Treatment of coronary heart disease with minimally invasive surgery

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In 1998, most cardiac surgical practices used cardiopulmonary bypass (CPB) and cardioplegic arrest as techniques to perform coronary artery bypass grafting (CABG) (1). More than 25% of patients undergoing CABG have ≥ 1 complications (e.g., atrial fibrillation, bleeding, myocardial infarction, sternal infection, stroke, or renal failure). Although some of the morbidity of CABG is directly related to patient comorbidity factors, some of these complications are due to the current technique of CABG.

The goal of minimally invasive CABG is to avoid the morbid complications of standard CPB-supported CABG. The 2 most common techniques of minimally invasive CABG are minimally invasive direct coronary artery bypass (MIDCAB) and off-pump coronary artery bypass (OPCAB). For example, the median sternotomy incision is avoided in techniques that gain access to the heart via a left anterior thoracotomy (MIDCAB, Port-Access). CPB is avoided in techniques that perform coronary bypasses on a beating heart (OPCAB). In MIDCAB, both the sternotomy and CPB are avoided.

One of the very first attempts at using the left internal thoracic artery (LITA) to revascularize the left anterior descending coronary artery (LAD) was done in a minimally invasive fashion, avoiding CPB. Professor Vasili I. Kolessov, in his pioneering 1967 work in LITA-to-LAD anastomosis, reported on an experimental study of 14 dogs with autopsy confirmation of patency at an intermediate-term (19 months) follow-up (2). In addition, he reported on 6 human patients. The surgery was conducted through a left anterior thoracotomy in the fifth intercostal space with LITA harvesting. Ischemic preconditioning for 6 to 8 minutes was afforded by coronary occlusion of the LAD using a snare. Anastomosis on a beating heart was performed with an interrupted silk suture technique, with or without a Vineberg-like intramyocardial tunnel technique. Among the human patients, Kolessov reported 4 excellent results, the return of angina in 1 patient after 1 year, and 1 perioperative death.

In this paper, I will examine the controversies related to the use of different techniques, present some pertinent data about them, perform Bayesian analysis comparing minimally invasive CABG and CABG-CPB, and review some comparative trials with the goal of clarifying the best uses of each technique.

CONTROVERSIES RELATED TO BEATING-HEART CABG

Pioneers who have championed beating-heart surgery posit that all of the short- and long-term benefits that originate from

pump-supported CABG are imminently achievable with minimally invasive CABG without the requisite side effects of CPB. However, the presumed benefit of minimally invasive CABG has recently been called into question in a number of widely published peer-reviewed editorials. These editorial statements outlined the points of controversy between those surgeons who fully embrace beating-heart OPCAB and those who champion the use of CPB.

Bonchek (from the Lancaster General Heart Institute, Pa) and Ullyot described conventional CABG as standardized, widely applicable, safe, effective, durable, reproducible, complete, versatile, and teachable (3). Referencing the oft-quoted percutaneous transluminal coronary angioplasty-CABG randomized megatrials of the past decade, they asserted that over time, cost savings are realized due to the low incidence of complications and repeat revascularizations. These results are dependent upon uncompromising selection of coronary targets, wide exposure, atraumatic technique, optimum conduit procurement, and reproducible rapidity. Bonchek and Ullyot countered the claims of minimally invasive CABG advocates by stating that operations through limited exposure are technically difficult, prolonged, less applicable, and incomplete (in terms of total revascularization) and that purported cost savings may not be realized due to device expense, prolonged operating time, and the requisite confirmatory patency studies.

In a similar editorial, Reardon et al (from Baylor College of Medicine, Houston) cited outside referrals to their institution for failed MIDCAB as evidence against the claims of excellent graft patency (4). They stressed the historical importance of complete revascularization, the reproducibility of results, and the importance of relying on real-time comparative randomized studies, not historical, age-matched controls.

The counterarguments to conventional CABG were 2-fold. First, Borst and Grundeman (from the Netherlands) (5) quoted the 1998 Society of Thoracic Surgeons Database of 170,895 CABG-only operations, noting a freedom-of-complication rate of only 65.4% and questioning the safety of CPB-supported CABG. They highlighted the 3.6% discharge to a nonacute care facility for patients aged ≥ 65 years, as well as the observation that

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only 81.9% of CABG patients were discharged to home within 2 weeks, with a 9.9% 2-month readmission rate. They remarked on the mechanisms of cognitive defects following CPB, emphasizing the role of extracorporeal membrane oxygenation more than aortic manipulation. They conceded that by avoiding CPB-related adverse effects, a host of new problems are generated (e.g., coronary motion, regional ischemia, hemodynamic deterioration, and target identification). They suggested that CPB-supported CABG using the LITA is associated with only a 91% patency rate and therefore should be the benchmark with which minimally invasive CABG should be measured.

