Bilateral internal mammary artery grafting: are BIMA better?

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Heart 2002;88:7-9

Current evidence supports a policy of increasing use of arterial grafts during CABG, in particular bilateral internal mammary arteries

The clinical and prognostic benefits of coronary artery bypass grafting (CABG) are well accepted for certain subgroups of patients with ischaemic heart disease,¹ and as many as one million patients undergo this operation annually on a worldwide basis. Most CABG patients require grafting of the three main native coronary arteries; for the last 15 years the "standard" operation has achieved this using a single internal mammary artery (SIMA) and supplemental vein grafts performed with cardiopulmonary bypass. Although this procedure achieves excellent short and medium term outcome, and over 70% of patients are alive 12 years after surgery,² the long term results are limited by progressive vein graft failure.³ Off pump coronary artery bypass (OPCAB) surgery and the increasing use of arterial conduits are now changing the nature of the standard CABG. This article reviews evidence for the routine use of bilateral internal mammary artery (BIMA) grafts in CABG patients.

EVIDENCE FOR SINGLE INTERNAL MAMMARY ARTERY GRAFTS

Large observational studies,^{4,5} rather than randomised trials, have established the internal mammary artery (IMA) as the "gold standard" graft in CABG. These studies have shown that the use of an IMA graft to the left anterior descending (LAD) coronary artery improves survival and reduces the incidence of late myocardial infarction, recurrent angina, and the need for further cardiac interventions.^{1,4,5} The evidence is so persuasive that in the UK over 90% of CABG patients now receive a SIMA graft.⁶

EVIDENCE FOR BILATERAL INTERNAL MAMMARY ARTERY GRAFT

There have been no randomised trials comparing SIMA and BIMA grafts. Nevertheless, the possibility that BIMA grafts may offer additional clinical and survival benefits to that observed with a SIMA graft has been addressed in several observational studies over the last decade (reviewed in Taggart and colleagues⁷). Lack of randomisation, along with small patient numbers and short duration and/or completeness of follow up in some of these studies, have precluded drawing any clear message about possible benefits of BIMA grafting. Furthermore, as BIMA

grafts were mainly reserved for younger and lower risk patients, any survival benefit observed in BIMA patients was, naturally, attributed to these more favourable patient characteristics rather than the use of BIMA conduits.

Three recent studies tilt the balance in favour of BIMA grafts. In one large observational study the Cleveland Clinic compared survival in over 8000 patients with a SIMA and 2000 patients with BIMA grafts.² To compensate for absence of randomisation several sophisticated statistical strategies, including propensity scores (to minimise confounding), multivariable risk factor analysis (to minimise heterogeneity), and bootstrap resampling (to minimise exaggeration of benefit) were used for risk adjustment in the two groups. Significant survival advantages occurred in BIMA patients irrespective of age, ventricular function, and diabetes. Furthermore, the benefits of BIMA grafts increased with duration of follow up and with particular reference to the need for redo surgery, being approximately 40% in SIMA and 8% in BIMA propensity matched patients at 12 years (hazard ratio (HR) 0.27, 95% confidence interval (CI) 0.19 to 0.37).

In possibly the most powerful study to date comparing SIMA and BIMA grafts we performed a meta-analysis of the best studies in the literature.⁷ Prespecified criteria for inclusion dictated that studies should consist of a minimum of 100 patients in each group followed for at least four years, and contain information on patient age, sex, ventricular function, and diabetes. In the resulting comparison of almost 16 000 patients, comprising 11 269 SIMA and 4693 BIMA patients followed for up to a mean of 10 years, we found a significant survival benefit in patients with BIMA grafts (hazard ratio for death 0.81, 95% CI 0.70 to 0.94). We stressed, however, that these results should be interpreted cautiously. Statistical compensation for differing clinical baseline characteristics is a weak substitute for randomisation and the inherent limitations of systematic reviews are compounded when the data are from non-randomised trials, as is the possibility of confounding by indication (that is, bias due to unmeasured variables). Notwithstanding these reservations, it is also possible that our systematic review underestimated the benefits of BIMA grafts as the second

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Abbreviations: BIMA, bilateral internal mammary artery; CABG, coronary artery bypass graft; IMA, internal mammary artery; LAD, left anterior descending; OPCAB, off pump coronary artery bypass; SIMA, single internal mammary artery

