ORIGINAL ARTICLE

Predisposing Factors for Orthopaedic Surgical Site Infection: A Retrospective Multicentre Study

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ABSTRACT

Introduction: Orthopaedic Surgical Site Infection (SSI) is the main category of hospital-acquired infections which complicates orthopaedic surgery that in turn delays recovery despite the risk factors for such infection that are previously determined. The study aimed to identify predisposing factors that made orthopaedic surgery patients in Jordan develop SSI. **Methods:** The study was cross-sectional in which data collected retrospectively about patients underwent orthopaedic surgery within the period from 1/1/2011 and 12/31/2015 in two hospitals. Data collection was through reviewing the patients' medical records using a tool included CDC definitions for SSI, NNIS risk index, ASEPSIS wound scoring system and instrument of assessment for orthopaedic SSI risk factors. **Results:** From the sample of 106 patients, it was found that increased age, female gender, increased duration of operation, prolonged postoperative stay, presence of chronic diseases, receiving blood units and increased number of blood transfusions can exacerbate surgical wound classification ($p < 0.05$). All types of orthopaedic SSI (superficial, deep incisional, bone/ joint) were significantly correlated with postoperative stay period only ($p < 0.05$). ASEPSIS score was significantly correlated with both preoperative and postoperative stay periods and the presence of postoperative anaemia ($p< 0.05$). **Conclusion:** Health care providers should apply and adhere to infection control measures cautiously with female and old age patients having one or more chronic diseases, and attempts to prevent postoperative anaemia, to shorten patient hospital stay period and duration of operation should be emphasized by health care policies makers to decrease the occurrence of orthopaedic SSI.

Keywords: Risk factors, Orthopaedic surgery, Surgical site infection

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INTRODUCTION

Amongst common categories of Hospital Acquired Infections (HAI) is surgical site infection (SSI), which accounts for about 25% of HAI universally (1). Orthopaedic SSI is a health problem occurring for patients undertaking orthopaedic surgical procedures (2), and SSI confounds 1-3 % of orthopaedic surgeries (3), which results in devastating complications postoperatively that in turn hinder the ordinary retrieval course (4). An Orthopaedic surgical procedure is considered dirt-free, and during which aseptic techniques are employed. However, SSI still presents as a devastating confounder to be addressed (5).

Several causes have been recognised previously as predisposing causes predicting the occurrence of orthopaedic SSI, and most of the studies identified those causes were conducted prospectively. The predisposing factors predicting orthopaedic SSI could be identified through the preoperative, intraoperative, or postoperative periods (6). Among the preoperative predisposing causes are gender (6, 7), age (3, 8), obesity (9, 10, 11), presence of preoperative anaemia (10, 11), the length of preoperative stay (4,8), malnutrition (4, 10), tobacco use (10, 13, 14), and compromised immunity (6, 15). The intraoperative predisposing causes are (but not limited to) the number of people in operation theatre (9, 15), duration of operation (4, 7, 8, 10) and type and location of operation (9, 16). The postoperative causes include the presence of postoperative anaemia (10, 17), length of postoperative stay (6, 11), use of prophylactic antibiotic and use of drains (6, 9), and blood transfusion (6, 9, 10, 11). One prospective study conducted in Jordan (18) has found that wound classification as 'contaminated' predicted the occurrence of orthopaedic SSI. Furthermore, wound classification as 'clean/ contaminated' or 'dirty/ infected' increased the possibility to develop orthopaedic SSI (8).

Many studies conducted worldwide identified the risk factors for orthopaedic SSI. In Jordan, few studies conducted to identify predisposing factors for orthopaedic SSI. Furthermore, most of those studies employed a

prospective approach while the retrospective approach has not been used. By applying the retrospective approach, the causes that the patients had before and made them at risk to develop orthopaedic SSI could be identified. After reviewing infection control departments' records several hospitals in Jordan, no statistical numbers were found about the incidence of orthopaedic SSI cases in Jordan and the causes attributed to the incidence of orthopaedic SSI cases have not been reported previously. However, the incidence of orthopaedic SSI in Jordan was 2.8% in one study conducted prospectively in Jordan (19). Although that percentage is relatively small, it will be reflected by hundreds of SSI cases for thousands of orthopaedic surgeries conducted annually in Jordan which in turn could raise the epidemiological concerns about effects of orthopaedic SSI on Jordanian population.