An accompanying editorial by Mack et al in favor of minimally invasive CABG equates satisfaction with CABG-CPB with the “inertia of success” (6). They asked the following question: If CABG-CPB for single-vessel coronary artery disease is so safe, simple, and rapid, why do surgeons experience no more than 2% to 3% of their practice as single-vessel revascularizations using the LITA-LAD? They concluded that culprit-lesion, ischemia-guided “functional revascularization” is equated with the same long-term benefit that complete anatomic revascularization is associated with (without long-term data to support this contention, however). Although 7 series are offered as proof of patency (short-term), 2 of the quoted studies have incomplete angiographic follow-up (15% and 62%), and all of the quoted studies report a 3% to 8% patent-but-stenotic anastomotic rate. Unfortunately, the proper tool for examining the best estimate of graft patency, a meta-analysis, was not offered as proof of efficacy. They also argued that total anatomic revascularization can be achieved by the use of hybrid procedures (percutaneous transluminal coronary angioplasty, transmyocardial laser revascularization) if deemed absolutely necessary but is unachievable with minimally invasive approaches alone (7, 8).

DELETERIOUS EFFECTS OF CABG-CPB

Central nervous system effects of CPB

Clear and convincing evidence shows that CPB, using extracorporeal membrane oxygenation, is associated with adverse central nervous system effects. Roach et al reported the results of a study comprising 2108 patients at 24 institutions in the USA who underwent CABG supported by CPB (9). There was a 3.1% incidence of focal stroke, stupor, or coma; this was associated with a 21% case fatality rate. Three percent of patients had decreased intellect, decreased memory, or seizures postoperatively, with a case fatality rate of 10%. Contrasted to this is the 2.1% fatality rate of patients without adverse central nervous system events. Compared with 8% of patients without adverse central nervous system events, 30% to 47% of patients with adverse central nervous system outcomes were discharged to skilled nursing facilities or rehabilitation centers.

Although stroke and focal defects occur at a finite, low prevalence following CABG-CPB, cognitive defects (related to memory, visuoconstruction, psychomotor speed, language, or attention) are more prevalent (10). In a study from Johns Hopkins University, Gardner et al reported that only 12% of 127 CABG-CPB patients had no measurable cognitive defect; 10% to 24% of cognitive domains remained depressed 1 year after the time of surgery (11). S100B protein release, from astroglial and Schwann cells, is a sensitive marker of blood-brain-barrier per-

meability disturbance; CABG-CPB caused a 10-fold increase in serum S100B concentration over that observed during MIDCAB in a randomized study (12).

Taylor also reported on the central nervous system effects of CPB (13). Patients who were determined to be at high risk for adverse central nervous system outcomes were more likely to be hypertensive, elderly (age, >70 years), or diabetic or to have had a previous stroke, carotid bruit, or atheromatous aortic disease. During CPB at mild hypothermia, there is an excess of cerebral blood flow and oxygen supply relative to metabolism. With this excess blood flow come excessive microemboli, and this is believed to be the mechanism of adverse central nervous system effects due to CPB.

Harris et al from the Hammersmith Hospital in London reported in 1993 the results of magnetic resonance imaging scanning following routine CABG-CPB; patients were extubated within 3 hours of surgery, were without neurological defects, and were discharged within 8 days after “uneventful” hospital courses (14). Surprisingly, magnetic resonance imaging scans (performed within 1 hour of surgery) showed cortical swelling and obliteration of sulci fissures and cisterns.

CPB-related neurologic complications stem from macroembolism, microembolism, and the systemic inflammatory response syndrome. Macroembolism refers to air trapped within the lumen of coronary arteries and the ascending aorta, intracardiac or intravascular thrombus, or atherosclerotic aortic debris. Microembolism refers to gaseous emboli and plasticizers that are in suspension form, as well as blood element aggregates (15). The systemic inflammatory response to CPB also contributes to adverse central nervous system effects consequent to cerebral edema and cerebrovascular endothelial injury.

