Current Trends in Surgical Revascularization of Multivessel Coronary Artery Disease With Arterial Grafts

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Summary

It is well known that graft patency determines prognosis in coronary artery bypass grafting. Numerous reports over the past 20 years have documented superior patency and prognosis when multiple arterial grafts are used. The use of the left internal thoracic artery to graft the left anterior descending artery has been widely accepted as the gold standard for surgical treatment of coronary disease for over 40 years. A considerable body of evidence suggests that the right internal thoracic artery behaves in the same way. Radial artery grafts are being studied in several randomized trials, but observational studies suggest a performance comparing favorably with the saphenous vein. The right gastroepiploic artery has been recognized as a suitable and reliable conduit for coronary bypass surgery. However, the use of multiple other arterial grafts is performed in less than 10% of surgical procedures, probably because of perceptions of technical complexity, prolonged time for conduit harvesting, and increased perioperative complications. As a result, most patients with multivessel coronary artery disease do not benefit from extensive revascularization with arterial conduits. The aim of this review is to summarize the current evidence for the extensive use of arterial conduits in the revascularization of multivessel coronary artery disease. (Int Heart J 2014; 55: 381-385)

Key words: Coronary artery bypass grafting (CABG), Internal mammary artery (IMA), Radial artery (RA), Gastroepiploic artery (GEA)

Since the first series of left internal mammary artery (LIMA) grafts published by Konstantinov, the LIMA has become the standard treatment for coronary artery bypass grafting (CABG), particularly when anastomosed on the left anterior descending coronary artery (LAD). Barner reported the use of bilateral IMA (BIMA) for CABG almost 30 years ago, even if it was not widely accepted initially. Tector and others introduced composite arterial grafting using free LIMAs, sequential grafts, T-grafts and other combinations for the treatment of multivessel coronary artery disease (CAD).

Total arterial revascularization (TAR) has been shown to improve survival and reduce morbidity in patients with multivessel coronary disease. Arterial grafts have the advantage of durability and may have a protective effect by reducing the progression of native CAD in grafted vessels. Even in patients receiving vein grafts, addition of a second arterial conduit, particularly on the left system, confers a significant survival advantage. Moreover, survival after bilateral versus single internal mammary artery (IMA) grafting is being assessed by the randomized controlled Arterial Revascularization Trial (ART) of Taggart, et al.

Despite the evidence for arterial grafting and its increasing use, only a few surgical groups have reported a BIMA grafting rate greater than 10%. Multiple arterial grafting has not proved popular for many reasons, mainly because of perceived technical complexity or fear of a potential increase in perioperative mortality, increased duration of operation, or serious wound complications such as sternal infection. On the other hand, some surgeons have adopted a policy of extensive or total arterial revascularization using one or both IMA and alternative conduits such as the RA or right GEA grafts.

CABG has been shown to be superior to percutaneous coronary intervention (PCI) and is established as the standard of care for treating patients with multivessel CAD. However, current discussions comparing CABG versus second generation drug eluting stents (DES) are often based on the historical outcomes of LIMA coupled with saphenous vein grafting (SVG). Thus, it appears essential to report results with contemporary arterial grafting techniques in order to use these results as the new benchmarks with which PCI should be compared.

Left internal mammary artery

The internal mammary arteries (IMAs) are commonly used as the conduit to bypass major coronary artery stenosis, and have shown greater long-term patency rates and improved...
survival as compared to SVG.¹⁷,¹⁸ Three decades ago the Cleveland Clinic group published their fundamental study describing that the routine use of an IMA graft during CABG led to improved survival and to reductions in the subsequent incidence of myocardial infarction, recurrent angina, and the need for repeat intervention.¹⁹ Since then a considerable body of evidence has emerged confirming the benefits of the IMA graft, much of which now extends into the second and third decades of follow-up.²⁰,²¹

The benefit of IMAs over SVGs on mortality has been consistently observed irrespective of age, gender, degree of luminal stenosis in the left main coronary artery or preoperative left ventricular function with the survival differences widening over time.²² The improved benefits of an IMA graft over exclusive use of SVGs is almost certainly due to structural differences between the IMAs and SVG. The IMAs have a discontinuous internal elastic lamina and a relatively thin media with multiple elastic laminae and absence of a significant muscular component. These characteristics can explain a reduced tendency for spasm and the development of atherosclerosis. On the other hand, SVG has a thinner, more permeable endothelium and a thinner, more muscular, and less elastic media. Moreover, the IMA has significantly increased rates of nitric oxide production in both basal and stimulated states.²³ As a consequence of these structural and functional differences the superiority of IMAs over SVGs could be attributed to the striking resistance of this conduit to atheroma, where multiple structural and physical properties of the IMA could be involved.²⁴ IMA grafting of the LAD is also associated with less progression of native atherosclerotic disease within the proximal LAD as compared to when a vein graft is anastomosed to the LAD, as well as greater and rapid native disease progression from the development of fibrosis and calcification. Consequently, while the IMA has patency rates of 90-95%, 10 to 15 years after CABG,²⁵,²⁶ angiographic studies demonstrated that, at 10-years, only 38% to 45% of SVG remain patent.²⁷ Interestingly, skeletonization of the IMA had no effect on long-term patency, but added extra length. However, this probably carries a decreased risk of deep sternal infection, which is likely related to significant postoperative reduction in sternal perfusion.²⁸

