Review Paper

Management and Prevention of Surgical Site Infections in Spine Surgery in a Resource Poor Setting: The Irrua Protocol

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ABSTRACT

Background and Aim: Surgical Site Infections (SSIs) in spine surgeries represent one of the most common hospital-acquired infections. SSI (refers to surgical wound infection within 30 days of surgery or 1 year after implant) portends a huge disease burden with devastating consequences for the patient and the hospital facilities with physical and psychological trauma to the patient and it is associated with an increased rate of morbidity and mortality. Despite improvements in the surgical protocol for asepsis and the role of prophylactic antibiotics in clean spine surgeries, a substantial increase still exists in the rate of SSIs. It is essential to review and identify factors predisposing patients with spinal problems to SSIs and its goal is to formulate a local protocol that helps to curtail SSIs and can be replicated in any setting in the world, considering the limitations of our setting. This study aims to review the risk factors for SSI following spine surgeries considering a 54-year-old woman with obesity who had SSI and highlights prevention ways.

Methods and Materials/Patients: This study includes the search of the literature using several platforms, such as Google Scholar, Hinari, PubMed, Academia, and other search engines with related keywords to surgical site infections in spine surgery. The retrieved articles were reviewed and in some parts, the narrative case of the 54-year-old obese woman was discussed in the literature.

Results: A total of 37 articles were found that matched the search words and satisfied the objective of the study. These articles were reviewed and used in writing this manuscript.

Conclusion: SSIs are on the increase, and identifying risk factors on a patient basis is key to prevention. Protocol on preventive measures should be strictly followed to avoid catastrophes associated with SSIs.

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Highlights

• Surgical Site Infections (SSIs) are a huge disease burden with significant loss of scarce resources and manpower.

• SSIs are one of the most common forms of hospital-acquired infection.

• Pre-, intra- and post-operative risk factors for SSIs following spine surgeries have been identified in the literature.

• Preventive measures in preventing SSIs are essential protocols to be adopted by all spine surgeons to mitigate SSIs.

Plain Language Summary

Surgical site infections (SSIs) following spine procedures are becoming frequent occurrences. The huge resource directed by individuals and the country in the management of SSIs can be directed to other sectors, such as increasing health finances, education, training, and re-training of health personnel. This study narrates the different risk factors that predispose the patient to SSIs following spine surgery and are categorized as before, during, and after surgeries. These risk factors include age, obesity, uncontrolled diabetes, cigarette smoking, hypothermia, drain use, etc. Adopting a holistic approach to preventing SSIs involves establishing a protocol aimed at addressing all identified and unidentified risk factors.

Introduction

In the last decade, we have seen a dramatic increase in the number of surgeries performed worldwide. Spine surgery has increased in number, and complexity and improved in quality over the years. This phenomenon is caused by the demand of an aging population, high expectations of patients, and a resultant need to constantly improve spine surgical skills and associated equipment, especially spinal instrumentation [1]. Despite the improvement in spine care as seen in spine surgeries, surgical site infections remain a source of great concern to the patients, surgeons, and healthcare systems of any nation.

In 1992, the center for Disease Control and Prevention (CDC) renamed wound infection a Surgical Site Infection (SSI) and defined it as an infection occurring in the surgical incision as well as organs and spaces manipulated during surgery, which starts within 30 days after surgery or 1 year, if an implant was used [2]. It is characterized by the proliferation of micro-organisms in the surgical site with resultant inflammation and pus formation (and discharge), wound dehiscence, and sometimes, implant failure.

SSI is the most common hospital-acquired infection [2] and its incidence following spine surgeries varies widely in the literature. The incidence after spine surgery is about 3.1% [3] with a range of 0.2% to 16.7% without instrumentation [4] and 2% to 20% with instrumentation [5]. This wide range of occurrences shows the disparity in patient volume, presentation, and pathology. It also reflects the variation in diagnostic approaches, definitions, treatment protocols, and follow-up evaluation [4, 6].

SSI has far-reaching impacts on the patient, the spine surgeon, and the healthcare system. For the patient, it leads to increased hospitalization, reoperation rates, and costs. In addition, it portends a risk of morbidity, an overall decrease in the quality of life, and sometimes, mortality [3, 7]. The occurrence of SSI constitutes a psychological and physical strain, and burden to the spine surgeon and can result in a reduction in operation confidence. Meanwhile, the healthcare system suffers a financial burden as SSIs increase the overall cost of spine surgery and the loss of valuable economic time. Blumberg et al found that, in addition to increased hospitalization, spine SSIs increase treatment expenses. At a single tertiary referral center, this cost averaged $16, 242 per case [8]. In our narrative case of a 54-year-old obese patient who had L1-L4 spine decompression and fixation and subsequent deep SSI, the further cost of surgery and postoperative care was estimated at $2,500.