According to our information, this is the chief study done retrospectively in Jordan aimed to identify predisposing causes for orthopaedic SSI, and as there are no causes identified before by researchers or health care providers as causes for orthopaedic SSI in Jordan other than identified previously in the literature. This research work aimed to determine predisposing causes for orthopaedic SSI in Jordan. Orthopaedic SSI harms orthopaedic patients regarding the span of patient vacation in the infirmary, the rate of re-hospitalization, and the costs of healthcare (20). For the above reasons, it was important to identify predisposing causes that made orthopaedic surgery patient develop SSI which in turn aid in setting up appropriate measures to prevent orthopaedic SSI (20). We believe that when the causes that made orthopaedic surgery patients develop SSI are identified, infection control members, nurses, and physician can set and employ strategies that help in reducing and minimizing the risk for orthopaedic SSI, particularly in hospital areas that are concerned to deal with patients undertaking orthopaedic surgical procedures.

MATERIALS AND METHODS

Study Design

The design for the current study was a retrospective cohort study, in retrospective studies, the results of interest have already occurred in each individual by the time he or she is enrolled, and the data are collected from records. In this type of design, the investigator looks back in time at archived data to investigate whether the risk factors of disease was different between infected and non-infected patients.

In this study, information was collected about Jordanian patients underwent orthopaedic surgery in the period from 1st January 2011 and 31st December 2015. The primary investigators of this study collected data about orthopaedic surgery patients who developed SSI, and after identifying those patients who developed orthopaedic SSI before the date of 1st January 2016, data from their medical records were obtained to find the risk factors they had and made them vulnerable to develop orthopaedic SSI.

Participants and Settings

The settings form which data collected were two hospitals in Jordan that provide care for orthopaedic surgery patients. These hospitals are the main referral for governmental hospitals that do not have specialized orthopaedic surgical units and therefore most cases that required orthopaedic surgery could be captured in those two hospitals.

The sample included those patients who underwent orthopaedic surgery in the selected two hospitals in the period from 1st January 2011 and 31st December 2015 and developed SSI, that is, the total number of patients who acquired SSI next orthopaedic surgical procedure. Patients who had a diagnosis of dehiscence or evisceration, bone or joint abscess, and/ or osteomyelitis were not included in the study as these complications or alterations could be misleading and not to be distinguished from orthopaedic SSI, so that the sample included orthopaedic SSI cases only.

Data collection

Data for this study were collected by reviewing the patients' medical records after identifying who developed orthopaedic SSI based on physician diagnosis and records of infection control departments, and the data collection tool used to obtain the required data from patients medical records included 'Centre for Disease Control and Prevention (CDC) definitions for surgical site infection surveillance' (21: p.37), National Nosocomial Infection Surveillance system (NNIS) risk index (22), ASEPSIS wound scoring scale (23) and 'instrument of assessment for orthopaedic SSI risk factors' (IAOSRF) (18: p.2). CDC definitions for SSI surveillance classify SSI into three categories: superficial incisional SSI, deep incisional SSI, or organ/ space SSI. These three categories are based on laboratory results, physical examination findings, and diagnosis of SSI made by the physician, and must happen within 90 days after operation day to be marked as SSI (21).

NNIS risk index (22) was used to assess the risk for orthopaedic SSI. The NNIS risk index score ranges from 0 to 3, which is based on three parameters, each one is scored as 0 or 1, these parameters are surgical wound category, American Society of Anaesthesiologists (ASA) physical status score, and length of surgery. When the scores on each element in the NNIS risk index are summed, the patient will get a score that ranges from 0 to 3. Patients with NNIS score of 0 are considered at low risk for orthopaedic SSI, patients NNIS score of 1 are considered at moderate risk, and scores of 2 and 3 are considered at high risk for orthopaedic SSI (24).

