IJID Regions 14 (2025) 100565

Contents lists available at ScienceDirect

IJID Regions

journal homepage: www.elsevier.com/locate/ijregi

Bacterial surgical site infections: prevalence, antimicrobial susceptibility patterns, and associated risk factors among patients at Bule Hora University Teaching Hospital, Southern Ethiopia

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ARTICLE INFO

Keywords:
Surgical site
Antimicrobial susceptibility
Bule Hora University
Teaching hospital

ABSTRACT

Objectives: Surgical site infections occur within 30 days of an invasive surgical procedure in the parts of the body where the surgery is performed. Therefore, this study aimed to determine the prevalence, antimicrobial susceptibility patterns, and associated risk factors of surgical site infections at Bule Hora University Teaching Hospital, Southern Ethiopia.

Methods: An institution-based cross-sectional study was conducted with 183 consecutively enrolled participants between 1 January and 30 June 2023. Microbiological identification and antimicrobial susceptibility testing of the organisms isolated from clinical samples were performed aseptically. Data were collected using a questionnaire and analysed using SPSS version 26.

Results: The overall prevalence of surgical site infections was 15.8% (95% CI, 10.9-22). The predominant isolate was *Staphylococcus aureus* (n = 14; 34.1%). There were 18 (43.9%) multidrug-resistant isolates. Age group >54 (adjusted odds ratio [AOR] = 4.76, 95% CI, 1.10-20.560), hospital stay ≥10 days (AOR = 2.66, 95% CI, 1.06-6.66],), operation duration ≥2 hours (AOR = 2.64, 95% CI, 1.01-6.90), clean-contaminated wound (AOR = 3.17, 95% CI, 1.21-8.30), open surgical site (AOR = 2.64, 95% CI, 1.02-6.86), and malnutrition (AOR = 4.3, 95% CI, 1.42-12.97) were significantly associated with surgical site infections.

Conclusions: The prevalence of surgical site infections and multidrug-resistant isolates is higher compared with World Health Organisation reports or previous studies. This finding emphasises the need for routine screening and antimicrobial susceptibility testing to prevent and control site infections.

Background

Surgical site infection (SSI) is an infection that occurs after an invasive surgical procedure in parts of the body where surgery is performed. It occurs within 30 days after surgery and affects the incision or deep tissue at the surgical site [1,2]. SSI is responsible for over one-third of postoperative deaths [3]. These infections prolong the duration of a patient's hospital stay and, therefore, increase the cost of healthcare [3–5].

The occurrence of SSIs is determined by the contamination level of the surgical site and the pathogenicity of microorganisms, balanced against the host's immune response [5]. The level of surgical site contamination at the time of surgery influences the probability of SSIs. Surgical wounds are categorised as clean, clean-contaminated, or contaminated [6,7]. The predominant organisms isolated from SSIs are *Staphylococcus aureus, Escherichia coli, Klebsiella, and Pseudomonas* species [8–11]. An organism causing SSIs is usually derived from the host's internal environment, surgical materials, or the theatre environment during the operation, leading to exogenous causes of infection. Therefore, infection prevention and control practices can minimise the risk of SSIs [12].

The resistance patterns of bacteria vary globally. An increase in antimicrobial resistance in hospitals and communities, such as Methicillin-resistant *S. aureus* and Vancomycin-resistant *S. aureus*, is associated with the use of antibiotics [13,14]. Although the development of antibiotic resistance presents a challenge to the efficient management of bacterial infections, the introduction of antimicrobial therapy in SSI management reduces treatment costs, prolonged hospital stays, and significant morbidity and mortality caused by these infections [15]. Risk fac-

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https://doi.org/10.1016/j.ijregi.2024.100565
Received 23 December 2024; Received in revised form 29 December 2024; Accepted 30 December 2024

tors for developing SSIs include patient age, duration of surgery, prolonged hospital stay, comorbidities, malnutrition, and the surgical site [16,17].

SSIs are among the most common postoperative complications and represent the most common type of health-care-associated infection (HAI) in both developed and developing countries [6,9,18]. They are responsible for approximately 20% of readmissions [19]. SSIs lead to increased mortality, morbidity, reoperation, prolonged hospital stays, loss of daily wages, and increased healthcare costs, all of which are considerably higher in cases involving antimicrobial-resistant organisms [20]. The global proportion of SSIs ranges from 2.5-41.9%, with a high risk of HAI in patients undergoing surgery, and 77% of hospital-acquired infections are related to SSIs [21]. In the USA, the proportion of SSIs is 2-5%, accounting for 3% of postoperative mortality [8]. In Latin America, Asia, and China, SSI prevalence has been reported at 7%, 4%, and 4%, respectively [22].

In developing countries, the prevalence of SSIs is higher than in the developed world, with varied reports [23]. In African hospitals, SSIs are the primary infections [24], with a cumulative incidence ranging from 2.5-30.9% [3,25]. In Ethiopia, the incidence rate of SSIs ranges from 10.9-75% [26,27]. The antimicrobial resistance patterns of bacteria related to SSIs vary globally, depending on local epidemiology reports, region, and susceptibility testing methodology. Bacterial resistance presents a significant challenge and requires complex treatment. Most antimicrobial resistance data have been obtained from advanced countries [28]. Limited reports exist on the prevalence and incidence of resistant bacteria causing SSIs, especially in developing countries [29].