Bilateral internal mammary arteries

Bilateral internal mammary arteries (BIMA) have been used since the early 1980s, and numerous reports from centers world over have consistently found similar excellent perioperative and especially long-term results, which are superior to those with traditional revascularization with LIMA-SVG.²⁹-³² The recurrent cardiac events rate is lower, reoperations are fewer, and long-term patencies are better (80-90% for RIMA versus 50-60% for SVG at 10 years), and survival is superior, with 40-50% fewer deaths (10% versus 20%) over 10 years.¹¹,¹⁷,²⁰,³³-³⁷

Tatoulis recently published results of a series of 991 right IMA grafts from 5,766 patients. There were similar patencies between the LIMA and the RIMA when grafted to the LAD (96.5% versus 94.5%) and no significant differences between IMA grafts were found when grafted to the circumflex system (90.5% and 88.5%, respectively). When grafted to the right coronary artery, the pedicled RIMA results were less satisfactory, but arterial grafts were far superior to SVG.³⁸ These data support the belief that the RIMA behaves in a similar way to the LIMA. As life expectancy is increasing, this evidence should have profound implications for these patients. However, the use of multiple other arterial grafts is performed in less than 10% of surgical procedures. Commonly raised concerns regarding BIMA use are related to the perception of technical complexity, prolonged time required for conduit harvesting, and potential increased perioperative complications.

The only published randomized trial to address these issues is the Arterial Revascularization Trial (ART).³⁹ This is an ongoing trial of 3,102 patients randomized to single or bilateral IMA grafts and conducted in 28 centers. The primary outcome of ART is 10-year survival, with final results expected in 2018; however, patient enrolment has been completed and a one-year analysis has already been published.⁴⁰ The one-year outcomes showed that the application of a second IMA added around 23 minutes to the duration of surgery but made no difference to the incidence of death, stroke or myocardial infarction, at both 30 days and one year.

Importantly, a statistically significant increase in the incidence of sternal wound reconstruction was found from 0.6% in the single IMA group to 1.9% in the bilateral IMA group.⁴¹ However, it should be considered that almost half of the patients requiring sternal wound reconstruction in the trial had diabetes, and that the presence of diabetes, coronary obstructive pulmonary disease, obesity and advanced age are well-recognized risk factors for impaired sternal wound healing. Consequently the use of both IMA should be used cautiously in such patients and particularly when more than one risk factor is present. Interestingly, there is strong evidence that using a skeletonized technique to harvest IMA grafts, rather than a pedicled technique, results in better preservation of blood supply to the chest wall and a reduced incidence of sternal wound problems.³⁹

The radial artery

Alain Carpentier first used the RA in 1971.⁴² However, within 2 years of adopting the RA there were reports of early failure rates⁴³ and significant intimal hyperplasia,⁴² which resulted in almost complete abandonment of its use as a graft. Techniques of early RA harvesting, particularly skeletonization, resulted in vessel trauma and spasm, and the use of mechanical dilatation were advocated as main causes of endothelial injury and subsequent early graft failure. The RA remained a “forgotten conduit” until its use was reported again by Christophe Acar in 1992.⁴⁴ In this later experience Acar and colleagues used a more refined “no-touch” method of graft harvesting and used pharmacological rather than mechanical vasodilatation to overcome RA spasm.

Structurally the RA has a thin continuous intima of endothelial cells, a single internal elastic lamina and a relatively thick muscular media, which predisposes to spasm, occlusion and thrombosis.⁴⁴ Although the incidence of atherosclerosis is greater in the RA compared to the IMA (5.3% versus 0.7%), this is still very low and demonstrates overall resistance to atherosclerosis.⁴⁵

Further reports of excellent outcomes with the RA⁴⁵,⁴⁶ coupled with a number advantageous characteristics (for example, ease of harvest, ability to reach all coronary territories, size match with the coronary arteries, uniform caliber along length of graft when compared to the SVG. RA harvest allows for quicker and easier ambulation following surgery) led to the
widespread adoption of the RA as the second or third arterial graft of choice.

A number of randomized trials have compared the RA to the SVG or the free right internal mammary artery (FRIMA) predominantly as the graft of choice to the best non-LAD target. The 5-year results of the Radial Artery Patency Study (RAPS) confirm a functional benefit of the RA in comparison to the SVG. Recently, Cao and colleagues compared angiographic outcomes in 859 RA and 849 SVG from 5 RCTs at one- and four-years. At one-year there was no significant difference in the occlusion rate between the RA and SVG (9.1% versus 12.7%, OR 0.71) but a far higher incidence of “string sign” in the RA grafts (7.4% versus 1.0%, OR 7.97). At 4 years RA occlusion was reduced significantly (2.7% versus 14.7%, OR 0.17) with no significant difference in string sign (2.7% versus 0%, OR 3.55). In a propensity score-matched analysis, Rutt- mann compared two strategies of revascularization: BIMA-SVG and LIMA-RA-SVG. The incidence of perioperative major adverse cardiac and cerebrovascular events was significantly lower in the RIMA compared to the RA groups (1.4% versus 7.6%, P < 0.001). They concluded that this study provided strong evidence for the superiority of a RIMA graft in comparison to a RA graft as a second conduit in multiple arterial revascularization.

