The percutaneous coronary angioplasty gets better, but the surgical coronary artery bypass does not stay behind

Ruggero De Paulis *, Giulio Folino, and Raffaele Scaffa

Division of Cardiac Surgery - European Hospital, and UniCamillus University, Rome

Coronary artery bypass grafting remains one of the most frequently performed cardiac operations, with well-established prognostic benefits in patients with multivessel coronary artery disease and left main disease. Despite an increasingly higher patients’ risk profile, the results of this procedure have significantly improved over time, with an evident and striking decrease in operative mortality and peri-operative complications. A fair amount of technical and technological refinements has further improved the short- and long-term results of coronary artery bypass surgery. The improvements in the beating heart coronary surgery and aortic ‘no-touch’ technique, in the appropriate use of conduits (bilateral internal mammary artery, radial artery, and composite conduits configuration), and in the optimization of venous grafts’ patency are reviewed.

In 2024, myocardial revascularization through coronary artery bypass grafting (CABG) will celebrate its 60th anniversary. The choice of the revascularization strategy (surgical or percutaneous) is still based on the overall clinical evaluation of the individual patient and on the angiographic characteristics of the lesions. Despite the progressive widening of the indications for percutaneous angioplasty (PCI), CABG remains the treatment of choice in multivessel disease, left main disease, and patients with diabetes.

Coronary artery bypass grafting has technically improved over the past 20 years. The latest refined revascularization strategies include the use of arterial conduits and the ‘off-pump’ beating heart techniques. The most commonly adopted revascularization strategy is to bypass the lesion in the left anterior descending artery using the left mammary artery in situ and to bypass the other target vessels with a segment of saphenous vein attached to the ascending aorta. The traditional procedure involves the use of cardiopulmonary bypass (CPB), aortic clamping and cardioplegic arrest. This strategy remains to date a procedure with superior results compared with PCI for patients with complex multivessel disease.

Despite the excellent results in terms of patency for the left mammary artery graft to the left anterior descending, the use of other conduits for the completion of revascularization has been further refined in the last two decades. Since the end of 90s, the benefit of using bilateral internal mammary arteries has been demonstrated in terms of survival, reoperation, and the need for ‘repeated’ PCI. The risk of sternal complications related to the removal of both mammary arteries (especially, in obese women, in diabetic patients with poor glycemic control, in case of renal insufficiency, and chronic obstructive pulmonary disease) was partially mitigated by the ‘skeletonized’ harvesting technique. This technique preserves sternal vascularization with a consequent reduction in superficial and deep sternal complications.

In the literature, revascularization by means of multiple arterial grafts has progressively accumulated robust evidence of better long-term outcomes. Among the arterial conduits, beyond the right mammary artery,
the radial artery has had increased interest in the last years. In a recent study, the use of the radial artery proved to be superior, in terms of adverse cardiac events and patency, compared with the venous grafts at a follow-up of 5 years.6

The progressive dysfunction of the venous conduits remains, in fact, one of the major limitations to the long-term results of CABG. Intra-operative damage during venous graft harvesting is a major cause of dysfunction; the pathological remodelling of the vein begins immediately after its implantation and after exposure to ‘arterial’ pressures. In this sense, the preparation of the saphenous vein adopting the ‘no-touch’ technique allows greater long-term patency compared with the conventional harvesting technique.7 This technique preserves the tissues surrounding the vein and guarantees better preservation of the endothelial integrity of the conduit.

Another improvement for the long-term vein graft patency is in the field of intra-operative preservation solutions. To further preserve the endothelial integrity, specific ‘buffered’ preparations have been optimized. Compared with the traditional preservation in saline solution, these new solutions prevent neo-intimal hyperplasia with consequent reduced risk of accelerated thrombosis and atherosclerosis.8

Finally, the exposure of the vein to haemodynamic conditions of ‘high flow’ could contribute to the dysfunction of the graft due to its dilation and consequent thickening of the wall because of intimal hyperplasia. In this regard, in recent years, the use of external stents capable of supporting the venous graft could prevent dilation with two mechanisms: by improving the uniformity of the calibre of the conduit and by reducing the vessel wall tension. Despite the promising results in pre-clinical and clinical studies, further large-scale and longer follow-up studies are still needed.9

Recently, CABG, like the most advanced endovascular procedures, can be routinely assessed intra-operatively in qualitative and quantitative terms using the transit-time flow technique.10 The possibility of verifying the good function of the graft immediately after its implementation has certainly reduced the incidence of technical errors and improved the overall results.

The post-operative cerebral stroke rate of coronary artery bypass surgery compared with PCI remains the Achilles heel of the procedure. The major cause of peri-operative neurological complications is embolic, and it is related to the ‘intrinsic’ manoeuvres of traditional surgery (i.e. CPB and cardioplegic arrest), such as aortic manipulation associated with cannulation, aortic cross clamping, and proximal anastomosis of the graft, rather than the patient’s clinical characteristics. Any strategy aimed at reducing or avoiding aortic manipulation has demonstrated a protective effect on neurological events.11

To reduce the surgical trauma and in particular, the trauma related to the institution of the CPB, in the mid-90s there was a renewed interest in the ‘beating heart’ CABG, already practised sporadically before the introduction of the CPB. However, after the initial enthusiasm, in the following years, this technique had a relatively limited diffusion. Actually, ‘off-pump’ CABG is technically more demanding and requires specific training programs and its outcomes in terms of long-term graft patency are equivalent to the ‘on-pump’ coronary surgery. However, within the years, ‘off-pump’ beating heart surgery demonstrated a benefit in terms of peri-procedural stroke rate compared with the traditional ‘on-pump’ surgery. Therefore, the beating heart strategy has recently been refined, evolving towards a strategy for a total safeguard of aortic manipulation (‘anaortic’ strategy). ‘Anaortic’ surgery is based on ‘composite’ revascularization grafts that involve the use of bilateral internal mammary artery, mammary/radial or mammary/vein conduits. Composite grafts are based on the concept that the source of flow derives from one of the mammary arteries and not from the aorta,12 avoiding tangential aortic clamping for the proximal anastomosis. In fact, by using a beating heart approach coupled with techniques that avoid any clamping or touching of the aorta, a 0% stroke rate is virtually guaranteed.

**Conclusions**

In the last two decades, surgical coronary artery bypass has evolved and improved simultaneously to percutaneous coronary angioplasty. Currently, the most advanced and effective surgical myocardial revascularization strategy is, therefore, represented by a beating heart procedure, without the use of extra-corporeal circulation and a composite graft configuration that completely avoids any aortic manipulation.

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