Several risk factors exist for SSIs in spine surgery, including patient and surgery-related factors. To prevent these infections, several measures are effective and aimed at modifying the identified predisposing factors. However, no universally accepted protocol exists for the prevention and treatment of SSIs in spine surgery in the literature. Many areas of controversy are still observed in the diagnosis and treatment of SSIs [6]. Nonetheless, the management of spine SSI depends on early diagnosis (clinical and laboratory) and treatment. Treating SSI after spine surgery is daunting because the spine surgeon must choose between removing the implants for proper bacteria clearance and risking spinal instability. Ultimately, this shows why prevention is more profitable than hoping for proper treatment.

Materials and Methods

This was a narrative study that included a literature search using several platforms, such as Google Scholar, Hinari, PubMed, Academia, and other search engines with the search word surgical site infections in spine surgery. Subject articles relevant to the search words were displayed, thoroughly screened, retrieved, and reviewed and in some parts, the narrative index case of the 54-year-old obese woman managed in our neurosurgical unit was discussed in the literature which was reviewed. This article reviewed the literature on the current trends in the prevention and management of SSI in spine surgery to establish a local protocol which has now become a unit standardized protocol that significantly reduces surgical site infections in our spine patients who had spinal surgeries.

Results

A etiopathogenesis

Surgical Site Infections (SSIs) occur following the inoculation of microorganisms into a surgical wound. A study conducted by Donara et al showed that up to 98% of spinal implant-associated infections were acquired during surgery [6]. This issue occurs from contamination with microorganisms that make up the patient's normal flora mainly at surgical sites and nasal nares as well as those transferred from the theatre environment, including members of staff and equipment. This emphasizes the need for good preoperative and intraoperative preventive measures. Aside from this direct route of microbial acquisition, infectious agents can be acquired by diffusion from a nearby focus and rarely through the hematogenous route [6, 9].

Gram-positive infection is more common than gram-negative infection in most cases of spine SSIs [3, 10]. Following a systematic review, Jiaming Zhou et al found that the proportions of gram-positive and gram-negative bacteria were 60.4% and 25.7%, respectively [3]. Gram-negative organisms were predominant in patients who used topical vancomycin intraoperatively [11]. However, a negative culture was found in some cases [6, 10, 12]. The most common pathogens isolated in various studies were Staphylococcus aureus (30%-45.2%) and Staphylococcus epidermis (25%-30.4%) [3, 6, 10, 13]. Other organisms implicated include Methicillin-Resistant Staphylococcus Aureus (MRSA), Proprionibacterium acnes, Enterococcus faecalis, Escherichia coli, Enterobacter cloacae, Acinobacter spp, Klebsiella spp, Pseudomonas aeruginosa and Candida [3, 6, 10, 12, 13]. It is also not uncommon to find polymicrobial infection following spine surgery [6, 10, 12].

The bacteria varied with the anatomical site of the surgery. Staphylococci organisms predominated in the cervical spine, Cutibacterium spp. in the thoracic and lumbosacral region, and gram-negative bacilli in the lumbosacral part [6]. The finding in the distal spine may be connected to its proximity to the perineum and gut bacteria. Once in the surgical wound, the micro-organisms proliferate using several virulence factors (such as toxins, proteins, and enzymes) and when the immunological defense is overwhelmed, infection ensues. In addition, many organisms (especially the staphylococci genus) form a biofilm on the implant, which is a glycocalyx made up of extracellular polymeric substances [12]. By so doing, they evade detection and elimination, and this makes treatment difficult.

Classification

According to the center for Disease Control and Prevention (CDC), Surgical Site Infections can be classified as incisional, which was further divided into superficial and deep infections, and organ/space infections [2]. When applied to spine SSI, superficial infections are those involving the skin and subcutaneous tissues (supra-fascial) while deep infection affects the paraspinal fascia and muscles. Organ /space SSI includes infection affecting anatomical structures that were manipulated during surgery, other than the skin incision, fascia, or muscle layers. These include osteomyelitis, discitis, meningitis, or empyema [14]. This classification is vital because the different SSI types vary in clinical presentation, causative pathogens, and treatment approach. SSI following spine surgery can also be classified into early- and late-onset SSI, depending on the duration of presentation after surgery. However, there is controversy about the duration required to perform this classification. While some authors indicated 6 weeks [6], others have used 1 month or 3 months [6, 12]. Depending on the category, SSI differs in presentation and treatment.

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For example, while patients with early SSI did not require removal of the implant, patients with late-onset SSI occasionally need partial or complete retrieval of their hardware to allow for proper wound debridement and subsequent wound care [6].

Following a retrospective study of 1279 patients who underwent spinal surgery, Rishi Mugesh and colleagues proposed an anatomical classification and a treatment algorithm for each of the identified types of infection [15]. In this system, SSIs were classified into 5 types, according to the structures affected, as follows:

Type 1: Suprafascial necrosis

Type 2: Wound dehiscence

Type 3: Pus around screws and rods

Type 4: Bone marrow edema

Type 5: Pus in the disc space.

