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Strategies to reduce deep sternal wound infection after bilateral internal mammary artery grafting

Lokeswara Rao Sajja [a, b, *]

[a] Star Hospitals, Hyderabad, India
[b] Sajja Heart Foundation, Hyderabad, India

HIGHLIGHTS

- Incidence of DSWI following BIMA harvest is on decline.
- Optimization of risk factors prior to BIMA harvest reduce DSWI.
- IMA harvest technique with minimal tissue mobilization preserves sternal blood supply.
- Stable sternal closure is associated with reduction of DSWI.
- Combination of reported strategies brings down DSWI to a minimum.

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ABSTRACT

Deep sternal wound infections (DSWI) continue to be an infrequent but potentially devastating complication after cardiac surgical procedures. Its prevalence is more after coronary artery bypass grafting using single internal mammary artery (IMA) graft. Bilateral internal mammary artery (BIMA) harvesting carries a higher risk of sternal infection than harvesting single IMA. Several risk factors have been identified with sternal wound infections and a few are modifiable. Strategies that reduce DSWI target the modifiable risk factors that include microbiological factors, appropriate antibiotic prophylaxis, tight glycemic control. Surgical strategies to reduce DSWI following BIMA harvest include techniques of IMA harvesting with lesser devascularization of sternum using skeletonized, semiskeletonized and modified pedicle harvest are associated with greater preservation of sternal blood supply and sternal closure and stability techniques. The various strategies to minimize sternal wound infections during preoperative, intra and postoperative periods are summarized in this article.

1. Introduction

Large observational studies have established the internal mammary or thoracic artery (IMA or ITA) as the “gold standard” graft in coronary artery bypass grafting (CABG) [1,2]. Studies have demonstrated that the use of the left internal mammary artery graft to left anterior descending (LAD) coronary artery improves survival, reduces the incidence of recurrent angina, late myocardial infarction, the need for repeat revascularization and provides excellent graft patency compared with saphenous vein grafts [1–4]. Although many studies are not randomized, the evidence is so convincing that over 90% of CABG patients in United Kingdom, India and over 95% of CABG patients in the United States currently receive single IMA graft [5,6]. Several observational studies have reported the use of two IMAs, also referred to as “bilateral internal mammary artery (BIMA) grafting” is associated with significant long-term survival benefit over single IMA graft irrespective of age, left ventricular function and diabetes [7,8]. Furthermore, the benefits of BIMA grafts increase with duration of follow-up with particular reference to the need for redo CABG, being approximately 40% in SIMA and 8% in BIMA in propensity matched patients at 12 years [hazard ratio (HR) 0.27, 95% confidence interval (CI) 0.19 to 0.37]. This was also supported by a meta-analysis of studies published by Taggart and colleagues [9]. In spite of substantial evidence supporting a long-term survival benefit with bilateral internal mammary artery grafts in CABG, this technique remains grossly underutilized worldwide: 4.1% of all coronary artery bypass

* Department of Cardiothoracic Surgery, Star Hospitals, Road No: 10, Banjara Hills, Hyderabad, 500 034, Telangana, India.
E-mail address: sajjalr@yahoo.com.

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grafting procedure in the US, 12% in Europe, 12.6% in Australia and 30% in Japan use BIMA [6,10–13].

Several reasons for limited use of BIMA grafts include longer operating times, technical challenges, perceived conduit-coronary perfusion mismatch, and the risk of deep sternal wound infection (DSWI) [14,15]. The reported incidence of superficial sternal wound infections ranges between 1.6% and 6.4% [16,17]. According to the National Society of Thoracic Surgeons (STS) database, the incidence of deep sternal wound infections was 0.4% among 1,40,000 isolated coronary bypass procedures performed in 2002 irrespective of coronary bypass conduits used, while other studies have reported the incidence of DSWI between 0.4% and 2.7% [18–22]. The incidence of deep sternal wound infection following bilateral internal mammary artery harvest ranges from 0.6 % to 4.2 % [23,24]. There are several risk factors for the development of deep sternal wound infections following CABG using single or two internal mammary arteries that are modifiable [20,25,26]. The prevention and subsequent management of this complication poses a problem for every cardiac surgeon and the cost of hospitalization for a patient with a sternal infection is approximately three times that of patients without wound infection. There are several strategies adopted to reduce deep sternal wound infections following the harvest of bilateral IMAs.

