

Microbial surgical site infections in association with post cardiac surgery

Abstract

Cardiac surgeries are considered as a big problem around the world; because of the consequences of surgical site infections. There are several risk factors which may lead to surgical infections. However, the factors are categorized into three groups of preoperative, perioperative and postoperative risk factors that may lead to microbial surgical site infections in patients with post cardiac surgery. The medical (morbidity and mortality) and financial consequences in association with surgical site infections are very significant and considerable. But, the use of standard sterilization protocols and accurate surgical methodologies may help to reduce the microbial infections in patients with cardiac surgery. For this reason, the focused aim of the present literature is to have a deep review in epidemiology, microbiology, pathogenesis and virulence and the risk factors pertaining to microbial surgical site infections in patients with post cardiac surgery.

Keywords: cardiac surgery, surgical site infection, infectious disease

Volume 2 Issue 2 - 2015

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Received: January 07, 2015 | **Published:** April 02, 2015

Abbreviations: SSIs, surgical site infections; CDC, centers for diseases control and prevention; ASA, American society of anesthesiology; MRSA, methicillin-resistant *staphylococcus aureus*; SIP, surgical infection prevention; SCIP, surgical care improvement project; CMS, center for medicare and medicaid services; HAIs, health care acquired infections; MDRB, multi drug-resistant bacteria; MDRE, multi drug-resistant fungi; HBV, hepatitis B virus; HCV, hepatitis C virus; HIV, human immunodeficiency virus; CFU, colony forming unit; NNIS, national nosocomial infections surveillance

Introduction

Surgical site infections (SSIs) are in association with surgeries incisions which may lead to unserious superficial infections and/or serious deep infections within soft tissues or organs in human bodies during 30days after the surgery. The general reported signs and symptoms pertaining to SSI include fever, pain, redness and pus drainage from the incision. The aforementioned properties of SSI are defined by the Centers for Diseases Control and Prevention (CDC).¹⁻⁷ Because of the importance of SSIs and the related medical services, the National Nosocomial Infections Surveillance (NNIS) was founded in 1970 in the United States of America.⁷ The risk factors and the time length of surgical procedures for different patients including individuals who undergo cardiac surgical procedures and the score of American Society of Anesthesiology (ASA) are recorded by NNIS to forecast the category of SSIs.^{2,7}

According to different studies, the morbidity and mortality of SSI after cardiac surgery is high. However, the reduction of triggering peripheral predisposing factors may lead to decrease the number of infections. There are several parameters which influence the occurrence of SSI including individual and personnel hygiene, surgical methodologies, application of antibiotics, sterilization techniques, blood quality and the type of incisions. It is known that the cardiac operations are needed for a huge amount of blood.^{2,8-11}

Due to the CDC reports, Methicillin-Resistant *Staphylococcus aureus* (MRSA) is the most important pathogenic bacterium which

may cause life threatening post cardiac operation infections in hospitalized patients.^{2,8,10,12,13} The previous literatures show a level up to 20% of microbial wound infections among patients with post cardiac surgeries.^{9,14} Because of the importance of cardiac SSIs, in the years of 2002 and 2006 the National Surgical Infection Prevention (SIP) and the Surgical Care Improvement Project (SCIP) were respectively started their missions for decreasing the prevalence of SSIs in the international level. The SCIP was supported by the Center for Medicare and Medicaid Services (CMS).^{6,15} The goal of this review was to study the most important microbial agents and risk factors relating to cardiac postoperative infections.

Epidemiology

The post SSI in association with cardiac surgery is a considerable problem in hospitals worldwide. According to previous investigations, SSI involves about 15% of hospitalized patients. Thus, SSI ranks second among health care acquired infections (HAIs). Furthermore, the post SSI relating to cardiac surgery has unfavorable consequences medically and financially. Of course, the SSI relating to cardiac surgery may lead to a considerable increase in length of hospitalization; in the majority of reported cases more than 7days with a cost of \$26000 ± \$3000. Long duration of hospitalization after cardiac surgeries increases the death risk up to 11times.^{8,10,14,16}

SSI is a direct reflection of the surgery procedure quality. The result of an epidemiological census showed a percentage of 35%-40% as the commonest nosocomial infection among operated patients. The ratio of surgical incisional SSIs to surgical organ SSIs is recognized as 2:1. The rate of mortality in association with nosocomial SSIs is estimated about 77% which 93% of the deaths were belonging to patients with organ SSIs. In accordance with different recorded reports relating to previous studies, the incidence of cardiac SSIs ranges from 0.25%-4% with the mortality rate of 10%-30%.^{2,3,6,10,17,18}

