

## Review Article

# Orthopedic Surgical Site Infection: Incidence, Predisposing factors, and Prevention

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### ABSTRACT:

**Purpose:** The purpose of this review paper is to explore the risk factors contributing to incidence of orthopedic surgical site infection in addition to exploring the causative microorganisms for orthopedic surgical site infection and to set the strategies preventing such type of infection since this type of infection increases morbidity and burden on both patients and their healthcare institutions. **Methods:** A review was carried out on Wiley Online Library, MEDLINE via PubMed, Medscape, and Science Direct, in addition to Google Scholar. The searching period limited to studies published between 1998 to 2015. **Results:** Twenty-Nine studies were included and analyzed in the review that generated four major domains: incidence of orthopedic surgical site infection, risk factors for orthopedic surgical site infection, causative microorganisms of orthopedic surgical site infection, and prevention of orthopedic surgical site infection. Analyzed literature revealed the predisposing factors of orthopedic surgical site infection and strategies to prevent such predisposing factors. **Conclusion:** The risk factors of orthopedic surgical site infection are both iatrogenic and patient-related and can be managed by evaluating patient's health status and establishing policies to control risk factors of orthopedic surgical site infection.

**Abbreviations:** SSI: Surgical Site Infection. PJI: Peroprosthetic Joint Infection. MRSA: Methicillin Resistant Staph. Aurues. HIV: Human Immunodeficiency Virus. BMI: Body Mass Index. ASA: American Society of Anesthesiologists.

**Key words:** Surgical site infection/orthopedic, Surgical site infection/risk factors, Surgical site infection/incidence , Surgical site infection/prevention.

### INTRODUCTION

Surgical Site Infection (SSI) for orthopedic surgery is a clinical problem that occurs in orthopedic wards for patients undergoing orthopedic surgery [1]. Although orthopedic surgery is categorized as clean and strict measures of aseptic techniques and antibiotic prophylaxis are commonly employed, SSIs continue to be present as important complications to be addressed [2].

In Jordan, about 6000 orthopedic surgeries are conducted annually at the Jordanian Ministry of Health hospitals [3]. In United states, about 2 million orthopedic surgeries are conducted annually [4]. Globally, SSI was reported in 1% to 3% of patients who had orthopedic surgery [5], which represents an acquired health problem among hospitalized orthopedic patients, especially at the post-operative period [6].

Orthopedic SSIs prolong patient hospital stay to about two weeks, double the rate of rehospitalization, and triple the overall healthcare costs [7], in addition to the physical limitations imposed on the patient [8], such as prosthesis removal or loss of limb function [9].

Identifying patients at high risk of orthopedic SSI would enable providing both patient and healthcare provider with information that helps in improving preoperative assessment of the risk of developing orthopedic SSI, and make healthcare providers raise the index of suspicion for orthopedic SSI in

high-risk individuals [9]. Determining the risk factors of orthopedic SSIs preoperatively allows the application of protective interventions that may inhibit the occurrence of orthopedic SSIs [10].

There are many causes of SSI, which have been documented and reported as risk factors. A risk factor is any factor that is recognized as a contributor to increase of susceptibility to SSI [11]. The risk factors of orthopedic SSI have been identified in the literature as preoperative risk factors, intraoperative risk factors, and postoperative risk factors [12, 13].

To our knowledge, this is the first study to be conducted in Jordan to explore the risk factors of orthopedic SSI and to set the strategies required to prevent orthopedic SSI. The purpose of this review paper is to explore the risk factors that contribute to the incidence of orthopedic SSI in addition to exploring the causative microorganisms for orthopedic SSI and to set the strategies to prevent orthopedic SSI.

### METHODS

This review process was guided by the review aims. The following electronic databases were searched to identify relevant studies: Wiley Online Library, MEDLINE via PubMed, medscape, and ScienceDirect in addition to Google Scholar. The initial search terms used were surgical site

infection, orthopedic surgery, and risk factors.

Initial search was run to include all published literature from 1998 to 2015. The general inclusion criteria for analysis purpose were published studies with full text and presented in English, which discussed the risk factors for orthopedic SSI. A preliminary search resulted in a number of 1200 studies. After the implementation of inclusion criteria, 300 studies were identified. After the removal of duplicates, 271 studies were eliminated. The final number of relevant articles that met the eligibility criteria and underwent the analysis process was 29 articles. Figure (1) shows a flow chart of the selection process.

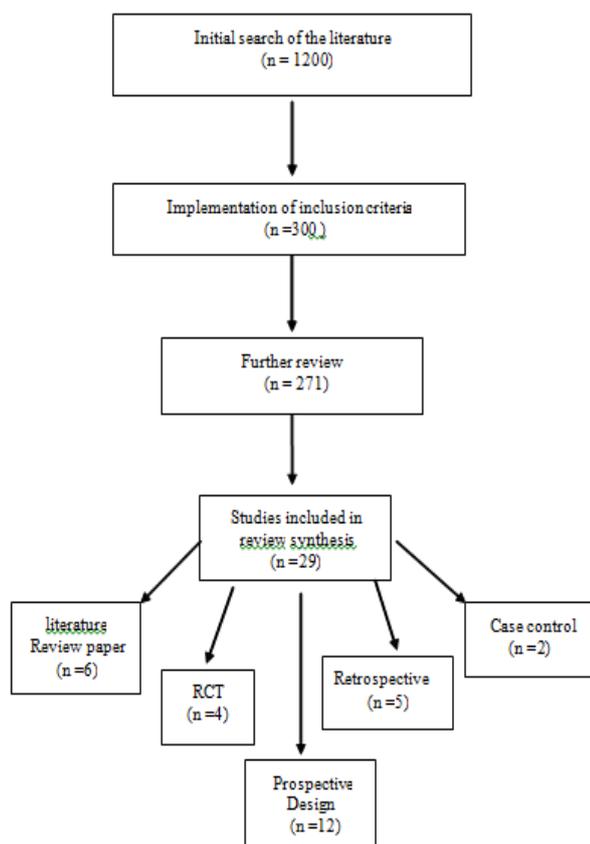


Figure 1. Flow Diagram for a Systematic Review of the Literature

**RESULTS**

A final number of 29 studies were included in this systematic review. Each one of selected studies identified risk factors of orthopedic SSI. The selected 29 studies include: four randomized clinical trials, six literature review papers, twelve prospective studies, two case-control studies, and the remaining five studies were retrospective studies. Appendix A displays further details of the included studies.