The adverse central nervous system effects (especially cognitive) of CPB are used by some minimally invasive CABG enthusiasts as the rationale for routinely using beating-heart OPCAB. Interestingly, reports of cognitive defects following MIDCAB or OPCAB are lacking. An illuminating report from Duke University by Newman and Harpole examined cognitive decline following noncardiac surgery (16). Twenty-nine patients aged 35 to 85 (mean, 61 years) scheduled to undergo vascular or general thoracic procedures were prospectively enrolled in a neuropsychological test battery to be performed preoperatively and 6 to 12 weeks postoperatively. Cognitive decline was defined as a $\geq 20\%$ decrement in $\geq 20\%$ of the completed tests. Overall, 13 of 29 patients experienced cognitive decline (45%; confidence level, 27% to 64%). Multivariate predictors of cognitive decline were age and educational status. Clearly, this level of sophisticated neuropsychological testing should also be performed in patient cohorts undergoing minimally invasive CABG.

Inflammatory response to CPB

Convincing evidence also exists regarding the deleterious effects of CPB on the systemic inflammatory response. CPB affects the plasma protein system, including the contact phase, intrinsic coagulation cascade (via activation of Hageman factor), extrinsic coagulation cascade (via activation and release of monocyte tissue factor), fibrinolytic cascade, and the complement system. CPB also increases levels of proinflammatory cyto-

kines, tumor necrosis factor- α (cachectin) (17), interleukin-1 (endogenous pyrogen, lymphocyte-activating factor, proteolysis-inducing factor, catabolin), interleukin-6 (interferon β 2), interleukin-8, thrombin-antithrombin complex, prothrombin activation peptide, neutrophil lactoferrin, and myeloperoxidase (18). The anti-inflammatory cytokine interleukin-10 is also increased by CPB in a counterregulatory fashion. Interleukin-6 has been demonstrated to increase following sternotomy alone. In a prospective study, Gu et al demonstrated that C3a, β -thromboglobulin, and neutrophil elastase increased during CABG-CPB but not during MIDCAB in patients undergoing single-vessel CABG (19).

Avoiding the deleterious effects of central nervous system injury and the systemic inflammatory response from CPB was dependent upon technological advancements and safety and efficacy data.

TECHNOLOGICAL ADVANCES IN BEATING-HEART CABG

Prior to 1995, beating-heart CABG was accomplished by first-generation retraction techniques. Coronary inflow and outflow occlusion was afforded by perivascular snares. This, however, led to an unacceptably high incidence of early anastomotic failures. In 1995, development of prototypical stabilization platforms allowed for superior regional stabilization of the coronary artery of interest; these platforms were approved for marketing and release in 1997 (20). The stabilizing platform is the single most important advance in the broad applicability of minimally invasive CABG. Other important advances include intracoronary stents and cardiac herniation (21), luminal arteriotomy seal (22), endoscopic vein harvesting (23), carbon dioxide insufflation (24), cerebral blood flow and electroencephalogram monitoring, anesthetic management, and ischemic preconditioning.

LITA PATENCY DATA FOR MINIMALLY INVASIVE CABG VS CABG-CPB

Patency of the LITA-LAD anastomosis during CABG-CPB has been documented in many trials and registries. A representative contemporary study documenting the LITA-LAD patency for standard bypass surgery is found in the International Multicenter Graft Patency Experience trial (25). This angiographically controlled comparative trial enrolled 870 patients, all of whom were studied at a mean of 10.8 days postoperatively. The LITA patency was 98.2%.

The perfect patency rate (TIMI-III flow, no anastomotic stenoses) in the poststabilizer era is the most suitable measure when comparing minimally invasive and pump-supported CABG. Prior to the use of the stabilization platform, LITA-LAD patency rates performed on a beating heart were reported as 88% to 92% (26, 27). Calafiore reported that of 109 patients in the poststabilizer era undergoing MIDCAB in Chieti, Italy, the perfect patency rate was 104 of 109, or 95.4% (26). Subramanian reported a MIDCAB LITA-LAD patency rate of 97% from Lenox Hill, New York (27). A multicenter experience presented in abstract form at the 1997 Society of Thoracic Surgeons meeting by Mack et al demonstrated an 86% perfect patency rate. Another MIDCAB series from Gill et al (University of Ottawa) reported a 97.5% LITA-LAD graft patency (at 6 hours after surgery); however, 19% of the anastomoses had >50% stenosis (28).