Despite advances in ventilation of operation rooms, covering systems, sterilization protocols, hi-tech operating tools and antibiotics prophylaxis, the rate of morbidity and mortality due to post SSI in

cardiac surgeries is high; however, hospitals with appropriate, standard and qualified surgical cares and strategies are able to decrease the risk of postoperative site infections up to 30%.^{14,19-21}

There are some realistic problems including Multi Drug-Resistant Bacteria (MDRB) and Multi Drug-Resistant Fungi (MDRF), numerous aged cardiac surgery patients and several patients with defective Immune systems which hindering efforts to eliminate SSIs. The SSIs are categorized into three groups of superficial wounds, deep wounds, and organ or tissue implants.^{2,3,7,13}

Cardiac surgery procedures

There is a diversity of cardiac operations which include the three forms of superficial and deep incisions and organ/tissue implants. Naturally, time, procedures, methodologies, the skill of surgeons and personnel and risk factors may vary in a wide range depending on the type of cardiac procedures. (Table 1) shows the surgical methodologies and type of infections.^{2,3,7} Previous studies corroborate that the increase of surgery duration time leads to strengthening of high risk for SSIs. Furthermore, the preoperative duration and hospitalization time are other considerable factors which directly influence the frequency of surgical infections.^{2,3,7,8,10,16}

Table 1 The presence/absence of SSIs depending on cardiac surgery procedure

Cardiac surgery procedure	Surgery duration (hour)	Superficial SSI	Deep SSI/ Organ implant
Cardiac Valvular replacement	1≤X≤9	Yes	Yes
Congenital cardiovascular disease	0.25≤X≤5	No	No
Coronary artery bypass graft (CABG)	1.5≤X≤7	Yes	Yes
Heart transplantation	2.5≤X≤9	No	Yes
Mechanical circulatory supporter	0.5≤X≤5.5	Yes	Yes
Pericard disease	0.2≤X≤2	No	No
Vessel disease	2≤X≤10	No	No

The mean ranges for preoperative and postoperative hospitalization stay length depending on type of cardiac surgery procedure respectively are reported 1-5days and 8-34days.^{3,7} To evaluate the importance of risk factors in association with cardiac surgery procedures, NNIS represented a system risk index for different cardiac surgery procedure scoring 0-3. The score of 3 represents the highest of contamination. The scores 2-3 confirms the persistence of SSIs in association with cardiac operations.^{3,7}

Microbiology

According to recorded reports from different countries, there are a variety of microbial infectious agents such as bacteria and fungi which may lead to post SSIs in patients with cardiac surgery. In the most cases, MDRB such as MRSA and MDRF such as *Candida* spp. play a key role in postoperative infections relating to cardiac surgery incisions and organ implants. Simultaneously, the presence of viral transfusion-borne infectious agents including Hepatitis B Virus

(HBV), Hepatitis C Virus (HCV) and Human Immunodeficiency Virus (HIV) are concerned as important pathogenic biological particles in infected blood products which may be consumed during the cardiac operations.^{2,8,11,16,22}

Some bacterial and fungal Genera including *Staphylococcus* spp., *Enterococcus* spp., *Candida* spp. and *Apergillus* spp. are reported as common microbial agents causing postoperative infections. However, there are a wide range of bacterial and fungal agents which may cause SSI in patients. The majority of pathogenic microorganisms are belonging to MDR strains (Table 2).^{2,8,10,16,22}

Several studies approve the pioneer ranking of MSRA in association with all types of SSIs including cardiac SSIs. Sometimes, uncommon microbial pathogenic agents are responsible for SSIs, which must be checked as an urgent alternative. The appearance of SSIs caused by uncommon microbial pathogenic strains may be isolated from contaminated sterile wound bandages and dressings, germicidal solvents and surgery personnel's.^{2,3,6-8,10,12,13,23}

Table 2 The detected microbial pathogenic agents causing SSIs

Microorganisms	Microbial pathogenic agent	percentage
Common Bacteria	<i>Staphylococcus aureus</i>	20%
	<i>Coagulase-negative Staphylococci</i>	14%
	<i>Enterococcus</i> spp. (Vancomycin resistant strains)	12%
	<i>Escherichia coli</i> (Cefotaxime, Ceftazidime, Ceftriaxone (Cef3), Quinolone-resistant strains)	8%
	<i>Pseudomonas aeruginosa</i> (Ciprofloxacin, Ofloxacin, Levofloxacin, Imipenem, Ceftazidime, Piperacillin-resistans strains)	8%
	<i>Enterobacter</i> spp. (Cefotaxime, Ceftazidime, Ceftriaxone (Cef3), Carbapenem-resistant strains)	7%
	<i>Proteus mirabilis</i>	3%
	<i>Klebsiella pneumoniae</i> (Cefotaxime, Ceftazidime, Ceftriaxone (Cef3)-resistant strains)	3%
	* <i>Streptococcus</i> spp. (Penicillin, Cefotaxime, Ceftriaxone-resistant pneumococci)	5%
	<i>Clostridium perfringens</i>	<2%
Uncommon Bacteria	<i>Rhodococcus bronchialis</i>	<2%
	<i>Nocardia farcinica</i>	<2%
	<i>Leginella dumoffii</i>	<2%
	<i>Legionella pneumophila</i>	<2%
	<i>Pseudomonas multivorans</i>	<2%
Yeast	<i>Candida albicans</i>	3%
Fungi	<i>Aspergillus</i> spp.	<2%
	Mold	<i>Rhizopus oryzae</i>