Centers for Disease Control and prevention (CDC) criteria for the diagnosis of deep sternal wound infection are (1) organisms cultured from mediastinal tissue or fluid obtained during a surgical operation or needle aspiration, (2) evidence of mediastinitis seen during a surgical operation or histopathological examination, (3) atleast one of the following signs or symptoms with no other recognized cause; fever > 38 °C, chest pain or sternal instability and one of the following (i) purulent discharge from the mediastinal area, (ii) organisms cultured from the blood or discharge from mediastinal area (iii) mediastinal widening on X-ray [27].

2. Microbiological considerations

The most common pathogens identified in deep sternal wound infections are Gram positive cocci, *Staphylococcus epidermidis* and *Staphylococcus aureus* account for more than two-third of cases [28–30]. Gram negative bacteria (*E. coli*, Pseudomonas species, Klebsiella) and Corynebacterium have been isolated in 5–22% of cases, while multiple pathogens are reported in upto one quarter of cases [14,29,30]. For most surgical site infection (SSI) the source of pathogens is the endogenous and is from the flora of the patients' skin. Exogenous source of SSI pathogens include surgical personnel, the operating room environment, all tools, instruments and materials brought to the surgical field during an operation [31]. Superficial wound infection may convert to deep sternal infections when there is sternal instability or sternal dehiscence which disrupts the mechanical barrier between mediastinal tissue and presternal tissue. Route of entry, virulence of organisms, and initial pathogen load in combination with the immune status of the host can influence the risk of infection.

3. Anatomical considerations of sternal blood supply in the genesis of sternal wound infections

The IMA supplies blood to the pericardium, phrenic nerve, sternum, anterior chest wall, pectoralis major muscle, mammary gland, anterior abdominal wall, and the diaphragm. The arterial blood supply of the adult human sternum is derived solely from its periosteal plexus, fed by the segmental sternal branches of the IMA. There is no intramedullary nutrient system comparable to that in the long bones. Despite the richness of longitudinal anastomoses within the periosteal plexus of both the body and manubrium, there exists little communication between the body and manubrium across the manubrio sternal joint [32]. The sternal branches of IMA bifurcate approximately 0.5 cm from the sternal margin into branches that pass to the anterior and posterior periosteum. Each of these branches generally split into upper and lower divisions. They anastomose in the periosteum with those above and below and with their counterparts on the opposite side. The plexus thus formed is denser on the posterior than the anterior surface. Often, within the structure of this plexus, a series of anastomotic vertical loops or arcades can be discerned, fed by the segmental sternal vessels. Manubrial branches of the ITA are regularly large, and the periosteal plexus of this segment is characteristically denser than elsewhere. There are 1–3 branches on each side. Preservation of certain branches of the ITA promotes development of collateral blood supply to the sternum following ITA harvest. There are two possible sources of collateral blood supply to the sternum after ITA harvesting: the anterior intercostal branches of the ITA and the musculophrenic artery, anastomosing with the posterior intercostal arteries arising from the aorta, and the perforating branches of ITA, anastomosing with branches of the thoracoacromial and lateral thoracic arteries [33,34].

The blood supply of the sternum plays a major role in healing of the sternum after sternotomy. The sternal blood supply is derived mainly from the medial horizontal branches of the ITA. Three types of vessels were identified that have the potential to carry blood to the sternum after mobilization of the internal thoracic artery (ITA): (1) branches of the ITA that supply both the sternum and the pectoralis major ("sternal/perforating branches"), (2) branches of the ITA that supply both the sternum and an adjoining intercostal space ("sternal/intercostal branches"), and (3) posterior intercostal arteries that do not anastomose with an ITA branch but continue past the ITA to reach the sternum [35]. Preservation of intercostal/sternal trunks, perforating/sternal trunk, perforator/intercostal/sternal common trunks are necessary to keep the blood supply of the sternum when the use of both internal mammary arteries in surgical myocardial revascularization in order to prevent sternal devascularization [36].