This was compared with a contemporary series, from the same surgeon, of 96% perfect patency using pump-supported CABG.

The reasons for decreased immediate graft patency following beating-heart surgery are multifactored. Coronary motion is never completely eliminated but continues by as much as 1 to 1.5 mm in 3 orthogonal planes (x, y, z axes) with the suction-cup stabilizing platform (Octopus) (20). Some investigators believe the inflow coronary occlusion afforded by the use of perivascular snares is associated with an intimal injury pattern, but causality has never been firmly established (29).

One of the shortcomings of comparative trials between minimally invasive and pump-supported CABG is that patients with coronary anatomy suitable for either technique have not been entered into a randomized trial. Anatomic features that would predictably be associated with unfavorable patency rates in minimally invasive CABG are an intramyocardial LAD, a heavily calcified LAD vessel, and a small LAD (>2 mm); these findings typically contraindicate a minimally invasive bypass approach. These same findings typically do not contraindicate pump-supported CABG.

MORBIDITY OF MINIMALLY INVASIVE CABG VS CABG-CPB

Most series of beating-heart CABG report improved morbidity endpoints when compared with comparable CPB-supported CABG cohorts. Buffolo et al reported on their series of 519 patients undergoing OPCAB compared with 3086 patients undergoing CABG-CPB controlled for extent of disease, age, and left ventricular function (30). Mortality was reduced 1.7% vs 3.8%, arrhythmias were reduced 5.5% vs 12.6%, stroke decreased 1.1% vs 3.8%, and transfusion of blood products decreased 30% vs 55%. Calafiore was able to demonstrate a decreased intensive care unit and hospital length of stay in MIDCAB vs transsternal CABG-CPB (31).

Atrial fibrillation following standard CABG remains problematic in regards to prolongation of the hospital stay. Although atrial fibrillation has consistently been shown to be decreased in Port-Access pump-supported CABG (5% to 6%), this has not been universally demonstrated in OPCAB. Cohn et al from the Beth Israel Deaconess Medical Center in Boston reported that the incidence of atrial fibrillation was 24% in their MIDCAB experience compared with 20% in a conventional CABG-CPB cohort that was age matched (32). This observation was in spite of a protocol of routine beta-blocker prophylaxis for atrial fibrillation in both groups.

MORTALITY OF MINIMALLY INVASIVE CABG VS CABG-CPB

Most registries and trials of MIDCAB and OPCAB demonstrate equivalent mortality rates, a surprising finding if one assumes a substantial beneficial effect of avoiding CPB. To explain this observation, one must examine the populations served by each technique. Most large series of OPCAB enroll patients who are generally categorized as relatively "good risk" as estimated by systolic function, Canadian Cardiology Score class, New York Heart Association class, and comorbid illnesses. On balance, these populations are anticipated to have low risk regardless of the technique used to revascularize them. There are small registries that demonstrate favorable survival statistics compared with predicted risk, on estimates based on CPB-associated risk (33).

CONTRAINDICATIONS TO MINIMALLY INVASIVE CABG

Patient factors that have been identified as contraindications to OPCAB include decompensated congestive heart failure, malignant ventricular arrhythmia, severe cardiomegaly, morbid obesity, and conduit factors such as untreated subclavian artery stenosis. Coronary factors include calcified vessels, intramyocardial LAD, rightward displaced LAD (“tubular heart”), or excessively rotated leftward LAD (severe cardiomegaly). In addition, vessels that are small (diameter, <1.5 mm) are not suitable for OPCAB.

A different minimally invasive technique focuses on the avoidance of the median sternotomy rather than CPB: this is the Port-Access CABG.

PORT-ACCESS CABG

Port-Access CABG (Heartport Inc., Redwood City, Calif) avoids the morbidity of a sternotomy but does not avoid the morbid effects of CPB. Port-Access CABG was tested and validated by the research laboratories of Stanford University and New York University. CABG is performed on a motionless heart in a bloodless field; hence, studies of LITA-LAD anastomotic patency have consistently been reported as equivalent to standard CABG and typically higher than beating-heart techniques (OPCAB, MIDCAB). The Port Access International Registry reported on 1063 patients from 121 centers, including 583 isolated CABG (48% were single-vessel CABG) from April 1997 to January 1998 (34). The low incidence of atrial fibrillation (5%) compares favorably with the 18% to 25% incidence of atrial fibrillation in large CABG-CPB series. However, reports of aortoiliac dissection with this technique (0.75%) have been alarming. CPB duration and endoclamp times tend to be longer than the trans-sternotomy technique, raising the question whether a smaller incision is worth a longer CPB time (35). Likewise, intensive care unit and total hospital length of stay has not typically been lower than in CABG-CPB. Port-Access surgical techniques for CABG have waned in favor of off-pump techniques; however, this technology remains applicable to valve surgery, especially mitral valve procedures.

