Using skeletonised grafts for coronary artery bypass grafting

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Abstract

Coronary artery bypass graft surgery relieves angina symptoms and reduces mortality among ischaemic heart disease patients. It remains the gold standard for the treatment of multi-vessel and left main coronary artery disease. It is a well-known fact that internal mammary artery conduits have excellent and long-lasting patency when used for coronary artery bypass grafting. Its supremacy is largely because it prevents atherosclerosis. The old-style internal mammary artery bypass grafting, classically known as pedicle grafting, includes a circular rim of tissue around the graft. Bilateral pedicled internal mammary arteries, especially among diabetic patients, have been reported to cause complications in the sternum like sternal osteomyelitis. In many studies it has been reported that dissection of pedicled internal mammary artery can lead to sternal devascularisation which can lead to higher incidence of infections. Considering the higher incidence of deep sternal infections in patients with double pedicled arterial grafts, dissection of internal mammary artery in skeletonised manner was proposed. In this review, we outline the advantages of skeletonised grafting with respect to incidence of sternal infection, patency rates, blood flow, post-coronary artery bypass graft pain and the length of the graft.

Keywords: Internal mammary artery, Coronary artery bypass grafting, Skeletonisation.

Introduction

It is a well-known fact that internal mammary artery (IMA) conduits have excellent and long-lasting patency when used for coronary artery bypass grafting (CABG). Its supremacy is largely because it prevents atherosclerosis.[1] In addition, these conduits have their own blood source from the vaso-vasorum, a well-constructed internal elastic lamina, its nerve supply and relatively fewer myocytes in tunica media. Despite these advantages, use of IMAs as bypass grafts is restricted to specific settings. These grafts can undergo severe vasoconstriction and reduced blood flow, especially in the initial post-operative phase particularly when vasoactive drugs are administered. These grafts are also associated with loss of sternal blood flow[2] and increased incidence of sternal wound infection, importantly in diabetics.[1] Accessibility of conduit of appropriate length is often limited and IMA grafts are also linked to greater and continuous post-CABG pain.[1]

There are several advantages of using left IMA grafts over the use of saphenous vein grafts for CABG. Venous grafts can only be used as free graft in CABG whereas IMA can be used as free graft, pedicle or skeletonised. Moreover, in IMA grafts there is a greater supply of nutrients to the vessel wall, fast elimination of metabolic products and release of larger amounts of nitric oxide and prostacyclin from artery wall. This leads to improved graft patency, decreased occurrence of unfavourable future cardiac events, decreased need for future revascularisation interference and improved survival.[1] Initially surgeons used only left IMA for bypass grafting that allowed one distal anastomosis to one coronary artery, usually the left anterior descending (LAD) artery. With medical advancement surgeons are now able to create many distal anastomosis using bilateral IMAs and sequential grafting. However, use of bilateral IMAs has resulted in greater operative deaths, increased risk of sternal wound infections (perhaps due to decreased blood flow to the sternum), prolonged post-CABG ventilation and increased reoperation for bleeding.[1]

The conventional IMA harvesting procedure, also known as pedicle grafting, requires IMA graft with its surrounding tissue. Recently another surgical technique known as skeletonisation of IMA has been put forward as an answer to many of the complications related to the conventional IMA grafting procedure. Benefits of skeletonised IMA include greater perfusion, longer length (allowing easy revascularisation distally), increased calibre, lower risk of sternal infection and reduced pain.[3] Although skeletonisation of bilateral IMA is more time consuming, the studying of the haemostasis of the chest wall takes

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lesser time. Skeletonisation of IMA graft involves careful separation of surrounding tissue and could potentially cause arterial rupture. Generally, the main reason for early graft failure after bypass grafting is thrombogenesis.[2] Tunica intima of a graft may get injured at the anastomotic site and during its preparation when a vessel clamp is applied to interrupt the graft for a short time. The graft may also get injured during its dissection. As skeletonised grafts lack surrounding tissue including veins and fatty tissue, it is more predisposed to the mechanical force applied by a clamp. However, IMA can be effortlessly and rapidly skeletonised by using an ultrasound scalpel. Clinical efficacy and safety of this device is well documented.[2]

In this review, we outline the advantages of skeletonised grafting with respect to incidence of sternal infection, patency rates, blood flow, post-CABG pain, length and IMA harvest time.

