

Coronary artery surgery: now and in the next decade

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ABSTRACT

In coronary artery surgery the superiority of the internal mammary artery graft in 10-year survival was documented in 1986. In 1999 it was demonstrated that death, reoperation and percutaneous transluminal coronary angioplasty were more frequent in patients undergoing single rather than bilateral internal mammary artery grafting. Today coronary artery bypass grafting surgery is challenged by the success story of modern interventional cardiology. The Syntax Study, however, clearly underlined the better outcome for patients with triple-vessel and/or left main disease undergoing coronary artery bypass grafting in terms of repeat revascularization. Another point of ongoing discussion is the comparison between on-pump and off-pump coronary artery revascularization techniques. Even if mixed results exist in the literature, in experienced hands the combination of aortic no-touch and total arterial revascularization, probably leads to the superiority in off pump coronary artery bypass grafting in terms of significantly decreased rates of mortality, stroke, major adverse cardiac and cerebral vascular events. Coronary artery surgery in the next decade will be influenced by the further progression of minimally invasive surgical principles and by a variety of other factors. The role of robotics and hybrid surgery has yet to be defined. Alternatives within surgery will not only need to move to a less disruptive strategy (e.g. from on-pump to off-pump bypass) but also have to secure sustained innovation, as we can be sure that the current coronary artery bypass grafting activity will change substantially.

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NOW

Arterial revascularization

Coronary artery surgery has been the cornerstone of treatment of coronary artery disease since the introduction of aortocoronary bypass as a routine clinical procedure by Favaloro in Cleveland in 1968 (1).

In 1986 Loop and colleagues documented the superiority of the internal mammary artery graft for 10-year survival and other cardiac events.

They had compared 2306 patients who received an internal mammary artery graft to the anterior descending coronary artery alone or combined with one or more saphenous vein grafts, with 3625 patients who had only saphenous vein grafts.

They found that patients who had only vein grafts had a 1.61 times greater risk of death over a 10-year period, as compared with those who received an internal mam-

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mary artery graft. Other disadvantages for the isolated vein grafting were an increased risk of late myocardial infarction (1.41 times), risk of hospitalisation (1.25 times), risk of cardiac reoperation (2.0 times) and risk of late cardiac events (1.27 times). This technique is nowadays a routine in modern coronary artery bypass grafting (2).

In 1999 Lytle, again from the Cleveland Clinic, published a retrospective, non-randomized study with a mean follow-up interval of 10 postoperative years including patients who received either single (8123 patients) or bilateral internal thoracic artery (ITA) grafts (2001 patients) with or without additional vein grafts. Death, reoperation and percutaneous transluminal coronary angioplasty were more frequent in patients undergoing single rather than bilateral ITA grafting. The differences were greatest in regard to reoperation (decrease of risk of reoperation by 12 years at least 8.3%) (3) (Figure 1). Although this finding sent a clear message throughout the world of coronary artery surgeons, this technique has yet not found predominant use.

Coronary artery surgery - Syntax study

Today, coronary artery bypass surgery is challenged by the success story of modern interventional cardiology. The discussion of which patient goes to what treatment modality has been clarified by the recent Syntax study. The Syntax study compares outcomes of coronary artery bypass grafting with percutaneous coronary intervention in patients with triple vessel and/or left main disease. Complexity of coronary artery disease was quantified by the Syntax score, which combines the anatomic characteristics of each significant lesion. The study aimed to clarify whether Syntax score affects the results of bypass grafting. Outcome was defined by major adverse cerebrovascular and cardiac events and its consequences over a period that is now over 4 years (4) (Table 1).

