Journal of Bioequivalence & Bioavailability

Tariq et al., J Bioequiv Availab 2017, 9:1
DOI: 10.4172/jbb.1000321

Review Article | OMICS International

A Systemic Review on Surgical Site Infections: Classification, Risk Factors, Treatment Complexities, Economical and Clinical Scenarios

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Abstract

Objective: To signify the risk factors, treatment complexities, economical and clinical scenarios related to Surgical Site infection (SSIs). The second most common health care associated infection is the Surgical Site infection, which may increase morbidity and mortality rate among surgical patient and produce a greater influence on length of stay during hospitalization, readmission and economic cost.

Method: A methodical literature investigation was conducted to recognize the extent of studies in relation to SSI. Procedural details of SSI, quality attributes in term of various components of SSI were assessed.

Results: The incident rate reported in different countries shows divergent variation because of the numerous systems integrated in the epidemiological control of Hospital acquired Infection. *Staphylococcus aureus* is most frequent pathogen associated with SSI. Increased treatment cost is mostly associated with additional length of hospitalization and supplementary diagnostic testing's, extra medication/antibiotic utilization and maybe any other minor surgical procedure in certain conditions.

Conclusion: This Literature review elaborates the risk factors, classification, economical and clinical scenario and also demonstrates the treatment challenges in various perspectives.

Keywords: Surgical site infections; Economic cost; Prophylaxis antibiotic; Multi factorial risk; Epidemiological control

Introduction

Health Care-Associated Infections (HAIs) remain as an important public health concern. Amongst the prominent HAIs, Surgical Site Infections (SSIs) contributing to substantial rate of mortality, significant morbidity, considerable prolongation in length of hospitalization and added treatment expenses. Despite the technical advancements that have been practiced over the past few years in surgical and wound management system, wound infections are still viewed as the most widely recognized nosocomial infections, particularly in patients experiencing surgery. SSIs were estimated approx. 31% of all HAIs, which contributed 20% postsurgical readmissions as well [1-2]. Over the years, the amplified interest of various investigators for surgical infection has generated various guidelines for control of post-surgical infection. But still In the United States, 14-16% of estimated 2 million of Nosocomial infections, which affects hospitalized patients; develop SSI. The rate of SSIs is reported in numerous literatures in the range of 2.5-41.9% [3-6]. The patients of SSIs have 2-11 times greater risk of death as compared to the patients having no SSI [7]. The number of incidences reported for SSI may be different across several countries due to the various systems applied for the epidemiological control of hospital related infection. Surgical Wound Infection Task Force USA published a standardized application for the SSI in 1992 which includes "the existence of purulent drainage; impulsive drainage of fluid, apart from the culture sensitivity for specific bacterial specie; localized symbols of contagion for outward sites or radiological verification of infections from deep sites; an eruption/abscess or additional infection of direct surgical procedure; or an identification of an infection by a surgeon [8-9].

Classification of SSIs

Surgical Site infection is categorized into three different types according to The Centers for Disease Control and Prevention (CDC's) and National Nosocomial Infections Surveillance System (NNIS) characterized by Superficial incision which include only the skin and subcutaneous tissue, whereas Deep incision in which infection penetrate in deep tissue, such as facial and layer of muscle; It also includes infections which involve both superficial and deep incision sites, organ/space SSI drainage through incision. While organ/space defined as an infection in any organ or space other than the incision site [10]. Literature Survey conducted by Isik et al. reports the incident rate in superficial incision is found to be 42.19%, which is more frequent, followed next in frequency by deep incision having an SSI 40.1% while organ space shows 17.71% rate of infection [11].

In 1964 National Research Council group (United States) categorize post-surgical lesion (wound) in four major categories considering the degree of microbiological contagion (Table 1) [12]. However, recently the contaminated and dirty wound infections are conjointly classified

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Received August 27, 2016; **Accepted** December 29, 2016; **Published** January 12, 2017

Citation: Tariq A, Ali H, Zafar F, Sial AA, Hameed K, et al. (2017) A Systemic Review on Surgical Site Infections: Classification, Risk Factors, Treatment Complexities, Economical and Clinical Scenarios. J Bioequiv Availab 9: 336-340. doi: 10.4172/jbb.1000321