Predisposing Factor for Spine Surgical Site Infections (SSIs): Challenges and local protocols for optimal surgical outcomes

SSIs are caused by the interaction of the pathogenic organism, the environment, and the patient's immune system. Any factor that encourages the colonization and proliferation of pathogens predisposes a patient to infection. Several of these factors have been identified with corresponding measures to mitigate the associated risk factors. These risk factors will be discussed at their time of occurrence, as preoperative, intraoperative, and postoperative factors.

Preoperative factors

Age

Although SSIs are more common in older persons who had spine surgeries, it was not an independent risk factor for surgical site infection [7]. The increased incidence with age was related to the presence of other co-morbidities that usually occurs in the older age group and also decreasing organ-system functions with increasing age. The patients are more or less immunocompromised and age as a factor predisposes this age group susceptible to SSIs. We routinely admit them a day or two before surgery into a clean spine area and are made to do snare and intended surgical wound swabs as a baseline. They are also made to have chlorhexidine baths, a practice noted to significantly reduced SSIs.

Obesity

Obesity is an independent risk factor for developing spine SSI [3, 7, 16]. According to the findings of Meng F et al, a Body Mass Index (BMI) of greater than 30 kg/m^2 was associated with a high risk of SSIs [7]. In addition to the BMI, an increase in the thickness of subcutaneous fat (skin to lamina distance) was positively correlated with increased odds for SSI [17]. The predisposition comes from the fact that fatty tissue is poorly perfused and therefore does not support good healing. Moreover, a thick subcutaneous layer often requires more retraction, which can result in local tissue ischemia. To reduce the risk of obesity, patients should be optimized before spine surgery through dietary, physical, and sometimes, surgical methods. Administration of higher doses of prophylactic antibiotics may be necessary [18]. It is essential to involve dieticians, physiotherapists, and psychologists to achieve better outcomes. In the above narrative, a 54-year-old obese patient who had a deep SSI after lumbar spine decompression and fixation, whose BMI was 38 kg/m^2. This underscores the role of obesity in predisposing to SSIs compared to the above literature. As part of our routine, our spine unit set up a program of weight loss as advised by the dieticians

Diabetes mellitus

Enough evidence proves that Diabetes Mellitus (DM), when poorly controlled, places the patient at great risk of SSIs [4, 7, 17, 18]. This is due to the microangiopathic changes associated with DM, which reduces blood flow to tissue and thus discourages proper wound healing. Also, a persistently elevated blood sugar level inhibits leukocyte function (sick cell syndrome) and thus makes the patient prone to infection [17, 19]. As part of preparing DM patients for spine surgery, the surgeon should pay attention to the preoperative blood sugar level and establish the level of glycaemic control using hemoglobin A1C (HbA1C). Later it gives an idea about the level of control in the last 3 months. An HbA1C level of more than 7% is associated with a high risk of SSIs [16, 17]. Furthermore, Hikata et al. showed that no patient in his study with an HbA1c of far less than 7% developed SSI [20]. It is essential to cooperate with the endocrinologist to achieve optimal glucose level, as Zach et al. [21] recommend, it should be between 110 and 150 mg/dL. Furthermore, it is crucial to continue tight glucose control in the postoperative period because postoperative hyperglycemia has been identified as an independent risk factor for infection [21]. Estimating glucose levels is routine in all adults in our spine clinic but for diabetic patients, the degree of control should be established by doing HbA1c. We aim to ensure tight glycaemic control before spine surgeries.

Other Medical Co-morbidities

The presence of co-morbidities puts the patient at risk of SSI. Identified conditions include Chronic Kidney Disease (CKD), Congestive Cardiac Failure (CCF), hypertension, malignancy, Chronic Obstructive Airway Disease (COAD) as well as HIV/AIDS and other immunosuppressive conditions [4, 12, 13, 16]. These co-morbid conditions are routinely considered in our review and preparing such patients for surgery should include collaboration with the specialist physicians in our settings.

Smoking

Smokers undergoing spine surgery are at risk of SSIs [7, 13, 16, 19] and this risk is higher for persons who smoke 20 to 40 pack-years [4]. Smoking is associated with a higher carbon dioxide level which results in vasoconstriction and eventually leads to reduced tissue perfusion, reduced oxygenation and increased levels of reactive oxygen free radicals, and poor wound healing. Additionally, cigarette smoke contains a lot of contaminants that can impede wound healing [4, 16]. Cessation of smoking reduces this risk, although the benefits become appreciable after 4 to 6 weeks of smoking cessation [16, 17]. In our local setting, all our spine patients who are known smokers are identified and further counseled against smoking for four weeks before spine surgery.

Nutrition

Malnutrition is a risk factor for poor wound healing and SSIs. A serum albumin of less than 3.5 mg/dL was associated with an increased rate of SSIs [22]. Therefore, routine nutritional assessment (history, examination, and investigations) for patients before spine surgery to identify deficiencies as is done in most centers is an essential part of our surgical protocol. When this is found, the patients are optimized before surgery in conjunction with a nutritionist.

