identifying these risk factors is essential in preventing or eliminating SSI. Multivariate logistic analysis in our study revealed that demographic factors such as sex was strongly associated with SSI among orthopedic surgeries. Males were twice as likely to develop infections compared to females. This finding corroborates other findings where SSI was higher in males who underwent orthopedic surgical procedures compared to females, [32] Moreover, a study in India confirmed our findings [19]. In contrast, SSI was identified to be high among females who underwent different surgical procedures other than orthopedic procedures. Notably, one study reported that females who underwent heart, vascular, and hernia surgeries were more likely to develop SSI than males [32]. A possible explanation for the gender-related disparity in SSI rates among orthopedic cases could potentially be the result of higher colonization rates with *Staphylococcus aureus* where higher colonization is seen in men [33]. Factors such as increased tobacco and alcohol usage [3, 24] and increased mechanisms of injuries [34] associated more with male sex may be the reason they develop SSI in orthopedic cases compared to females. Contrary, some studies did not corroborate our finding [35, 36] thus making sex an inconclusive determinant of SSI. Besides, another demographic factor such as status of employment was found to be significantly associated with SSI among orthopedic surgeries. Patients who were unemployed and self-employed were more likely to develop SSI. The reason is that being unemployed or self-employed may place financial burden on the individual and this may result in poor hygiene, nutrition, and access to healthcare. Our finding is congruent with another finding which reported that unemployment and self-employment are associated with an increased risk of SSI [18].

Additionally, postoperative antibiotic usage was a determinant in SSI among orthopedic surgical cases. In clinical practice, broad-spectrum antibacterial medications are predominantly employed to suppress or eradicate microorganisms thereby preventing SSI. Administration of prophylactic antibiotics before surgery helps to reduce SSI rates to 1–3% compared to 4–8% among patients who did not receive prophylactic antibiotics. The timing of prophylactic antimicrobial administration is even more essential as it is associated with SSI rates [31]. De Jonge et al. reported that prophylactic antibiotics should be administered within 1 h before a surgical incision [37]. Nonetheless, long usage of antibiotics increases the chances of antibiotic resistance which may likely contribute to SSI [19]. Our study reported that the prolonged duration of postoperative antibiotic usage influenced the development of SSI. The current finding is consistent with a previous finding [19]. Microbial resistance to antibiotics predisposes patients to various forms of complicated infections. There needs to be a review of antibiotic usage in surgical cases, especially among orthopedic surgeries, and the WHO is leading this course. The WHO global guidelines for preventing SSI recommend the importance of appropriate timing, dosing, and administration of antibiotics to eliminate any possibility of resistance. The guidelines further require that the decision to use an antibiotic should be based on local epidemiology and susceptibility patterns and duration of administration should be shortened [7].

Admission-related factors such as prolonged number of days on admission was associated with SSI in this study. In our study, the median length of hospital stay was significantly higher (44 days) among patients with infections while it was (23 days) for those without infections. Overall, the median length of stay was 23 days in the current study. This finding corroborates other studies in India, Rwanda, and Tanzania respectively where prolonged hospitalization was associated with SSI [16, 19, 31]. Prolonged preoperative stay may have contributed to SSI. Prolonged stay is associated with increased bacterial colonization. It is also associated with long antibiotic usage causing bacterial resistance against antimicrobial agents. Interestingly, St. Theresa's Hospital does not have a specialized ward where orthopedic surgical cases are managed. All surgical cases are managed in the general female and male surgical wards. Cleanliness and set up of the wards, level of staff training on wound care, and availability of infection prevention and control measures could promote infections in the ward while the patients are on admission. Therefore, shortening preoperative hospital stays, training staff on effective wound care practices, effective ward cleanliness, and adherence to hand hygiene practices are crucial to prevent SSI.

Furthermore, an important biomarker of infection, white blood cell (WBC) is an established risk factor for SSI [38]. In the current study, an increased level of WBCs was identified as a risk factor for orthopedic SSI. A high level of WBCs may indicate a compromised immunity making the body unable to fight infections. This may lead to higher chances of SSI. Elevated white blood cells may also indicate an ongoing inflammatory process in the body, which may indicate infection at the surgical site [38]. Instructively, healthcare professionals should monitor postoperative WBC levels early to detect and treat these infections promptly.

Lastly, surgical-related factors such as revision surgery was associated with orthopedic SSI. Our finding corroborates a recent similar study that reports that revision surgery for orthopedic trauma is associated with a high risk of infection [39]. Revision surgery is often associated with re-operating previously healed tissues, which can damage surrounding soft tissues allowing for bacterial colonization and subsequent infections. Another possible explanation is that revision surgeries usually take a longer time increasing the risk of infections among orthopedic surgeries [40, 41]. Measures such as appropriately sterilizing surgical instruments before use, disinfecting used instruments, encouraging patients to bath the night before surgery, and ensuring a competent surgical team [6, 7] will likely reduce the chances of infections related to revision surgeries.

Logistic regression analysis is a useful statistical tool for modeling in medical research due to the categorical nature of many response variables in the medical field [42]. This tool is recommended when the response variable is dichotomous and needs to be predicted using independent variables. This statistical tool is both a regression method and a machine learning algorithm applicable in regression and classification models [43]. In this study, SSI is a dichotomous response variable, hence the logistic regression model became very useful. This method has been widely applied, especially in medical research [43, 44].

5 Strengths of the study

This study presented many strengths amidst some limitations.

- This study is the first to be conducted in a primary health facility in Ghana. The inclusion of a plethora of factors in the data analysis with results of highly significant associations and odds of SSI in the regression model validates the data used.
- This study provides a valuable basis for a large-scale study on the prevalence and risk factors of orthopedic surgical site infection in Ghana.

6 Limitations of the study

- Due to poor records keeping, there were incomplete records pertaining to the data resulting in the exclusion of these incomplete records from the final data set.

- This was a single facility-based study and thus limits the possibility of generalizing findings. Nonetheless, the findings are relevant to inform policy dialog on SSI prevention.
- Also, information such as characteristics of healthcare professionals involved in the surgery, the types of antiseptic lotions used for skin preparation, methods used for equipment sterilization, and the type of anesthesia used which could influence the outcome of orthopedic surgery were not included.
- Lastly, body mass index and smoking which have previously been found to be associated with SSI were not included in the current due to insufficient data.

7 Conclusion

The overall prevalence for this study was 9.3%. Factors such as sex, occupation, prolonged use of postoperative antibiotics, elevated white blood cell count, and revised surgery, and prolonged number of days on admission were the determinant of orthopedic surgical site infections. The findings provide evidence on the prevalence and risk factors associated with orthopedic surgical site infections. These findings provide the basis for scaling up national surveillance on the impact of orthopedic surgeries in Ghana. The findings further provide a platform for policy dialog on developing and implementing evidence-based protocols on surgical wound management, and the effective use of antibiotics postoperatively.

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Author contributions SMS, RA, and HB conceptualized the study; RA, HB, and CWL curated the data; SMS developed the data extraction tool; SMS, RA, DA, HB, and CWL extracted the data; SMS, DA, and HB processed the data (cleaning and coding); DA conducted the formal data analysis; SMS wrote the original draft; SMS, RA, DA, HB, and CWL administered the project; SMS and RA Validated the study; SMS, RA, DA, HB, and CWL reviewed and edited the final paper.

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Data availability The authors declare that all data for the study are available to the general public upon a reasonable request from the corresponding author.

Declarations

Competing interests The authors declare no competing interests.

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