The surgical advantages were relevant in terms of repeat revascularisation, but also underlined a significant surgical benefit concerning myocardial infarction and survival rates. In patients associated with greater complexity of coronary pathology,

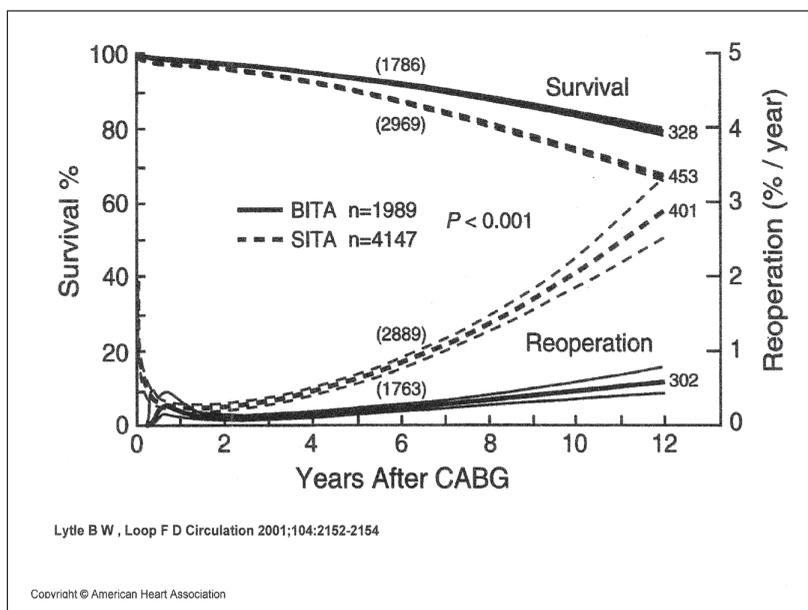


Figure 1 - Superiority of bilateral internal thoracic artery grafting. CABG = coronary artery bypass, BITA = bilateral internal thoracic artery; SITA = single internal thoracic artery.

Table 1 - Syntax Results after 4 years (Serruys P, EACTS Meeting 2011 Lisbon).

Endpoint	Cardiac Revasc.	PCI/Stent	p-value
MACCE (death, stroke, myocardial infarction, revascularisation)	23,6 %	33,5 %	< 0,001
Death/Stroke/Myocardial infarction	14,6 %	18,0 %	0,07
Total mortality	8,8 %	11,7 %	0,048
Cardiac mortality	4,3 %	7,6 %	0,004
Stroke	3,7 %	2,3 %	0,06
Myocardial infarction	3,8 %	8,3 %	< 0,001
Stroke	3,7 %	2,3 %	0,06

MACCE = major adverse cerebrovascular and cardiac events; PCI/Stent = percutaneous coronary intervention

percutaneous coronary intervention demonstrated substantial disadvantages (5). The Syntax study also recommended that incomplete revascularisation is associated with adverse events during follow-up after percutaneous coronary intervention but not following coronary artery bypass grafting. Another message of the Syntax study is the recommendation of a heart team in which the interventional cardiology and the surgeon work closely together to provide adequate therapy for coronary artery patients. The Syntax study should have a substantial impact on the treatment of coronary artery disease. Its consequences are already found in the new European Society for Cardiology/European Association for Cardiothoracic Surgery guidelines for myocardial revascularization (6).

On-pump vs off-pump

Another point of ongoing discussion is whether on-pump or off-pump coronary artery revascularization is superior for the coronary artery disease patient. A recent study that analyzed 4752 patients from 79 centers in 19 countries randomly assigned patients in whom coronary artery bypass (CABG) was planned, to undergo off-pump or on-pump CABG. The first co-primary outcome was a composite of death,

non-fatal stroke and non-fatal myocardial infarction. The results demonstrated that there was no significant difference between the two procedures with respect to the 30-day rate of death, myocardial infarction, stroke or renal failure requiring dialysis. The use of off-pump CABG, however, led to reduced rates of transfusion, reoperation for perioperative bleeding, respiratory complications and acute kidney injury, but also revealed an increased risk of early revascularization (7).

Others reported that the quality of the off-pump surgery, including the combination of aortic no-touch and total arterial revascularization with complete revascularization, leads to the fact that off-pump coronary artery bypass (OPCAB) patients benefit from significantly decreased rates of mortality, stroke, major adverse cardiac and cerebral vascular events (MACCE). In particular, the no-touch technique leads to a significantly lower rate of stroke and should therefore be the procedure of choice in patients with atherosclerotic ascending aortic disease (8).