Group D (2%) and other *Streptococcus* spp. (3%) excluding *Enterococcus* spp. (8)

Pathogenesis and virulence

The microbial contamination of cardiac surgical incisions and organ implants beside the rate of virulence of pathogenic microorganisms are the parallel etiological parameters for SSI. The presence of skin normal flora may lead to appear postoperative infections. Therefore, an accurate antiseptic procedure is needed to minimize the skin microbial flora in prior to cardiac surgery and along the operation is ongoing.^{2,7,8}

The characteristics of microbial pathogens, patients and surgery procedures directly determine the quality of pathogenesis and the likelihood of SSIs. The likelihood of SSI can be calculated as the following equation;^{2,8,10}

$$\text{Likelihood of SSI} = \frac{\text{Number of bacterial cells} \times \text{Pathogen virulence}}{\text{Patient's resistance}}$$

Depending on the type of incision and the effective operation procedure, the number of infectious microbial agents may vary from 1 colony forming unit (CFU) to 10^6 cells. The use of foreign medical tools increases the likelihood of SSI by the low number of microorganisms.^{2,8,10}

Not only the number of pathogens is important, but also, the virulence abilities of the pathogens are absolutely significant. According to table 2, gram positive *cocci* are the most important microorganisms that cause SSI in patients. Gram positive and Gram negative bacteria which cause cardiac SSIs encompass multifactorial virulent systems including adhesins (for attaching to cells and proteins), polysaccharide glycocalyx or capsules (for covering pathogens from the host's defense system and antibiotics), exotoxins (for damaging tissues, neutralizing phagocytosis mechanisms and cell metabolic pathways), and biofilm formation (colonization and devastating host's immune system mechanisms).^{2,7,8,24,25}

The presence of endogenous and exogenous microbial agents may lead to infect tissues or organs during the operation (peri/intraoperative predisposing factors). In the case of cardiac surgeries, exogenous microbial agents including aerobic and gram positive cocci and some fungi cause the cardiac SSIs throughout several outsider sources such as skin normal flora, contaminated surgical team and operating room (OR), poor ventilation, contaminated operation tools and materials increase the risk of cardiac SSIs.^{2,7,8,10,26}

Risk factors

At the same time, the probability of the SSI occurrence is depending on risk factors which are classified into three groups of preoperative, perioperative (intraoperative) and postoperative predisposing factors.^{2,7-10} A risk factor is defined as a considerable independent variable which may lead to progression of SSI. However, the independency of variable often is ignored by the researchers and authors.^{2,8} The risk factors depending on their attributions are categorized into 2 main groups of patient and surgical attributes. The patient and surgical attributes are respectively classified in (Table 3) & (Table 4)

The preoperative risk factors involve age (more than 65years old), overweight, active smoking, corticosteroid consumption, diabetes, malnutrition, blood transfusion, MDRB and/or MDRF colonization within patients or carriers among surgeons or hospital personnel and

long hospitalization. Furthermore, preoperative bath with germicidal solutions such as alcohol and iodine may help to decrease the appearance of SSI. Moreover, hindering patients from shaving in the last 24hours prior to surgery reduces the risk of SSI.^{2,8,10} Consumption of antibiotics by the patients before the beginning of cardiac operation is known as an effective antimicrobial prophylaxis to decrease the probability of cardiac SSI. The use of broad spectrum antimicrobial agents for sterilizing operation team's hands and surgical tools before operation procedure is absolutely recommended.^{2,8,10}