Sternal Wound Infections

Sternal wound infection, particularly mediastinitis, is one of the most documented and vital complication of bypass grafting.[4] It is proposed that the type of harvesting technique, either skeletonised or pedicled, has a significant effect on the occurrence of post-CABG sternal infection.[4]

A meta-analysis and met-regression study, conducted by Sa et al, involving 4817 patients (2424 skeletonised and 2393 pedicled) showed a statistically significant difference in the incidence of sternal infections between the two types of grafting.[5] Skeletonised grafting (fixed effect model: odds ratio [OR] 0.443; 95% confidence interval [CI] 0.323-0.608; p< 0.001; random effect model: OR 0.443; 95% CI, 0.323-0.608; p<0.001) was associated with a reduction in the incidence of post-CABG sternal infection, with diabetes having a major influence. These findings may be due to improved sternal blood flow after skeletonisation of IMA.

Boodhwani et al. conducted a study with 48 patients to compare sternal perfusion between skeletonised and pedicle grafting.[6] Each patient underwent bilateral IMA grafting, with skeletonised graft on the left side and pedicled graft on the right side. Sternal perfusion was then studied through scintigraphy radio nuclear imaging. The results indicated that sternal perfusion was greater in skeletonised IMA (left side) compared to pedicled IMA (right side) (perfusion improved by 17.6%; p=0.03). A study has also highlighted that oxygen saturation in microvasculature of sternal tissue is better in skeletonised IMA.[7]

Although various studies suggest that female gender, elderly population and bilateral IMA (BIMA) grafting benefit from skeletonised harvesting,[8] a met-regression analysis[5] shows no statistically significant coefficients for sternal infection and female gender, use of BIMA and age. This means that these variables have no control over the effects of skeletonised IMA. Interestingly, met-regression coefficient was significant for sternal infection and proportion of diabetics (coefficient: -0.02; 95% CI: -0.03 to -0.01; p=0.016). This means that diabetics are more protected in relation to occurrence of sternal infection if they undergo skeletonised grafting compared to pedicled grafting. This notion was confirmed by sub-group analysis in the same study.[5] Sensitivity analysis of sub-categories like diabetic patients, BIMA plus diabetic patients and BIMA showed a statistically significant difference in favour of skeletonised IMA in relation to post-CABG sternal infection.[5] Sensitivity analysis also showed that non-randomised trials, when combined, reveal benefit of skeletonised IMA compared to pedicled IMA in relation to sternal infection.[5] However, randomised trials, when combined, do not show any benefit of skeletonised IMA.[5] The main reason for such a difference between non-randomised and randomised trials was sample size for each category of trail.

A study claims that incidence of sternal infection after bypass surgery can be no more than 5%.[5] Four studies have been shown to cross this value for incidence.[9-11] From these 3 studies, two studies[9,11] included a very small size (less than 25 patients) and therefore rare events resulted in increased incidence. The other study[10] involved specific risk groups, in which one would naturally expect a higher incidence. Therefore, these three studies do not highlight the true incidence of post-CABG sternal infection in general population. In other studies the incidence was under 5% as they had a larger sample size and included all categories of patients.[4,12]

Another meta-analysis also compared type of harvesting with occurrence of sternal infection.[13] It was published before an earlier one and therefore did not include nine studies involving 1154 patients. The analysis also showed that skeletonisation technique reduces the incidence of sternal wound infection (OR 0.41; 95% CI 0.26 to 0.64). The reduction in incidence of sternal infection was more prominent in diabetic patients who underwent BIMA grafting (OR 0.19; 95% CI 0.10 to 0.34).

Although results of meta analysis[5] and other studies reveal that skeletonisation of IMA is associated with decreased incidence of sternal infection (an effect primarily controlled by existence of diabetes), a large randomised, prospective, multi-center trial should be

conducted to confirm the presence of significant difference in the occurrence of post-CABG sternal infection between the two types of harvesting.

Patency rates and anastomoses

A retrospective cohort study was conducted in which patients underwent isolated CABG with BIMA harvesting.[14] Skeletonised grafts were used in 162 patients, while pedicled grafts were used in 23 patients. Skeletonised group underwent off-pump CABG while pedicled group underwent on-pump CABG. Post-CABG angiography was performed (within one month) in 137 patients who experienced skeletonised IMA grafting and 23 patients who underwent pedicled IMA grafting. Left IMA (LIMA) harvesting showed 96.4% and 100% post-operative patency in skeletonised and pedicledgrafts respectively. Right IMA (RIMA) harvesting showed 97.8% and 95.7% post-operative patency in skeletonised and pedicled grafts, respectively. However, the study did not assess long-term patency of grafts.

A prospective study involved 115 patients who underwent skeletonised BIMA grafting and 99 patients who underwent pedicled BIMA grafting.[15] Post-CABG angiography was performed (within one month) in 87 patients who underwent skeletonised grafting and 36 patients who underwent pedicled grafting. Hundred percent patency rates were recorded for both skeletonised (LIMA with 100 anastomoses and RIMA with 95 anastomoses) and pedicled (LIMA with 39 anastomoses and RIMA with 38 anastomoses) bilateral grafting. Mean number of distal anastomoses recorded were 4.1±1.1 for skeletonised group and 3.6±1.1 for the pedicled group. However, again the study did not assess long-term patency rates of grafts.