The analysis of the included studies in this review generated four major domains: incidence of orthopedic surgical site infection, risk factors of orthopedic SSI, causative microorganisms of orthopedic SSI, and prevention of orthopedic SSI. The domain of risk factors of orthopedic SSI included preoperative risk factors, intraoperative risk factors, and postoperative risk factors.

**Incidence of orthopedic SSI**

To our knowledge, no study conducted in Jordan reported the

rates of orthopedic SSIs, regardless of the type of orthopedic surgery studied. However, incidence rates of orthopedic SSI were reported in several studies globally. For example, Ridgeway et al. [14] reported that the incidence of SSI after hip arthroplasty procedures ranged from 2.23 % to 7.6%, whereas for adult spinal surgery the incidence of SSI ranged from 0.7% to 12% [15], and for primary total knee arthroplasty incidence of deep SSI it was 0.72% [16].

For spinal decompression and fusion surgeries, the incidence rate of SSIs was found to be 3.04%, 1.16% of these SSIs were deep incisional, and 1.88% were superficial incisional [10]. Another retrospective study conducted by Olsen et al. [6] found that the incidence rate of SSI following orthopedic spinal operations was 2%; 43% of the orthopedic SSI cases were classified as deep incisional, 17% were classified as organ space, and 39% were classified as superficial incisional. For patients who had SSI after hip arthroplasty, 74% of them had superficial incisional SSI, 16% of them had deep incisional, and 10% of them had a joint infection [14].

**Preoperative risk factors**

The preoperative risk factors for orthopedic SSI that have been identified in the literature are gender, age, obesity, use of prophylactic antibiotics, presence of preoperative anemia, length of preoperative stay, malnutrition, ASA score, tobacco smoking, presence of a chronic disease, and preoperative hyperglycemia (table 1)

Table 1: Risk factors for orthopedic SSI

Surgical stage	Risk factor
Preoperative	Gender
	Age
	Obesity
	Use of prophylactic antibiotics
	Presence of anemia
	Length of preoperative stay
	Malnutrition
	American society anesthesiologists (ASA ) score
	Tobacco smoking
	Presence of chronic disease
Intraoperative	Preoperative hyperglycemia
	Operating room traffic
	Skin and surgical site preparation
Postoperative	Surgical procedure time
	Type and location of operation
	Length of postoperative stay
	Use of prophylactic antibiotics
	Use of drains
	Blood transfusion

### 1. Gender

The male gender has been associated with increased risk of deep SSI following primary total knee arthroplasty [16], which was also identified by Daines et al. [13] as a risk factor for SSI after total knee arthroplasty. The same was reported by Gheiti and Mulhall [12] that the male gender is a predisposing factor for peroprosthetic joint infection (PJI). Kalmeijer et al. [2] also identified male gender as an independent risk factor for orthopedic SSI. Compared to females, the male gender increases the risk of deep SSI following primary total knee arthroplasty by 1.85 times [16]. Mawalla et al. [17] explained that male patients had multiple risk factors such as tobacco smoking and HIV and so they will be more vulnerable to have SSI for such risk factors.

### 2. Age

Beiner et al. [18] reported that age alone does not predict the occurrence of orthopedic SSI after spinal operations. Similarly, Namba et al. [16] found no relationship to exist between age and deep SSI following primary total knee arthroplasty.

On the other hand, Ridgeway et al. [14] found that the risk of SSI following hip arthroplasty will increase with age, especially when the age is 75 years and older, which increases the possibility of developing orthopedic SSI by 1.5 times. Lee et al. [5] emphasized that orthopedic SSI has a greater impact on elderly patients than on young patients, which is represented by more than fivefold mortality and twofold duration of hospitalization.

### 3. Obesity

Obese patients have more adipose tissue that is minimally perfused, which in turn limits oxygen delivery. In addition, adipose tissue causes extra weight that imposes additional pressure on the incision, which may decrease its blood supply [19].

A retrospective nested case-control study conducted by Olsen et al. [6] has identified obesity as a factor increasing the risk of SSIs of orthopedic spinal operations, which was also identified by Veeravagu et al. [10] as a significant predictor of SSI after spinal decompression and fusion surgeries. Moreover, ter Gunne et al. [15] found that obesity is an independent risk factor for SSI following spinal deformity surgery, providing the fact of increased subcutaneous fat layer thickness, which in turn increases the need for more retraction forces during the surgery to provide exposure and subsequently increases tissue necrosis and, therefore, there is increased risk of SSI. Obesity can increase the risk of developing SSI following spinal operations by 4.5 times [6].

Namba et al. [16] concluded that deep SSIs after primary total knee arthroplasty had high incidence with large body mass index (BMI) (i.e. obesity). Morbid obesity (BMI of greater than 40 kg/ m<sup>2</sup>) has been identified as an independent risk factor for PJI [20], which was also considered as a risk factor for PJI by Panahi et al. [21] and Daines et al. [13]. BMI of

greater than 40 kg/ m<sup>2</sup> increases the risk of PJI by 3.23 times [20].