Steroids

Steroids are known to inhibit wound healing by affecting the formation of collagen. Also, they promote immunosuppression by inhibiting the function of the immune cells and phagocytic functions of the white blood cells. Thus, patients on perioperative steroids are at high risk of developing SSIs [18, 23]. It may be necessary to reduce the medications as part of preparing the patients for spine surgery. Unidentified prolonged steroid use that is concealed has been known to be associated with severe SSIs. More so, adrenocortical insufficiency (Addison's crisis) has been noted as sequelae of the sudden stoppage of steroids. The above 54-year-old woman earlier mentioned had concealed the steroid use and subsequently had features of adrenocortical insufficiency. In our setting, a high index of suspicion is routine in patients with a history of arthritis, obesity, chronic low back pain, and asthma who would have a share of the providence of being on steroids.

Other predisposing factors include preoperative exposure to radiation, cancer patients, American Society of Anesthesiologists (ASA) >2, and revision spine surgery [7, 10, 18].

Intra-operative factors

Surgery-Related Factors: The rate of SSIs depends on the type of spine pathology procedure performed. A higher rate of infection has been observed with surgeries for degenerative spinal disorders and corrective surgeries for scoliosis [1, 3]. Also, surgeries that include instrumentation have an overall higher rate of SSIs. This results from the formation of biofilm on the surface of the spinal implants, which leads to antibiotic resistance [3, 13]. Studies have also shown that infection rates differ with the part of the spine operated on. Some authors have noted that surgeries performed on the lumbosacral spine have a higher incidence of surgical site infections [10] compared to other spine regions. The infection rate varied with the surgical approach used. The combined approach posed the highest risk of SSIs, followed by the posterior-only approach, while the least rate of infection was seen with the anterior approach [3, 4]. Another surgical factor for SSI was the number of spinal segments operated, especially with instrumentations [13, 18]. The risk was found to increase with an increasing number of spinal levels instrumented and patients on whom greater than 2-spinal levels were operated have a significantly higher risk [18]. These may be related to longer operation time, prolong use of electrocautery and the need for blood transfusion in longer spine segment surgeries.

The total duration of surgery is essential when considering the risk of spine infection. Surgeries longer than 3 hours were associated with higher SSI rates [3]. This is likely due to the prolonged exposure to the theatre environment as well as the breach in aseptic technique as surgeons and other staff gets fatigued over time.

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Data from a study by Wathen et al suggested that an hour increase in the duration of surgery results in a 19% increase in infection risk [24] with a tendency toward more exposure to contamination [16], more blood loss, and prolonged use of electrocautery. Lastly, minimally invasive spine surgery is associated with a lower risk of infection compared to the open methods [4, 14].

Intra-operative Contamination: A major determinant of the occurrence of SSIs after spine surgery is the contamination of the surgical site with pathogens. The sources may be the patient, the surgeons, other staff, or the air in the theatre. Due to the importance of this factor, several measures have been recommended to help prevent its occurrence. Firstly, all surgeries must be performed in a sterile theatre with staff knowledgeable in asepsis. In addition, the surgeon must scrub adequately and wear a proper, sterile theatre outfit which should include double gloves. Also, confirmed carriers should be decolonized using intranasal mupirocin [16]. Another method of decolonization is the use of a whole-bod antiseptic bath or scrubbing of the proposed surgical site [4, 25]. This should be done 3 times before surgery (2 nights before, the night before, and the morning of surgery). However, daily baths for about 5 days before spine surgery is also safe and effective in preventing SSIs [25]. The best antiseptic solution for skin preparation before surgery is still controversial. While some studies found no difference between the use of povidone-iodine and chlorhexidine [26]; however, in our spine unit, our approach is to have the patient take a chlorhexidine bath the night before and morning of surgery and this helps to reduce SSIs. Others observed fewer infections when povidone or chlorhexidine was used with alcohol than when either of them was used alone [4]. However, our approach is to use chlorhexidine, alcohol, and the surgical site painted with povidone-iodine at the time of surgery. The use of sterile, impervious drapes impedes the translocation of pathogens from the patient's skin, resulting in a lower infection rate, a practice adopted in our local center. Skin shaving on the day of surgery and adequate skin preparation on-table also reduces the bacterial load on the skin, thus reducing the risk of SSIs. Our approach is to do on-table shaving of hair and this, with all intended purposes, helps reduce the incidence of SSI.

The administration of prophylactic antibiotics is an evidence-based method to prevent SSIs. It is recommended that an antimicrobial agent with activity against Staphylococcus is given 30 to 60 minutes before commencing surgery [13, 18]. This allows the Minimum Inhibiting Concentration (MIC) of the drug at the surgical site before making a surgical incision. Many authors use cephalexin 1 g or 20 mg/kg before surgery. The dose is repeated after 4 hours (or after 1500 mL of blood loss) and continued every 6-8 hours until 24 hours after the operation [3, 13, 19]. In our local protocol, we prescribe intravenous ceftriaxone at 1 g for adults and 100 mg/kg as our surgical antibiotics prophylactic, 4 hours after the commencement of surgery or when 1.5 L of blood is lost.