Methods and materials

Study area, period and design

The study was conducted at Bule Hora University Teaching Hospital, which is located in Bule Hora town, from 1 January to 30 June 2023. The town is situated 470 km from Addis Ababa, the capital of Ethiopia. Bule Hora University Teaching Hospital was established in 1990 E.C. and currently provides healthcare services to more than 1.3 million people in Bule Hora and neighbouring regions, including the Southern Nations, Nationalities, and Peoples' Region. This was an institution-based, cross-sectional study.

Study population

The study population comprised all individuals who underwent surgical treatment at Bule Hora University Teaching Hospital during the study period and exhibited signs of SSIs.

Inclusion and exclusion criteria

All patients with signs of SSI, based on the criteria stated by the World Health Organisation (WHO) and the Centers for Disease Control and Prevention (CDC) during the data collection period, were included. Patients with incomplete charts, those who underwent surgery at another institution, and those with nonoperative wounds or abscesses were excluded.

Sample size determination

The sample size was calculated using a single population proportion formula, considering a 95% confidence level (CI), a 5% margin of error, and a 13% estimated proportion of SSIs among patients who underwent surgery in Ethiopia [31].

$$n = \frac{Z^2_{\alpha/2}\ P(1-p)}{d^2} = n = \frac{(1.96^2\ )(0.13)(1-0.13)}{0.05^2} = 174 + 5\% = 183$$

Sampling technique and data collection procedure

Samples were collected consecutively from all participants who fulfilled the inclusion criteria until the required sample size was obtained. Two trained nurses collected data and samples under the supervision of the principal investigator. Training was provided to the data collectors for two days (one day theoretical and one day practical) by a principal investigator prior to data and sample collection. Sociodemographic and clinical data were collected using a predesigned semi-structured questionnaire through face-to-face interviews and medical record reviews. This study followed the CDC SSI surveillance methods [31].

The clinical diagnosis of SSIs was performed by the attending physician. Clinical features of the surgical site, such as pain, redness, swelling, warm skin around the wound, yellow or green discharge, unpleasant odour, fever, and chills, were considered indicative of SSI. Participants were asked to sign an informed consent form before participating in the study. Wound swabs were collected aseptically using sterile cotton swabs, and deep wound aspirates were collected aseptically by trained nurses. Specimens were coded using a specific identification number. The sample was transported to the Medical Laboratory Sciences Department microbiology skill laboratory of Bule Hora University within 2-4 hours using Amies transport medium, maintaining a temperature of 37°C.

Microbiological analysis

Culture and identification

Clinical samples collected were seeded on blood agar, nutritional agar, MacConkey agar, and mannitol salt agar, then incubated for 24-48 hours at 37°C to observe bacterial growth. The organisms were identified based on colony characteristics, haemolytic appearance, differential properties of the culture media, and Gram reaction [32,33]. Identification by biochemical tests, including catalase and coagulase for Gram-positive cocci, as well as catalase, oxidase, urease, indole, and citrate utilisation, lysine decarboxylation, glucose and lactose fermentation, gas and H_2S production, and motility tests, was performed [34].

Antimicrobial susceptibility test

The antimicrobial susceptibility patterns of the isolated organisms against locally available antimicrobials were determined using the Kirby-Bauer agar diffusion method on Mueller-Hinton agar. Three to five colonies from the overnight growth strains were inoculated into a tube containing peptone broth and incubated overnight at 37°C. Standardisation of the inoculum was performed by diluting the broth cultures until turbidity matched the 0.5 McFarland standard, according to the recommendations of the Clinical Laboratory Standards Institute (CLSI) [36,37]. Antibiotic discs were placed using sterile forceps, and the plates were incubated for 24 hours at 37°C. The diameter of the zone of inhibition around the discs was measured and recorded to the nearest millimetre using a ruler, and the isolates were classified as sensitive, intermediate, or resistant based on the CLSI standard table [38]. Antimicrobial susceptibility tests were carried out using the following antibiotics (Oxoid, UK): Amoxicillin (AMC, 20/10 μg), Ceftriaxone (CRO, 30 μg), Ampicillin (AMP, 25 μg), Cloxacillin (COX, 5 μg), Ceftazidime (CAZ, 30 μg), Cefoxitin (FOX, 30 μg), Gentamicin (GN, 10 μg), Clindamycin (DA, 2 μg), Penicillin (P, 10 μg), Tetracycline (TE, 30 μg), and Chloramphenicol (CAP, 30 μg). The selection of antimicrobials was based on the availability of drugs in the study area and recent CLSI recommendations [35].

