Review Article

Coronary Artery Revascularisation : Past, Present and Future

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Abstract

The high prevalence of coronary artery disease has inspired the development of technologies and techniques for coronary revascularisation, including coronary artery bypass grafting (CABG) and percutaneous coronary interventions (PCI). PCI have witnessed the impact of innovation with newer hardware and drug eluting stents (DES). DES have indisputably reduced restenosis, however there is an emerging concern over the risk of late stent thrombosis associated with their use. We discuss the limitations of the current generation DES and review advances in the stent technology. The technology used in CABG has improved, resulting in off-pump coronary artery bypass (OPCAB), endoscopic, video-assisted, and robot-assisted CABG with automated one-shot distal anastomotic devices being used increasingly. The difference in adverse outcomes between CABG and PCI continues to decline and the future may witness a close collaboration between the two.

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Introduction

Coronary artery bypass surgery (CABG) and percutaneous coronary intervention (PCI) are based on the principle that the myocardial ischemia related to the coronary artery obstructions can be corrected resulting in relief of the underlying ischemia. The recent technological advances have been so fast paced that there has not been ample time to fully assess each new facet of technology and pharmaceutics before another arrives. The progress in PCI from balloon angioplasty to drug eluting stents has seen a progressive decline in restenosis and reintervention but relief of symptoms has not at par with CABG. In this review we highlight the developments in the field of coronary artery revascularization and the future modalities.

History of PCI and CABG

Coronary revascularisation is built on three centuries of research. Stephen Hales performed the first cardiac catheterization in 1711.The modern techniques have evolved from the works of Drs. Werner Forssmann, Andre Cournard and Dickinson Richards. Dr. Mason Sones discovered selective coronary angiography accidentally in 1958. Dr. Grüntzig performed the first percutaneous transluminal coronary balloon angioplasty (PTCA) in 1977, initiating the modern era of PCI [1]. In 1986 Jacques Puel and Ulrich Sigwart inserted the first stent into a human coronary artery [2].

CABG is the most common surgical procedure performed on the heart. In 1910, Alexis Carrel described the principles of CABG for which he was awarded the Nobel Prize in Medicine in 1912 [3]. In 1953, Dr. John Gibbon performed the first heart-lung bypass and in 1968 Dr. Rene Favaloro first used a saphenous vein graft for coronary artery disease [4].The internal mammary artery was used for the first time in 1951 when Vineberg reported an experimental technique to revascularize the cardiac muscle using the internal mammary artery (IMA) directly implanted in the myocardium[5]. The first CABG in humans using IMA was done by Longmire in 1958[6].

Coronary Artery Bypass Graft

The advent of the cardio-pulmonary bypass (CPB) machine permitted cardiac surgeons to perform complex operations on the defective heart. With the refinement of perfusion science, the impact of the pump run on the postoperative recovery of a patient has been lessened considerably since the pioneering days. The drive to reduce the well documented, if somewhat historical, adverse effects of CPB has resulted in attempts to perform coronary artery grafting off-bypass (OPCAB). Kolessov reported the first experience with coronary artery surgery on the beating heart in 1967, but the technique was soon abandoned [7]. However OPCAB experienced a revival beginning in the early 1990s with the work of Benetti [8]. The benefits of OPCAB in terms of less neurocognitive dysfunction and reduced

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incidence of multi-organ failure are controversial. More grafts are usually placed with ONCAB than the OPCAB technique, and some data suggests that OPCAB graft patency may be compromised and that revascularisation in some cases incomplete [9]. At present, the benefits of ONCAB and OPCAB revascularisation remain debatable and the outcome differential is likely to be trivial.