It is now very well established that the severity of stenosis in the native coronary artery is critical to both the short- and long-term patency of the RA, because of the potentially negative effects of competitive flow when the stenosis is below 70-80%. Furthermore, it needs to be recognized that visual estimates of the severity of coronary stenoses are frequently very inaccurate when compared to more objective measurements such as fractional flow reserve.

In summary, higher mid- and long-term patency rates of the RA in comparison to SVG support the hypothesis that a wider use of RA grafts could be translated into substantial improvements in clinical outcomes.

**Gastroepiploic artery**

The right gastroepiploic artery (GEA) was used for indirect myocardial revascularization (Vineberg’s procedure) for the posterior or inferior wall of the heart in the late 1960s by Bailey, et al. The GEA graft already has a 27-year history in CABG, and its clinical results are excellent, without an increase in perioperative risk.

Two large studies of approximately 1,000 gastroepiploic artery (GEA) conduits have indicated 5-year patencies of 62% and 86%. The GEA patency was similar to that of the SVG. More recently, Suzuki reported that skeletonized GEA grafts have a far higher 5-year patency as compared to that of SVGs. From a sizeable number of experiences, it is well recognized that the use of this artery does not increase surgical risk, and no gastric ischemia or abdominal complications occur with takedown of the GEA. This artery seems to show less significant arteriosclerosis and demonstrates physiological adaptability as seen in the IMA. From the experience of Suma with over 1,500 GEA grafts, the operative mortality was 1.26%, and 5-, 10-, and 15-year survival rates were 91.7%, 81.4%, and 71.3% respectively, while the cardiac death-free survival rates were 95.8%, 91.7%, and 88.6%, respectively. The cumulative patency rate of the GEA graft was 98.5% at 1 month, 93.7% at 1 year, 86.2% at 5 years, and 70.2% at 10 years. The GEA graft is a safe and effective arterial conduit for CABG.

**Special patient situations**

**Patients comorbidities:** Patients with diabetes mellitus are at an increased risk of sternal complications from the use of extensive arterial grafting, particularly from BIMA grafting. In this subset of patients the risk of sternal complications has increased from less than 1% to about 3%. An alternative technique is using skeletonization of the graft pedicle to reduce trauma to the chest wall, to preserve the intercostal blood supply to the sternum, and minimize sternal infections. In addition, the combination of single ITA grafts with one or both RA conduits may also reduce chest wall complications.

In patients with known preoperative renal dysfunction, emerging evidence suggests that BIMA/TAR can be performed with low perioperative mortality and morbidity (similar to LIMA/SVG), and may have further prognostic advantages in these patients.

**Elderly patients:** Total arterial grafting is technically applicable in many very elderly patients. However, with an ageing and increasingly complex cohort of patients undergoing CABG, it needs to be proven if there are significant advantages to complete arterial revascularization in older patients. While it is clear that the use of at least one IMA graft improves survival even in octogenarians, the advantages of BIMA grafting appear to reduce with advancing age. For these reasons some groups suggest that there is no benefit to using a BIMA strategy in patients over 70 years of age. Compared with SV harvesting, a single IMA graft to the LAD, combined with RA conduits, is a safer alternative with a higher degree of patient satisfaction in the elderly. Longer follow-up and increased experience and reporting will dictate the use of these techniques in the elderly group of patients.

**Off-pump arterial CABG:** Total arterial, off-pump bypass grafting is being advocated by many groups as the optimal operative strategy for coronary revascularization. A recent meta-analysis has suggested that aortic OPCAB is associated with a reduction in neurological events due to avoidance of aortic manipulation. This low incidence of postoperative neurologic morbidity associated with the long-term survival advantage reported with TAR makes it an attractive alternative to conventional on-pump surgery. However, in consideration of the well known concerns regarding reduced patency rates with OPCAB surgery, this technique has not gained widespread acceptance. Many surgeons limit its use to patients with heavily calcified aortas in whom the risk of stroke with clamping is prohibitive.

**Contraindications to BIMA/TAR:** There are probably no absolute contraindications to BIMA harvesting or total arterial revascularization. However, it is preferable to avoid BIMA harvesting in grossly obese (BMI > 40) patients, insulin dependent patients, diabetics, or those with severe COPD. In obese patients the best approach could be probably achieved with LIMA and RA. Patients with severe COPD are at great risk of coughing, and sternal dehiscence, regardless of the ster-
Conclusions: Total arterial revascularization is achievable in most patients with three-vessel CAD with excellent clinical and angiographic results. The major deterrent in this group of patients is the risk of sternal complications. This is found in patients with diabetes, obesity, and pulmonary complications. With careful selection by avoiding these high-risk patients, complete arterial revascularization is readily achievable using skeletonized ITAs and yields good long-term results, even in high-risk patients.

References