Wound Type	Class	Definition/Major Characteristics of Respective Classes
Clean	I	No inflammation stumbles upon and the gastrointestinal (GI), respiratory, genital & urinary tract is not involved. Discretionary (elective), not emergency, principally closed and without rupture/break techniques involved.
Clean-contaminated	II	Operative method involved a colonized viscera or cavity (opening) of the body, although with controlled and elective situations with nominal spillage. Furthermore, emergency and urgent cases are clean otherwise, inconsequential break in technique.
Contaminated	III	Operative procedures are carried out with major interruption/breaks in desolate/aseptic/sterile method (like open cardiac massage) or gross/foul spillage/drain from the GI tract, access into genitourinary or biliary system in the existence of contaminated bile/urine contents and incisions with non-purulent, sensitive and acute inflammation are integrated into this group.
Dirty	IV	Dirty wounds are demonstrated with surgical processes mainly involved active infections prior to surgery.

Table 1: Classification of wounds [14].

as "dirty wounds" [9]. Furthermore, Class I is used as a useful indicator for the referral in case of hospital associated problems [13].

Rationale of Clinical Implications and Complexities Associated with SSI

Surgical procedures create widespread challenges due to its undesirable events related to post-surgical Infection in both developing and developed countries. Treatment of the SSI on the earlier basis is essential step otherwise they could be fatal or deadly to the patient. The main picture behind this situation is that the hospital environment in different divisions of our country is not as up to the mark as required to control the spread of germ strains. Multiple visitors are not prohibited in different hospitals which in turn increases the rate of Surgical Site infection. In view of the fact, skin is in general occupied by a variety of microorganisms that may lead to an infectious condition. Description of SSI involves verification of indisputable signs and symptoms of contagion along with microbial facts. SSIs often have an effect on the outward tissues; however, few severe infections impinge on the deeper sites of tissues and other body regions affected at some stage in the procedure. The mainstream of SSIs occurs within 30 days surgery and the largest part frequently accompanied by the 5^{th}-10^{th} postoperative days. While in case of prosthetic implant utilization, effects of SSIs on deeper tissues may happen quite a few months later following to the operational process. Prophylaxis antibiotics are primarily prescribed for the avoidance of SSI, although the amplified antibiotic resistance pattern poses larger therapeutic challenges for the physician. In Pakistan, inadequate data documented on the post-operative wound Infection. This article reviewed the literature based measures for the consequences related to SSI, their risk factor, treatment and preventive dimensions [14].

Prevalence

Surgical Site Infection has been increased over the past few years. World Health Organization (WHO) documented that 66% of establishing countries have no imprinted data related to the burden of SSI and also the data based on the surgical prophylaxis is insufficient. For the information regarding SSI few pilot studies are carried out in a single place. WHO recommended that in a particular country the studies carried out in a single setup is not measured as representative for the Epidemiology of the infections related to health care [15].

Literature reported in Pakistan illustrates the incidence rate of SSI may be outdated because various factors influences the infection rate For instance, Ahmed et al. conducted a study in Surgical Unit, showed that the incidence rate of SSI was 11% [16]. While Khan et al. reported in their study that the infection rate was found to be 9.294% [9]. Globally, the incident rate of SSI is 2.6% documented in the USA, Tanzania reports 19.4% of cases, multi-center Italian study shows 2.7% SSI, while the Belgian study documented 1.47% cases of SSI [17].

Risk factors related to SSI

In various investigational studies, based on routine examination of multiple clinical scenarios, a wider magnitude of risk factors and their burden related to the occurrence of SSI can be evaluated. Such studies have focused multi variant patient groups, in relation to the particular type of risk factors within various clinical trials [18]. Two models including Efficacy of the National Nosocomial Infections Surveillance (NNIS) index and the Nosocomial Infection Control (SENIC) index were developed to control the strategies and reduce the morbidity and mortality rates in consequence of post-surgical infection.

Multi factorial risk coupled with SSI in which Patient correlated factors include diabetes mellitus, obesity, anemia, immune-suppressant drugs, use of corticosteroids, malnutrition [19]. Similarly, other factors include the duration of surgery, poor postoperative glycemic control; prolong post-operative stay, duration of surgery, different type of surgery, preoperative stay and surgery techniques employed. Infection at remote sites, preoperative temperature and presence of drains also key elements in the progress of SSI [20-21]. Literature survey shows that American Society of Anaesthesiologists (ASA) score is also associated with post-surgical infection. ASA>2 is most likely associated with post-surgical patient [22]. Table 2 illustrates the classification of ASA [23].