IMA graft was frequently used in situations now known to compromise long term patency. Placing both IMA grafts to the left side of the heart maximises their benefits, while use as free grafts from the aorta or placement to the right coronary artery compromises long term patency.⁸⁻¹⁰

Most recently Endo and colleagues reported clinical outcome in 688 SIMA and 443 BIMA patients in a retrospective study.¹¹ The baseline characteristics of the groups were similar with respect to age and ventricular function, although the SIMA group contained a higher proportion of females (19% *v* 10%) while the BIMA group contained a higher proportion of treated diabetic patients (18% *v* 13%). At a relatively short period of follow up (median of 6.1 years) the combined incidence of death, repeat myocardial infarction, and need for redo CABG was lower in the BIMA group (*p* = 0.06). In the 782 patients with an age below 71 years and an ejection fraction greater than 0.4 the hazard ratio for this combined incidence of adverse outcomes was significantly reduced in the BIMA group (HR 0.61, 95% CI 0.38 to 0.98, *p* = 0.04). The authors speculated that as vein graft failure does not become commonplace until seven years after CABG the benefits of BIMA grafts are likely to increase with longer duration of follow up.

One recent study has, however, reported no additional benefit of BIMA grafts in women.¹² No difference in long term (mean of 10 years) or event-free survival was observed in 261 women with BIMA grafts and a computer matched cohort of 261 women with a SIMA graft. The study should be interpreted cautiously as only around 120 patients in each group were available for comparison at 10 years and, despite computer matching, the BIMA group had a significantly higher proportion of patients with triple vessel disease (81% *v* 66%, *p* < 0.001)

ANGIOGRAPHIC PATENCY OF BIMA GRAFTS

The survival benefit of the IMA graft is almost certainly due to its inherent resistance to the development of atherosclerosis in contrast to native coronary vessels and vein grafts. Barring technical errors during implantation, which result in early failure, the IMA appears to remain patent indefinitely. Ten years after CABG up to 95% of IMA grafts remain in pristine condition whereas around three quarters of vein grafts are blocked or severely diseased.¹³

Several studies have now refuted the assertion that the inferior patency rates of vein grafts, compared to IMA grafts, is caused by their use in anatomical territories with less favourable run-off than the LAD territory. The most comprehensive current angiographic data on the "natural history" of early graft failure is from Japan where it is routine practice for CABG patients to undergo repeat angiography before hospital discharge. Endo and colleagues studied early angiographic graft patency data in 96% of their 1131 CABG patients, and reported an overall patency rate of 98% for all IMA grafts to all coronary vessels, with reduced patency for gastroepiploic arteries (95%) and vein grafts (92%) at hospital discharge.¹¹ Angiographic patency rates exceeding 95% for all IMA anastomoses, regardless of the coronary vessel grafted, have also been reported at 18 months by Calafiore's group⁸ and, more importantly, at seven years by Dion and colleagues.¹⁴

RISKS OF BIMA GRAFTS

While BIMA grafting is commonly used in several of the best European,^{8 14} US,^{2 15} Australian,¹⁶ and Japanese centres¹¹ there is little evidence of UK surgeons increasing their use of BIMA grafts. In 1998 only 15% of all UK CABG patients received two or more arterial grafts.⁶ Opposition to BIMA grafting is largely based on the perception of increased perioperative risk and in particular the risk of sternal wound, and myocardial and respiratory morbidity.

Firstly, and most importantly, there is consistent evidence from several large observational studies that BIMA grafting does not increase perioperative mortality. In appropriately chosen patients, in experienced surgical hands, BIMA grafting can be performed with an operative mortality in the region of 1–2%.^{2 8 14-16}

In terms of morbidity, sternal dehiscence as a consequence of sternal devascularisation is the most worrying potential complication of BIMA grafts, particularly in diabetic patients. In reality, most studies have documented only a minimal increase in the risk of impaired wound healing, even in diabetic patients. In contrast to harvesting a SIMA graft, Ioannidis and colleagues reported that harvesting BIMA grafts increased the risk from 0.4% to 1.3%,¹⁵ and Matsa and colleagues found it increased the risk from 1.7% to 2.6%.¹⁷