The increased incidence of sternal wound complications that is reported after ITA bypass grafting is believed to be caused by damage to the blood supply of the sternum [14,37–41]. Green has stated that there are important collateral blood vessels lying close to the ITA that, if unharmed, can provide a continued blood supply to the sternum after mobilization of the ITA. To avoid damage to these collateral vessels, Green has recommended that when the ITA is mobilized, its branches should be divided as close to the ITA trunk as possible [42]. This recommendation also has been made by Galbut and associates [43] who presented a large series of bilateral ITA bypass procedures in which mobilization of the ITA in a painstaking, "skeletonized" fashion was associated with an unusually low wound complication rate. Parish and colleagues in a canine model demonstrated that chest wall blood flow was significantly decreased from pre harvest levels after internal mammary artery mobilization regardless of the technique used – skeletonize or as a pedicle. The reduction of manubrium blood supply was 46.9%, body of sternum 22.1% of the baseline values. The residual sternal blood flow on the side of the skeletonized vessel was significantly greater than on the side of the pedicled graft (2.60 ± 0.68 vs 1.77 ± 0.27 cm^3/min/100 g, $p < 0.001$). They concluded that minimization of tissue mobilization during internal mammary artery harvesting may reduce sternal devascularization and this has clinical significance with respect to lowering the incidence of sternal complications in CABG using IMA grafts [44].

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4. Strategies to reduce sternal wound complications following BIMA harvest

Preventive measures for surgical site infections (SSI) include proper skin preparation, prophylactic antibiotic therapy, control of operating room environment and improvement of surgical techniques. Strategies to minimize deep sternal wound infections (DSWI) in patients undergoing CABG using BIMA grafts can broadly divided into preoperative, intraoperative and postoperative strategies (Table 1).

5. Preoperative reduction strategies

A few of the risk factors are modifiable such as hyperglycemia, preoperative colonization of microorganisms, smoking, obesity, chronic obstructive pulmonary disease.

5.1. Strategies to reduce DSWI in diabetics and hyperglycemic states

Diabetes mellitus has been identified as independent risk factors for deep sternal wound infections and glucose control lowers the risk of wound infection in diabetics after open heart operations [20,45,46]. Hyperglycemia promotes pathogen proliferation, impairs neutrophil function and possibly has other effects on host defense. Optimization of preoperative levels of glycosylated hemoglobin (HbA1c) and blood glucose results in good early outcomes and reduction in sternal wound infections in patients undergoing CABG [47]. Most retrospective studies indicate that poor glucose control is associated with early adverse outcomes including sternal wound infection and mortality rates [48,49]. Investigators at the Mayo Clinic concluded that intraoperative hyperglycemia is an independent risk factor for complications: a 20 mg/dL increase in the mean intraoperative glucose level correlated with an increase of more than 30% in adverse outcomes (a composite of death, infections, or major organ-system complications) [50]. Investigators with the Portland Diabetic Project, a large prospective study of diabetic patients undergoing cardiac surgery, confirmed that hyperglycemia was an independent risk factor for death, length of hospital stay, and infection, and showed that continuous insulin infusions during the perioperative period reduce these risks [51–53]. The control of diabetes, as evaluated by hemoglobin A1c (HbA1c) levels should be optimized, although preoperative glucose levels per se matter less than the intraoperative and immediate postoperative levels. Tight glycemic control appears to be effective in significantly reducing rates of DSWI [54]. In addition, Lazar and colleagues demonstrated improved coronary surgery outcomes with a strategy for strict glucose control (125–200 mg/dL) using glucose insulin potassium solution reduced rates of sternal wound infection in a cohort of diabetic patients undergoing CABG [55]. Zerr and coworkers studied the effect of glycemic control and the incidence of sternal wound infections in 1585 CABG patients with diabetes. The sternal wound infections dropped from 6.7% in patients with blood glucose levels of 250–300 mg/dL to 1.3% in patients with mean glucose values of 100–150 mg/dL [56]. Glycemic control is best achieved with continuous insulin infusion rather than intermittent subcutaneous insulin injections or intermittent intravenous insulin boluses (level of evidence A). All patients with diabetes undergoing cardiac surgical procedures should receive an insulin infusion in the operating room, and for atleast 24 h postoperatively to maintain serum glucose levels $\leq$180 mg/dL (level of evidence B) [57]. Patients receiving IV infusion of insulin should have their blood glucose monitored every 30–60 min. During period of rapidly fluctuation sensitivity a more frequent monitoring as often as every 15 min is needed to maintain serum glucose level between 110 mg/dL to 180 mg/dL. Oral hypoglycemic medication should be restarted in patients who have achieved target blood glucose levels if there are no contraindications after 4 weeks of surgery (level of evidence C).

