

# Surgical Options for Beating-Heart Aortic Valve Replacement in Patients with Patent Coronary Artery Bypass

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**Background and aim of the study:** The study aim was to assess the surgical options and advantages of beating-heart aortic valve replacement (AVR) in patients with patent coronary artery bypasses.

**Methods:** In this prospective study, conducted between January and August 2006, four consecutive patients (mean age  $77.5 \pm 6.6$  years) each with patent coronary artery bypasses, underwent beating-heart AVR using two specific methods of myocardial perfusion based on the origin and status of the grafts, as assessed by preoperative angiography. Preoperatively, all patients were in NYHA functional class III, and each received an aortic valve bioprosthesis.

During aortic valve replacement (AVR), despite improvements in cardioplegia, optimal protection of the hypertrophic myocardium remains a major challenge, since the tolerance of global ischemia is essential if the surgery is to be successful. The classic techniques of AVR, with cardiopulmonary bypass (CPB), aortic cross-clamping and cardioplegia, form the basics of the procedure which, fundamentally, has not changed for many years. However, redo operations for AVR with patent coronary artery bypasses may not follow the usual surgical guidelines, as cardioplegic arrest may not adequately protect all regions of the heart. Moreover, the procedure involves a demanding surgical dissection to control the grafts, which may be injured and lead to a clear risk of subsequent complications. Herein is described an alternative surgical strategy of beating-heart AVR, which was utilized in four consecutive patients with patent in-situ arterial conduits and saphenous vein grafts.

**Results:** There were no hospital deaths. The mean duration of ICU stay was  $3.2 \pm 1.3$  days. One patient presented with transitory atrial fibrillation. At discharge, echocardiography confirmed normally functioning bioprostheses, with no significant transprosthetic gradient.

**Conclusion:** Beating-heart AVR with patent coronary artery bypasses using continuous myocardial perfusion is a reliable, simple and effective technique to reduce the risks of graft and myocardial injuries, and to achieve optimal preservation of the hypertrophic myocardium with coronary artery disease.

The Journal of Heart Valve Disease 2007;16:235-239

## Clinical material and methods

### Patient characteristics

Four consecutive male patients (mean age  $77.5 \pm 6.6$  years), each with patent coronary artery bypasses, were considered for beating-heart AVR. Previous coronary artery surgery had been performed on these patients at 2, 11, 6, and 11 years, respectively, prior to the diagnosis of aortic valve stenosis. Among these patients, a total of 11 bypasses had been achieved with either in-situ left internal mammary artery (LIMA), right gastroepiploic artery (RGEA), radial artery or venous grafts. Preoperatively, all patients were in NYHA functional class III, and one patient had angina. All patients had significant comorbidity factors (Table I). Echocardiographic and angiographic data for the patients are summarized in Table I.

Because conventional AVR with cardioplegic arrest mandates dissection of both the patent grafts and the myocardium, the decision was taken to perform valvular surgery on the beating heart, using specific technical options aimed at achieving adequate myocardial perfusion and minimal dissection in order to avoid graft injury.

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Table I: Patient characteristics and status of coronary artery bypasses.\*

Patient no.	Age (years)/gender	Comorbidity factors	Previous coronary surgery	Angiographic results	Aortic valve disease	Echocardiographic data
1	78/M	COPD, PVD, hypertension, chest radiotherapy	2 years (bypass ×2)	Patent LIMA/LAD bypass; Inferior MI	Aortic valve stenosis	EOA 0.7 cm <sup>2</sup> ; Max. grad. 62 mmHg; LVEF 40%
2	83/M	COPD, hypertension, diabetes	11 years (bypass ×5)	Patent LIMA/Diag; Patent saphenous vein/OM1-OM2; Patent RGEA/PDA	Aortic valve stenosis	EOA: 0.6 cm <sup>2</sup> ; Max. grad. 59 mmHg; LVEF 45%
3	81/M	COPD, obesity, PVD	6 years (bypass ×3)	Patent LIMA/LAD -Diag; Stenotic radial artery/PDA (post-surgery PTCA); Anterior + Lateral MI	Aortic valve stenosis	EOA: 0.6 cm <sup>2</sup> ; Max. grad. 55 mmHg; LVEF 33%
4	68/M	COPD, obesity, PVD	11 years (bypass ×1)	Patent LIMA/LAD; Anterior MI	Aortic valve stenosis; aortic valve regurgitation 2/4	EOA: 0.9 cm <sup>2</sup> ; Max. grad. 45 mmHg; LVEF 45%

\*Only patients #1, #3 and #4 had coronary sinus retrograde perfusion.