Quality assurance

The questionnaire was initially developed in English and translated into Afaan Oromoo by consulting experts from related fields. Pretesting of the questionnaire and processing of all activities were performed using the principal investigator. For all microbiological investigations, swabs were collected using an aseptic technique. All laboratory processes were quality assured using standard operative procedures and quality control. All swabs and isolation procedures were performed aseptically. Media were prepared according to the manufacturer's instructions, and sterility was tested. *E. coli (*ATCC 25922*), S. aureus (ATCC 25923), and P. aeruginosa (ATCC 27853)* strains were used to check the quality of the prepared media and the antimicrobial susceptibility testing procedure. All laboratory microbiological results were checked, recorded, and documented.

Data analysis

The collected data were coded, entered by EpiData version 4.6, then exported to the Statistical Package for the Social Sciences (SPSS) version 26 software program for analysis. Data were organised, summarised, and presented using descriptive statistics. Bivariate and multivariate logistic regression analyses were performed to assess associations between variables. The strength of the association between SSIs and risk factors was expressed using the adjusted odds ratio. Variables with a *P*-value <0.25 in the bivariate analysis were further analysed using multivariate logistic regression. A multivariate logistic regression analysis model was fitted to control for confounders and obtain independent predictors of the prevalence of SSI. A backward stepwise regression was used. A *P*-value <0.05, with 95% CI, was considered statistically significant.

Results

Sociodemographic characteristics of the study participants

In total, 183 participants were enrolled in this study. The age of respondents ranged from 1-95 years, with a mean age of 31.65 (±19.357). Most study participants (40.5%) were in the age range of 19-36 years. Among the participants, males accounted for 55.2%, and more than half of the participants were rural residents (57.4%). A total of 50.3% of the participants had no formal education, and most (72.7%) were unemployed (Table 1).

Distribution of clinical factors

Concerning clinical factors, 130 (71.0%) participants had no history of hospitalisation, and 167 (91.3%) were admitted to the public wing ward. Among all respondents, 100 (54.6%) had a hospital stay of less than 10 days. Emergency surgery was performed in approximately 139 (76.0%) participants, and for 146 (79.8%) participants, the procedure took less than two hours. Local anaesthesia was administered 117 (63.9%) participants; 38 (20.8 %) had a clean-contaminated wound, 45(24.6%) had an open surgical site, and 23(12.6%) showed signs and symptoms of malnutrition. Antibiotic prophylaxis was administered to 97 (53.0%) participants, and 34(18.6%) had an implant inserted at the site of surgery (Table 2).

Table 1
Sociodemographic characteristics of study participants in Bule Hora University Teaching Hospital, Bule Hora, 2023 (n = 183).

Variables	Category	Frequency	
		Number (N)	Percent (%)
Sex	Male	101	55.2
	Female	82	44.8
Age group	1-18	46	25.1
	19-36	74	40.5
	37-54	35	19.1
	>54	28	15.3
Residence	Urban	78	42.6
	Rural	105	57.4
Have a formal education	Yes	91	49.7
	No	92	50.3
Occupation	Employed	50	27.3
	Unemployed	133	72.7

Table 2
Distribution of clinical factors associated with SSIs at Bule Hora University Teaching Hospital, Bule Hora, 2023.

Variables	Category	Frequency	
		Number (N)	Percent (%)
History of previous hospitalisations	Yes	53	29.0
	No	130	71.0
Ward condition	Private	16	8.7
	Public	167	91.3
Total duration of hospital stays	<10 days	100	54.6
	≥10 days	83	45.4
Duration of operation	<2 hours	146	79.8
	≥2 hours	37	20.2
Type of surgery	Elective	44	24.0
	Emergency	139	76.0
Type of anaesthesia	Local	117	63.9
	General	66	36.1
Type of wound	Clean	145	79.2
	Clean-contaminated	38	20.8
Condition of surgical site	Opened	45	24.6
	Closed	138	75.4
Implant inserted at surgical site	Yes	34	18.6
	No	149	81.4
Antibiotic prophylaxis given	Yes	97	53.0
	No	86	47.0
History of alcohol use	Yes	41	22.4
	No	142	77.6
Symptom of malnutrition	Yes	23	12.6
	No	160	87.4

Prevalence of surgical site infections

In this study, the general prevalence of culture-confirmed SSIs was 15.8% (29/183) (95% CI, 10.9-22). A total of 41 bacteria were isolated, and about 21(51.2%) of them were Gram-positive cocci, whereas the remaining 20 (48.8%) were Gram-negative rods. Approximately 12 (44.4%) swabs showed mixed bacterial growth, and the remaining were single bacterial isolates. *S. aureus* (14, 34.1%) was the predominant isolate, followed by coagulase-negative *staphylococci* (7, 17.1%), *E. coli* (6, 14.6%), *P. aerogenosa* (6, 14.6%), *Klebsiella spp.* (5, 12.2%), and *Proteus spp.* (3, 7.3%).