Table 1
Strategies to reduce sternal wound infection.

Preoperative strategies	Intraoperative strategies	Postoperative strategies
Optimization of glycemic control in diabetics (HbA1C $\leq$ 8.0%)	Avoidance of long operative period ($\leq$7 h)	Avoidance of low cardiac output status
Reduction of weight in obese (BMI < 30 kg/m^2)	Avoidance of long cardiopulmonary time ($\leq$180 min)	Avoid the usage of sympathomimetic agents and vasopressors
Cessation of cigarette smoking	Avoidance of the need for IABP support	Reduction of ventilatory support time <48 h
Optimization of pulmonary function COPD patients (FEV1/FVC < 0.70)		Avoidance of need for postoperative CPR
		Avoidance of re-exploration for excessive mediastinal bleeding
		Avoiding transfusion of packed red blood cell, single donor platelets

BMI: body mass index, COPD: chronic obstructive pulmonary disease, CPR: cardiopulmonary resuscitation, FEV: forced expiratory volume, FVC: forced vital capacity, IABP: intra-aortic balloon pump.

5.2. Strategies to reduce sternal infections in smokers

Nicotine use delays primary wound healing and may increase the risk of sternal wound infection. In a large prospective study, current cigarette smoking was found to be an independent risk factor for deep sternal infection following cardiac surgery [58]. Another study corroborated cigarette smoking as an important risk factor for median sternotomy wound dehiscence which predisposes to spread of infection to the sternum and mediastinum [59]. A recent meta analysis found that smokers have a higher incidence of wound healing complications across all surgical specialties and 4 weeks of smoking cessation before surgery substantially reduces surgical site infections [60]. Postoperative patients who smoke show delayed wound healing and increased complications such as infection and wound dehiscence following coronary bypass surgery [61] and hence abstinence from smoking in the postoperative period is mandatory to reduce sternal wound complications.

5.3. Strategies to prevent DSWI in patients with chronic obstructive pulmonary disease (COPD)

In a univariate analysis, Diez and colleagues determined that COPD is a potential risk factor for the development of DSWI [62]. Chronic obstructive pulmonary disease is also found to be associated with an increased risk of deep sternal infection even in patients where BIMA have been harvested using skeletonized technique [26]. Patients with severe COPD are at great risk of coughing, and sternal dehiscence, regardless of the sternal closure method used. Preoperative optimization of pulmonary function reduces the incidence of sternal wound infection in patients undergoing CABG. Avoiding BIMA harvest is recommended in patients with severe COPD.

5.4. Strategies in obese patients

Obesity defined as body mass index (BMI) greater than 35 kg/m^2, is a high risk factor for sternal wound infection [63]. In studies conducted in UK, BMI >30 kg/m^2 was found to be an independent risk factor for sternal wound infection [OR 2.0 (95% CI 1.3–2.9), $p < 0.001$] [25]. In addition morbidly obese ($\geq$40–44.9 kg/m^2) patients were 4.17 ($p < 0.001$) times more likely to develop harvest site infections compared with normal weight patients [64]. When analyzed as a continuous variable, increasing BMI was a strong risk factor for both superficial and deep sternal infections [65]. In obese patients efforts directed at perioperative infection prophylaxis employ more aggressive use of antibiotics in the postoperative period. Use of enhanced techniques for sternal closure could be helpful in reducing sternal infection. However, it is preferable to avoid BIMA harvesting in grossly obese (BMI > 40) patients. In obese patients the best approach could be probably achieved with LIMA and radial artery grafts. However no data available in the literature to suggest that delaying surgery in obese patients to promote the use of BIMA after weight loss [66–68].

5.5. Strategies for preoperative skin preparation to reduce microbiological colonization

A multivariate analysis demonstrated that microbiological colonization was one of the most powerful independent risk factor for SSI following cardiothoracic operations [69]. When patients shower or bathe preoperatively with antiseptic agents, it reduces bacterial colonization. This approach is widely used prior to cardiac surgery [70]. Chlorhexidine reduces skin bacterial-colony counts to a greater extent than does povidone-iodine or other agents that have been studied [71]. In a comprehensive, systematic literature review published in 2012, the authors concluded that preoperative antiseptic showers may alone be effective in preventing postoperative infections [71]. Preoperative hair removal of the surgical site in the night before operation is associated with significantly higher SSI risk than the hair removal done immediately before the operation (7.1% vs 3.1%). Clipping of hair is associated with lesser SSI risk compared to either shaving or use of depilatory agents (1.8% vs 4.0%) [72–74].

