Aortic valve replacement following previous coronary surgery

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Summary
Aortic valve replacement following previous coronary surgery is associated with high risk. Major intraoperative problems include those associated with reentry, damage to the left internal mammary artery and myocardial protection. These factors influence operative results and eventual outcome to a large extent. The available evidence largely consists of retrospective series and case reports, with their own institutional bias, and it has been difficult to make specific recommendations on the basis of this evidence. However the article reviews the various surgical options available to manage this difficult subset of patients and discusses their pros and cons.

1. Introduction
Progression of aortic stenosis is increasingly encountered in patients who, at the time of coronary artery bypass grafting (CABG), have only minimal aortic valve gradients. As the population ages, an increasing number of patients with previous CABG will require subsequent aortic valve replacement. Aortic valve replacement (AVR) after CABG poses specific risks due to the underlying ischemic and valve disease. The risk of AVR after previous CABG is not inconsiderable. Hoth and associates [1] performed AVR without no operative death on 23 consecutive patients who had undergone CABG an average of 7.6 years previously. In a series of 125 patients who underwent AVR or AVR + redo CABG (following previous CABG), Odell and associates [2], reported a mortality of 12%. Fighali et al. [3] reported an early mortality of 14%, and a late mortality of 17% in 104 patients who underwent AVR following previous CABG. In smaller series', Collins and Aranki [4] reported a mortality of 18.2% (44 patients), while Fiore et al. [5] reported a mortality of 18%.

2. Risks
Fighali et al. [3] identified preoperative renal failure, prior myocardial infarction (MI), multivessel coronary disease, and prolonged bypass time as predictors of operative mortality, while prolonged cross-clamp time was the only predictive factor in Odell’s [2] series. Perioperative MI, low cardiac output, requirement of IABP support, and ventricular arrhythmias were associated with mortality. The incidence of perioperative MI ranges from 1.9 to 13% [3,6,7], while the need for an IABP is about 18–19% [3,7].

3. Search strategy
A systematic search for published studies on aortic valve replacement following previous CABG was performed using the Medline and Embase databases. The references cited by these articles were then searched for further articles. The list of reviewed studies is listed in Table 1.

4. Surgical problems
Repeat sternotomy, the handling of patent vein or mammary grafts and the need to relocate sites for aortic perfusion, cross clamping, cardioplegia and aortotomy because of previously placed bypass grafts all add technical complexity to the procedure and potentially increase perioperative risk [6]. Reentry problems include injuries to grafts, the right atrium and ventricle, the pulmonary artery, aorta, and the innominate vein [2].

The presence of a patent left internal thoracic artery (LITA/LIMA) graft creates specific risks, including the possibility of graft injury and potential difficulties with myocardial protection. Injury to the LITA graft can occur at any stage of the operation, and can have catastrophic...
Table 1
Summary of reviewed studies

<table>
<thead>
<tr>
<th>Sr No</th>
<th>Author</th>
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<th>Type of report</th>
<th>Patient number</th>
<th>Mortality (%)</th>
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<td>Case report</td>
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consequences. The incidence of graft injury varies from 9 to 40% of coronary reoperations [2,8,9]. Gillinov and colleagues [10] reported a 5.3% prevalence of graft injury, which has been associated with a mortality rate up to 50% [8,11,12]. Operative mortality is caused by ineffective revascularization of the LAD. While 40% of patients in Gillinov’ series sustained a perioperative MI after LITA injury, only those (8.6%) with ineffective LAD revascularization died post-operatively, thus emphasizing the critical importance of ensuring adequate myocardial blood flow to the LAD territory [10]. Strategies to restore flow to the LAD include a new vein graft to the LAD, vein graft to the LITA stump, and a vein graft to the LAD with concomitant repair of the LITA graft.

The other issue pertains to the adequacy of myocardial protection in these graft-dependent hypertrophied hearts. Antegrade cardioplegia often results in poor protection, particularly in the LAD territory due to native coronary artery disease, and retrograde cardioplegia is not reliable for protection of the right ventricle [13]. Optimal protection is generally achieved by a combination of both techniques, but this too can result in variable protection depending on the inherent native coronary anatomy.