Antimicrobial susceptibility patterns

Antimicrobial susceptibility patterns for Gram-positive isolates

Of the 14 (34.1%) *S. aureus* isolates, the highest sensitivity was observed for CAP (13, 92.9%), followed by DA (12, 85.7%), ciprofloxacin (10, 71.4%), cloxacillin (10, 71.4%), COX (9, 64.3%), AMC (8, 57.1%) and FOX (6, 42.9%). The highest resistance rates were observed for CAZ (11, 78.6%) and P (11, 78.6%). Additionally, 8 (57.1%) of *S. aureus* isolates were resistant to FOX, indicating the presence of Methicillin-resistant *S. aureus.*

The antimicrobial susceptibility patterns of coagulase-negative *staphylococci* showed the highest sensitivity for COX (7, 100%), AMC (7, 100%) and CAP (7, 100%), followed by CRO, ciprofloxacin, and DA (6, 85.7%) each, and FOX (4, 57.1%), whereas the highest resistance was observed for P (5, 71.4%), followed by CAZ (4, 57.1%) (Table 3).

Antimicrobial susceptibility patterns for Gram-negative isolates

In this study, Gram-negative Enterobacteriaceae, such as *E. coli, P. aerogenosa, Klebsiella spp.* and *Proteus spp.* were isolated. Of the six (14.6%) *E. coli* isolates, the highest sensitivity was observed for ciprofloxacin (5, 83.3%), followed by TE (4, 66.7%), CRO (3, 50%), and GN (3, 50%). The highest resistance was observed against CAZ (5, 83.3%) and AMP (5, 83.3%), followed by P (4, 66.7%) and AMC (4, 67.7%).

Table 3
Antimicrobial susceptibility patterns of Gram-positive bacteria isolated from SSIs in Bule Hora University Teaching Hospital, 2023 (N = 21).

		Antimicrobials								
Bacterial species	P	Cefoxitin	Penicillin	Ceftriaxone	Ciprofloxacin	Cloxacillin	Amoxicillin	Clindamycin	Chloramphenicol	Ceftazidime
S. aureus (n = 14)	S	6 (42.9%)	3 (21.4%)	9 (64.3%)	10 (71.4%)	10 (71.4%)	8 (57.1%)	12 (85.7%)	13 (92.9%)	3 (21.4%)
	I	0 (0%)	1 (7.1%)	3 (21.4%)	1 (7.1%)	2 (14.3%)	1 (7.1%)	0 (0%)	0 (0%)	1 (7.1%)
	R	8 (57.1%)	10 (71.4%)	2 (14.3%)	3 (21.4%)	2 (14.3%)	5 (35.7%)	2 (14.3%)	1 (7.1%)	10 (71.4%)
CONS (n = 7)	S	4 (57.1%)	2 (28.6%)	6 (85.7%)	6 (85.7%)	7 (100.0%)	7 (100.0%)	6 (85.7%)	7 (100.0%)	3 (42.9%)
	I	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (14.3%)
	R	3 (42.9%)	5 (71.4%)	1 (14.3%)	1 (14.3%)	0 (0.0%)	0 (0.0%)	1 (14.3%)	0 (0.0%)	3 (42.9%)
Total (n = 21)	S	10 (47.6%)	5 (23.8%)	15 (71.4%)	16 (76.2%)	17 (81.0%)	15 (71.4%)	18 (85.7%)	20 (95.2%)	6 (28.6%)
	R	11 (52.4%)	16 (76.2%)	6 (28.6%)	5 (23.8%)	4 (19.0%)	6 (28.6%)	3 (14.3%)	1 (4.8%)	15 (71.4%)

CONS, Coagulase-negative *staphylococci*; I, intermediate; P, pattern; R, resistance; S, sensitive; SSIs, Surgical site infections.

Table 4
Antimicrobial susceptibility profiles of Gram-negative bacteria isolated from Bule Hora University Teaching Hospital, 2023 (N = 20).

		Antimicrobials							
Bacterial species	P	*Penicillin*	*Ceftriaxone*	*Ciprofloxacin*	*Amoxicillin*	*Tetracycline*	*Ampicillin*	*Ceftazidime*	*Gentamycin*
E. coli (n = 6).	S	2 (33.3%)	3 (50.0%)	545 (83.3%)	2 (33.3%)	4 (66.7%)	1 (16.7%)	1 (16.7%)	3 (50.0%)
	I	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (16.7%)	0 (0%)	0 (0%)	0 (0%)
	R	4 (66.7%)	3 (50.0%)	1 (16.7%)	4 (66.7%)	1 (16.7%)	5 (83.3%)	5 (83.3%)	3 (50.0%)
P. aerogenosa (n = 6)	S	3 (50.0%)	3 (50.0%)	6 (100.0%)	4 (66.7%)	3 (50.0%)	2 (33.3%)	2 (33.3%)	4 (66.7%)
	I	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (33.3%)	0 (0%)	1 (16.7%)	0 (0%)
	R	3 (50.0%)	3 (50.0%)	0 (0.0%)	2 (33.3%)	1 (16.7%)	4 (66.7%)	3 (50.0%)	2 (33.3%)
Klebsiella spp. (n = 5)	S	4 (80.0%)	3 (60.0%)	5 (100.0%)	4 (80.0%)	3 (60.0%)	4 (80.0%)	4 (80.0%)	4 (80.0%)
	I	1 (20.0%)	1 (20.0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
	R	0 (0%)	1 (20.0%)	0 (0.0%)	1 (20.0%)	2 (40.0%)	1 (20.0%)	1 (20.0%)	1 (20.0%)
Proteus spp. (n = 3)	S	2 (66.7%)	3 (100.0%)	2 (66.7%)	3 (100.0%)	1 (33.3%)	3 (100.0%)	2 (66.7%)	1 (33.3%)
	I	0 (0%)	0 (0%)	1 (33.3%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
	R	1 (33.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (66.7%)	0 (0.0%)	1 (33.3%)	2 (66.7%)

I, intermediate; P, pattern; R, resistance; S, sensitive.

