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Review

Surgical strategies for bilateral internal mammary artery grafting

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HIGHLIGHTS

- The internal mammary artery (IMA) is the preferred conduit for CABG.
- Current evidence supports superior outcomes with BIMA compared with single IMA.
- BIMA can be used in several configurations.
- Each of these configurations has its merits and demerits.
- Awareness of these configurations can increase BIMA usage.

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ABSTRACT

The internal mammary artery is universally recognised as the preferred conduit for coronary artery bypass grafting. Accumulating evidence in recent years has demonstrated the superiority of bilateral internal mammary artery (BIMA) grafting over single internal mammary artery grafting in terms of survival, event-free survival, and freedom from re-intervention. The survival benefit seen with BIMA grafting has been associated particularly to grafting the myocardium supplied by the left coronary artery system. Several surgical strategies have been used to achieve left-sided myocardial revascularisation with BIMA grafting. These include in-situ right internal mammary artery (RIMA) to the left anterior descending and the left internal mammary artery (LIMA) to circumflex marginal branches, directing the RIMA through the transverse sinus in a retroaortic course, and free RIMA graft connected proximally either to the LIMA (composite grafting) or to the ascending aorta. Each one of these surgical strategies for BIMA grafting has its merits and demerits. This review article provides an overview of the various surgical strategies for BIMA grafting focussing on their technical aspects, pros and cons as well as outcomes.

1. Introduction

Complete revascularisation and arterial grafting are associated with improved long-term outcomes after coronary artery bypass grafting (CABG) [1]. Amongst the arterial grafts the superiority of the internal mammary artery as a graft in CABG is widely accepted with documented excellent long-term results [2]. Following the publication of the landmark study by Loop et al. in 1986, validating the impact of the internal mammary artery graft on 10-year survival and other cardiac events, the use of the left internal mammary artery (LIMA) as a graft to the left anterior descending (LAD) artery is universally recognised as the 'gold standard' procedure in CABG [3].

Recognition of the long-term benefits of LIMA grafting led to more widespread use of bilateral internal mammary arteries (BIMA) [4] with development of different surgical techniques [5].

Despite the well-recognised advantages of BIMA grafting including enhanced long-term survival and freedom from repeat revascularisation the universal adoption rates of BIMA grafting have remained very low [6]. Concerns regarding perioperative results, possible myocardial hypoperfusion, lack of randomised trials, and the potential heightened vulnerability of such patients to deep sternal wound infections are some of the commonly cited reasons for the very low use of BIMA [6]. Another important reason for reluctance to adopt BIMA grafting is the perceived complexity and unfamiliarity with the operative techniques [6].

The survival benefit seen with BIMA grafting has been associated particularly to grafting the myocardium supplied by the left coronary artery system [7–12]. However, while the concept of BIMA grafting is becoming well established due to improved late survival [7,8], controversy still surrounds the optimal surgical

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strategy for the simultaneous use of both IMAs. Several arrangements of grafting have been used to achieve left-sided myocardial revascularisation with BIMA. These include in-situ right internal mammary artery (RIMA) to the LAD and the LIMA to circumflex marginal branches [9], directing the RIMA through the transverse sinus in a retroaortic course [10], and free RIMA grafts connected proximally either to the LIMA [11] or to the ascending aorta [12].

This review analyzes the range of surgical strategies of using BIMA focussing on the technical aspects, pros and cons as well as outcomes of each strategy.

2. Retroaortic in-situ RIMA via transverse sinus to circumflex marginal branches with in-situ LIMA to LAD

2.1. Technical aspects

In 1984, Puig et al. [10] were the first to report the use of retroaortic in-situ RIMA via the transverse sinus for circumflex artery grafting. The surgical technique for in-situ pedicled RIMA harvest is similar to the one used to take down the LIMA. The RIMA is mobilised with its adjacent veins, the surrounding fat or muscular tissues, and the endothoracic fascia. This pedicle is about 2 cm wide. The RIMA is extensively dissected from its distal bifurcation in the rectus muscle up to the level of the subclavian vein. The RIMA at its subclavian origin is freed from its pleural and thymic attachments and if necessary the confluence between the RIMA vein and the azygos vein is divided to gain a maximum [13]. Care is taken during this dissection not to injure the phrenic nerve. After dissection the RIMA is forcefully sprayed with a solution of papaverine (40 mg/100 ml) and wrapped with gauze soaked in the same solution. The RIMA is divided after cannulation for on-pump CABG or prior to exposing the target vessels in off-pump CABG. The RIMA flow is usually assessed by checking the force of free bleeding.