Researchers retrospectively collected data for 842 patients who underwent myocardial revascularisation using skeletonised BIMA and 304 patients who underwent CABG using pedicled BIMA.[16] Post-CABG angiography was performed at two time periods (<1 month and <16 months) in 133 patients who underwent skeletonised grafting and 71 patients who underwent pedicled grafting. Graft patency within 1 month was 98.2% and 97.5% for skeletonised and pedicled grafts, respectively. Graft patency within 16 months was 96.8% and 94.3% for skeletonised and pedicled grafts, respectively. Moreover, decrement in sternal complications was observed with skeletonised procedure. Again, however, the study did not assess long-term patency.

Ryu et al. studied 37 skeletonised LIMA grafts. Post-operative angiography was conducted at 14 days (early) and 348 days (mid-term) to assess graft patency.[17] Thirty-six patients who underwent early angiography revealed 97.2% patency rate, while 32 patients who underwent mid-term angiography revealed 100% patency rate. It was concluded that skeletonisation of left internal thoracic artery-gastroepiploic artery (LITA-GEA) composite conduits result in outstanding early graft patency and may be used in cases when accessibility of BIMA is limited.

Researchers conducted a retrospective study on 1,000 patients who underwent isolated CABG with skeletonised BIMA harvesting.[18] Post-CABG angiography, performed at 78 months in 87 patients, revealed 91% patency rate and 160/176 anastomoses. It was concluded that skeletonisation of BIMA results in reasonable early and mid-term outcomes.

A retrospective cohort study involved 1,050 patients who underwent CABG using BIMA grafts.[19] Post-operative angiography, done at < 36 months, revealed 95.4% graft patency. The authors concluded that bypass surgery using skeletonised BIMA gives outstanding graft patency.

Phung et al. also studied the effects of skeletonized gastroepiploic artery. The authors found that skeletonisation technique provides excellent early patency rates even when the gastroepiploic artery is used as a sequential graft. Angiography showed that all the grafts were patent before discharge.[20]

Ali et al. showed in their systematic review that patency rates exceeded 95% in skeletonised IMAs when angiographic follow-up was within three years of surgery, and the authors concluded that use of skeletonised IMA should be preferred over pedicled IMAs. The review showed that short and mid-term patency rates of both skeletonised and pedicled grafts are excellent. The authors believe that more long term studies should be conducted to fully confirm the long-term patency results in skeletonised grafts.[21] Suzuki et al. showed in their study that overall early (4 to 21 days after surgery) patency rate of the skeletonised gastroepiploic artery was 98.2% (599 out of 610 anastomoses). The overall patency rate at 73 months of follow-up rate in skeletonised gastroepiploic artery was found to be 94.4%. The cumulative patency rate of the skeletonised gastroepiploic artery was 97.8% at 1 month, 96.7% at 12 months, 96% at 36 months, 94.7% at 5 years and 90.2% at 8 years after bypass surgery. The authors of the study concluded that skeletonisation technique gives superior long term patency outcomes as compared to pedicled technique.[22]

Research is limited in this field of cardiac surgery. In addition, skeletonised conduits have not been used for a

long time to determine its patency after many years. Only two papers discussed above,[18,22] highlight the patency rate exceeding 5 years. Studies discussed above reveal that both skeletonised and pedicled grafts are associated with outstanding early and mid-term patency. Of the studies discussed above, only 3[14-16] compared skeletonised with pedicled grafts. In these 3 comparative studies, patency of skeletonised grafts was at least similar to patency of pedicled grafts and in two studies[14,16] it was even greater.

Blood flow and post-CABG pain

A study reported that skeletonisation of IMA is associated with decreased incidence of injury to tissue blood supply in the middle and lower retrosternal area compared to pedicled harvesting.[9] Another study done by Hu et al. showed that skeletonisation of IMA significantly increases free flow capacity (23.24 ml/min, 95% CI 7.52-38.96) as compared to pedicled harvesting technique.[2] The reason for increased conduit flow in the skeletonised IMA is that the skeletonisation technique allows increased conduit caliber for anastomosis. Skeletonisation of IMA grafts also results in greater diameter of anastomosis and reduces vascular resistance of the conduit, thereby preventing hypo perfusion syndrome. This is particularly important in off-pump CABG that is done without assisted circulation. Phung et al. concluded in their study that skeletonisation of gastroepiploic artery results in sufficient luminal diameter with excellent blood flow (median blood flow in the graft and pulsatile index were 65 mL/min and 3.1, respectively).[20]