5.6. Strategy for antibiotic prophylaxis

The preoperative administration of antibiotics is a universal component of prophylaxis against sternal wound infection. The most common prophylaxis antibiotic regimen are based on two important conclusions: first, antibiotic prophylaxis significantly reduces the prevalence of sternal infections when compared to placebo, secondly, increasing the duration of prophylaxis beyond 36–48 h does not further reduce sternal infection rates [75,76]. The current practice is to use second generation cephalosporins and in patients allergic to penicillin, vancomycin is substituted. Prolongation of antibiotic prophylaxis in high risk patients with score >199 points may be considered to reduce DSWI after cardiac surgery [77].

5.7. Miscellaneous strategies to reduce DSWI following BIMA harvest

Appropriate timing of discontinuation of antiplatelet agents prior to CABG is important in reducing blood loss and blood transfusion requirements which increases the risk of DSWI. Preoperative optimization of renal function, correction of hypoalbuminemia are also reduce the incidence of DSWI [78]. Avoiding BIMA grafting in patients with BMI > 30 kg/m^2, uncontrolled diabetes especially in females, severe chronic obstructive pulmonary disease is recommended to prevent DSWI.

6. Intraoperative measures to reduce DSWI

Strategies may be grouped as environmental, general surgical strategies, and specific techniques of IMA harvesting and closure of sternum.

6.1. Environmental strategies

In minimizing intraoperative risk factors, considerations include a sterile operating room with adequate ventilation, as airborne pathogens such as Aspergillus and Legionella species can cause outbreaks of infection in cardiac surgery [79–82]. The standard aseptic operating-room practices and limited traffic flow in operating rooms reduce the incidence of SSI.

6.2. General surgical strategies

Adherence to basic surgical principles are of paramount importance. The general measures to minimize DSWI include control of bleeding, accurate anatomic dissection, use of completely sterile equipment, strict adherence to aseptic operative techniques, exact approximation of tissue in wound closures without excessive tightness and gentle handling of tissues. The control of bleeding is especially important and excessive bleeding and hematoma formation creates a culture medium that is a major risk factor for mediastinitis [83].

6.3. Strategies to reduce cardiopulmonary bypass related risks for DSWI

Intraoperative strategies to minimize cardiopulmonary bypass and cross clamp times and avoidance of the need for intra-aortic balloon pump support by adequate myocardial protection and optimal pharmacological support to avoid low cardiac output status postoperatively [83,84]. In one study, 71 of 136 patients (52%) who had been supported with an intra-aortic balloon pump during cardiac surgery developed a postoperative infection [83]. Avoiding delayed closure of the sternum and reexploration for excessive mediastinal bleeding are important measures to prevent SWI. Minimizing the routine application of bone wax as a hemostatic agent following sternotomy reduces bacterial inoculum required to produce sternal osteomyelitis in the presence of bone wax [84]. The use of topical vancomycin and powdered absorbable gelatin mixed with topical thrombin to form a hemostatic paste which when applied to cut sternal edges, this paste facilitates hemostasis and also reduces postoperative sternal infections [85]. Many of the studies published today have demonstrated the prophylactic use of gentamycin-impregnated collagen sponge (GICS) placed retrosternally before sternal closure significantly reduced the sternal wound infection following cardiac surgery [86]. Meta-analyses of randomized controlled trials (RCTS) suggested that the application of GICS implants perioperatively may be beneficial in preventing DSWI in patients undergoing cardiac surgery [87,88]. Bennedetto and Raja developed a scoring system and suggested that use of GICS implant should be considered in patients with predicted risk >2% corresponding to an overall score of 136 or higher. The scores above 199 points are considered high risk for DSWI and additional strategies like prolonged antibiotic prophylaxis needs to be considered [77]. Blood transfusion also seems to increase the risk of infection and could be a major preventable intraoperative risk factor for mediastinitis [89,90]. The benefits of transfusing leukocyte-reduced blood are unclear [91].