Pathogens

Microorganisms may contain or distribute poisonous substances that expansion their capacity to attack a host, create harm inside the host, or get by on or in host tissue. Numerous gram-negative microscopic organisms deliver endotoxin, which animates cytokine formation. Thus, cytokines can activate the systemic inflammatory reaction disorder that occasionally escorts to several framework organ malfunctions. In the light of CDC reports, the most widespread organism responsible for the occurrence and progress of SSI is *Staphylococcus aureus*, followed by *Escherichia coli*, Coagulase-Negative *Staphylococci* (CNS), *Pseudomonas aeruginosa*, *Enterococcus* species, *Enterobacter* species, *Klebsiella pneumoniae*, *Proteus mirabilis*, *Candida albicans* and *Streptococcus*. Enlarged numbers of SSI cases have been reported with Methicillin-resistant *Staphylococcus aureus* (MRSA) species [24].

Clean surgeries, in which abdomen or genital tract is not involved such as neurosurgeries, cardio thoracic, ophthalmic, orthopaedic, and breast surgeries, *Staphylococcus aureus* (MRSA) is the predominant isolate causing SSI and related to poor outcome. The emergence of

I	Healthy, normal individuals
II	Persons with mild disease of systemic origin
III	Patient with severe systemic illness/infection, but not devastating/incapacitating
IV	Patients are with consistent life threatening conditions and have incapacitating sickness
V	A dilapidated patient with least expectation to live up to 24 hrs with or without surgical process

Table 2: Categorization of ASA.

MRSA has increased the morbidity and mortality rate from wound infections. Other gram positive organisms such as enterococci, coagulase negative staphylococci, and *Streptococcus* species, are less frequently involved. Surgeries which involved hollow viscera like appendectomy, gastroduodenal, colorectal, biliary tract and urologic operations, exposes surrounding tissues to gram negative bacilli include *Escherichia coli*, *Enterobacter*, *Klebsiella*, *Proteus* species whereas a gram-positive organism such as *Enterococcus*, and anaerobes [25].

Selection and impact of prophylaxis antibiotic

A greater challenge has been faced by the surgeons, in the handling of post-surgical lesion and selection of appropriate antibiotics as magnitude of multidrug resistance is depicted to be high in number of recently reported literature. For that reason, to acquire significant knowledge concerning the widespread pathogens in different surgical units and respective susceptibility and resistant behaviour to antibiotics for the appropriate treatment initiation on judicious basis.

Inappropriate antibiotic selection, prolong the duration of prophylaxis antibiotic, timing of administration may cause complication and also lead to increase the cost of therapy and produce more resistance against specific bacterial strain. Literature Surveys of various countries showed that the adherence rate with all parameters of surgical prophylaxis antibiotic guideline differ from hospital to hospital like Canada shows 5% adherence, while in Jordan, 1.7%, in Iran 0.9%, in Korea 0.8%, in Nicaragua 7% [26,27]. In 2002, the Centers for Medicare and Medicaid Services (CMS), in collaboration with CDC developed and execute the Surgical Infection Prevention Project. The rationale of this project was to provide an evidence based performance measure regarding appropriate selection, administration and termination of prophylactic antibiotic for the patient undergoing the clean contaminated surgical procedure. Further, in 2003 the CDC, CMS, and 10 other different national organizations developed the Surgical Care Improvement Project (SCIP) [28].

Even though the recommendations for the utilization of prophylaxis antibiotic in various surgical procedures are evidently established over the past few decades along with relevant guidelines which have been documented in order to prevent SSIs. But the execution of such guidelines among different institutional settings is reported to be intricated with low standard of care [29]. Antibiotic selection is based on numerous parameters including patient history, allergic evidences of beta lactam group etc. The most frequent prophylactic antimicrobials are cephalosporin (first generation) intravenous (IV) cephalothin or cefazolin, peroral tinidazole (for anaerobic infectivity) IV gentamicin, IV or rectal metronidazole (if anaerobic infection is expected) IV flucloxacillin (in case of MSSA infection) and while for MRSA infection, vancomycin is administered intravenously [25,30]. The most favorable drug administration time is within 60 min earlier than the incision, rather than at the time of anesthesia induction [31]. Some customary guidelines suggest that the third-generation cephalosporin like ceftriaxone and cefotaxime should not be chosen prophylactically, though the application of such medications is still in practice in various institutional setups [32].