Various studies highlight that skeletonisation of IMA is associated with greater perfusion and reduced post-CABG pain.[2] However, these are mainly observational studies involving small sample sizes. The first in-patient randomised study compared skeletonised with non-skeletonised IMA grafting in a large sample (n=96 grafts in 48 patients, each patient underwent skeletonised on one side and non-skeletonised on the other side).[6] In contrast to the results of previous studies, the study[6] showed that skeletonised IMA did not increase the flow (7.4±0.9 versus 10.1±1.0 mL/min; p=0.01). Graft flow was lower in skeletonised IMA just after grafting, perhaps due to vasospasm subsequent to closer graft manipulation. It was also found that flow in skeletonised and non-skeletonised IMA was comparable subsequent to distal division, topical papaverine use and anastomosis.[6] One reason for opposing IMA flows in this study and other studies may be due to variation in skeletonisation procedure and type of vasodilator that is used.

The internal thoracic artery (ITA) syndrome is a triad comprising of pain, allodynia and dysesthesia subsequent to IMA grafting that can continue for up to 60 weeks. A study concluded that skeletonisation of IMA grafts reduces post-CABG pain at 3 months follow-up and reduces the incidence of main sensory deficits at 1 month and 3 month (17% versus 50%; p=0.002) follow-ups.[6] It was found that patients did not detect any significant difference in post-CABG pain between skeletonised and non-skeletonised sides immediately after bypass grafting. This may be due to competing sources of pain from midline skin incision and sternotomy.[6] Bawany et al. confirmed that skeletonisation of IMA results in a significant reduction in post-bypass pain both at 1 and 3 months follow-up.[23] The reason for reduced pain in skeletonized IMA is that skeletonised grafting protects the anterior branch of intercostal nerve that decreases the incidence and severity of post CABG pain.[23]

Length and IMA harvest time

It is a well-known fact that skeletonisation of IMA is associated with greater length of graft.[3] Benefit of increased length of the graft is that it allows composite grafting. For instance, a randomised, double-blind, in-patient comparison of skeletonised versus non-skeletonised IMA showed that skeletonisation results in increased length of graft (18.2±0.3 versus 17.7±0.3 cm; p=0.09).[6] A systematic review done by Hu and his colleagues showed that skeletonisation technique significantly increases the graft length (increment of 1.99 cm, 95% confidence interval [CI] 0.87-3.11).[3] Different studies have reported different increments in length from the skeletonisation procedure. Such variation in increment of graft length may be due to skeletonisation technique and vasodilator use and preferences in selection of patients. Another study showed that skeletonisation technique requires more IMA harvest time as there is a need of meticulous preparation of the graft.[3] Vallely et al. also confirms that skeletonisation of IMA grafts results in maximum length of the conduit.[24]

Radial artery harvesting became increasingly popular for myocardial revascularisation because of its long-term patency rates.[25] The vessel can be harvested in a skeletonised or pedicled fashion. A study involving 40 patients compared harvesting procedure (i.e. skeletonised with pedicled preparation) using either scissors or ultrasonic scalpel.[25] In one half of the patients, the radial arteries were harvested using scissors (group 1: skeletonised; group 2: pedicled) and in the other half the arteries were prepared using ultrasonic scalpel (group 3: skeletonisation; group 4: pedicled). The results indicated that skeletonisation technique for radial artery is more time-consuming than pedicled when either scissor or

ultrasonic scalpel is used for graft preparation (group 1 versus group 2: 37.1±3.5 minutes versus 24.4±3.9 minutes; p<0.001 and group 3 versus group 4: 31.1±3.5 minutes versus 25.6±3.7 minutes; p<0.01). Skeletonisation using scissors and clips increases the graft length (20.8±1.5cm) compared to pedicled grafting (19.1±0.9 cm; p<0.01). In contrast, skeletonisation of grafts with ultrasonic scalpel does not produce extra graft length. It was further concluded that pedicled technique, either using scissors or ultrasonic scalpel, is less complicated and less time-consuming.[25]

Conclusion

Benefits of skeletonisation of grafts for bypass surgery range from decreased incidence of sternal infection, greater conduit length, reduced post-CABG pain and increased conduit flow. Many studies also highlight that skeletonisation of grafts is associated with outstanding early and midterm patency rates. However, there is a need for multi-institutional, randomised controlled trials to confirm the long-term patency rates of grafts prepared by skeletonisation technique. Until such randomised studies that should involve follow-ups of 15 to 20 years, current evidence allows us to say that skeletonisation technique results in acceptable patency rates and that skeletonised grafts can be safely used for coronary artery bypass surgery.

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