ASEPSIS wound scoring scale assesses the severity of SSI based on many parameters such as wound characteristics, use of antibiotics, debridement of the wound, and so on. The score can range from 0 to 70; patients without SSI will have a score of 10 or less, and scores among 11 to 70 represents SSI with varying degrees of severity from disturbance of healing to severe wound infection (23).
The IAOSRF includes probable patient-related and medical-related predisposing causes for orthopaedic SSI, which are categorised into preoperative, intraoperative, and postoperative predisposing causes. The items in the tool are either nominal (e.g.: gender, presence of malnutrition, use of drain), or numeric (e.g.: age, body mass index).

Ethical issues

The study was conducted after obtaining the permissions from IRB committees' of Jordan University Hospital (Ref No: 10/2016/3173) and of King Abdullah University Hospital (Ref No: 13/1/1818) so that right of entry to patients' medical records is possible. The right of entry to patients' files was based on the principle of 'only need-to-know', which means accessing patients' medical records only for the purpose to collect data related to orthopaedic surgery based on the variables identified previously in the data collection instrument. Furthermore, the secrecy of patients' data was retained by encrypting data collected and not relating the data to patients' tags. The data were retained in a secure location known by the main investigators only, and the collected data were destroyed after the study is published.

Reliability was assessed for IAOSRF, within which both KR21 and alpha coefficients have been used to determine scale reliability; KR21 value for the binary variables was 0.95, and alpha coefficient value for the numeric variables was 0.82.

Data Analysis

The data attained about patients who developed orthopaedic SSI were screened for the presence of missing data and treated appropriately based on how much missing data are found. After that, the data were analysed using SPSS programme version 21.0 within which both descriptive and inferential statistics have been employed. Numeric variables were defined by means and standard deviations. Nominal variables were defined by relative frequencies as well as percentages. Bivariate correlations (Both Pearson's and Spearman's correlation coefficients) were employed to determine the relationships between the dependent variables which are levels of severity of orthopaedic SSI, risk levels of orthopaedic SSI, classifications of surgical wounds (dirty-infected, contaminated, clean-contaminated, clean (25)), type of orthopaedic SSI (based on CDC definitions) and the potential risk factors in the IAOSRF that are considered as independent variables. All correlations conducted at two-tailed α level of significant = 0.05. Further statistical analysis tests, such as Mann- Whitney and Kruskal-Wallis have been used when required and when further validations of study results are necessary. For example, when the results of bivariate correlations needed further clarifications and explanations so that they are better understood, either Mann- Whitney or Kruskal-Wallis statistical tests were employed, depending on the type of variables (nominal, ordinal, or numerical) being analysed.

RESULTS

From 11500-screened orthopaedic patients in the two hospitals, 6400 had orthopaedic surgery in the period from 1st January 2011 and 31st December 2015 and only 108 (1.7 %) patients had orthopaedic SSI. Of the 108 patients who had an orthopaedic SSI, two patients had incomplete information in their medical records to a degree that made them excluded from data analysis. The final sample was 106 patients valid for analysis.

The characteristics of patients in the study sample as they are shown in tables I and II reveal that majority of patients were males, non-smokers, non-immunocompromised, had no preoperative anaemia, and have been prepared for operation by preoperative bath, shaving surgical site (time of shaving preoperatively is not identified in the medical record), and applying the head cap. Majority of patients had no chronic diseases, and the entire sample contained no patients with renal failure, COPD, or coronary artery disease. Intra-operatively, the average duration of operation was about one and half an hour (M = 106.08), in which five personnel have participated and was present in the operation theatre, and povidone-iodine to be predominantly used for preparing the surgical site. The highest frequency of surgical procedure conducted was fracture fixation (n = 45, 42.5 %) that

Table I: Characteristics of continuous (numeric) variables for orthopaedic SSI patients (*N* = 106)