Surveillance and Preventive Measurements

Surveillance is an essential step to limit the rate of infection because it enlightens the magnitude of the problem and also facilitate the regulatory bodies to take valuable measurements [33]. In order to decrease the rate of SSI it is essential to create a safer environment by controlling four major sources of infection, which include: patient`s risk factors, other personnel in the area, equipment and the environment [34]. Prophylaxis antibiotic should be prescribed to prevent from post-surgical infection [35].

Economical Saddle Related to SSI

Additional cost associated with SSI has not been elucidated accurately because of the difference in study designs and diverse cost evaluation method. Aforementioned studies usually show that the allocated hospital cost coupled with SSI, using an additional length of hospitalization may produce biasness and may result in disputed outcomes. Despite of these problems current studies based on comparing the extent of the cost reveals that economic cost associated with SSI is approximately two-fold in contrast to the patient having no SSI. This conflict with the most recent imputed hospital cost due to SSI anticipated by the National Institute for Health and Clinical Excellence (NICE) of £469 per infection [36]. Shepherd, along with his companion analyze that the daily entire cost associated with SSI is found to be \$7493 (95% CI, \$7101 to \$7884) as compared to the patient having no SSI (95% CI, \$7788 to \$8060) (P=0.99). The mean Length of Stay is 10.56 days reported in SSI patient, and 5.64 days (95% CI, 5.34 to 5.95) for those having no SSI reported [37]. MRSA patient was found to be at greater risk of mortality and increased hospital cost as compared to the MSSA patient. MRSA patient also had a longer duration of action. The study conducted by Engemann et al., found that hospital cost for the control subject is much lower than the patient having SSI due to MSSA or MRSA (P<0.001) The average hospital cost was found to be ~\$40,000 greater for the patient having SSI due to MRSA Patient (median, \$92,363; mean, \$118,415) than for MSSA (median, \$52,791; mean, \$73,165; P<0.001.

International experiences and evaluations of specific study situations can be used as a comparator to draw significant conclusions. For example, 6.5% readmissions within 30 days of bariatric operation were reported in a study [38]. Ranges of mortality for open and laparoscopic cholecystectomy were reported to be in the range of 0.0066-0.0074 and 0.0014-0.0016 respectively [39]. The incidence of readmissions within the first 6 weeks, 6 weeks-1 year, 1-2 years and >2 years were 2.8%, 1.5%, 1.4% and 0.7% respectively in elective laparoscopic cholecystectomy [40].

Discussion

Among health care associated infections, SSI is ranked second. Their incidence rate may vary in several countries due to the various system integrated in the epidemiological control of hospital associated infection. In Pakistan frequency of SSI reported may show variation due to the numerous reasons like the data incorporated in their studies is not appropriate or may be the infection occurs after the hospital discharge which is not reported in the hospital. Several studies conducted in Pakistan to find out the most common pathogen involved in SSI. Bashir et al., reported in their studies that *E. coli* found in 33.33% cases followed next in frequency by *Staphylococcus aureus* and *Klebsiella* in 20%, *Proteus* in 13.33%, *Pseudomonas* in 6.66% cases [41]. While Bibi et al., also reported *E. coli* (33.8%) as a most common pathogen followed by *Pseudomonas aeruginosa* (16.9%) and *Staphylococcus aureus* (15.5%) [42]. Similarly, Qaiser et al. also report the frequency of the isolated organisms in which *Escherichia coli* shows 40.7%, followed by *Pseudomonas aeruginosa* 26.31% and *Staphylococcus aureus* 19.73% [43]. All these studies highlight the prevalence of *E. coli* as the causative agent of SSI along with *Pseudomonas aeruginosa*, *Staphylococcus aureus* and *Klebsiella*. On the contrary basis, CDC also defined the most common pathogen associated with SSI is *S. aureus*.