Diabetic patients are those with potentially most to gain from BIMA grafts as they often have more severe, diffuse, and distal disease. Appropriate patient selection and modification of the IMA harvesting technique can significantly reduce the risk of impaired wound healing in these patients. Firstly, BIMA grafts are not contraindicated in diabetes, *per se*, unless the patient is significantly obese¹⁷ or has significant chronic lung disease.¹⁸ Secondly, harvesting the IMA with the traditional pedicled technique additionally involves harvest of surrounding parietal pleura, venae comitantes, muscle, and fascia to leave a completely denuded and devascularised strip of chest wall. Harvesting only the IMA itself ("skeletonising" technique) preserves intercostal collateral vessels and some sternal blood supply. Using photon emission computed tomography Cohen and colleagues demonstrated that the skeletonisation technique results in superior sternal blood flow preservation.¹⁹ Several groups have reported that skeletonisation of IMA grafts significantly reduces risk of wound healing in all patients^{20 21} and in diabetics in particular.^{17 18 21 22} It is our routine practice to use bilateral skeletonised IMA in all patients, including diabetics, unless they are significantly obese or likely to require prolonged ventilation.

Suggestions that the use of BIMA grafts increases the risk of myocardial and pleuro-pulmonary morbidity are unfounded. Using cardiac specific biochemical markers of myocardial injury we reported no difference in troponin T release in patients receiving SIMA or BIMA grafts.²³ Likewise we reported no difference in serial arterial oxygen tension, alveolar-arterial gradients, or percentage haemoglobin saturation in patients undergoing SIMA or BIMA grafting,²⁴ discounting concerns that the additional chest trauma caused by BIMA harvesting leads to additional respiratory impairment.

From a practical point of view BIMA grafting is technically slightly more demanding than SIMA grafting and adds to the duration of the operative procedure. In our experience harvesting of bilateral skeletonised IMA grafts adds approximately half an hour to the total surgical procedure.

COMPATIBILITY OF BIMA GRAFTS WITH OFF PUMP SURGERY AND TOTAL ARTERIAL REVASCULARISATION

In the last few years, the availability of improved stabilising devices, allied to an increased recognition of the higher risks of the adverse sequelae of cardiopulmonary bypass in a rapidly aging surgical population, have been major driving forces in the development of OPCAB surgery.

BIMA grafting and total arterial revascularisation are not only compatible with but, indeed, facilitate OPCAB surgery. Anastomosis of the radial artery to either IMA in a composite fashion allows three or four coronary arteries to be grafted not only as an OPCAB procedure but simultaneously eliminating the need for any aortic manipulation. It is manipulation of the diseased aorta which is the major risk factor for stroke after

CABG.²⁵ Cannulation (for connection to cardiopulmonary bypass), cross-clamping (for administration of cardioplegia) or side-biting (to attach vein grafts) of the aorta during conventional CABG can be eliminated with OPCAB surgery performed with composite arterial grafts.²⁵

OTHER DEVELOPMENTS WHICH MAY IMPACT ON USE OF BIMA GRAFTS

Aspirin and lipid lowering agents improve vein graft patency rates over the medium term,²⁶ but it is not known if this will significantly improve long term patency rates. In any event, it is extremely unlikely they will achieve the patency rates obtainable with IMA grafts.

Continuing advances in the pharmacological and percutaneous interventional management of coronary artery disease is likely not only to increase the overall number of patients who eventually become candidates for surgical intervention but, more importantly, to change their profile to that of an older and sicker population. This is already happening in the UK where the mean age of patients undergoing CABG has increased from 57 years in 1990 to 61 years in 1994 and 63 years in 1999.⁶

The development of OPCAB techniques now makes surgery a more feasible proposition in some patients whose advanced age would previously have precluded conventional CABG using cardiopulmonary bypass. Several series of OPCAB surgery in octogenarians have been reported with excellent results. For the reasons outlined above composite arterial grafts with a no touch aortic OPCAB technique offers major advantages in such a population who are at highest risk of stroke.

CONCLUSION

Accepting the inherent weaknesses of the currently best available data, there is a suggestion that the use of BIMA grafts improves survival and significantly reduces the need for redo surgery, without increasing perioperative mortality or morbidity.

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