	Variables	*M (SD)*
Independent	**Preoperative** :	
	Age (years)	43.86 (19.54)
	BMI	26.06 (4.58)
	Average fasting blood glucose level (mg/dL)	150.97 (45.54)
	Length of preoperative stay (hrs)	155.76 (191.97)
	Intraoperative:	
	Duration of operation (min)	106.08 (51.07)
	Surgeon experience (years)	11.75 (4.59)
	Number of people in the operation	4.81 (1.23)
	Postoperative:	
	Length of postoperative stay (hrs).	489.77 (472.95)
	Number of blood units transfused (if received blood transfusion)	2.09 (2.78)
	NNIS risk index score	0.76 (.68)
Dependent	ASEPSIS Score	30.96 (7.99)

Table II: Characteristics of categorical variables for orthopaedic SSI patients (*N* = 106)

	Variables	*n* (%*)
Independent	Preoperative:	
	Gender	
	Male	80 (75.5)
	Female	26 (24.5)
	Smoking(*n*= 105)	
	Yes	37 (34.9)
	No	68 (64.2)
	Immunocompromization	
	Yes	4 (3.8)
	No	102 (96.2)
	Malnutrition	
	Yes	1 (.9)
	No	105 (99.1)
	Chronic diseases	36 (34)
	Yes (HTN, DM, others such as rheumatoid arthritis)	70 (66)
	No	
	Preoperative anaemia(*n* =102)	40 (37.7)
	Yes	62 (58.5)
	No	
	Patient preoperative bath(*n* = 65)	46 (43.4)
	Yes	19 (17.9)
	No	
	Shaving surgical site(*n* = 65)	35 (33)
	Yes	30 (28.3)
	No	
	Applying headcap to patient(*n* = 67)	65 (61.3)
	Yes	2 (1.9)
	No	
	Intraoperative:	
	Location of operation	
	Arm and shoulder	8 (7.5)
	Wrist and hand	8 (7.5)
	Spine	11 (10.4)
	Hip	18 (17)
	Femur	23 (21.7)
	Knee	8 (7.5)
	Leg	20 (18.9)
	Ankle and foot	5 (4.7)
	More than one site	5 (4.7)
	Type of surgical procedure:	
	Arthroscopy	3 (2.8)
	Reconstruction of damaged tissue	5 (4.7)
	Fixation of fracture (both internal and external)	45 (42.5)
	Arthroplasty	12 (11.3)
	Tendon repair	2 (1.9)
	Bone biopsy and graft	3 (2.8)
	Amputation and tissue excision	26 (24.5)
	Spinal fusion and decompression	5 (4.7)
	Mass or foreign body excision	2 (1.9)
	Lumbar fixation and laminectomy	2 (1.9)
	Arthrodesis (joint surgical ossification)	1 (.9)
	Product used for skin preparation	
	Povidone- iodine	88 (83)
	Chlorhexidine- alcohol	18 (17)
	Postoperative:	
	Use of drain (*n* = 103)	
	Yes	40 (37.7)
	No	63 (59.4)
	Use of prophylactic antibiotic(*n* = 98)	
	Yes	85 (80.2)
	No	13 (12.3)
	Postoperative anaemia (*n* = 102)	
	Yes	66 (62.3)
	No	36 (34)
	Blood transfusion(*n* = 102)	
	Yes	52 (49.1)
	No	50 (47.2)
Dependent	**Surgical wound classification**	
	Clean	64 (60.4)
	Clean- contaminated	9 (8.5)
	Contaminated	29 (27.4)
	Dirty/ infected	4 (3.8)
	Type of surgical site infection	
	Superficial	25 (23.6)
	Deep	65 (61.3)
	Bone/ joint	16 (15.1)

* Percentages are rounded to one decimal place so that may not be exactly equal to 100% accumulatively.

was mainly conducted in either leg or femur.