Patients requiring an AVR, following a previous CABG, especially one with a patent LITA-LAD graft require meticulous pre-operative planning in terms of access, dissection, cannulation, and myocardial protection. Evaluation of the coronary angiograms and posteroanterior and lateral chest X-ray films is useful to determine whether the LITA is adherent to the sternum. This increases the risk of LITA damage during resternotomy and subsequent dissection. Multidetector computed tomography is a new noninvasive tool for three-dimensional preoperative assessment of complex cardiac and graft anatomy. Aviram et al. [14] and Morishita et al. [15] evaluated the contribution of multidetector computed tomography angiography in repeat cardiac operations. Relation of the grafts to the midline, graft patency and course, potential aortic cannulation and cross-clamp sites, distances between the right ventricle to the sternum, distension of the right atrium or right ventricle, and aortic calcification can be assessed using pre-operative CT scans. This additional information can reduce the graft injury and potential cardiac damage during re-entry [15].

5. Surgical options

The commonest strategy involves resternotomy, dissection and temporary occlusion of the LITA, with subsequent aortic clamping and cardioplegic arrest. It has the advantage of short bypass times, the use of moderate rather than deep hypothermia and the maintenance of a uniformly cooler myocardium thereby reducing regional myocardial rewarming and cardioplegia ‘washout’ in the IMA territory.

The patent LIMA could be isolated and controlled before or after the initiation of CPB. If the LITA graft has been previously identified, it is controlled with a soft clamp. If not, systemic cooling is initiated until the graft is controlled. To isolate the LITA graft, the safest approach is to dissect along the diaphragm to the apex of the heart and then continue the dissection lateral to the LAD. This produces a strip of tissue containing the LITA graft, and entire pedicle can be controlled with an atraumatic clamp. Blunt, blind dissection during LV mobilization should be avoided. Additional cardioplegia can then be delivered.

6. Deep hypothermia

One way to avoid LIMA injury is to perform limited dissection of the heart, leaving the graft patent throughout the procedure. This strategy has been employed in conjunction with moderate-to-deep hypothermia and cardioplegic arrest by antegrade and retrograde routes [16].

Byrne et al. [16] reported this technique in 94 patients with a patent LIMA. Cardiopulmonary bypass [CPB] was instituted in many patients before re-sternotomy to protect the LITA graft. Patients were then weaned from bypass for mediastinal dissection.

They did not attempt to control the LITA, but cooled the patient to 20 °C, cross-clamped the aorta, delivered antegrade and/or retrograde cardioplegia, and replaced the aortic valve. Electrical activity was rarely present at 20 °C, and in these cases the administration of additional cardioplegia achieved cardiac quiescence. If back-flow from the left main ostia (from the patent LIMA) obscured the operative field, pump flows were temporarily turned down for better visualization.
The operative mortality, perioperative MI, and stroke rates in this series were 6.4, 7, and 11%, respectively. Twenty percent of the patients had low cardiac output, and 6% died. Damage to the LITA still occurred in 5% of the patients. The authors claim that this strategy may have particular relevance, with the recent development of minimally invasive valve reoperations [17,18], in which isolation and clamping of the IMA pedicle is difficult.

This approach is characterized by a discrepancy in myocardial protection between the anterior myocardium supplied by the IMA, where the CP is gradually washed out, and the remainder of the myocardium. Reoperative sternotomy and dissection while on CPB can increase the risk of bleeding and mediastinal edema. Systemic hypothermia does not provide the same degree of myocardial protection as does antegrade and retrograde cardioplegia with control of the LITA pedicle [19].

This strategy may be appropriate for patients with cardiac structures that are adherent to the sternum, LITA grafts that cross the midline, or when patent LITA grafts are hard to identify and isolate. However, the disadvantages of prolonged heparinization and bypass outweigh their advantages for most patients with patent LITA grafts [19].

7. Circulatory arrest

The third strategy involves deep hypothermia and circulatory arrest without controlling the LIMA or cross clamping the aorta. This technique is occasionally indicated in patients with ‘porcelain’ aorta [20], but is time consuming.

8. Beating heart procedures

An alternative approach is to operate on the ‘beating heart’ i.e. to perfuse the grafts throughout the procedure, allowing dissection to be confined to the region of the aorta and right atrium. The essential principle behind beating heart procedures is that the perfused beating heart undergoes less myocardial ischemia. These procedures continue to use CPB, but eliminate the ischemic component by keeping the heart beating throughout the operation. Cardioplegic arrest inevitably produces some degree of reperfusion injury. In contrast, keeping the heart beating results in less myocardial edema and better cardiac function [21].