### 4. Use of prophylactic antibiotics

Olsen et al. [6] identified the use of aminoglycosides as a prophylactic antibiotic and giving the antibiotic one hour or more before the incision as a factor increasing the risk of SSIs of orthopedic spinal operations. They found the suboptimal timing of administering prophylactic antibiotic (i.e. antibiotic administration more than one hour before the incision) to increase the risk of SSI following orthopedic spinal operation by 3.1 times. However, the use of cefazolin as antibiotic prophylaxis and increasing the antibiotic dose according to obesity have been associated with reduced risk of SSIs after orthopedic spinal operations [6]. Similarly, Gheiti et al. [12] recommend that cefazolin or cefroxamine should be used as antibiotic prophylaxis and clindamycin and vancomycin for patients with MRSA or for patients with  $\beta$ -lactam allergy and to administer antibiotic within one hour before skin incision.

### 5. Presence of anemia

Periopertive anemia is associated with higher transfusion rates, postoperative infections, longer hospital stay and poor recovery [22].

Greenky et al. [23] revealed that the presence of anemia preoperatively is an independent risk factor for PJI by increasing the risk of PJI to 1.88 times, which in turn causing failure in arthroplasty surgery and subsequently increasing the morbidity after total joint arthroplasty. The same was reported by Gheiti et al. [12] that preoperative anemia is a predisposing factor for PJI. Veeravagu et al. [10] also identified preoperative anemia as a significant predictor of SSI after spinal decompression and fusion surgeries; they found that preoperative anemia increases the risk of SSI after spinal decompression and fusion surgeries by 1.37 times.

### 6. Length of preoperative stay

As the patient's hospital stay is prolonged, the patient will be more exposed to nosocomial microorganisms that may result in orthopedic SSI [20]. Beiner et al. [18] reported that extended prehospitalization predisposes the patient to SSI. Ridgeway et al. [14] found that the risk of SSI following primary total hip replacement will increase by 1.53 times and for revision total hip replacement to increase by 2.24 times if the preoperative stay was longer than 48 hours. Lee et al. [5] found that admission to hospital within the same day of surgery is associated with a low risk of SSI.

### 7. Malnutrition

Beiner et al. [18] revealed that malnourished patients are at increased risk of SSI after spinal surgery. Veeravagu et al. [10] also found that the risk of SSI after spinal decompression and fusion surgeries will increase by 2.14 times if there was severe weight loss along with malnutrition. On the other hand, Olsen et al. [6] revealed that malnutrition was not associated with orthopedic SSI after spinal surgery. Gheiti et al. [12] reported that poor nutritional status is a predisposing factor for PJI.

#### 8. American Society of Anesthesiologists (ASA) score

An ASA score of 3 or more has been associated with increased risk of deep SSI following primary total knee arthroplasty by 1.91 times [16]. An ASA score of more than 2 has been identified as an independent risk factor for PJI [12, 20, 21]

Veeravagu et al. [10] also identified an ASA score of 3 or more as a significant predictor of SSI after spinal decompression and fusion surgeries; they revealed that an ASA score of 3 increased the risk of SSI after spinal decompression and fusion surgeries by 1.45 times, and an ASA score of 4 or 5 increased the risk of SSI after spinal decompression and fusion surgeries by 1.66 times.

#### 9. Tobacco smoking

Tobacco smoking has been found to impair tissue oxygenation and cause hypoxia via vasoconstriction, thus impairing wound healing [17].

Veeravagu et al. [10] identified tobacco use as a significant predictor of SSI after spinal decompression and fusion surgeries by increasing the risk of SSI by 1.19 times. Moreover, tobacco smoking was found to be a risk factor for SSI after hip and knee replacement [24]. However, the results of randomized controlled trial conducted by Näsell et al. [25] showed that superficial SSI after orthopedic surgery for fractures was not affected by tobacco smoking, despite the effect of smoking on the development of osteomyelitis following tibial fracture.

#### 10. Presence of chronic disease

Olsen et al. [6] identified diabetes as a factor increasing the risk of SSIs of orthopedic spinal operations by 8.4 times, which was also identified by Veeravagu et al. [10] as a significant predictor of SSI after spinal decompression and fusion surgeries by increasing the risk of SSI by 1.15 times. Namba et al. [16] found that the risk of deep SSIs after primary total knee arthroplasty would increase with diabetes by 1.63 times. Similarly, Daines et al. [13] have reported diabetes as a risk factor for PJI.

Rheumatoid arthritis has been associated with increased risk of PJI [9, 20], which was also identified by Daines et al. [13] as a risk factor for SSI after total knee arthroplasty. Namba et al. [16] found that the risk of deep SSIs after primary total knee arthroplasty would increase with osteoarthritis by 0.55 times, and to increase with posttraumatic arthritis by 3.58 times.

#### 11. Preoperative hyperglycemia

There is an association between hyperglycemia and exposure to surgical intervention, regardless of if the patient is diabetic or not, which in turn impairs the wound healing process and subsequently increases the risk of SSI [26].

Olsen et al. [6] has identified elevated preoperative blood glucose level of more than 125mg/dl as a factor increasing the risk of SSIs of orthopedic spinal operations by 5.3 times. In addition, Gheiti et al.[12] reported that elevated blood glucose

level is a predisposing factor of PJI.

#### Intraoperative risk factors

The intraoperative risk factors for orthopedic SSI that have been identified in the literature are operating room traffic, skin and surgical site preparation, surgical procedure time, and type and location of operation.

##### 1. Operating room traffic

A clinical trial study conducted by Beldi et al. [27] in Bern, Switzerland, has revealed that personnel change in the surgical team during the operation, presence of visitors and family members in the operating room, and a high level of noise contribute significantly to SSIs. The increased number of people in the operation theatre can increase the risk of SSIs [17]. Olsen et al. [6] have identified that two or more surgical personnel participating in the operation is a factor increasing the risk of SSIs of orthopedic spinal operations by 2.5 times. Panahi et al. [21] have also identified increased operating room traffic as a risk factor for PJI, providing the fact that opening the door of the operating room disrupts the laminar airflow and allows pathogens to enter the site of the operation. Moreover, increased operating room traffic itself can increase the risk of the patient developing PJI.