Likewise, another study carried out in Bangalore demonstrated that *Staphylococcus aureus* (*S. aureus*) was the most common pathogen followed by *Escherichia coli* and Coagulase Negative *Staphylococcus* [44].

In this Literature review, certain examples are included to evaluate the relation of SSI to their risk factors like Ismat et al., reported in their study that diabetic patient undergoing Cholecystectomy is more likely associated to cause wound infection (11.67%) as compared to the non-diabetic patient (6.67%) [45]. Cheng et al., conducted a study to show the incidence rate of SSI is more in emergency surgeries (8.4%) then the elective surgeries (2.5%) [46]. Fan et al., illustrates an example showing the relation of SSI with different surgical procedure according to this, abdominal surgery has a higher rate of SSI (8.3%, 95% CI: 6.5-10.0) in contrast to the orthopaedic surgery has the lowest SSI rate (1.0%, 95% CI: 0.5-1.6) [47]. High risk of SSI associated with an emergency C-section as compared to the elective C-section [48]. Chattopadhya et al. conducted a study to show the incidence rate, according to the degree of contamination like 3.50% in clean wound, 6.77% in clean contaminated, and in contaminated or dirty wounds 14.58% cases are reported while the overall rate reported for SSI was 5.54% [49].

Economic outcomes are also associated with Post-Surgical Infection due to the increase length of hospitalization along with the antibiotic used to treat Post-Surgical infection. The study carried out by Shojaei et al.; demonstrate that the 5.4% infection rate was reported in those patients who received prophylaxis antibiotic while 16.8% reported in those who do not receive prophylaxis antibiotic. So, this example supports that prophylactic antibiotic should be administered prior to surgery to reduce the rate of SSI [13,18].

Role of healthcare provider in reducing SSI

Physician, Pharmacist and other related personnel's can minimize the risk of surgical site infection by providing guidance to the patient who undergone to surgery, help them to select the appropriate post-surgical wound care products, the array of accessible resources, and provide knowledge about wound care. Pharmacist role is considered crucial in optimizing the healing outcome through appropriate and targeted drug services; education and counselling under specific condition and with respect to the patient's need [50].

Guidelines of SSI are mainly built to precise standards of pharmaceutical utilization

- Administration of prophylactic antibiotics prior to surgery within 1 hr.
- Selection of suitable prophylactic antibiotics in accordance with specific clinical condition.
- Discontinuation of prophylactic use of antibiotics in 24 hrs following completion of surgical intervention.
- Preoperative control of serum glucose levels in major surgeries of cardiovascular type.

Additional measures include the deterrence of hypothermic condition before, during and after the surgical process, maintaining/keeping the elevated inspired oxygen levels, and avoidance of shaving of the specific operation place [50,51].

Recommendation and suggestions

Isolation and identification of causative agent are the prime concern, followed by the specific antibiotic prescribing in controlling and treating SSI. External visitors to the patient should be restricted in order to prevent the progress of the infection. Categorize all factors (basic events) leading to an SSI. A preliminary list of essential events should be formulated depending on the most important risk factors documented in the existing literature for SSIs. Then identification of interactions and dependencies among various risk points must be rationalized. Events (basic) may be divided into different components of the core process including pre-operative, operative, & post-operative, and should be scrutinized for the associations (dependencies and interactions) between the numerous risk points to determine how they may lead to SSIs. Furthermore, appropriate control strategies in the light of these events should need to be formulated and imposed in efficient way.

Conclusion

Initial researchers credited the significance of micro flora (anaerobic) to postoperative infection and paved the ways for momentous advancements in antibiotic therapy (prophylactic/therapeutic) for patients. Afterward studies have centred on prediction of postoperative infection rates and the recognition of risk factors. This literature review concluded the importance of obligatory protocol implementation of related area/hospital settings in order to minimize incidences of infection with respect to the institution policies perspectives. From this standpoint, proper surveillance/feedback is mandatory and all personals should be restricted to maintain and follow the set of rules related to the patient's safety prior and after surgery.

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Citation: Tariq A, Ali H, Zafar F, Sial AA, Hameed K (2017) A Systemic Review on Surgical Site Infections: Classification, Risk Factors, Treatment Complexities, Economical and Clinical Scenarios. J Bioequiv Availab 9: 336-340. doi: 10.4172/jbb.1000321

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