The use of robot-assisted computer-enhanced CABG surgery in its initial development was dependent on CPB, as instrumentation ports and camera scopes could not be gated to cardiac motion (36, 37). Newer developments in robotic surgery have allowed remote-access surgery to a beating heart, using stabilizing platforms.

BAYESIAN ANALYSIS

Bayesian analysis applied to clinical studies can be used to apply minimally invasive CABG to certain subpopulations of patients needing bypass surgery to estimate overall benefit in a scientifically rigorous and valid fashion.

In the following, an experimental procedure is compared with a control group. The presence or absence of a certain adverse event is recorded.

Treatment/series	Adverse event present	Adverse event absent	Total
	a	b	
Experimental	a	b	a + b
Control	c	d	c + d
Total	a + c	b + d	a + b + c + d

The experimental event rate (ERR) is the rate of an adverse clinical outcome in the experimental group and is calculated by $EER = a/(a + b)$.

The control event rate (CRR) is the rate of an adverse clinical outcome in the control group, given by $CER = c/(c + d)$.

The absolute risk reduction (ARR) of an adverse event by the experimental group over the control group is given by

$$ARR = CER - EER = [c/(c + d)] - [a/(a + b)].$$

The relative risk reduction (RRR) of an adverse event by the experimental group over the control group is given by

$$RRR = ARR/CER = (CER - EER)/CER.$$

The number needed to treat (NNT) is the number of patients needed to treat with an experimental procedure in order to prevent 1 adverse event: $NNT = 1/ARR$ (in %).

The odds ratio (OR) is the odds that an experimental patient will experience an adverse event compared with a patient in the control group, given by $OR = (a/b)/(c/d)$.

Stroke prevalence

Cognitive deficits following CPB are prevalent, as high as 40% to 60%. Although equivalent studies have not been performed in patients undergoing minimally invasive CABG, it is assumed that cognitive deficits are much more common in pump-supported CABG. With regard to strokes, however, the prevalence in minimally invasive CABG and CABG-CPB is known. Taking data from the 1996 Society of Thoracic Surgeons Database for pump-supported CABG (1) and the Buffolo series for stroke following minimally invasive CABG (30), the following Bayesian values can be constructed:

Treatment/series	Stroke present	Stroke absent	Total
Buffolo	6	513	519
Society of Thoracic Surgeons 1996	4188	170,318	174,506

The following values can be calculated with stroke as the adverse event. The event rate in the Buffolo series is 1.15%, and in the Society of Thoracic Surgeons Database it is 2.4%. The absolute risk reduction is low (1.25%), but the relative risk reduction is rather high (52%). The number of patients needed to treat with minimally invasive surgery to prevent 1 stroke is 80. The odds that a patient in the minimally invasive group will experience a stroke compared with a patient undergoing pump-supported CABG is 0.47.

Transfusion prevalence

The same Bayesian analysis can be performed for transfusion of blood products using the databases from Buffolo for minimally invasive and pump-supported CABG (30).

Treatment/series	With transfusion	Without transfusion	Total
Buffolo MIDCAB	156	363	519
Buffolo CABG-CPB	1697	1389	3086

The rate of transfusion was lower ($EER = 30\%$ vs $CER = 55\%$), and the absolute risk reduction was high (25%), as was the relative risk reduction (45%). The number of patients needed to treat with minimally invasive surgery to prevent 1 transfusion was 4, and the odds that a patient in the minimally invasive group

would require a transfusion compared with a patient undergoing pump-supported CABG was 0.35.

Graft patency rates

The LITA-LAD graft patency rate in the stabilization era (for MIDCAB) in the Calafiore series (26) and the Society of Thoracic Surgeons 34th session series (1) can be compared with the International Multicenter Graft Patency Experience trial (25) of pump-supported CABG.