##### 2. Skin and surgical site preparation

Skin preparation for surgical intervention plays a role in the incidence of orthopedic SSIs. Owens et al. [28] reported that clippers should be used instead of shaving if hair removal is necessary in order to prevent microscopic cuts in the skin that act as foci for infection. In addition, Gheiti et al. [12] recommended the use clippers instead of razors for hair removal.

Mawalla et al. [17] identified the use of povidone-iodine to prepare the skin as a predictor of SSIs, providing the fact that povidone-iodine has a short activity when compared to chlorohixidine and it can be inactivated by serum proteins and blood. The same was also found by Darouiche et al. [29] in their clinical trial that chlorhexidine-alcohol is better than povidone-iodine in preventing SSIs when used to cleanse surgical sites. In addition, Swenson et al. [30] reported that combining chlorhexidine and isopropyl alcohol is superior to using 4% chlorhexidine alone or 70% isopropyl alcohol alone for skin preparation since the combination of both offers a better antimicrobial effect. Johnson et al. [31] encouraged the use of chlorhexidine to prepare patient's skin preoperatively at night before the surgery and in the morning of the surgery. Furthermore, Bode et al. [32] and Kim et al. [33] added the idea of administering intranasal mupirocin besides chlorhexidine shower to reduce the risk of orthopedic SSI.

In general, Beldi et al. [27] emphasized that adherence to asepsis by the surgical team without applying more extensive measures other than the usual aseptic measures can reduce the occurrence of SSIs.

##### 3. Surgical procedure time

Beldi et al. [27] identified a long surgical procedure lasting more than three hours as a risk factor for developing SSIs as the percentage of patients who developed SSI was 24%. The same was also identified as a risk factor by Malone et al. [34] and Mawalla et al. [17]. Al-Zaru et al. [19] and Mawalla et al. [17] reported that increased surgical procedure time increases the susceptibility of wound exposure to bacterial contamination from the environment.

Beiner et al. [18] and Veeravagu et al. [10] identified a long operative duration of three hours or more as a significant risk factor for SSI after spinal surgery by increasing the risk of SSI by 1.33 times and more. Ridgeway et al. [14] found that the risk of SSI following hip arthroplasty will increase if the operation lasted for 2 hours or more by 1.58 times. Namba et al. [16] concluded that each 15 minutes increase in operation time is associated with a 9% increment in the risk of deep SSI following primary total knee arthroplasty.

#### *4. Type and location of operation*

Olsen et al. [6] identified operations for seven or more intervertebral levels as a factor increasing the risk of SSIs of orthopedic spinal operations by 3.3 times. However, an operation on the cervical spine and an operation at one vertebral level have been associated with a reduced risk of SSIs in orthopedic spinal operations. ter Gunne et al. [15] reported that surgeries for adult spinal deformities such as kyphosis and scoliosis have longer surgical times compared to other spinal surgeries and are, therefore, susceptible to a higher rate of infection postoperatively.

#### **Postoperative risk factors**

The postoperative risk factors for orthopedic SSI that have been identified in the literature are length of postoperative stay, use of prophylactic antibiotics, use of drains, and blood transfusion.

##### *1. Length of postoperative stay*

Gheiti et al. [12] reported that prolonged hospital stay postoperatively is a predisposing factor of PJI. Pulido et al. [20] revealed that a longer hospital stay can increase the risk of PJI by 1.09 times.

##### *2. Use of prophylactic antibiotics*

Olsen et al. [6] identified antibiotic prophylaxis with aminoglycosides and the use of antibiotic solution to irrigate surgical wounds as factors that increase the risk of SSIs after orthopedic spinal operations by 2.7 times for both. Gheiti et al. [12] recommended that antibiotic prophylaxis should not exceed the first 24 hours postoperatively.

##### *3. Use of drains*

Olsen et al. [6] identified the use of drain for three days or more postoperatively as a factor to increase the risk of SSIs after orthopedic spinal operations by 2.8 times. Daines et al. [13] reported that prolonged surgical site drainage after joint arthroplasty can result in deep PJI, providing the fact that with prolonged drainage subcutaneous hematoma can develop and

subsequently foster bacterial growth and impose tension on the healing surgical wound. In addition, Gheiti et al. [12] reported that continuous wound drainage is a predisposing factor of PJI. ter Gunne et al. [15] established the fact that obese patients may need the use of drain postoperatively due to increased subcutaneous tissue thickness, thereby creating a dead space between the skin stitches and the fascia.

#### *4. Blood transfusion*

Blood transfusion has been found to enhance inflammation and to suppress immunity, and immunomodulation occurs in relation to the transfused blood, thereby increasing the risk of nosocomial infection, primarily surgical site infection [35].

Olsen et al. [6] identified perioperative transfusion of packed red blood cells and platelets as a factor increasing the risk of SSIs of orthopedic spinal operations by 3.4 times, which was also identified by Veeravagu et al. [10] as a significant predictor of SSI after spinal decompression and fusion surgeries. Allogenic blood transfusion has been identified as an independent risk factor for PJI [12, 20]. Daines et al. [13] have also reported blood transfusion postoperatively as a risk factor for PJI.

#### **Causative microorganism of orthopedic SSI**

Kim et al. [33] reported that the patients themselves bring the microorganisms responsible for SSI, primarily staphylococcus aureus found in their anterior nares.

Lee et al. [5] found in their nested, matched case-control study that the most common causative microorganism of orthopedic SSI is staph. aureus [including methicillin resistant staph. aureus (MRSA)], followed by coagulate-negative staphylococci, and E. Coli. Berbari et al. [9] revealed that staph. aureus was the most common microorganism causing PJI. Whereas Phillips et al. [36] found in their prospective survey that deep prosthetic infections are most commonly caused by coagulase-negative staphylococci, followed by staph. aureus as well as enterococci and streptococci.