Postoperatively, most patients had no drain in the surgical site. However, most of them developed postoperative anaemia (n = 66, 62.3 %), which made it necessary to receive a blood transfusion in an average of two units for each patient. Majority of patients were given antibiotic prophylaxis. Length of patient stay period in the hospital was 27 days in average; about seven days preoperatively (M = 155.76) and about 20 days postoperatively (M = 489.77), this prolonged hospital stay could be explained by the need for follow up and treatments due to presence of orthopaedic SSI. Most patients had clean wounds (n = 64, 60.4%), and a large percentage of them developed deep incisional SSI (n = 65, 61.3%). The risk level to develop orthopaedic SSI (according to NNIS risk index score) was low to moderate.

To assess the relationship between the predisposing factors for orthopaedic SSI and surgical wound classification, Spearman's correlation coefficient has been used. The results are shown in Table III indicate the presence of significant correlation between surgical wound classification and age, gender, duration of

Table III: Relationships between the independent variables and surgical wound classifications (*N* = 106)

Variable	Spearman's Correlation coefficient	*p*-value
Age	-0.28	0.003*
BMI	0.1	0.33
Average fasting blood glucose level	-0.07	0.46
Length of preoperative stay	-0.01	0.93
Duration of operation	-0.26	0.007*
Surgeon experience	0.07	0.49
Number of people in the operation	-0.15	0.13
Length of postoperative stay	0.23	0.021*
Female Gender	0.19	0.048*
Smoking	0.06	0.52
Malnutrition	-0.08	0.43
Immmunocompromization	-0.05	0.59
Chronic diseases	-0.32	0.001*
Preoperative anaemia	0.04	0.71
Patient preoperative Bath	-0.01	0.93
Shaving surgical site	0.025	0.84
Applying head cap to patient	0.00	1
Location of operation	0.05	0.6
Type of surgical procedure	0.15	0.14
Product used for skin preparation.	0.01	0.92
Use of drain	-0.14	0.17
Use of prophylactic antibiotic	-0.12	0.24
Postoperative anaemia	0.08	0.42
Blood transfusion	0.23	0.02*
Number of blood units transfused	0.29	0.004*

* Correlation is significant at α = 0.05 level

operation, length of postoperative stay, presence of chronic diseases, receiving blood units, as well as the number of blood units given ($p < 0.05$). These results indicate that surgical wound classification progress from clean to dirty/ infected is having a likelihood association with age, female gender, duration of operation, length of postoperative stay, presence of chronic diseases, receiving blood units, as well as the number of blood units given which in turn made the patients vulnerable to develop orthopaedic SSI.

The correlation results for age, duration of operation, and presence of chronic diseases as they were shown in table III are negative (hold the minus sign), which can be misleading and concluded that as the duration of operation decreases, the age decreases, and when the patient has no chronic diseases, classification of surgical wound exacerbates from clean to contamination or infection. For this reason, further statistical analysis was conducted included ANOVA and t-test. However, the data in the study sample did not meet the assumptions for both of these statistical tests, so analogous non-parametric tests were used.

Using Mann-Whitney test to compare the means between patients with and without chronic diseases among surgical wound classification levels, a significant dissimilarity was discovered between patients who have chronic diseases and who do not have chronic diseases ($p < 0.05$). The mean rank for 36 patients with chronic disease was 41.8 compared with 56.4 for 70 patients with chronic diseases, which indicates that the correlation direction with surgical wound classification is in the favour of patients with chronic diseases.

The results of conducting Kruskal-Wallis test to compare the means of surgical wound classification categories regarding the duration of operation and age groups were also significant ($p < 0.05$), with higher mean ranks in patients who had a duration of operation of 60 minutes or less and of 120 minutes or more, which means that surgical wound can become contaminated or infected with either very short or very long duration of the operation. The mean ranks for age groups were the highest in patients of age 60 years and more, indicating that as the age increases, the surgical wound classification exacerbates from cleanliness to contamination due to effects of ageing on the surgical wound (rationales provided below in discussion section).