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6.4. Effect of off-pump and on-pump techniques on DSWI

The relationship of incidence of DSWI to off-pump and on-pump CABG is inconsistent. Kai and colleagues reported lower incidence of DSWI in patients undergoing off-pump CABG compared to on-pump group (0.6% vs 13.0%) [92]. Gummert and colleagues reported that incidence of DSWI equal in both on-pump and off-pump CABG patients (1.8%) [93]. Crabtree et al. reported the incidence of deep sternal wound infection was 1.8% for on pump procedures and 2.3% for off pump procedures [65]. In a meta-analysis, deep sternal wound infection occurred in 3.1% and 1.6% for the BITA and LITA cohorts, respectively. The risk ratio for deep sternal wound infection development was 1.71 (95% CI - 1.37–2.14) for BITA compared with LITA [94].

6.5. Techniques for IMA harvest

Several techniques of ITA harvest have been reported with varying incidence of DSWI. The popular pedicled harvest technique, the IMA is dissected as a pedicle that includes the artery and accompanying veins, endothoracic fascia and a part of the parietal pleura and distally that transverses thoracis muscle. Electrocautery is used to divide the branches of IMA after the application of clips on the artery side. This pedicled harvest of BIMA is associated with higher incidence of DSWI [15,95]. However, a few authors reported equal incidence of DSWI with pedicled and skeletonized IMA harvest [96].

A skeletonized technique of IMA harvest is a method in which the IMA is dissected as an isolated artery without accompanying veins and endothoracic fascia. The IMA branches are clipped on the artery side and low strength electrocautery is used to divide these branches. Many studies reported skeletonization of IMA harvest technique is associated with lesser incidence of SWI [97,98]. This technique of harvest is time consuming and technically more demanding.

In semiskeletonized technique of IMA harvest the internal mammary artery along with the accompanying veins is harvested as a thin pedicle without endothoracic fascia and transverses thoracis muscle [99].

In modified pedicled harvest the internal mammary artery along with the accompanying veins, and narrow strip of endothoracic fascia are dissected as a pedicle. The IMA is transected distally one cm proximal to its terminal bifurcation and the communication between the musculophrenic and superior epigastric arteries are preserved [23]. The above three techniques are associated with lesser devascularization of sternum following IMA harvest. The incidence of DSWI in various published series is shown in Table 2. The bilateral internal mammary artery harvesting carries a higher risk of sternal infection than harvesting single internal thoracic artery. Skeletonization of both IMAs significantly decreases DSWI risk. However, the technique of harvesting, the presence of peripheral arteriopathy, resternotomy for bleeding are independent predictors of deep sternal wound infection [24].

Table 2
Shows the incidence of deep sternal wound infection in various studies.

Study	Year	Patient, *n* SIMA/BIMA	Deep SWI *n*(%) SIMA/BIMA	Harvesting method SIMA	Harvesting method BIMA	*P* Value
Sajja et al. [23]	2012	2730/342	19(0.7)/2(0.6)	P	P	0.83
Dorman et al. [21]	2012	414/414	7(1.7)/13(3.1)	P/S	P/S	0.180
Puskas et al. [100]	2012	2715/812	27(1.0)/10(1.2)	P	P/S	0.56
Kinoshita et al. [101]	2012	217/217	3(1.4)/2(0.9)	S	S	0.43
Kelly et al. [102]	2012	6554/1079	46(0.7)/13(1.2)	P	P	0.014
Grau et al. [103]	2012	928/928	3(0.3)/3(0.3)	P	P	1.00
Elmistekawy et al. [104]	2012	3581/359	46(1.3)/11(3.1)	P/S	P/S	0.0005
Hassanein et al. [105]	2010	389/415	7(1.8)/10(2.4)	S	S	0.54
De Paulis et al. [24]	2005	450/450	5(1.1)/19(4.2)	P	P/S	0.004

BIMA: bilateral internal mammary artery, SIMA: single internal mammary artery, SWI, sternal wound infection, P: pedicled, S: skeletonized.