Staph. aureus was identified to affect 50% of the cases of SSIs after hip arthroplasty [14]. Kalmeijer et al. [2] also revealed that staph. aureus affected half of the cases of SSIs after orthopedic surgery; 36 % of all orthopedic SSI cases were superficially incisional, and 71% of all orthopedic SSI cases were deeply incisional.

#### **Prevention of orthopedic SSI**

Once the risk factors for orthopedic SSI are identified, rapid and definitive prevention of such risk factors can be established [18]. Gheiti et al. [12] added that the idea of improving the patients' health before surgical intervention is important to reduce the risk of SSI. They also emphasized screening for MRSA in orthopedic patients, the necessity for smoking cessation, use of staples for wound closure instead of traditional suturing, blood transfusion only when indicated, and control of blood glucose level preoperatively and postoperatively. Rutan et al. [26] recommended monitoring of the blood glucose every two hours during the surgery if the

surgery lasts for more than two hours, especially if the patients' preoperative blood glucose level was more than 110 mg/dL and to establish protocol for monitoring blood glucose level postoperatively for the patient with blood glucose level of more than 180 mg/dL.

Spahn [22] suggested managing the anemia by iron and erythropoietin supplementation instead of allogenic blood transfusion in order to reduce postoperative complications such as SSI.

Daines et al. [13] recommended to initiate the first dose of antibiotics within 60 minutes before making the surgical incision, discontinuing the prophylactic antimicrobial therapy within the first 24 hours postoperatively, limiting the number of healthcare personnel exiting and entering the operating room to decrease the level of airborne microbial contamination and replacing prolonged wound drainage with irrigation. Namba et al. [16] focused on optimizing patient body weight and controlling diabetes mellitus to decrease rates of deep SSI after total knee arthroplasty. The preventive strategies for orthopedic SSI are summarized in table 2.

Table 2: Preventive strategies for orthopedic SSI.

1. MRSA screening.
2. Administering intranasal mupirocin for nasal carriers of staph. aureus.
3. Using clindamycin and vancomycin for patients with MRSA or for patients with  $\beta$ -lactam allergy.
4. Use of cefazolin or cefroxamine as antibiotic prophylaxis and adjusted according to obesity.
5. Smoking cessation.
6. Optimizing patient body weight.
7. Using chlorhexidine to prepare patient skin preoperatively at night before the surgery and in morning of the surgery.
8. Use of staples for wound closure.
9. Use of clippers instead of razors for hair removal.
10. Use of chlorhexidine- alcohol rather than povidone-iodine in cleansing surgical site.
11. Control of operating room traffic.
12. Irrigation of wound needing prolonged drainage.
13. Establishing protocols for controlling blood glucose levels preoperatively and postoperatively.
14. Optimal timing of administering and discontinuing prophylactic antibiotic therapy.
15. Blood transfusion only when indicated, treatment of anemia with iron and erythropoietin to replace blood transfusion as an option for anemia management.

## CONCLUSION

SSI following orthopedic surgery is a devastating complication that results in physical limitations and delayed recovery from orthopedic surgical intervention, so it is important to identify risk factors and causative agents for orthopedic SSI so that appropriate prevention strategies can be implemented. A number of risk factors for orthopedic SSI have been identified in the literature and are categorized as preoperative, intraoperative, and postoperative risk factors. The preoperative risk factors are mainly patient-related, while intraoperative and postoperative risk factors are mainly iatrogenic.

The incidence rates of orthopedic SSI ranged from 0.7 % to 8%; although it is a small percentage, it will be reflected in hundreds of patients suffering from delayed healing, increased treatment costs and extended hospital stay. Orthopedic SSIs are caused by a number of microorganisms, the most prevalent of which is staph. aureus. Prevention of orthopedic SSI requires evaluating patient's health status and establishing protocols and policy to manage the risk factors of orthopedic SSI through the preoperative, intraoperative and postoperative phases..

## LIMITATIONS

Only 29 primary references were included in the matrix table; this is due to the limited scope of accessibility to the most recent and available literature which may contribute to a lack of validity of our findings. An inadequate number of the reviewed studies is a limitation in this systematic review. In addition, it is likely that valid and further of recent studies were not incorporated since the review was specific to risk factors of orthopedic SSI and may have been restricted by the previously mentioned databases. Using different methods of measurements in the reviewed studies is another drawback that makes it difficult to control for variance in evaluation methods, and this will lead to potential bias to draw an inference from these studies. The majority of reviewed studies used the self-developed instrument to explore the risk factors of orthopedic SSI and not all studies evaluated the patient's risk level of developing orthopedic SSI.

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## References

1. Bader T, Kadhim H. 2012. Evaluation of nurses' practices toward orthopaedic wound infection. *Ira Nat J Nurs Spec* 25: 58 – 70.
2. Kalmeijer MD, Nieuwland-Bollen EV, Bogaers-Hofman D et al. 2000. Nasal carriage of *Staphylococcus aureus* is a major risk factor for surgical-site infections in orthopedic surgery. *Infect Control Hosp Epidemiol* 21: 319-323.
3. Allouzi D. 28 Oct. 2015. 6 thousands orthopedic surgeries conducted annually in ministry of health hospitals . *Addustour* p. 8.
4. Steiner C, Andrews R, Barrett M, Weiss A. *HCUP Projections: Mobility/Orthopedic Procedures 2003 to 2012*. 2012. *HCUP Projections Report # 2012-03*. ONLINE September 20, 2012. U.S. Agency for Healthcare Research and Quality. Available at: <http://www.hcup-us.ahrq.gov/reports/projections/2012-03.pdf>.