Table 3 Risk factors and patient attributes

Patient attributes	
Active smoking	No smoking from 5-7weeks prior to operation. It decreases the risk of SSIs significantly. The use of tobacco slows down the process of wound healing ^{2,8,10,23,27}
Age	The SSIs increase in elder patients until 65years old. The risk of SSIs decreases in patients over than 65years old ^{28,29}
Blood transfusion	The blood must be checked for decreasing the probability of viral infectious diseases ¹¹
Corticosteroid consumption	The use of steroids may raise the risk of SSIs ^{2,8}
Defective and suppressed immune system	Any defect and suppression of immune system may lead to severe increase of SSIs ^{2,8-10}
Diabetes	The level of blood glucose must be kept within normal range. The increase of blood sugar leads to a sharp raise of SSIs ^{2,8,10}
Long hospitalization	Long duration of hospitalization increase the risk of SSIs with exponential rate ^{2,8}
Malnutrition	A rich nutritional diet has a significant effect on SSIs reduction ^{2,8,10}
MDRB and/or MDRF colonization within patients or carriers among surgeons or hospital personnel	Microbial elimination (especially MDRB and/or MDRF) by correct sterilization methods and the use of effective antimicrobial solutions. The presence of microbial contamination may lead to severe morbidities and mortalities. Nares carriers of <i>Staphylococcus aureus</i> involve 30% of healthy people. The bacterium is known as predominant pathogen for cardiac SSIs ^{2,8,10,13,16,30-32}
Overweight	Obese patients are predisposed for complicated SSIs. Weight reduction is completely a wise decision ^{2,8,10}

The perioperative risk factors which are recognized as intraoperative risk factors conclude unsafe microbial sterilization relating to operating room (OR), bad air flow or ventilation, contamination of surfaces in OR, and insufficient real-time sterilizing methodologies for operation tools. On the other hand, the lack of body covers including sterilized mask, gloves and gowns among the operation team members increases the risk of SSIs as a big treat for the patients' health safety. The surgical methodologies involving the quality and the quantity of incisions and the applied operative techniques determine the level of SSI risks.^{2,8,10} The postoperative risks include unsafe and incorrect methodology for caring operation incisions and the loss of unsuitable discharging program for patients.^{2,8,10}

Table 4 Risk factors and surgical attributes

Surgical attributes	
Presurgical distributions	
Bath/Shower of antiseptic materials	Antiseptic showering process helps to reduce the number of patient's skin normal flora. Chlorhexidine, Alcohol, Povidone-iodine and triclocarban soap are well-known antiseptic materials. Chlorhexidine is recommended for the most. It reduces the number of bacteria ninefold. However, alcohol is good but has no effect on spores and is flammable too. ^{2,33,34}
Shaving/hair clipping	Hair clipping via razor (causing tiny skin cuts and injuries) or depilatory (causing hypersensitivity presentation) may increase the risk of SSIs. Shaving performed 24h before the operation in comparison with just before surgery increases the risk of SSIs. There is no need for hair removal before the operation. If needed, electric clippers are the best choices. ^{2,8,35,36}
Surgical scrub with antiseptic agents	Surgeons and the members of surgical team must wash their hands and forearms before wearing their sterile gloves and gowns. Alcohol is the European gold standard for surgical scrub while povidone-iodine and chlorhexidine gluconate are the replaced choices for operative hand and forearm preparation in the United states. Before wearing sterile gloves and gowns, the hands and forearms must be dried by sterile towel. ^{2,8}
Antimicrobial prophylaxis	A suitable choice of antimicrobial prophylaxis may guarantee the reduction of pathogenic microorganisms. Moreover, an appropriate antimicrobial prophylaxis is cheap, qualified and germicide with broad spectrum efficacy. The infusion time of the antimicrobial agent in serum and tissues must be switched in parallel with operation incisions. The therapeutic effect of the germicidal material must work during the operation and several times after operation. ^{2,8,10}

Discussion

Surgical incision repair system in human being is a harmonic orchestra which involves cellular and molecular biology. It is a natural arrangement of several events including cellular division, cellular growth and tissue remodeling. For example, re-epithelialization without any microbial infection is a normal process of healing mechanism when an accurate and standard sterilization procedure is applied along with an operation. But, the normal course relating to surgical incision healing may be go wrong because of different aforementioned pre-, peri- and postoperative risk factors.^{14,37} There are some bald risk factors including the number and type of microorganisms, the condition of cardiac surgery procedure and OR, and the health of host's immune system that determine the challenges relating to management of cardiac incisions in hospitals and medical care centers.^{8,10,14,37}

According to several investigations, the use of intravenous broad spectrum antimicrobial prophylactic injections in cardiac operations

reduces up to five times the occurrence of SSI caused by antibiotic sensitive microorganisms, MDRF and MDRB. The decrease of cardiac SSIs may directly lead to a significant reduction of long hospitalization, health care costs and mortality.^{2,23,37,38}

Conclusion

The cardiac SSIs may be prevented if the following procedures are considered and performed one by one;³⁷

- Preoperative preparations pertaining to patients are handled.
- Preparing members of surgical team in accordance with standard sterilization procedures.
- Accurate and standard sterilization handling and maintenance of OR.
- Application of prophylactic drugs
- Standard and sterilized surgical technologies and methodologies.
- Sterilized and reliable management handling of surgical incisions and wounds.

Acknowledgements

None.

Conflict of interest

The author declares no conflict of interest.

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