The results of conducting bivariate correlations using Spearman correlation coefficient to assess the relationship between the predisposing factors for orthopaedic SSI and types of SSI indicated a significant relationship between the length of postoperative stay and types of orthopaedic SSI (Rho (104) = 0.23, $p = 0.02$ (two-tailed). This result means as the length of postoperative stay increases, the type of SSI may exacerbate from superficial to deep incisional or from deep incisional to bone/ joint infection. All types of orthopaedic SSI (superficial, deep incisional, bone/ joint) were correlated with length of postoperative stay.

The results of conducting bivariate correlations between NNIS risk index scores and the predisposing factors for orthopaedic SSI showed no significant correlations between variables ($p > 0.05$), which means that NNIS risk index score is not affected by any of the predisposing factors for orthopaedic SSI. Finally, the results of bivariate correlations between ASEPSIS scores and the predisposing factors for orthopaedic SSI using either Pearson or Spearman correlation coefficient are shown in table IV. The results indicate the presence of a significant relationship between ASEPSIS scores and preoperative stay period, postoperative stay period, and the presence of postoperative anaemia. These results mean that the severity of orthopaedic SSI is aggravated with increased length of both preoperative and postoperative stay, and presence of postoperative anaemia.

Table IV: Relationships between the independent variables and ASEPSIS score (*N* = 106)

Variable	Correlation coefficient	*p*-value
Age	-0.03[1]	0.78
BMI	0.13[1]	0.19
Average fasting blood glucose level	0.04[1]	0.68
Length of preoperative stay	0.21[1]	0.033*
Duration of operation	-0.16[1]	0.09
Surgeon experience	-0.03[1]	0.78
Number of people in operation	0.11[1]	0.26
Length of postoperative stay	0.28[1]	0.003*
Gender	0.04[2]	0.7
Smoking	0.05[2]	0.61
Malnutrition	0.03[2]	0.75
Immmunocompromization	-0.11[2]	0.17
Chronic diseases	-0.05[2]	0.65
Preoperative anaemia	0.07[2]	0.47
Patient preoperative Bath	0.12[2]	0.36
Shaving surgical site	-0.11[2]	0.39
Applying head cap to patient	0.03[2]	0.78
Location of operation	-0.03[2]	0.75
Type of surgical procedure	0.16[2]	0.11
Product used for skin preparation.	-0.04[2]	0.67
Use of drain	-0.15[2]	0.12
Use of prophylactic antibiotic	0.15[2]	0.08
Postoperative anaemia	0.2[2]	0.04*
Blood transfusion	0.16[2]	0.11
Number of blood units transfused	0.12[1]	0.25

1: Pearson's r correlation coefficient used
2: Spearman's rho correlation coefficient used
* Correlation is significant at $\alpha = 0.05$ level

DISCUSSION

Orthopaedic SSI is a major complication that needs to be addressed and acknowledged in orthopaedic surgery patients in Jordan and it is necessary to determine what made orthopaedic surgery patients at risk to develop orthopaedic SSI as there is no enough data present about what caused orthopaedic SSI in Jordan Hospitals. This study identified predisposing causes that made orthopaedic surgery Jordanian patients developed SSI by examining the relationships between a group of independent variables in the three perioperative periods (preoperative, intraoperative, postoperative) and the hallmarks of orthopaedic SSI which are surgical wound classification, NNIS risk index, ASEPSIS score and type of orthopaedic SSI. All of which are strong indicators of orthopaedic SSI, which can lead to increased risk to develop orthopaedic SSI. Thus, it was necessary to make an in-depth investigation about predisposing factors in the three perioperative periods that made the patients develop orthopaedic SSI.

Multiple predisposing causes for orthopaedic SSI were evident. However, most studies conducted included a specific type of orthopaedic surgery and large samples were employed. For instance, a study conducted by Namba et al. (7) included knee arthroplasty surgery only and analysis of more 50 thousands of cases. Several studies analysed potential confounding variables that might affect the process of identifying orthopaedic SSI risk factors (4, 8, 13, 14 – 16, 26, 27). In the current study, numerous types of orthopaedic surgery have been included in the sample so predisposing causes for orthopaedic SSI could not be adherent to certain types of orthopaedic surgery and confounding variables could not be captured and analysed because this study was retrospective in nature. However, the results of this study are consistent and comparable with previous studies investigated orthopaedic SSI predisposing causes which in turn make it possible to discuss our study findings.