These findings were underlined by a recent multicenter, randomized, parallel trial which had enrolled patients for elective or urgent isolated coronary artery bypass grafting with an additive European System for

Cardiac Operative Risk Evaluation of 6 or more. The composite primary end-point included operative mortality, myocardial infarction, stroke, renal failure, reoperation for bleeding and adult respiratory distress syndrome within 30 days after surgery.

A total of 195 patients could be treated on-pump and 216 off-pump. According to the intention to treat analysis, the rate of the composite primary end-point was significantly lower (unadjusted $P = .009$, adjusted $P = .010$) in the off-pump group (5.8% vs 13.3%). The risk of experiencing the primary end-point was significantly greater for the on-pump group. The authors concluded that off-pump coronary artery bypass grafting reduces early mortality and morbidity in high-risk patients (9).

Neurological complications

One of the most devastating complications of coronary artery surgery is definitely a postoperative adverse neurological outcome, as stroke or cognitive decline. Recent large, prospective, randomized studies analyzing the rate of negative neurologic outcome after conventional on-pump surgery and after off-pump surgery were not able to show a significant risk reduction following off-pump surgery, as it had been presumed. As a consequence, investigations aiming to reduce the incidence of adverse neurological outcome following bypass surgery have shed light on the role of patient-related factors, such as the degree of atherosclerosis of the aorta or pre-existing cerebrovascular and systemic vascular disease and adequate preoperative screening and preparation, instead of focusing on the impact of surgery-related factors.

In a paper addressing the cognitive and neurological outcome after coronary artery bypass surgery the authors concluded that the risk for both points should not be influencing the choice of surgical therapy for coronary artery bypass grafting. Rather,

strategies should focus on the preoperative assessment of specific risk factors and on an individualized surgical approach, especially in high-risk patients.

Undiagnosed cognitive impairment is not rare in coronary artery disease patients and is evaluated as a surrogate marker for underlying cerebrovascular disease. Its long time effect should be addressed predominantly by reducing modifiable risk factors for cerebrovascular disease, since it is well known that late cognitive decline is more related to the progression of systemic vascular disease rather than being a late consequence of extracorporeal circulation (10).

Our own experience

In experienced groups with over 95% off-pump procedures a mortality rate below 1% in elective patients can be achieved. Our own therapy regimen is given in *Table 2*. By strictly adhering to the principle of the aortic no-touch technique, we were able to eliminate neurological deficits due to embolism from the aorta directly related to the surgical procedure and could document a 30 day mortality for our group of 0.6% in 2011.

Contributing was the principle of complete arterial revascularization, whenever possible. Some surgeons at our institution could reach, or are already close to, zero mortality. We also employed successfully the principle of OPCAB in reoperative coronary artery surgery, which could be used in the majority of our redo patients, excluding those who had strong adhesions from prior pericarditis.

Hybrid procedures

Hybrid coronary revascularization is combining minimally invasive coronary artery surgery and percutaneous coronary intervention, thus allowing sternal preservation for the treatment of patients with

Table 2 - Current decision making in our institution in coronary artery surgery.

	Decision making factors	Applied technique	Short description
1.	Procedure of first choice	Clamp-less OPCAB with double IMAs as T-graft or in situ configuration	OPCAB & No-touch-technique & TAR
2.	Octogenarians, insulin dependent diabetes, severe COPD, short RIMA	Clamp-less OPCAB with LIMA and radial artery/vein as T-graft	OPCAB & No-touch-technique
3.	Short or small RIMA	Tangential clamping of the aorta for proximal vein anastomoses	OPCAB
4.	Conversions due to hemodynamic instability, ischemia, intraseptal LAD	On-pump CABG, Single Clamp	OPCAB conversion
5.	Unstable hemodynamics, EF < 25	On-pump CABG with LIMA & vein graft or TAR	CABG (poss.: TAR)