The Evolution of Grafts used in CABG

All surgically constructed grafts not only treat the target lesion but also protect against the subsequent development of new lesions in the portions of the target vessel proximal to the anastomosis for the entire life of the graft. No similar claim can be made of any currently available PCI. Saphenous vein grafts (SVGs) remain the most frequently used conduits in CABG. Historically, during the first year after bypass surgery, 10–15% of vein grafts fail and by 10 years 40–50% close, and of those remaining patent, half have significant obstructive disease [10]. For reasons that are unclear, the LIMA graft is surprisingly immune to atherosclerosis. If a LIMA-to-LAD graft is successfully constructed, there is a 95% chance the graft will be patent and functioning after 15 years or more. Moreover, a patent LIMA-to-LAD graft is associated with a significant survival advantage. The general superiority of the IMA as a bypass conduit is probably due to inherent vascular biological properties of the conduit itself and to the quality of the anterior coronary artery flow and resistances (LIMA anastomosed to the circumflex or right coronary artery provides worse results) [11]. As a consequence, the LIMA to the left anterior descending coronary artery anastomosis is considered the standard of care in coronary surgery.

The right internal mammary artery (RIMA) has superior long term patency as compared to the veinous grafts. It is used either as a pedicled in-situ graft or as a composite Y graft anastomosed to the LIMA. The radial artery, which is less demanding to dissect than the RIMA is a popular arterial graft for CABG. So far, early and intermediate-term results indicated a superiority of the radial artery against the saphenous vein in term of graft patency (radial artery patency is between 90 and 95% after one or two years) but, unfortunately, long term results are not known [12]. The GEA (Gastroepiploic artery) has been used as an in-situ graft to revascularise the lower part of the heart and long-term clinical results have been similar to those of SVG (68% patency at 10 years) [11]. Its use has generally been discontinued. Furthermore an arterial conduit to the right coronary artery does not have better long term patency than an SVG, therefore SVG remains the conduit of choice to the right side.

Coronary Artery Stenting

Percutaneous coronary intervention (angioplasty) using stents is a common procedure in which two basic stent types are used: bare-metal stents (BMS) and drug-eluting stents (DES). Introduced to prevent abrupt closure, BMS were initially used exclusively for failed balloon angioplasty cases. BMS went through an initial phase of slow acceptance by physicians on account of stent thrombosis, the occurrence of which was overcome by the combined strategy of high pressure deployments and dual anti-platelet regimens. The pendulum then swung to the other extreme. Within a couple of years in the early 90's, stenting became the default procedure heralding the era of *'stent-o-mania'*.

DES were introduced in 2001 [13]. Until recently, two types of drug-eluting stents have been available: sirolimus- or paclitaxel-eluting stents. Both these drugs have a potent anti-proliferative action and are embedded in a non-reabsorbable polymer matrix completely covering the stent struts, thus allowing slow release of the drug in high concentrations to the local surrounding tissue. The net result is the inhibition of the neointimal hyperplastic response to vessel injury, which is the predominant cause of restenosis with the use of BMS. The Achilles Heel of stenting i.e restenosis seemed to be conquered with the unbelievable initial results of DES.

DES - The Myth of Sisyphus-Subacute Stent Thrombosis

After the initial widespread use of DES the potential downside in the use of DES-stent thrombosis emerged. Stent thrombosis is a serious complication that causes major myocardial infarction in more than 70% of cases and carries a mortality rate of 31-45% [14]. The drugs in the DES markedly inhibit or delay endothelialisation of the stent struts, thus making the stent more susceptible to thrombosis, particularly if dual antiplatelet therapy with aspirin and clopidogrel is interrupted after implantation.

A furore was generated when media highlighted that the incidence of late stent thrombosis (i.e more than 30 days post-implantation) was higher with DES as compared to BMS much to the dismay of the patients and the implanting cardiologists. Pooled analysis of the initial randomized studies comparing DES with BMS showed a substantial (three- to four fold) reduction in restenosis at 12 months with DES sans any apparent increased risk of stent thrombosis with DES [15]. However, four year follow-up data recently released now indicates a higher rate of stent thrombosis with DES as compared with BMS (1.3% v 0.8% for the paclitaxel-eluting stent, and 1.2% v 0.6% for the sirolimus-eluting stent) [16] . To allay considerable