Table 5
Multidrug resistance pattern of bacteria isolated from Bule Hora University Teaching Hospital, 2023.

Bacterial isolates	Ro	R1	R2	R3	≥R4	MDR
S. aureus (N = 14)	0 (0%)	2 (14.2%)	4 (28.6%)	4 (28.6%)	4 (28.6%)	8 (57.1%)
CoNS (N = 7)	0 (0%)	2 (28.6%)	2 (28.6%)	2 (28.6%)	1 (14.2%	3 (42.8%)
E. coli (N = 6)	0 (0%)	0 (0%)	3 (50%)	1 (16.7%)	2 (33.3%)	3 (50%)
P. aerogenosa (N = 6)	0 (0%)	1 (16.7%)	2 (33.3%)	1 (16.7%)	2 (33.3%)	3 (50%)
Klebsiella spp. (N = 5)	1 (20%)	2 (40%)	2 (40%)	0 (0%)	0 (0%)	0 (0%)
Proteus spp. (N = 3)	0 (0%)	1 (33.3%)	1 (33.3%)	0 (0%)	1 (33.3%)	1 (33.3%)
Total (N = 41)	1 (2.4%)	8 (19.5%)	14 (30.4%)	8 (19.5%)	10 (24.4%)	18 (43.9%)

Ro, resistance for no antimicrobials; R1, resistance for one class of antimicrobials; R2, resistance for two class of antimicrobials; R3, resistance for three class of antimicrobials; R4, resistance for four class of antimicrobials and above.

The antimicrobial susceptibility profile of *P. aerogenosa* showed the highest sensitivity to ciprofloxacin (6, 100%), AMC (4, 66.7%), GN (4, 66.7%), CRO (3, 50%), TE (3, 50%), and P (3, 50%). The highest resistance was observed for AMC (4, 66.7%) and CAZ (4, 66.7%).

The antimicrobial susceptibility profile of *Klebsiella spp*. showed good sensitivity to all antimicrobials tested. Among the total of 5 (12.2%) isolates, the highest sensitivity was observed for ciprofloxacin (5, 100%), followed by CAZ (4, 80%), GN (4, 80%), AMP (4, 80%), AMC (4, 80%), P (4, 80%), as well as CRO (3, 60%) and TE (3, 60%). Of the three (7.3%) *Proteus* isolates, the highest sensitivity was observed for CRO (3, 100%), AMC (3, 100%), and AMP (3, 100%); followed by ciprofloxacin (2, 66.7%), CAZ (2, 66.7%) and P (2, 66.7%), whereas the highest resistance was observed for tetracycline (2, 66.7%) and GN (2, 66.7%) (Table 4).

Multi-drug resistance pattern of bacteria isolated from Bule Hora University Teaching Hospital

Multidrug resistance is considered a significant health problem with a high rate of increase. In this study, among the 41 isolates, 18 (43.9%) (95% CI, 43-45) were multidrug-resistant (Table 5).

Factors associated with SSIs

Age groups above 54, duration of hospital stay more than 10 days, duration of surgery exceeding two hours, clean-contaminated wound type, open surgical site, and the presence of symptoms of malnutrition showed statistically significant associations with SSIs in both univariate and multivariate analyses. This study demonstrated that SSIs were higher in older age groups compared to other age groups. Participants aged above 54 were 4.76 times more likely to develop SSIs when all other factors remained constant (AOR = 4.76, 95% CI, 1.10-20.56). According to this study, patients with a prolonged hospital stay (>10 days) developed SSIs almost twice as often (22.9%) as those who stayed for less than 10 days (10%). They were 2.66 times more likely to develop SSIs when all other factors remained constant (AOR = 2.66, 95% CI, 1.06-6.66).

This study also identified that SSIs were higher in patients undergoing prolonged operations (>2 hours) (70.3%) compared to those with shorter procedures (<2 hours) (12.3%), and they were 2.64 times more likely to develop SSIs when all other factors remained constant (AOR = 2.64, 95% CI, 1.009-6.901). In this study, SSIs were found to be higher in patients with clean-contaminated wounds (31.6%) than in those with clean wounds (11.7%). Patients with clean-contaminated wounds were 3.17 times more likely to develop SSIs when all other factors remained constant (AOR = 3.17, 95% CI, 1.21-8.30).