9. Technique

Following resternotomy, minimal dissection is performed to cannulate the aorta. Right atrial or bicaudal cannulation with snares is performed depending on the subsequent mode of coronary perfusion. No attempt is made to dissect the left heart, hence avoiding potential LITA damage. Normothermic CPB is established. Vents are placed in the ascending aorta, and the left ventricle through the right superior pulmonary vein. While the aortic and left ventricular vents are draining the heart maximally, the aorta is cross-clamped. Cardiac perfusion is then achieved by antegrade or retrograde routes or a combination of the two.

10. Retrograde perfusion

Gersak et al. [22] described a technique of AVR using continuous retrograde coronary sinus perfusion with warm oxygenated blood in 34 patients. Retrograde coronary sinus perfusion is commenced at 100 mL/min, and then increased to between 300 and 500 mL/min, at a pressure of 50—60 mmHg. With the heart empty and beating the aorta is opened, and the valve is replaced. Backflow from the coronary ostia drains into the left ventricular vent. When suturing around the coronary ostia, a small soft vent is placed into the corresponding coronary artery.

Right ventricular protection is maintained by securely positioning the retrograde catheter at the ostium of the coronary sinus, by ensuring adequate filling of the veins of the right ventricle and checking backflow from both coronary ostia. The warm blood vasodilates the venous system, thereby allowing increased flows up to 500 mL/min in hypertrophic ventricles. An infusion of Milrinone causes further coronary venous dilatation, thus allowing greater flows [23].

The optimal level of retrograde CS perfusion flow is unknown. Resting coronary blood flow in humans averages approximately 225 mL/min, which is about 0.7—0.8 mL/g of heart muscle [24]. However, patients with hypertrophied hearts require higher flow rates for adequate myocardial protection, thus necessitating the use of high pressures during retrograde CS perfusion.

In Matsumoto’s series [23], tissue oxygen saturation was maintained at 79±2%, and partial oxygen pressure of coronary sinus perfusion blood and the returned blood were maintained at 383±29 mmHg and 38±2 mmHg, respectively. This difference in PO2 values indicates that an aerobic myocardial environment was maintained by retrograde CS perfusion. Postoperative levels of creatine kinase MB, troponin T, and required levels of catecholamine were significantly lower in the beating heart patients [23].

The advantages of retrograde CS perfusion include: (1) avoidance of injury and postcannulation coronary ostial stenosis; (2) performance of AVR without interruption; (3) a period of continuous oxygenated blood delivery, which maintains cardiac contraction, appropriate pH, and allows effective delivery of substrates and removal of metabolites; and (4) more uniform oxygenated blood distribution in the presence of coronary stenosis [23].

Despite motion of the heart, the on-pump and well-decompressed state of the heart caused by cardiac venting resulted in visualization equal to that of conventional valvular operations, and technical accuracy was not compromised. A perceived advantage of this technique is the ease of weaning patients from CPB, especially in patients with impaired left ventricular function [25]. Gersak et al. [25] demonstrated a reduction in aortic cross-clamp and bypass times using this technique.

11. Antegrade perfusion

Savitt et al. [26] cannulated the coronary ostia directly for antegrade coronary perfusion. This continuously perfuses the coronaries, keeps the field dry and prevents ostial back flow
from the patent LIMA graft. Coronary perfusion is discontinued as the aortotomy is closed, ensuring adequate deairing during catheter removal. The potential for dislodgement of the cannulae and the risk of ostial stenosis are the drawbacks of this technique. No major complications were reported in 16 patients who underwent AVR using this technique.

A combination of antegrade and retrograde perfusion has also been used as described by Salerno et al. [27]. The two largest studies [22, 23] that used beating heart techniques reported no mortality or cardiovascular complications. In comparison to the patients who underwent AVR on arrested heart, bypass times have been shorter in the beating heart group, in both these studies. All patients remained hemodynamically stable, with minimal need for inotropic support. In most published studies that have reported the use of beating heart techniques, the results have been good.