Our findings indicated that orthopaedic SSI was related to prolonged hospital stay preoperatively, which was already determined as a risk factor for orthopaedic SSI (4, 8). Prolonged hospital stay preoperatively leads to colonization with antibiotic-resistant microorganism and affect patient's susceptibility to infection by lowering host resistance (22).

Pereira et al. and de Boer et al. (26, 28) revealed that preoperative stay over 4 days was a predisposing cause for orthopaedic SSI. In our study, the mean preoperative stay period was more than 6 days which confirms that preoperative stay period of more than 4 days make the patient at risk to develop orthopaedic SSI, so it is necessary to shorten the length of preoperative stay and to avoid delay in conducting orthopaedic surgery as much as possible. An important point to consider for decreasing vulnerability of orthopaedic SSI is preoperative optimization, which focuses on rising adjustment of baseline physiological functioning and ensuring that the patient is in an ideal clinical status before surgery (29). Preoperative optimization clinics were found to foster efficiency in the operating room, limit cancellations in the same day of surgery, and make patient clinical outcomes better (30, 31). Baek (32) revealed that acknowledging risk factors for orthopaedic SSI through applying preoperative optimization reduced the occurrence of bone/joint infection in prosthetic joints.

Our study results indicate a significant relationship between postoperative stay period and orthopaedic SSI, which is previously identified in the literature (6, 11, 8). The duration of patient stay postoperatively should be considered as an important cause to influence the existence of orthopaedic SSI because in this period the patient has a surgical wound, which increases vulnerability for wound contamination and subsequently orthopaedic SSI existence. (11). We recommend shortening postoperative stay period based on the patient's health status and the healing progress of surgical wound so that the negative effects of patient stay in the postoperative period on the existence of orthopaedic SSI is minimized.

The use of oxygen during postoperative recovery should be considered for enhancing wound healing process as oxygen was evident to increase the oxidative capacity of neutrophils in killing bacteria reaching surgical wound, especially that the vascular supply of wound tissue is impaired by surgical trauma and oedema creating a low oxygen environment that impairs leukocyte killing ability (33). Stall et al. (34) revealed in their randomised clinical trial that using a high concentration of oxygen preoperatively reduced SSI in patients underwent open reduction internal fixation for lower extremities fractures. The use of a high fraction of inspired oxygen was shown to be beneficial to decrease SSI in orthopaedic trauma patients (35). Maragakis et al. (36) found that a low fraction of inspired oxygen less than 50% increased the risk for SSI after spinal surgery.

Our study indicated that orthopaedic SSI is related to the female gender, a result that was found by Ridgway et al. and Namba et al. (8, 16). Dissimilarly, several studies revealed that males are at increased risk for orthopaedic SSI (5-7, 16). A plausible explanation of these results may be attributed to a difference that exists between male and female regarding immunological and physiological response to infection (28, 37), in which females exhibits different sex steroid hormone response to infection from males and females also have a more active immunological response to infection than males (37). Therefore, we recommend including only one gender (either male or female) in future studies on orthopaedic SSI so that studies results could not be affected by gender.

Age is related to orthopaedic SSI, a result that has been confirmed previously (3, 8, and 38). However, few studies reported that age alone is not related to orthopaedic SSI (7, 39). Old age patients are vulnerable for SSI because of the amplified rigorousness of their critical illness, reduced host reaction to bacterial infections, and increased prevalence of comorbid conditions (40). Therefore, aged patients undergoing orthopaedic surgery should be carefully monitored for the presence of orthopaedic SSI and to apply preventive strategies to modify or control other predisposing factors that make them at risk to develop orthopaedic SSI.