This study shows that patients with an open surgical site are more susceptible to SSIs than those with a closed surgical site, and were 2.64 times more likely to develop SSIs when all other factors remained constant (AOR = 2.64, 95% CI, 1.02-6.86). According to this study, SSIs were higher in patients with symptoms of malnutrition (34.8%) compared to those without (13.1%), and malnourished patients were 4.3 times more likely to develop SSIs when all other factors remained constant. This indicates that the presence of symptoms of malnutrition has a statistically significant association with SSIs (AOR = 4.30, 95% CI, 1.42-12.97) (Table 6).

Discussion

In the present study, the overall prevalence of SSI was 15.8%. A total of 41 different bacteria were isolated. This result is consistent with studies conducted in Addis Ababa (11.1%) [38], Harari (11.8%) [39], Mizan-Tepi (12.6%) [40], Wolaita Sodo (13%) [30], Hawassa (19.1%) [41], western Ethiopia (19.6%) [42], and Jimma (21.1%) [43]. Similar findings have been reported in other countries, such as Sierra Leone (11.5%) [44] and India (20.8%) [45]. However, the results of this study are lower than those of other studies conducted in Dessie (23.4%) [46], Arba-Minch (29.4%) [47], and Egypt (67.6%) [48]. Conversely, the results were slightly higher than those of similar studies conducted in Addis Ababa (9.8%) [49], Gonder (9.9%) [50], the USA (7.8%) [51], and Mexico (7.9%) [52]. This variation may be attributed to differences in study populations, study periods, and sample sizes, as well as the fact that those studies involved a larger and more diverse group of participants and benefited from advanced facilities with superior infection control practices, such as modern surgical procedures, improved ventilation in operating rooms, advanced sterilisation methods, and proper patient care. Additionally, variations could result from inadequate preoperative wound care, insufficient infection control techniques due to poor hygiene, and a lack of water. Poor-quality equipment and infrastructure, a shortage of advanced supplies and trained personnel, substandard infection control techniques, and severe financial constraints in developing countries frequently contribute to the incidence of SSIs and compromised patient care [53].

In this study, among the 41 bacteria isolated from 29 patients with SSIs, approximately 21 (51.2%) were Gram-positive bacteria. This predominance of Gram-positive organisms aligns with previous studies conducted in Arbaminch [46] and Yekatit 12 hospitals [54]. The predominant organism in this study was *S. aureus* (14, 34.1%), followed by coagulase-negative *staphylococci* (7, 17.1%), *E. coli* (6, 14.6%), *P. aerogenosa* (6, 14.6%), *Klebsiella spp.* (5, 12.2%), and *Proteus spp.* (3, 7.3%). This predominance of *S. aureus* agrees with findings from previous studies in Addis Ababa (37%) [54], Arbaminch (76%) [46], Harari (30.3%) [39], Ethiopia (36%) [55], as well as studies from other countries, including India (34%), [56], and India (45.3%) [48], and Egypt (27.4%) [47]. This supports the observation that most organisms isolated from SSIs are derived from the patient's flora and the theatre environment, where *S. aureus* is a common isolate [12].

According to this study, *E. coli* was the third most predominant isolate, accounting for approximately 6 (14.65) of cases, following coagulase-negative *staphylococci*. However, other studies conducted in Addis Ababa (23.1%) [49], Mizan-Tepi, Ethiopia (29.3%) [401], and Mexico (27.5%) [52], reported *E. coli* as the most predominant isolate. This variation in predominance may be attributed to differences in study populations and the variety of surgical procedures performed. It is well established that the bacterial ethology of SSIs varies with geographical location, between countries, and even between hospitals [50]. The diversity of organisms isolated in this study is consistent with similar findings from studies conducted in Addis Ababa, Ethiopia [54], Nigeria [57], and India [56]. Furthermore, the results of this study support CDC reports, which indicate that *S. aureus,* coagulase-negative *staphylococci,* and *E. coli* are the most predominant bacteria associated with SSIs. This may be because these organisms are common causative agents of hospital-acquired infections and are frequently isolated from inanimate surfaces and medical equipment.

Among Gram-positive isolates, *S. aureus* was found to be highly resistant to P (11, 78.6%) and CAZ (11, 78.6%). The highest sensitivity of *S. aureus* was observed against CAP (13, 92.9%), followed by DA (12, 85.7%), ciprofloxacin (10, 71.4%), COX (10, 71.4%), and others, respectively. This high resistance to P and CAZ is in agreement with similar studies conducted in Harari (100%) [39], Addis Ababa (89%) [54], and India (100%) [47]. Unlike *S. aureus,* coagulase-negative *staphylococci* showed little variation in the degree of sensitivity, as they were almost 100% sensitive to COX, AMP, and CAP, and 85.7% sensitive to CRO, ciprofloxacin, and DA. They also showed high resistance to penicillin (5, 71.4%) and ceftazidime (4, 57.1%). This result supports that of a previous study in India [47]. This high resistance may be due to self-medication practices and the frequent and inappropriate use of antimicrobial agents.