Next the pericardium anterior to the superior vena cava is cut down transversely and the RIMA is passed behind the ascending aorta and the pulmonary artery through the transverse sinus. The pleural strip that covers the ventral side of the pedicle is used as a guide to avoid any twisting of the RIMA. The pedicle is considered adequately positioned in the transverse sinus only when the free bleeding from the RIMA remains brisk. The left ventricle is then lifted and rotated to the right to expose its lateral wall. Anastomosing the RIMA to the circumflex marginal branches in this position is easier than when the heart is not rotated but, on the other hand, requires additional length of the RIMA. The pedicle may sometimes be tight during this part of the operation. However, the release of the heart after completion of the anastomoses always restores adequate length and looseness to the RIMA. The in-situ LIMA is anastomosed to the LAD in the conventional fashion.

2.2. Pros and cons

This surgical strategy offers a series of advantages: (1) the LAD is revascularised by the in-situ LIMA, which is well accepted as a gold standard technique; (2) the left coronary system is perfused by 2 in-situ IMAs; (3) it avoids the difficulties of anastomosing a thin-walled vessel, such as the free RIMA, to a thick-walled vessel, such as the aorta; (4) there are no grafts crossing the midline behind the sternum, and both IMAs are in a safe position, which decreases the risks in case of mediastinal revision or reoperation; and (5) it offers the possibility to easily apply the no-touch principle by using different composite graft configurations.

The major drawbacks of the retroaortic course of the in-situ RIMA include the inability to control bleeding from retroaortic RIMA branches, aortic compression of the in-situ RIMA, and compromised graft patency because of undetected kinks, graft overstretching, rotation, and spasm of distal RIMA.

Skeletonisation of the in-situ RIMA with its retrocaval routing is proposed as a strategy to tackle these disadvantages [14].

2.3. Outcomes

Puig et al. [10] for the first time reported outcomes of this surgical strategy in 56 patients. The angiographic control was performed in 17 of 56 patients and showed all the RIMA grafts patent and functional. On the contrary another study by Rankin et al. [15] reported only 75% of RIMA grafts patent, using the same technique, whereas the patency rate of RIMA to LAD or LIMA to circumflex system was 100%. Subsequent larger studies [14,16–24] confirmed good clinical outcomes and excellent angiographic patency of pedicled RIMA to posterolateral wall through transverse sinus comparable with that of the LIMA to the LAD. Gerola et al. [16] reported LIMA patency rate of 97.6% at 1 year and 93.8% at 5 and 10 years of follow-up in a group of 201 patients. The RIMA patency was 92.1% at 1 year and 84.1% at 5 and 10 years (no statistical significance). In another study, Buche et al. [17] reported a patency rate of the LIMA to LAD of 92.3%, and of RIMA grafts via the transverse sinus of 89.9% at 56 months. Cumulative patency rates (actuarial curves) at 6 years were 94.5% and 89.3% for LIMA and RIMA, respectively, with differences not reaching statistical significance.

Bonacchi et al. [25] evaluated early and late outcomes of in-situ skeletonised RIMA routed through the transverse sinus (eventually retrocaval) for grafting circumflex marginal branches in the setting of BIMA grafting. In this retrospective study, between January 1997 and July 2003, 552 consecutive patients underwent grafting of the circumflex artery system with an in-situ skeletonised RIMA routed through the transverse sinus (eventually retrocaval). The mean age of the study population was 63.8 ± 11 years. Total arterial myocardial revascularisation was performed in 331 (60%) patients. Mean follow up was 26 ± 9 months. The success rate of skeletonised RIMA grafting to the circumflex branch was 100%. The in-hospital mortality was 3.4% (19 patients). Twelve patients (2.2%) sustained perioperative myocardial infarction. Two patients out of 155 undergoing postoperative angiography had an occluded RIMA and a string-like phenomenon was seen in three RIMA and one left IMA (LIMA). Three RIMA and three LIMA had stenotic lesions. The patency rates of RIMA and LIMA were 94% and 97.4%, respectively. Cumulative actuarial survival at three years was 96.4% and event-free cumulative survival was 93.8%.

3. Retrosternal crossover in-situ RIMA to LAD with in-situ LIMA to circumflex marginal branches

3.1. Technical aspects

The in-situ RIMA is harvested as a pedicled or skeletonised conduit. Following assessment of flow and length the RIMA is directed anterior to the aorta to graft the LAD. Preventive measures are taken with respect to repeat sternotomy. The RIMA is tunnelled through a right pericardial incision at the level of the aorta and pulmonary trunk and directed leftward, crossing the midline at the most cranial point before angling toward the LAD. This manoeuvre allows free space on the aorta for future instrumentation and provides a safety distance between the IMA and the sternum. An in-situ LIMA Is used to graft the circumflex branches.

A giant metal clip is used to mark the RIMA midline location with respect to the sternum for a possible future median sternotomy [9]. Mediastinal fat is used to cover the artery and fix it in the