During spine surgery, immersing screws in a solution of vancomycin and ceftriaxone for 5 seconds before using them on the patient resulted in fewer postoperative SSIs [27]. Another measure of reducing the risk of colonization of the surgical site is copious irrigation of the wound with at least 2 L of normal saline, before wound closure [3, 28]. In addition, Ming-Te C et al. found that when the surgical wound is soaked with diluted povidone iodine for about 3 minutes before irrigation with saline, the infection rate was lower [28]. The use of vancomycin powder on the surgical site before the closure is very effective in reducing the occurrence of SSI in spine surgery. This is a routine practice in our units in which we pour 1 g of vancomycin powder into a surgical wound. It is a safe method that results in a higher concentration of the drug at the surgical wound with a lower toxicity profile compared to systemic administration [3, 29] which has a higher toxicity profile. All this is to reduce the possibility of contamination.

Finally, the rate of SSI correlates positively with the number of staff and personnel turnover in theatre. Following the analysis of over 12,500 patients, Wathen et al. noted a 6% increase in the risk of infection for every additional individual in the theatre [24]. Also, the use of intra-operative equipment (such as microscopes, fluoroscopy, and intraoperative computed tomography [CT]) scan increases the risk of infection through breaches in the aseptic technique [12]. In our spine suite, we limit our team members to seven (two surgeons, two anesthetists, one anesthetist technician, and two nurses) which is aim to reduce theatre congestion and help reduce the rate of SSI.

Hypothermia

Intraoperative hypothermia is a risk factor for postoperative SSIs [16, 19]. It can lead to hypo-coagulation which can lead to increased blood loss. Based on current evidence, it is recommended that the body temperature is maintained between 36.5°C and 37.5°C during spinal procedures for optimal results [4]. Despite this, the temperature at our spine suite is maintained at

18.0°C-20.0°C and we have had a record of hypocoagulopathy causing significant blood loss with SSIs.

Blood loss

Increased intraoperative blood loss is associated with an increased rate of SSIs. As Zhou et al. in their study revealed that losing more than 500 mL of blood intraoperatively doubled the rate of infection [3]. This may be connected to the invasiveness/duration of surgery and the higher chances of anemia with associated poor tissue oxygenation cum perfusion, and peri-operative blood transfusion all of which are risk factors for SSI [7, 18]. Therefore, efforts should be made to minimize blood loss as much as possible.

Dura tear

Spine surgery complicated with leakage of Cerebrospinal Fluid (CSF) is associated with a higher infection rate [7]. This emphasizes the need to achieve a water-tight repair of the dura following a durotomy for a spinal tumor or unintended durotomy.

Postoperative factors

Drain

The use of a closed suction drain (such as a Redivac drain) decreases the risk of SSI after spine surgery by reducing the formation of epidural hematoma and tissue edema. However, unnecessarily prolonged use of a drain can become a nidus for the microbial portal of entry and proliferation as microorganisms can migrate into the wound via the drain tract. This is especially true when a drain is left in place after 1 week [23]. There is controversy in the literature regarding the best time to remove a wound drain. Some authors recommend removing drains when the output is less than 50 mL/day or on the fifth postoperative day if the output remains more than 50 mL/day [30]. However, recent knowledge suggests that drains can be safely discontinued within 24-48 hours, rather than using a specific drain volume [13, 16]. This method has been found to reduce SSI without any increased incidence of hematoma. For us at Irrua Specialist Teaching Hospital (ISTH), we often use a wound drain (closed suction drain) and it is removed after 48 hours aiming to prevent epidural hematoma collection, and minimize SSI when removed early.

Position

Following a posterior approach to the spine, nursing a patient in the supine position is associated with an increased risk of SSI. In the supine position, the tissues around the surgical site are compressed against the bed and this can lead to local tissue ischemia, hypoxia, and muscle necrosis, resulting in poor healing and infection [30]. In addition, the wound is contaminated by the bed sheets and other fomites predisposing the surgical wound to infections. This can become a serious risk in patients with urinary and fecal incontinence [12, 30]. Thus it is recommended that patients be nursed in the lateral position with frequent turning and pressure-relieving beds. In addition, early immobilization after surgery greatly reduces the risk of surgical site infections [18].

Post-Operative Contamination

As noted previously, the surgical site can become inoculated with microbes on the bed coverings which can lead to infection. Another source of contamination is the direct acquisition during changing wound dressing. Laia et al. found that most dressing changes are unnecessary and that leaving wound dressing until the fifth postoperative day did not increase the rate of SSIs. It was recommended that wound dressing be changed early if it is visibly stained with blood [18]. In any case, all wound dressing should be done under strict asepsis, by suitably qualified personnel. The surgical wound of our patient is examined on the third day after surgery and bandaged with povidone-iodine, and the patient is discharged home between the third and fifth postoperative day.

Orthoses

The use of a cervical collar after surgery on the cervical spine is prone to SSIs. Therefore, its use should be limited to 48 hours [4].

Prolong Hospitalization

The longer the duration of hospitalization, the more likely the patient is to develop SSI. More so, a prolonged admission is associated with infection by multi-resistant organisms, such as the Methicillin Resistant-Staphylococcus Aureus (MRSA) [6, 23].