This study indicated that Gram-negative isolates exhibited high resistance to commonly used antibiotics. All Gram-negative isolates showed different degrees of sensitivity to commonly used antimicrobial agents, including ciprofloxacin, TE, CRO, and GN, whereas most *E. coli* and *P. aerogenosa* isolates exhibited high resistance to AMP and CAZ, followed by P and AMC. This result is in agreement with similar studies from Addis Ababa [49,54], Arbaminch [46], Mizan-Tepi [40], and Tanzania [58]. This may be attributed to the fact that these antibiotics are easily obtained and are frequently taken without a prescription [6].

Among *Enterobacteriaceae, P. species* showed the highest resistance to TE (2, 66.7%) and GN (2, 66.7%). This result agrees with those reported from Mizan-Tepi [40], Arbaminch [46], and Addis Ababa [49]. According to the results of this study, the age group (>54 years) was significantly associated with SSIs ($P = 0.036$). This result agrees with similar studies conducted in Mizan-Tepi [40], Wolaita Sodo [30], Arbaminch [46], Hawaii [41], and Harar [39]. This result shows that as the age of patients increases, the risk of developing SSIs also increases. This confirms the findings of other authors, which reveal that as the age of the patients increases, the immune defence of the host decreases, the occurrence of chronic disease increases, and both predispose to the occurrence of SSIs [41]. In this study, a hospital stay duration of 10 days or more was found to be significantly associated with SSI risk. These significant associations support similar studies conducted in Mizan-Tepi [40], Wolaita Sodo [30], Hawaii [41], Shire, Ethiopia [27], and India [56]. This may be due to the fact that hospital wards are visited by a large population with poor infection prevention practices, and prolonged hospital stays increase the risks of nosocomial infections, as postoperative patients are more susceptible to HAIs [8].

This study indicate that longer durations of operations (≥2 hours) increase the rate of SSIs ($P = 0.048$). This result is in agreement with those of previous studies conducted in Hawaii [41], Ethiopian hospitals [50], Dassie [45], Jimma [44], and India [56]. This increased risk may be because prolonged operation times expose the surgical site to environmental contamination. In addition, prolonged surgical procedures increase the extent of tissue damage, the possibility of blood loss, and stress due to prolonged anaesthesia, all of which predispose patients to the development of SSIs [41]. In this study, contaminated wounds were significantly associated with SSIs ($P = 0.019$). This result supports other similar studies performed in Dassie [45], Ethiopian hospitals [50], Jimma [44], Wolaita Sodo [30], Western Ethiopia [42], and Harari [39]. This indicates that contaminated wounds have a higher risk of infection than clean wounds. In this study, open surgical sites were 2.64 times more likely to develop SSIs compared to closed surgical sites ($P = 0.046$). This agrees with similar studies conducted in India [56]. It might be due to the fact that open sites have more exposure to external environmental contaminants, and hospital environments are known to harbour various nosocomial pathogens. According to the present study,

Table 6
Univariate and multivariate analysis of factors associated with SSIs at the Bule Hora University Teaching Hospital, Bule Hora, 2023 (N = 183).