6.6. The effect of skeletonization and pedicled harvest of BIMA on DSWI

In meta-analyses by Dai and colleagues showed that BIMA grafting bears an intimate relationship with the increased risk of sternal wound infection. Even though the risk of infection really increases in the BIMA group, the incidence is relatively low. Moreover, with the age of onset of coronary artery disease (CAD) decreasing and the life expectancy prolonged, the excellent late outcomes of BIMA grafting become more and more compelling [106]. Patients who underwent skeletonized BIMA harvest had a similar risk of deep sternal wound infection compared with single IMA (OR 0.9 [95% CI 0.42 to 2.09]). The skeletonized BIMA is confirmed to carry a lower risk of sternal infection than pedicled BIMA [24] and bilateral pedicled harvest demonstrated increased risk of sternal wound infection (OR 1.77 [95% CI 1.4 to 2.23]) [94] although a few studies reported acceptable risk of deep sternal wound infection using pedicled BIMA harvest [107]. In non-diabetics, nonsmokers and non-obese patient's pedicled harvest of BIMA is associated with comparable low incidence of DSWI. However, it is associated with slightly higher incidence of DSWI in diabetics, obese and smokers. Whatever the technique of harvesting, either skeletonized/semiskeletonized/pedicled harvest, the important consideration is to preserve the continuity between the sternal and perforating branches of ITA and sternal and intercostal branches or the common trunk by dividing these branches close to the IMA. This ensures the preservation of sternal blood supply [36]. Similarly sparing of the communicating bifurcation of the IMA to the chest wall also promotes collateral blood supply to the sternum after BIMA harvest and is associated with lower incidence of DSWI even in diabetics [23].

6.7. Techniques of sternal closure and sternal stability

Numerous studies now support the concept that sternal instability is a major risk factor in the development of sternal wound infections [29,31]. It is opined that increased infection rate seen in unstable sternal fixation is due to increased bone movement, which leads to local tissue necrosis, and creates a milieu for bacterial growth at the time of transient inoculation. In contrast, stable bony fixation reduces the amount of tissue trauma and promotes rapid revascularization and primary bone healing. A precise midline sternotomy reduces the risk of sternal instability and dehiscence associated with lateral sternotomy [108]. A paramedian sternotomy predisposes to sternal instability regardless of sternal closure technique. Techniques of sternal closure such as use of figure -of-eight wires, figure of eight stainless steel cables, stainless steel plates, sternal screws with central lumen for wire placement, bone staples to buttress cerclage wires have been described with better sternal stability [109–112]. However, the simple peristernal cerclage technique is the most common method of sternal approximation [113].

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7. Postoperative strategies to reduce sternal infection

Aggressive environmental cleaning of the intensive care unit and cardiothoracic recovery room with proper surface disinfection between patients is important [71]. Early extubation is desirable and is associated with lesser incidence of DSWI [114]. Daily attention to indwelling central venous arterial and pulmonary artery catheter and urinary catheters is necessary. Central venous catheter related infection has been found to increase wound infection by 5-fold [115]. Peripherally inserted radial artery catheter is also associated with sternal infection [116]. A sterile dressing over the primary incision for 24–48 h postoperatively is recommended. Patient and his family need to be educated regarding the proper incision care, symptoms of SSI and early reporting for appropriate intervention.

8. Vigilance and medical audits

Strategies to reduce the risk of DSWI following CABG using BIMA grafts requires constant vigilance and attention to detail, both in caring for individual patients and in ensuring that policies conform with up-to-date knowledge and experience. Every case of deep sternal wound infection needs to be reviewed and the root cause analysis need to be carried out. Multidisciplinary medical audits of best practices need to be reviewed periodically [70].

9. Conclusions

Deep sternal wound infections continue to complicate CABG procedures particularly when using bilateral internal mammary artery grafts. Strategies to optimize preoperative, intraoperative, and postoperative risk factors may bring down DSWI to an irreducible minimum. Cessation of smoking, optimal control of hyperglycemia in the perioperative period, timely administration of appropriate prophylactic antibiotics, sterile operative conditions, in addition to appropriately selected and meticulously performed surgical techniques (IMA harvest and sternal closure) reduce the incidence of DSWI following BIMA harvest. Avoidance of low cardiac output state and use of IABP support, re-exploration for bleeding and multiple blood and platelet transfusions are associated with lower incidence of DSWI. Avoiding BIMA grafting in patients with BMI > 35 kg/m^2, uncontrolled diabetes, severe chronic obstructive pulmonary disease is recommended to prevent DSWI.

Ethical approval

As this is an invited review, this manuscript does not require Ethics approval. Hence there is no Judgement's reference number.

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Conflicts of interest

None.

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