Series	Not perfect patency	Perfect patency	Total
Calafiore	5	104	109
Society of Thoracic Surgeons	7	44	51
International Multicenter Graft Patency Experience	16	854	870

In this analysis, the adverse event is an imperfect graft between the LITA and the LAD that does not have “perfect patency.” In some instances, this represented graft occlusion, and in others it represented an open graft with significant (>50%) stenosis. In the Calafiore series the event rate was 4.58%, and in the Society of Thoracic Surgeons series it was 13.7%. In the International Multicenter Graft Patency Experience trial, the event rate was 1.83%. The absolute risk reduction in the Calafiore series was -2.75%, with a relative risk reduction of -150%. In the Society of Thoracic Surgeons series the effects were even more negative (ARR = -11.83%, RRR = -646%). This translates to a number needed to treat, or single LITA-LAD graft anastomoses that need to be performed on CPB in order to avoid 1 nonpatent anastomosis, of 36 in the Calafiore series and only 8 in the Society of Thoracic Surgeons series. The odds that a patient undergoing OPCAB will have a nonpatent LITA-LAD graft when compared with pump-supported CABG was 2.57 in the Calafiore series and 8.49 in the Society of Thoracic Surgeons series when compared with the International Multicenter Graft Patency Experience trial.

Using the number of patients needed to be treated as the basis for comparison and prorating to equivalent numbers of patients needed to treat to compare outcomes, the following observations could be made: Out of 100 nonselective patients each revascularized by OPCAB vs pump-supported CABG for single-vessel coronary disease, where the LITA was anastomosed to the LAD, 20 transfusions and 1.29 strokes would be avoided but at the risk of 2.7 to 12.5 patients who would have an unfavorable LITA-LAD patency.

Thus, Bayesian analysis of outcomes data is a useful tool to determine the appropriateness of minimally invasive and pump-supported CABG.

COMPARATIVE TRIALS

Percutaneous transluminal coronary angioplasty vs CABG

In the late 1980s and the early 1990s, 6 trials randomized patients with multivessel coronary disease to angioplasty or to CABG (pump-supported) (Table 1). The 6 trials had strikingly similar results. Representative of these trials was the Bypass Angioplasty Revascularization Investigation trial; at a 5-year endpoint, the need for repeat reinvestigation or revascularization in the group randomized primarily to percutaneous transluminal

Table 1. The angioplasty-surgery megatrials

Trial acronym	Trial name
EAST	Emory Angioplasty vs Surgery Trial
GABI	German Angioplasty Bypass Investigation
CABRI	Coronary Angioplasty Bypass Revascularization Investigation
RITA	Randomized Investigation in the Therapy of Angina
ERACI	Estudio Randomizado Argentino de Angioplastia vs Cirugia
BARI	Bypass Angioplasty Revascularization Investigation

coronary angioplasty was 54% compared with 8% for the group randomized to CABG (39). Piet Boonstra (Thorax Center, Gronigen, the Netherlands) reported on a small trial comparing MIDCAB with percutaneous transluminal coronary angioplasty and provisional stenting; at 6 months, reintervention was needed in 1 of 19 (5.3%) in the MIDCAB group vs 5 of 21 (23.8%) in the percutaneous transluminal coronary angioplasty-stent group (39).

In another study from the same group, 181 consecutive patients with isolated type C stenosis of the LAD were nonrandomly treated with percutaneous transluminal coronary angioplasty (n = 110) or MIDCAB (n = 71) (39). There was no difference in in-hospital death, periprocedural myocardial infarction, emergency reoperation, use of intra-aortic balloon pump support, stroke, or 1-year survival. One-year freedom from reintervention was $96.9\% \pm 0.2\%$ in the surgery group vs $67.6\% \pm 0.5\%$ in the percutaneous group ($P < 0.001$). Provisional stenting was employed, however, in the angioplasty group (15 of 94 patients, 16%).

Percutaneous transluminal coronary angioplasty (stent) vs CABG-CPB

Two trials attempt to compare more contemporary percutaneous intervention practice with CABG-CPB: the Arterial Revascularization Therapy Study and the Surgery or Stent trial.