Variables	Category	Frequency N (%)	SSI		COR (CI 95%)	*P*-value	Adjusted OR (95% CI)	*P*-value
			Yes	No				
Sex	Male	101 (55.2)	16 (15.8%)	85 (84.2%)	1			
	Female	82 (44.8)	13 (15.9%)	69 (84.1%)	1.001 (0.451-2.223)	.998		
Age group	1-18	46 (25.1)	5 (10.9%)	41 (89.1%)	1		1	
	19-36	74 (40.5)	11 (14.9%)	63 (85.1%)	1.432 (0.463-4.423)	.533	1.89 (0.519-6.862)	.335
	37-54	35 (19.1)	4 (11.4%)	31 (88.6%)	1.058 (0.262-4.270)	.937	1.62 (0.332-7.852)	.552
	>54	28 (15.3)	9 (32.1%)	19 (67.9%)	3.884 (1.146-13.171)	**.029**[a]	4.76 (1.104-20.555)	**.036**[a]
Residence	Urban	78 (42.6)	10 (12.8%)	68 (87.2%)	1			
	Rural	105 (57.4)	19 (18.1%)	86 (81.9%)	1.502 (0.656-3.442)	.336		
Have a formal education	Yes	91 (49.7)	13 (14.3%)	78 (85.7%)	1			
	No	92 (50.3)	16 (17.4%)	76 (82.6%)	1.262 (0.569-2.803)	.566		
Occupation	Employed	50 (27.3)	9 (18.0%)	41 (82.0%)	1.240 (0.523-2.943)	.625		
	Unemployed	133 (72.7)	20 (15.0%)	113 (85.0%)	1			
History of pre-hospitalisation	Yes	53 (29.0)	11 (20.8%)	42 (79.2%)	1.630 (0.711-3.736)	.250		
	No	130 (71.0)	18 (13.8%)	112 (86.2%)	1			
Ward condition	Private	16 (8.7)	2 (12.5%)	14 (87.5%)	1			
	Public	167 (91.3)	27 (16.2%)	140 (82.8%)	1.350 (0.290-6.283)	.702		
Duration of hospital stay	<10 days	100 (54.6)	10 (10%)	90 (90%)	1		1	
	≥10 days	83 (45.4)	19 (22.9%)	64 (77.1%)	2.672 (1.165-6.128)	**.020**[a]	2.66 (1.061-6.659)	**.037**[a]
Duration of operation	<2 hours	146 (79.8)	18 (12.3%)	128 (87.7%)	1		1	
	≥2 hours	37 (20.2)	11 (70.3%)	26 (29.7%)	3.009 (1.273-7.113)	**.012**[a]	2.64 (1.009-6.901)	**.048**[a]
Type of surgery	Elective	45 (24.6)	7 (15.6%)	38 (84.4%)	1			
	Emergency	138 (75.4)	22 (15.9%%)	116 (84.1%)	1.030 (0.408-2.599)	.951		
Type of anaesthesia	Local	117 (63.9)	20 (17.1%)	97 (82.9%)	1.306 (0.557-3.061)	.539		
	General	66 (36.1)	9 (13.6%)	57 (86.4%)	1			
Type of wound	Clean	145 (79.2)	17 (11.7%)	128 (88.3%)	1			
	Clean-contaminate	38 (20.8)	12 (31.6%)	26 (68.4%)	3.475 (1.484-8.137)	**.004**[a]	3.17 (1.208-8.303)	**.019**[a]
Condition of surgical site	Opened	45 (24.6)	13 (28.9%)	32 (71.1%)	2.098 (1.352-7.096)	**.008**[a]	2.64 (1.019-6.858)	**.046**[a]
	Closed	138 (75.4)	16 (11.6%)	122 (88.4%)	1		1	
Implant inserted at surgical site	Yes	34 (18.6)	9 (26.5%)	25 (73.5%)	2.322 (0.948-5.687)	.065	2.09 (0.777-5.606)	.144
	No	149 (81.4)	20 (13.4%)	129 (86.6%)	1		1	
Antibiotic prophylaxis given	Yes	97 (53.0)	13 (13.4%)	84 (86.6%)	1			
	No	86 (47.0)	16 (18.4%)	70 (81.4%)	1.477 (0.665-3.279)	.338		
History of alcohol use	Yes	41 (22.4)	8 (19.5%)	33 (80.5%)	1.397 (0.568-3.438)	.467		
	No	142 (77.6)	21 (14.8%)	121 (85.2%)	1			
Malnutrition	Yes	23 (12.6)	8 (34.8%)	15 (65.2%)	3.530 (1.334-9.341)	**.011***	4.30 (1.424-12.970)	**.010***
	No	160 (87.4)	21 (13.1%)	139 (86.9%)	1		1	

Bold indicates factors associated with SSIs.
[a] $P < 0.05$.
AOR = Adjusted odd ratio; CI, Confidence interval; COR, Crude odd ratios; SSIs, Surgical site infections.

signs of malnutrition were significantly associated with the development of SSIs ($P = 0.010$). This finding supports the results of similar studies [59]. This could be due to the fact that malnutrition reduces immunity, and surgical procedures themselves compromise patient immune defences, thereby predisposing patients to the emergence of microbial flora [60,61].

Conclusion and recommendation

The study found a high prevalence of SSIs (15.8%), with *S. aureus* being the most common isolate. Many organisms are resistant to multiple antibiotics, which highlights the issue of antimicrobial resistance. Factors such as older age, longer hospital stays, extended operative times, and malnutrition were significantly associated with SSIs. This study recommends reviewing current infection prevention practices, establishing a functional microbiology laboratory, and limiting the use of certain antibiotics. Future studies should include fungi and anaerobic bacteria, and a nationwide survey of SSIs and antimicrobial resistance is recommended.

Declarations of competing interests

The authors have no competing interests to declare.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Ethical approval and consent to participate

The Ethical Review Board Committee (IRBC/22) of Bule Hora University examined and approved the study. Bule Hora University Teaching Hospital received a formal support letter. The institution, parent or guardian, and study participants provided informed, voluntary, and written informed consent. Each participant received information regarding the study, including its objectives, methods, potential risks, and advantages. Participants were informed of their right to decline or leave the study at any time. The study participants were unaffected by their decision to decline participation. By omitting names and other identifiers from the questionnaire, the participants' data were kept confidential. Surgical site infection-positive participants were given access to their physicians and received care according to the national standards.

Acknowledgments

First, we give special thanks to Bule Hora University for giving us the opportunity to prepare this research project. Furthermore, we acknowledge the medical laboratory science staff for their support and good approach. Finally, we express our deepest appreciation to all participants.

Author contributions

All authors were involved in conceptualisation, proposal development, project management, research and monitoring, data analysis, supervision of the data collection process, document preparation, interpretation, writing, and manuscript preparation. All the authors have read and approved the final version of the manuscript.

Availability of data and materials

Data used in this study are available and included in this manuscript. Therefore, we can communicate with you if future processes are required.

Consent for publication

Not applicable.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.ijregi.2024.100565.

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