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Review

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].