OPCAB = Off-pump coronary artery bypass; IMA = internal mammary artery; COPD = chronic obstructive pulmonary disease; RIMA = right internal mammary artery; LIMA = left internal mammary artery; LAD = left anterior descending; CABG = coronary artery bypass; TAR = total arterial revascularization; EF = ejection fraction.

multi-vessel coronary artery disease. Revascularization of the left anterior descending coronary artery can be achieved by a robotically assisted endoscopic approach or conventional minimally invasive direct coronary artery bypass (MIDCAB) surgery. Early experience demonstrates the safety of the procedure, with perioperative clinical results comparable to those of conventional coronary artery revascularization.

Bonatti demonstrated the feasibility of a quadruple coronary artery bypass using a totally endoscopic technique (11).

Gender disparity

Female gender is still a risk factor for early mortality following coronary artery surgery. A recent study by Lehmkuhl analyzed 1559 consecutive patients treated between 2005 and 2008. As a result, self-assessed physical functioning should be more seriously considered in preoperative risk assessment, particularly in women.

Key mediators of the overmortality of women after CABG were age, physical function and postoperative complications (12).

Current trend

Coronary artery surgery has been a subject to constant change. To characterize trends in patients' characteristics and outcomes after CABG over the past decade ElBardissi et al. assessed 1,497,254 patients who had had a CABG procedure at STS participating institutions.

They concluded that from 2000 to 2009 the risk profile of patients undergoing CABG had changed, with fewer smokers, more patients with diabetes and better medical therapy characterizing patients referred for surgical coronary revascularization. The left internal artery had been nearly universally used and outcomes had improved substantially, combined with a significant decline in postoperative mortality and morbidity (13).

IN THE NEXT DECADE

Surgical perspective

Coronary artery surgery in the next decade will be influenced by the further progression of minimally invasive surgical principles. The role of robotics has yet to

be defined. In hybrid coronary artery revascularization, the advantage of closed chest revascularization has to be weighed against the risk of repeat revascularizations due to percutaneous coronary intervention in the right and circumflex artery.

Time will show how the evolution of the surgical techniques of CABG will develop. One of the challenges of the future will be to bring this progress in surgical technology to broad-scale application at a time when third world countries are lacking coronary artery surgery altogether or to a large degree. New treatment modalities for coronary artery disease will affect the incidence of surgical procedures as well as the decreased incidence of reoperations in patients in whom modern surgical principles, as complete arterial revascularization, have been used.

Possible influence of drug therapy

In this regard it remains to be seen what the consequences of modern drug therapy concerning coronary artery surgery will be: so far it is of relevance to know that, for example, statins clearly improve the outcomes of CABG patients.

All patients undergoing CABG are candidates for life-long statin therapy and its initiation is recommended as soon as coronary disease is documented (in the absence of contraindications).

Statins should be restarted early after surgery. However, the optimal postoperative lipid-lowering regimen remains unknown and is still the subject of upcoming trials. Therefore, statin prescription rates and patient adherence are examples of priorities for future research (14).

Drivers of change

In addition to these, coronary artery surgery will be influenced substantially by a variety of factors. Drivers of change will be: the industry, the patient, the health service, the health service purchaser, the craft

of coronary surgery itself, the resident, the surgeon, the media and the cardiologist, as pointed out by Sergeant in 2004 (15).

Christensen and Raynor underlined that we have to keep in mind that disruptive strategies create a 37% chance of survival versus only 6% for incremental strategies (16). So alternatives within surgery will not only need to move to a disruptive strategy (e.g. from on-pump to off-pump bypass) but also have to secure sustained innovation, since we can be sure that the current CABG activity will change substantially in the coming years. New strategies, numbers, facts and figures are undoubtedly important but what matters most, not only in coronary artery surgery in the next decade, will be the basic existence of so-called soft factors as morality, intelligence, excellence, integrity, compassion and surgical judgment.

Definitely, coronary artery surgery will have its own role during the next decade and further into the future.

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