5. Lee J, Singletary R, Schmader K et al. 2006. Surgical site infection in the elderly following orthopaedic surgery. *J Bone Joint Surg Br* 88: 1705-1712.
6. Olsen MA, Nepple JJ, Riew KD et al. 2008 Risk factors for surgical site infection following orthopaedic spinal operations. *J Bone Joint Surg Br* 90: 62-69.
7. Rao N, Cannella B, Crossett LS et al. 2008. A preoperative decolonization protocol for *Staphylococcus aureus* prevents orthopaedic infections. *Clin Orthop* 466: 1343-1348.
8. Whitehouse JD, Friedman ND, Kirkland KB et al. 2002. The Impact of Surgical-Site Infections Following Orthopedic Surgery at a Community Hospital and a University Hospital Adverse Quality of Life, Excess Length of Stay, and Extra Cost. *Infect Control Hosp Epidemiol* 23: 183-189.
9. Berbari EF, Hanssen AD, Duffy MC et al. 1998. Risk factors for prosthetic joint infection: case-control study. *Clin Infect Dis* 27: 1247-1254.
10. Veeravagu A, Patil CG, Lad SP, Boakye M. 2009. Risk factors for postoperative spinal wound infections after spinal decompression and fusion surgeries. *Spine* 34: 1869-1872.
11. Masaadeh HA, Jaran AS. 2009. Incident of *Pseudomonas aeruginosa* in post-operative wound infection. *Am J Infect Dis* 5: 1-6.
12. Gheiti AJC, Mulhall KJ. 2013. Peri-Prosthetic Joint Infection: Prevention, Diagnosis and Management. INTECH Open Access Publisher.
13. Daines BK, Dennis DA & Amann S (2015) Infection Prevention in Total Knee Arthroplasty. *J Am Acad Orthop Surg* 23: 356-364.
14. Ridgeway S, Wilson J, Charlet A et al. 2005. Infection of the surgical site after arthroplasty of the hip. *J Bone Joint Surg Br* 87: 844-850.
15. ter Gunne AFP, van Laarhoven CJHM, Cohen DB. 2010. Incidence of surgical site infection following adult spinal deformity surgery: an analysis of patient risk. *Eur Spine J* 19: 982-988.
16. Namba RS, Inacio MC, Paxton EW .2013. Risk factors associated with deep surgical site infections after primary total knee arthroplasty. *J Bone Joint Surg Br* 95: 775-782.
17. Mawalla B, Mshana SE, Chalya PL et al. 2011. Predictors of surgical site infections among patients undergoing major surgery at Bugando Medical Centre in Northwestern Tanzania. *BMC Surg* 11.
18. Beiner JM, Grauer J, Kwon BK, Vaccaro AR . 2003. Postoperative wound infections of the spine. *Neurosurg Focus* 15: 1-5.
19. Al-Zaru IM, Ammouri AA, Al-Hassan MA, Amr AA . 2010. Risk factors for deep sternal wound infections after cardiac surgery in Jordan. *J Clin Nurs* 19: 1873-1881.
20. Pulido L, Ghanem E, Joshi A. 2008. Periprosthetic joint infection: the incidence, timing, and predisposing factors. *Clin Orthop* 466: 1710-1715.
21. Panahi P, Stroh M, Casper DS .2012. Operating room traffic is a major concern during total joint arthroplasty. *Clin Orthop* 470: 2690-2694.
22. Spahn DR .2010. Anemia and Patient Blood Management in Hip and Knee Surgery A Systematic Review of the Literature. *J Am Soc Anesthesiol* 113: 482-495.
23. Greenky M, Gandhi K, Pulido L .2012. Preoperative anemia in total joint arthroplasty: is it associated with periprosthetic joint infection?. *Clin Orthop* 470: 2695-2701.
24. Møller AM, Villebro N, Pedersen T, Tønnesen H .2002. Effect of preoperative smoking intervention on postoperative complications: a randomised clinical trial. *Lancet* 359: 114-117.
25. Nåsell H, Adami J, Samnegård E et al. 2010. Effect of smoking cessation intervention on results of acute fracture surgery. *J Bone Joint Surg* 92: 1335-1342.
26. Rutan L, Sommers K. 2012. Hyperglycemia as a risk factor in the perioperative patient. *AORN J* 95: 352-364.
27. Beldi G, Bisch-Knaden S, Banz V et al. 2009. Impact of intraoperative behavior on surgical site infections . *Am J Surg* 198: 157-162.
28. Owens CD, Stoessel K. 2008. Surgical site infections : epidemiology, microbiology and prevention. *J Hosp Infect* 70: 3-10.
29. Darouiche RO, Wall Jr MJ, Itani KM et al. 2010. Chlorhexidine–alcohol versus povidone–iodine for surgical-site antisepsis. *N Engl J Med* 362: 18-26.
30. Swenson BR, Hedrick TL, Metzger R et al. 2009. Effects of Preoperative Skin Preparation on Postoperative Wound Infection Rates A Prospective Study of 3 Skin Preparation Protocols. *Infect Control Hosp Epidemiol* 30, 964-971.
31. Johnson AJ, Daley JA, Zywiell MG, Delanois RE & Mont MA (2010) Preoperative chlorhexidine preparation and the incidence of surgical site infections after hip arthroplasty. *J Arthroplasty* 25: 98-102.
32. Bode LG, Kluytmans JA, Wertheim HF et al. 2010. Preventing surgical-site infections in nasal carriers of *Staphylococcus aureus*. *N Engl J Med* 362: 9-17.
33. Kim DH, Spencer M, Davidson SM et al. 2010. Institutional prescreening for detection and eradication of methicillin-resistant *Staphylococcus aureus* in patients undergoing elective orthopaedic surgery. *J Bone Joint Surg* 92: 1820-1826.
34. Malone DL, Genuit T, Tracy JK et al. 2002. Surgical site infections : reanalysis of risk factors. *J Surg Res* 103: 89-95.
35. Bernard AC, Davenport DL, Chang PK et al. 2009. Intraoperative transfusion of 1 U to 2 U packed red blood cells is associated with increased 30-day mortality, surgical-site infection, pneumonia, and sepsis in general surgery patients. *J Am Coll Surg* 208: 931-937.
37. Phillips JE, Crane TP, Noy M et al. 2006. The incidence