12. Vein grafts

Patent vein grafts are either intermittently perfused through the aortotomy or are relocated above the clamp, hence allowing continuous perfusion. Diseased vein grafts are replaced by new grafts, which are then continuously perfused. Sutherland et al. [28] described a modification of this technique. The aortic cross clamp is positioned below any patent vein grafts, thereby allowing continuous vein graft perfusion, in addition to LIMA perfusion. Their patients however had occluded native coronary arteries, which precluded backflow through the coronary ostia. This technique depends on the quality of the aorta at the site of cross clamping and the disposition of previous vein grafts on the aorta.

13. Coronary malperfusion and arrhythmias

A significant problem with beating heart techniques is the occurrence of ventricular arrhythmias. This is attributable to coronary hypoperfusion. Adequate coronary perfusion is vital to prevent ventricular arrhythmias. It is recommended that the retrograde CS perfusion rate should always be more than 300 mL/min, at pressures of 50 to 60 mmHg.

There have been reports of ventricular fibrillation secondary to coronary hypoperfusion in some series [22, 23, 26]. Management involves defibrillation and increased coronary perfusion flows. The ECG is continuously monitored, and if any significant ST segment changes occur, the coronary perfusion flow is increased. This results in the restoration of sinus rhythm in most patients. The alternative is to abandon the beating heart procedure and use antegrade or retrograde cardioplegic arrest [23].

However most of the data on beating heart valve procedures pertains to primary aortic valve replacement. In patients with existing LITA grafts, while continuous cardiac perfusion is maintained, the anterior myocardium is additionally perfused by the LITA. However if coronary perfusion fails, then the establishment of cardioplegic arrest, especially under normothermic conditions, may not be entirely straightforward. This is an additional consideration in patients with a patent LITA graft, in the reoperative setting.

14. Endovascular techniques

Fuzellier and associates [29] described the endovascular control of the LITA graft by an angioplasty balloon catheter positioned in the operating room before the operation. Catheterization of the LITA graft was performed by an interventional cardiologist, under fluoroscopic guidance. This technique allows control of blood flow of the LITA graft during aortic cross-clamping without the risk of graft injury. The risk of endothelial damage to the LIMA graft is unknown, although there have been reports of good results with angioplasty of the ITA graft with dilatation of anastomotic sites [30]. Choosing the correct balloon size depending on the caliber of the ITA graft minimizes endothelial damage.

15. Supraclavicular control of the LITA graft

Extrathoracic proximal control of LITA flow prior to sternal reentry has been described by Kuralay and associates [31]. The left subclavian, vertebral artery, and left mammary arteries are exposed. The subclavian artery is controlled both proximal and distal to the LITA. Proximal control of LITA flow by extrathoracic supraclavicular occlusion reduces the incidence of myocardial failure due to nonhomogenous cardioplegia delivery to the anterior myocardium, resulting in improved myocardial protection and the elimination of the need for deep hypothermia. In 24 patients who underwent this procedure, Kuralay et al. [31] reported 1 perioperative myocardial infarction, three low cardiac outputs and no mortality.

16. Limitations

A systematic search of the literature revealed that the bulk of the evidence relating to the techniques and results of AVR following prior CABG consists of retrospective case series and case reports. There were no randomized controlled trials that compared the results of the various techniques of AVR following previous CABG. The risk of selection and reporting bias when institutions report their surgical management and results cannot be ruled out. Hence it has been difficult to draw specific conclusions as to the superiority of any procedure over the others.

17. Choice of procedure

The most popular strategy involves resternotomy, control of the LITA, with subsequent aortic clamping and cardioplegic arrest. This continues to be the commonest strategy in use and is perhaps currently the best option. The use of deep hypothermia has very specific indications as discussed earlier in this article. Circulatory arrest and the use of an open technique are cumbersome and only indicated in cases of "porcelain aorta". The results of clinical studies appear to
indicate that an on-pump beating heart procedure is a good surgical option. The efficacy of this procedure requires further study using larger prospective randomized trials comparing this method with cardioplegic arrest methods.

18. Conclusion

AVR following CABG is associated with high risk. Major intraoperative problems include those associated with reentry, damage to the LITA graft and myocardial protection. These factors influence operative results and eventual outcome to a large extent. It is important that cardiac surgeons be aware of the various strategies available to manage this difficult subset of patients. The advent of beating heart and endovascular techniques may improve results in these patients, but few authors have reported the results of these techniques, and a larger volume of data is required before the routine use of these procedures in clinical practice.

References