Presence of chronic diseases alongside with undergoing orthopaedic surgery was identified in our study as a predisposing cause for orthopaedic SSI. Among the chronic diseases that were considered by several studies (7, 9, 10, 37) as a cause increased risk to develop orthopaedic SSI is diabetes mellitus (DM). Furthermore, rheumatoid arthritis has been associated with increased risk to develop orthopaedic SSI (8, 16, 38), in addition to osteoarthritis and posttraumatic arthritis (7). DM, rheumatoid arthritis, and other comorbidities increase the probability of septic complications (41). Also, poor blood sugar control in diabetic patients leads to abnormalities in cell-mediated immunity and impairs leukocytes functions (42, 43).

Despite previous evidence in several studies that elevated blood glucose raises the risk for orthopaedic SSI and impairs wound healing process (9, 44, 45), our study findings indicated that blood glucose level was not related to orthopaedic SSI. However, the average fasting blood glucose was above 150mg/dl which indicates poor blood glucose control in the study sample which in turn made patients with chronic diseases, especially DM, vulnerable to develop orthopaedic SSI. The fasting blood glucose measurements were scheduled in both the preoperative and postoperative period and the number of fasting blood glucose measurements were not the same for each patient so the average fasting blood glucose has been considered during data analysis.

The duration of operation has been found in our study to be related with orthopaedic SSI, especially when the operation time exceeds 2 hours, which was consistent with the results reported in several studies (7, 8, 10, 39). It has been noted that contamination rates were high with prolonged operative times (46). As a result, it is recommended to avoid prolonging operation time so that it will not exceed 2 hours, depending on the type of orthopaedic surgery conducted.

Finally, postoperative anaemia was associated with orthopaedic SSI, and the relationship between anaemia and orthopaedic SSI has been reported in the literature (10, 17). Anaemia can impair tissue oxygenation, which reduces collagen synthesis and impairs oxidative killing by neutrophils as a primary defence mechanism (47). A related and subsequent result of postoperative anaemia is the need for blood transfusion, which was also related to orthopaedic SSI in our study. Several studies (6, 9-11, 48) reported the association between blood transfusion and orthopaedic SSI which support our study results. Blood transfusion both suppresses immunity and enhances inflammation, resulting in high rates of postoperative infections (49). Consequently, strategies to reduce blood transfusion are required. Blood transfusion should be given for orthopaedic surgery patients only when indicated (18). Spahn (17) suggested the treatment of anaemia with iron, in addition to erythropoietin and cell salvage to decrease the necessity for blood transfusions and to enhance patient health consequences.

This research work has some limitations, the size of the sample employed is limited and only two hospitals were selected as a study setting which might hinder analysing of possible confounding variables which could limit identifying all possible causes for orthopaedic SSI that could be identified in other hospitals. However, the study findings could be of value in other hospitals to raise the attention of health care providers while caring for high-risk patients. Furthermore, several possible causes for orthopaedic SSI could be undetermined before and eventually not recognized as causes to influence orthopaedic SSI. Although the missing data about patients are not great enough to distort the data and study findings, the data missed could enrich the findings obtained if were captured somehow and subsequently more risk factors could be identified. Finally, the study was retrospective, and the potential for information bias and unclear patients' clinical outcomes regarding orthopaedic SSI is possible as the patients were not observed clinically and only data from medical records were obtained, which in turn could not help in determining and controlling confounding variables that might be present.

CONCLUSION

The authors conclude that female gender, old age, prolonged patient hospital stay preoperatively and postoperatively, duration of operation of more than two hours, presence of one or more chronic diseases, presence of postoperative anaemia and receiving blood transfusion made orthopaedic surgery patients in Jordan at risk to develop orthopaedic SSI. Future studies should focus on one predisposing factor and one type of orthopaedic surgery so that confounding variables can be identified and controlled. The risk factors for orthopaedic SSI identified above should raise the attention of health care providers to apply and adhere to infection control measures cautiously with patients having those risk factors in addition to adopting and applying health care policies to prevent postoperative anaemia, to shorten patient hospital stay preoperatively and postoperatively and duration of the operation.

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