The Arterial Revascularization Therapy Study, reported in abstract form by Dr. Patrick Serruys (Erasmus University, Rotterdam, the Netherlands), is an attempt to improve on the restenosis rate (the “Achilles heel” of angioplasty) in the randomized percutaneous transluminal coronary angioplasty trials. The study comprised 16 countries and 65 clinical sites (North America, South America, Australia, New Zealand, Israel, and Europe). Seven cardiologist-interventionists and 7 cardiac surgeons at the study center in Salzburg, Austria, reviewed and randomized 1200 patients to stent therapy or pump-supported CABG. At the 30-day follow-up, the following data were observed:

Outcome	Stent	CABG-CPB
Target vessel revascularization	2.7	2.7
Crossover	3/600 (0.5%)	0
Cardiac enzyme release	30%	57%
Reintervention rate	22/600 (3.7%)	5/600 (0.8%)
Death, myocardial infarction, or reintervention	7.8%	6.8%

The absolute risk reduction of coronary reintervention was 2.9% when surgery was compared with stenting; this translated to a relative risk reduction of 78%. The number of patients needed to undergo bypass surgery to avoid a reintervention was 34, with an odds ratio of 4.5 that routine stenting would experience a reintervention when compared with surgery.

The Arterial Revascularization Therapy Study also observed that there was no difference in mortality relative to diabetics. Minimally invasive surgery was not used in the surgery cohort. Heparin-coated stents and platelet glycoprotein IIb/IIIa inhibitor use was not routine; the IIb/IIIa inhibitor use was only 30%. Interestingly, diabetic patients comprised only 16% of the total group of patients, reflecting the lower prevalence of diabetes in Europe compared with the USA.

The Surgery or Stent trial is being conducted in Brompton, England, using a format similar to that of the Arterial Revascularization Therapy Study.

Minimally invasive CABG vs CABG-CPB

At a national meeting, it was reported that The Netherlands National Health Insurance Council (in Utrecht) had initiated 2 trials by March 1998 to evaluate and further define the role for OPCAB. Both trials involve multivessel bypass surgery for multivessel disease and the use of arterial grafts only. One trial will evaluate the effect of minimally invasive CABG using a mechanical stabilizing device compared with pump-supported CABG. A second study will review multivessel coronary surgery compared with coronary stenting. Both studies will include an angiographic follow-up of 560 patients at 1 year.

CABG vs stent plus IIb/IIIa inhibitors

According to the 1996 Society of Thoracic Surgeons Database, approximately 2% of CABG procedures were used to treat single-vessel disease (1); this is due to the widespread application of percutaneous revascularization therapy for patients with single-vessel disease. Justification for percutaneous therapy is based on the known morbidity; the low, finite mortality risk; and the cost of CABG balanced against the procedural success and restenosis rates of percutaneous therapy. Cardiologists have improved their ability to provide increased target vessel revascularization success with provisional as well as routine stenting (to prevent elastic recoil) and platelet glycoprotein IIb/IIIa inhibitor therapy. The Evaluation of IIb/IIIa Platelet Inhibitor for Stenting study demonstrated that the addition of IIb/IIIa inhibitor therapy (abciximab) to stenting reduced the restenosis rate in diabetics as well as nondiabetics (40).

Restenosis rates (at 6 months) were decreased in the percutaneous transluminal coronary angioplasty plus abciximab group when compared with other trials and were below double-digit levels in the stent plus abciximab group in nondiabetics as well as diabetics (Table 2). Clearly, this trial should serve as the benchmark against which minimally invasive CABG trials should be compared when contrasting surgical vs percutaneous therapies. To date, no studies have compared CABG (either standard pump-supported or minimally invasive) with percutaneous transluminal coronary angioplasty-supported coronary stenting utilizing routine glycoprotein IIb/IIIa inhibitor therapy.

Table 2. Six-month restenosis rate of the Evaluation of IIb/IIIa Platelet Inhibitor for Stenting study

Procedure/treatment	Placebo	Abciximab
PTCA, diabetic	NA	18.4%
PTCA, nondiabetic	NA	15.4%
Stent, diabetic	16.6%	8.1%
Stent, nondiabetic	10.6%	8.7%

PTCA indicates percutaneous transluminal coronary angioplasty.

CONCLUSION

Thus, the debate continues between those who strongly support the routine use of OPCAB vs CPB-supported CABG. All available data support the notion of provisional minimally invasive (beating-heart) CABG (41); the greatest benefit is realized in patient subpopulations where there are medical reasons to avoid the morbid effects of CPB (42), when those comorbidities are predictably associated with outcomes that would surpass the "Achilles heel" of MIDCAB/OPCAB—the slightly higher incidence of incomplete revascularization, slightly decreased rate of graft patency, and need for hybrid procedures or reintervention (20). The differential benefit of OPCAB over conventional pump-supported CABG becomes less significant in low-risk patients and more meaningful in high-risk patients (43).

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