Management

Preventing spine SSIs is paramount but when it occurs, the best care possible must be offered to the patient. Managing such cases requires a high index of suspicion, especially in late-onset cases with non-specific clinical features. The management includes a detailed history, thorough examination, as well as laboratory and radiological investigation. Once the diagnosis is confirmed, appropriate treatment measures are deployed to completely eradicate the causative organism.

Clinical evaluation

In taking a history, attention is paid to identifying the clinical features and risk factors. The most common symptom is back pain, which can be similar to the pain before surgical intervention [12]. Moreover, non-relenting back pain may be the only complaint in late-onset SSI. Typically, worsening back pain that is disproportionate to the surgical site pain was the classical presenting symptom in a study by Rishi Mugesh et al. [15]. Other symptoms include purulent discharge from the surgical site, wound breakdown, fever, and other non-specific symptoms such as anorexia, malaise, and weight loss [19]. Examination findings include signs of inflammation such as erythema, swelling, tenderness, and differential warmth. These signs are particularly prominent in early SSI [19]. In addition, the patient may have various degrees of wound dehiscence, with the discharge of pus and necrosis of tissues. In most cases, the average duration for the development of infection was about 13 days, with a range of 3 to 23 days [27].

Investigations

The non-specific nature of the clinical features of SSIs necessitates the proper examination of patients. To achieve this, laboratory and radiological studies are often required.

Several laboratory investigations aid the diagnosis and follow-up evaluation of patients with spine SSIs. Firstly, the total White Blood Cells (WBC) count, which increases in response to infection, is a simple aid to diagnosis. Apart from microbial swabs for culture study, the WBC analysis is among the first line of the investigation requested. In a study conducted by Burak et al., a WBC of 10,000 cells/mL was a significant marker of postoperative infection [13]. However, it is non-specific as it can be elevated in other inflammatory conditions and trauma. In addition, increased WBC may be observed in patients on intraoperative steroids despite the absence of infection. In this case, a left shift in the white blood cells becomes a crucial finding in their diagnosis because it is not influenced by steroids [19]. Another laboratory test that is useful in evaluating cases of SSIs is the Erythrocyte Sedimentation Rate (ESR). The value of the ESR increases as a systemic response to inflammation. This is non-specific for spine SSI. However, it is more sensitive than the WBC level because the ESR is unlikely to remain within the normal range in the presence of an infection [19]. Therefore, it can be used to rule out an infection and for follow-up in patients with SSIs.

The most reliable hematological investigation is the measurement of the C-reactive Protein (CRP) level [12, 19, 31]. CRP is an acute-phase protein secreted by the liver in response to inflammatory cytokines, especially interleukin-6. Therefore, it is also non-specific for an SSI although it is more sensitive than ESR and WBC count. The CRP level rises early with the onset of SSI and reduces in response to treatment [31]. These features make it a veritable tool for diagnosis and monitoring of treatment response. In using CRP and ESR, establishing a rising trend in the postoperative period is more suggestive of infection than a single abnormal value since these markers may be elevated in the early postoperative period even in the absence of infection [31]. The serum CRP can be combined with ESR to improve its reliability [19, 31] However, no laboratory method has demonstrated excellent specificity and positive predictive value. Newer methods, such as the measurement of procalcitonin, serum amyloid protein A, leucocyte esterase, and pre-pepsin, require further studies to ascertain their relevance as diagnostic adjuncts [32]. We based our monitoring protocol of established SSIs on clinical evaluation, WBC, and ESR estimation with treatment.

Microbiological evidence of an ongoing infection is the most reliable means of making a diagnosis of SSIs after spine surgery [19, 32]. This involves the culture of effluent, tissue, and blood. By far, the most reliable diagnosis can be made from tissue culture which can be obtained at surgical debridement or percutaneously with CT scan guidance [19]. Thus, this is the gold standard for identifying the causative pathogen [12]. Furthermore, Donara et al. found that sonication of retrieved implants provided the highest yield of pathogens [6]. The importance of obtaining culture results cannot be overstated because understanding the microbiology of postoperative spine infections is valuable in choosing empiric antimicrobial treatment and infection prevention (as prophylactic antibiotics) [10]. It may be worthwhile to withhold antibiotics, for stable patients, until microbiology samples are collected [19].

Imaging studies such as plain radiographs, Computed Tomography (CT) scans, and magnetic resonance imaging (MRI) are useful methods for assessing a patient with spine SSI. Plain X-ray findings suggestive of infection include soft tissue swelling, a reduction in adjacent level disc height, end-plate erosion, and loosening of hardware. These features often become apparent after about 6 weeks postoperatively [33]. CT scan is more accurate than a plain x-ray in defining spine SSIs [12, 19]. It gives better details of the bone changes and state of the implants as well as shows the presence of fluid collection. Moreover, a CT scan can be used for image guidance when obtaining a biopsy for a culture study [19]. The best radiological modality to evaluate these cases is an MRI scan with gadolinium contrast. It has been shown to have a sensitivity of 93% and specificity of 97% for postoperative discitis, even after instrumentation [16]. In addition to the information derived from an MRI, it can clearly show the presence of discitis, osteomyelitis, and epidural abscesses after spinal surgery [12]. Other methods include Positron Emission Tomography (PET) scan, Positron Emission Tomography (PET)-CT, and Single Photon Emission Computed Tomography (SPECT) scans. As part of our protocol, the radiological request is for deep SSIs and we routinely request an MRI scan.