Authors.Year	Title	Purpose	Design	Sample	Results
Berbari et al. 1998.	Risk factors for prosthetic joint infection: case-control study.	To identify patient populations at increased risk for periprosthetic joint infection (PJI).	Case-control study.	26,505 patients	SSI not involving the joint prosthesis, NNIS risk index score of 1 or 2, presence of malignancy, and history of joint arthroplasty are associated with increased risk for PJI.
Kalmeijer MD, Nieuwland-Bollen EV, Bogaers-Hofman D et al. 2000.	Nasal carriage of Staphylococcus aureus is a major risk factor for surgical-site infections in orthopedic surgery.	To determine importance of risk factors for development of SSI with prosthetic implants.	Prospective.	272 patients	Male gender, surgeon 1 and high level of nasal carriage of staph. aureus were independent risk factors for development of SSI.
Malone DL, Genuit T, Tracy JK .2002	Surgical site infections: reanalysis of risk factors.	Reevaluating risk factors of SSI in noncardiac surgical patients.	Prospective	5031 patients	Diabetes, malnutrition, and postoperative anemia are significant risk factors for SSI.
Møller AM, Villebro N, Pedersen T, Tønnesen H .2002.	Effect of preoperative smoking intervention on postoperative complications: a randomised clinical trial.	To investigate the effect of preoperative smoking intervention on frequency of postoperative complications of hip and knee replacement.	RCT	120 patients	Effective smoking intervention program initiated 6 – 8 weeks before surgery reduces postoperative morbidity.
Beiner JM, Grauer J, Kwon BK, Vaccaro AR .2003.	Postoperative wound infections of the spine.	Discussing the incidence, risk factors, and the outcome of prophylactic antibiotic use with postoperative lumbar infections.	Integrated literature review	xxxx	Malnutrition, extended pre-hospitalization and prolonged operation time predispose the patient to SSI. First generation cephalosporin should be administered prior to skin incision.
Ridgeway S, Wilson J, Charlet A et al. 2005.	Infection of the surgical site after arthroplasty of the hip.	To estimate incidence of SSI after hip arthroplasty and its strength of association with major risk factors.	Prospective	24,808 patients	Overall incidence of SSI ranged from 1.6 – 7.1%. Age group, trauma, duration of operation, and American Society of Anesthesiologists (ASA) score are significant risk factors for SSI.
Phillips JE, Crane TP, Noy M et al. 2006	The incidence of deep prosthetic infections in a specialist orthopaedic hospital A 15-YEAR PROSPECTIVE SURVEY.	To estimate incidence of deep prosthetic infection in hip and knee replacement surgeries	prospective	10,735 patients (5947 hip surgeries , 4788 knee surgeries )	Incidence of SSI after hip replacement were 0.57%) Incidence of SSI after knee replacement were 0.86%)
Lee J, Singletary R, Schmader K, Anderson DJ et al. 2006.	Surgical site infection in the elderly following orthopaedic surgery.	To identify risk factors of SSI and impact of SSI on health outcomes in elderly following orthopedic surgery.	Nested, matched case-control study	15,218 patients	SSI was a strong predictor of mortality and increased length of hospital stay.
Olsen MA, Nepple JJ, Riew KD et al. 2008.	Risk factors for surgical site infection following orthopaedic spinal operations.	To determine risk factors for SSI following orthopedic spinal operations.	Retrospective case-control	2316 patients	Diabetes, suboptimal timing of antibiotic therapy, elevated serum glucose level, obesity, and participation by 2 or more surgical residents are associated with increased risk of SSI.

Pulido L, Ghanem E, Joshi A et al. 2008	Periprosthetic joint infection: the incidence, timing, and predisposing factors.	To determine risk factors of PJI after arthroplasty To determine incidence and timing of PJI.	Retrospective cohort study	9245 patients	Incidence of PJI was 0.7%, majority of incidence occurred within the first year after surgery.  High ASA score, morbid obesity, bilateral arthroplasty, allogenic transfusion, and longer hospitalization were independent predictors of PJI.
Owens CD, Stoessel K. 2008	Surgical site infections : epidemiology, microbiology and prevention.	To clarify epidemiology microbiology, and prevention of SSI	Integrated literature review	xxxx	Organisms responsible for SSI were identified.  Strategies to prevent SSI have been set up.
Veeravagu A, Patil CG, Lad S, Boakye M. 2009.	Risk factors for postoperative spinal wound infections after spinal decompression and fusion surgeries.	To determine preoperative, intraoperative, and patient characteristics that contribute to increased risk of SSI in patients undergoing spinal surgery.	prospective	24,774 patients	Insulin dependent diabetes, tobacco use, ASA score of 3 or more, weight loss, preoperative anemia, disseminated cancer, intraoperative transfusion, and operations of 3 hours or more are significant predictors of SSI.
Swenson BR, Hedrick TL, Metzger R et al. 2009.	Effects of Preoperative Skin Preparation on Postoperative Wound Infection Rates A Prospective Study of 3 Skin Preparation Protocols.	To determine the effect of different skin preparation solutions on SSI rates	prospective	3209 operations	Idophor-based compounds may be superior to chlorhexidine in lowering SSI rates.
Beldi G, Knaden S et al. 2009.	Bisch Impact of intraoperative behavior on surgical site infections.	To identify intraoperative risk factors of SSI.	prospective	1032 patients	Operation longer than 3 hours, visitors in the operation room, change of members within the surgical team, and loud noise were significantly associated with SSI.
Bernard AC, Davenport DL, Chang PK et al. 2009.	Intraoperative transfusion of 1 U to 2 U packed red blood cells is associated with increased 30-day mortality, surgical-site infection, pneumonia, and sepsis in general surgery patients.	To understand the effect of leukoreduced RBC's transfusion on general surgery patients.	Prospective	125,223 patients.	Intraoperative transfusion of packed RBC's increases the risk for mortality and several morbidities in general surgery patients.
Nåsell H, Adami J, Samnegård E et al. 2010.	Effect of smoking cessation intervention on results of acute fracture surgery.	To assess whether a 6-week postoperative smoking cessation program could reduce complications following surgical treatment of fractures.	RCT	298 patients	A 6-week postoperative smoking cessation program reduced risk of postoperative complications following fracture surgery.