However, current imaging modalities can only show anatomical alterations and abnormalities but cannot differentiate infection from aseptic loosening, or assess the extent of infection. Newer imaging methods are being tried to circumvent these shortcomings. An example is the use of a human monoclonal antibody (1D9), targeting the staphylococcal antigen A (IsaA) of S. aureus labeled with a radionuclide (89-zirconium [89Zr]), [34]. However, further research is still needed to prove their reliability.

Treatment

Treating spine SSIs following spine surgery is difficult and often requires prolonged hospitalization, multiple surgeries for debridement and reoperation, removal of implants, and prolonged antibiotics use [3, 19] with huge costs to the patient and the economy.

Once a patient is suspected to have SSI after spine surgery, the initial treatment is aimed at stabilizing the patient. This is particularly important for patients presenting with septic shock, which is a possible complication. Following resuscitation, the patient requires surgical debridement which should be done in the theatre. This involves drainage of pus and excision of necrotic tissue and slough. The excised tissues serve as specimens for microbial studies. Our protocol is aimed at wound care, targeted antibiotic therapy, and wound debridement with the sole aim to curtail microbes and allowing wound healing.

It is controversial to retain hardware used in surgery. Nonetheless, undoubtedly, the removal of the implant allows for thorough debridement with the removal of biofilm, thus making complete clearance a possibility. Despite the varying position, it is recommended that superficial and early (including deep SSIs) infections can be treated with complete retention of instrumentation [6, 19] and is our adopted standard of care. On the other hand, for late-onset deep SSIs, the decision to remove implants depends on the state of the implant as well as the condition of the spine [6]. Implants that are loosened can be replaced. Sometimes managing late-onset SSIs requires the complete removal of screws and cages [5, 6]. Furthermore, it is safer to remove hardware after arthrodesis is achieved to prevent instability, pain, and neurological deficit [5]. Using the algorithm described by Rishi Mugesh et al, type 1 infections can be managed by surgical debridement and closure while type 2 and 3 require prolonged wound care, including the use of Vacuum-Assisted Closure (VAC), however, VAC is not readily available in our settings and is not a part of our protocol. Treating type 4 and 5 SSIs requires partial and complete removal of implants, respectively [15].

After the complete removal of dead and dying tissues, the wound is washed with a hydrogen peroxide solution, normal saline, povidone-iodine solution, and normal saline again, in that order. After this, the wound is soaked with povidone-iodine for about 5 to 10 minutes. Yong Yin et al. [5] found this method beneficial as 42 patients under his management healed satisfactorily. A closed drain may be necessary if the wound is closed immediately after debridement and irrigation. The drain can be left for 7 to 10 days [5]. However, secondary closure is recommended to assess the adequacy of debridement since most patients require more than one session [4, 19]. A thorough wound debridement in which necrotic tissue is removed until a bleeding wound edge is achieved with or without implant removal is our standard of care. For these patients, negative pressure wound therapy (Vacuum-Assisted Wound Closure (VAC) is very effective and safe even in the presence of CSF leak [6, 15, 35]. When using VAC in spine SSI, a lower pressure of 50-60 mmHg is recommended versus pressure greater than 125 mmHg used for other types of deep wounds [35].

Patients with spine SSIs require long-term antibiotics use. The choice of antibiotics is guided by culture results and local antibiotic studies [19]. Some antibiotics commonly used include biofilm-active antibiotics, such as rifampicin-combination with quinolones, cotrimoxazole, doxycycline, or fusidic acid [6]. Ideally, it begins after the tissue has been obtained for microbiological study. However, unstable patients, with signs of systemic toxicity, should have immediate intravenous antibiotics [19]. The duration of antibiotics usage and the time for conversion to oral antibiotics are subjects of argument, although it is agreed that patient needs antibiotics for a long time, usually 6 to 12 weeks [5, 6]. Palmowski et al. found that patients on a regimen that used intravenous antibiotics for 1-2 weeks, followed by oral antibiotics for 6 weeks (when the implant was removed) and 12 weeks with retained implants, improved satisfactory [36]. Other authors have used intravenous antibiotic administration for 6 weeks, followed by oral antibiotic administration for another 6 weeks with good results [5]. Our antibiotics protocol follows a 12-week (4 weeks parenteral and 8 weeks oral with a strict warning on compliance) administration based on sensitivity testing. Decisions regarding the optimal use of antibiotics should involve an infectious disease expert.