Spahn DR . 2010.	Anemia and Patient Blood Management in Hip and Knee Surgery A Systematic Review of the Literature.	To understand epidemiologic characteristics of anemia in patients undergoing hip surgery.	Systematic review of literature.	xxxx	Treatment of postoperative anemia iron, with or without erythropoietin and preoperative cell salvage decreases the need for blood transfusion and improves patient outcomes.
ter Gunne AFP, van Laarhoven, CJHM, Cohen DB. 2010.	Incidence of surgical site infection following adult spinal deformity surgery: an analysis of patient risk	To identify predisposing factors for incidence of SSI following adult spinal deformity surgery	Retrospective	830 patients	Obesity and history of prior SSI were found to be risk factors for SSI following adult spinal deformity surgery.
Bode et al. 2010.	Preventing surgical-site infections in nasal carriers of Staphylococcus aureus.	To assess whether decolonization of the nostrils with mupirocin ointment and of the skin with chlorhexidine gluconate could prevent staph. aureus related SSI.	RCT	6771 patients	Number of staph. aureus related SSIs can be reduced by rapid screening and decolonization of nasal carriers of staph. aureus.
Kim et al. 2010.	Institutional prescreening for detection and eradication of methicillin-resistant Staphylococcus aureus in patients undergoing elective orthopaedic surgery.	To evaluate the feasibility and efficacy of screening program for detection and eradication of methicillin resistant staph. aureus (MRSA) and methicillin sensitive staph. aureus in patients undergoing orthopedic surgery.	Prospective	7019 patients	Implementation of screening program for detection and eradication of MRSA and methicillin sensitive staph. aureus is feasible and can lead to reduction of SSI rates.
Johnson AJ, Daley JA, Zywiell MG et al. 2010	Preoperative chlorhexidine preparation and the incidence of surgical site infections after hip arthroplasty.	To evaluate the effectiveness of at home skin preparation of chlorhexidine in decreasing incidence of deep periprosthetic hip arthroplasty infections.	Prospective	1134 patients	At home skin preparation of chlorhexidine is a simple and cost effective method to reduce periprosthetic hip infection rates.
Darouiche et al. 2010.	Chlorhexidine–alcohol versus povidone–iodine for surgical-site antisepsis.	To compare the efficacy of chlorhexidine-alcohol with that of povidone-iodine for preventing SSI.	RCT	897 patients	chlorhexidine-alcohol is superior to cleansing with povidone iodine for preventing SSI after clean contaminated surgery.
Mawalla B, Mshana SE, Chalya PL et al. 2011.	Predictors of surgical site infections among patients undergoing major surgery at Bugando Medical Centre in Northwestern Tanzania.	To establish prevalence, pattern and predictors of SSI	Cross-sectional prospective	941 patients	Use of drain, iodine alone for skin preparation, prolonged duration of operation and cigarette smoking were found to predict SSI.
Panahi P, Strohm M, Casper DS et al. 2012.	Operating room traffic is a major concern during total joint arthroplasty.	To define incidence of door opening during total joint arthroplasty.  To identify the etiology of door opening to develop strategies to reduce door opening.	Prospective	9657 door openings during 116 cases of surgical operations.	Traffic in operation room is a major concern during total joint arthroplasty.  Storage of instrument in operation room and education of operation room personnel is required to reduce door opening in operating room.
Rutan L, Sommers K. 2012.	Hyperglycemia as a risk factor in the perioperative patient.	To describe the pathophysiology of hyperglycemia as a risk	Integrated literature review	xxxx	Hyperglycemia is associated with increased SSI rates, increased mortality rates, and

			factor in the perioperative patient			intensive care units admissions which make it necessary to produce serum glucose management protocols.
Greenky Gandhi Pulido L et al. 2012.	M, K, et al.	Preoperative anemia in total joint arthroplasty: is it associated with periprosthetic joint infection?.	To determine the incidence of preoperative anemia in patients undergoing total joint arthroplasty . To assess association between preoperative anemia and subsequent PJI.	Retrospective	15,222 patients	Incidence of preoperative anemia was 19.6%. Preoperative anemia is associated with PJI.
Namba Inacio Paxton 2013.	RS, MC, EW.	Risk factors associated with deep surgical site infections after primary total knee arthroplasty.	To evaluate risk factors associated with deep SSI following total knee arthroplasty	Retrospective	56,216 patients	Body Mass Index (BMI), male sex, diabetes, and high ASA score were associated with increased risk for deep SSI.
Gheiti Mulhall 2013.	AJ, KJ.	Peri-Prosthetic Joint Infection: Prevention, Diagnosis and Management.	To explore diagnosis, management, and prevention of PJI.	Integrated literature review	xxxx	A number of risk factors for PJI has been listed. Diagnostic strategies and preventive measures for PJI have been set up.
Daines Dennis, Amann S. 2015.	BK, DA, S.	Infection Prevention in Total Knee Arthroplasty.	To describe risk factors of PJI and strategies for preventing PJI.	Integrated literature review	xxxx	Risk factors for PJI have been categorized into preoperative, intraoperative, and postoperative risk factors. Setting up strategies to prevent PJI.