Other novel treatment modalities have been tried and found to be effective. Mehmet et al. treated 19 patients with a combination of Hyperbaric Oxygen (HBO) and antibiotics. They administered an average of 22-hour sessions of Hyperbaric Oxygen (HBO) (at 2 atmospheres) to the patients and observed an improvement in wound healing [37]. Also, the application of a mixture of ozone and oxygen to a non-healing wound resulted in prompt healing [9]. These can be considered adjuncts to treatment.

Ultimately, it is difficult to treat spine SSI, and the best results are achieved when optimal care is instituted early. Moreover, the need for protocol-based care cannot be overstated. In an experimental study by Laia et al, a multidisciplinary approach to care that included the development of a preventive protocol, staff training, and the use of surveillance feedback from results was associated with a 78.1% decrease in the incidence of surgical infection in spinal surgery in the trauma service [18].

Our local protocol

Our practice is located in a rural setting in Irrua Specialist Teaching Hospital, Irrua, a Federal tertiary health institution in Edo state, Nigeria. It is a major referral center in Edo state and nearby neighboring states. The hospital is located along the Benin-Abuja expressway in Irrua, the headquarters of Esan Central LGA in Edo Central Senatorial District, serving the Central and Northern, and parts of the Southern Districts of Edo State. It also receives patients from the neighboring states of Delta, Kogi, and Ondo. The hospital provides services for both outpatients and inpatients.

Preventing surgical site infections involves clear-cut pre, intra, post-operative strategies which we have summarized in our local protocol below:

Preoperative

Duration of admission before surgery

Presenting at Irrua Specialist Teaching Hospital, Irrua, we routinely segregate our patients. This segregation and time of admission start when a decision is made to operate from the clinic or emergency department. We routinely admit our elective cases into the ward 24 hours before surgery and when these patients are admitted, a preoperative chlorhexidine bath is commence in the evening and the morning before surgery.

Ward patient is admitted into clean spine bay in each of the male and female wards.

Age: The surgical lists are prepared with age stratification. The pediatric age group and elderly with co-morbid state undergo surgery earlier than other age groups on the list.

Smoking: For elective spine cases, we commended a 4-week stoppage of smoking and this is strictly monitored

Obesity: For obese people, a program with a nutritionist is recommended to reduce BMI below 30 kg/m^2

Malnutrition: Malnutrition when evaluated clinically and laboratory-wise, over 4 weeks is advocated for nutritional rehabilitation.

Steroid: Patients on a short course of steroids are stopped, while steroid reduction is done along with the endocrinologist for those taking the long-term steroid.

Radiation exposure: Radiation exposure predisposes to SSI. We aim to give 2 weeks of the gap for tissue regeneration.

Repeated operation or revision: Repeated spine surgery predisposes to SSI because these groups of patients are at high risk of unintended durotomy with cerebrospinal fluid fistula.

Chronic medical illness: Chronic medical illnesses such as chronic kidney diseases, hypertension, diabetes mellitus, and pulmonary disease are identified and examined, and recommended by a specialist physician in the spine unit before intervention.

Pre-operative antiseptic bath: Two session baths are prescribed as earlier stated.

Intraoperative

Spine pathology is properly documented.

The region of spine surgery is appropriately recorded.

The approach of spine surgery is noted.

Use of instrumentation: Spine instrumentation, such as implants are highly protected from contamination.

A long segment incision/wound is noted.

Controlled hypothermia is maintained.

Duration of operation is noted.

Intraoperative contamination is noted and a replacement is done for such contamination.

Intraoperative shaving is on-table.

Choice of intraoperative antiseptic cleaning; Chlorhexidine followed by methylated spirit and 10% povidone-iodine is used.

The number of individuals in the theatre is restricted to seven.

Prophylactic antibiotic use (1g ceftriaxone 30-60 minutes before skin incision) is a routine.

The use of intra-wound powder vancomycin is routine.

The volume of blood loss is estimated and another dose of antibiotic (ceftriaxone) is repeated.

Use of diathermy (electrocautery) when necessary.

Intraoperative dura tears are repaired and a gravity drain is used.

Intraoperative equipment, such as C-arm is draped and strict asepsis is followed.

Wound irrigation is done with normal saline and gentamicin mixed.

Postoperative

Wound drains are removed for up to 48 hours.

Nursing positions are done to avoid soiling of wounds and or skin maceration.

Wound inspection and dressing are first done on the third day postoperatively, except in cases of obvious wound contamination when the wound dressing is changed.

Orthosis, such as neck collar usage is maintained and regularly kept clean.

Duration of hospitalization: A patient with no complications is discharged between 3-5 days.

Conclusion

SSIs remain a burden in spine surgical parlance and it is essential to develop a protocol to identify the risk, prevent the risk and manage its sequelae in caring for spine pathology. Surgical site infections are a huge disease burden. Risk identification, stratification, and prevention are a core part of the management of this patient. SSIs require a collaborative effort with all healthcare staff involved in caring for the spine patient.

Ethical Considerations

Compliance with ethical guidelines

All ethical principles are considered in this article.

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Authors' contributions

All authors equally contributed to preparing this article.

Conflict of interest

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