COPD: Chronic obstructive pulmonary disease; Diag: Diagonal branch; EOA: Effective orifice area; LAD: Left anterior descending artery; LIMA: Left internal mammary artery; LVEF: Left ventricular ejection fraction; MI: Myocardial infarction; OM: Obtuse marginal artery; PDA: Posterior descending artery; PTCA: Percutaneous transluminal coronary angiography; PVD: Peripheral vascular disease.

### Surgical technique

All procedures were performed through a full repeat sternotomy. Dissection of the heart, despite adhesions due to previous surgery, was limited solely to the ascending aorta, right atrium and right superior pulmonary vein (RSPV). Normothermic CPB was established, following cannulation of the ascending aorta and right atrium. Decompression of the left ventricle was obtained by a vent inserted through the RSPV. On the basis of preoperative angiographic data, myocardial perfusion was performed according to one of two techniques, namely with and without retrograde coronary sinus perfusion.

#### With retrograde coronary sinus perfusion (Fig. 1)

Three patients (#1, #3 and #4) were operated on with a beating-heart, using retrograde perfusion of normothermic oxygenated blood after catheterization of the coronary sinus. Coronary sinus perfusion was begun simultaneously with aortic clamping and left ventricular venting. The initial perfusion rate was 300 ml/min, increasing progressively to 450 ml/min; the

retrograde mean pressure ranged from 35 to 60 mmHg, resulting in a normal QRS shape. The electrocardiogram (ECG) was continuously monitored, and the coronary sinus perfusion flow rate increased with any significant segment elevation change. Special attention was paid to monitoring adequate filling of the right ventricle veins and backflow from the coronary ostia after aortotomy. The aorta was partially transected 1 cm above the right coronary artery, and AVR performed as in any aortic valve operation, using a bioprosthesis (Baxter Perimount 21 and 23 mm). Following closure of the aortotomy and placement of an aortic venting, deairing of the left ventricle was completed by a progressive reduction in RSPV venting. Following aortic clamp removal, the patients were weaned from CPB and cardiac performance and reasonable systemic pressures restored. The cross-clamp times for the three patients were 83, 57 and 48 min, respectively; the ischemia time was zero in all cases.

#### Without retrograde coronary sinus perfusion (Fig. 2)

Due to the presence of a patent in-situ LIMA grafted

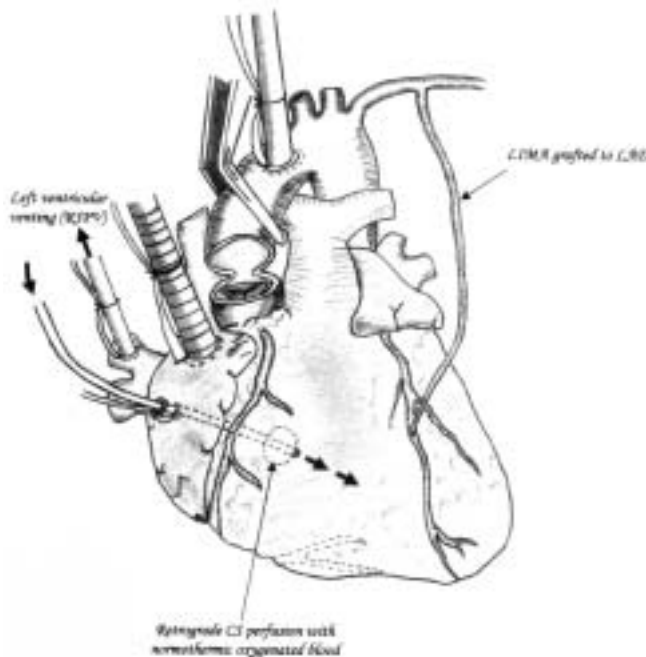


Figure 1: Beating heart aortic valve replacement using retrograde coronary sinus (CS) perfusion with oxygenated normothermic blood. The left ventricle is vented through the right superior pulmonary vein. Dissection of the patent left internal mammary artery (LIMA) is not mandatory. LAD: Left anterior descending artery.

sequentially to the diagonal and left anterior descending (LAD) arteries, a patent in-situ RGEA grafted to the posterior descending artery, and a patent saphenous vein grafted to the 1st and 2nd obtuse marginal branches, retrograde coronary sinus perfusion was not mandatory in patient #2. Consequently, positioning the aortic clamp below the venous graft was the only condition required to provide adequate myocardial perfusion. No segment elevation was identified by continuous ECG monitoring. The AVR was achieved using a bioprosthesis (Baxter Perimount 23 mm), in the normal manner. The cross-clamp time was 88 min, and the ischemia time zero. Weaning from CPB was uneventful.

## Results

There were no operative deaths. Due to severe preoperative respiratory failure, two patients required prolonged mechanical ventilation of 36 and 48 h, respectively. There was no evidence of systemic embolization or neurological complications in any of the patients. One patient presented transitory atrial fibrillation. The mean duration of ICU stay was  $3.2 \pm 1.3$  days.

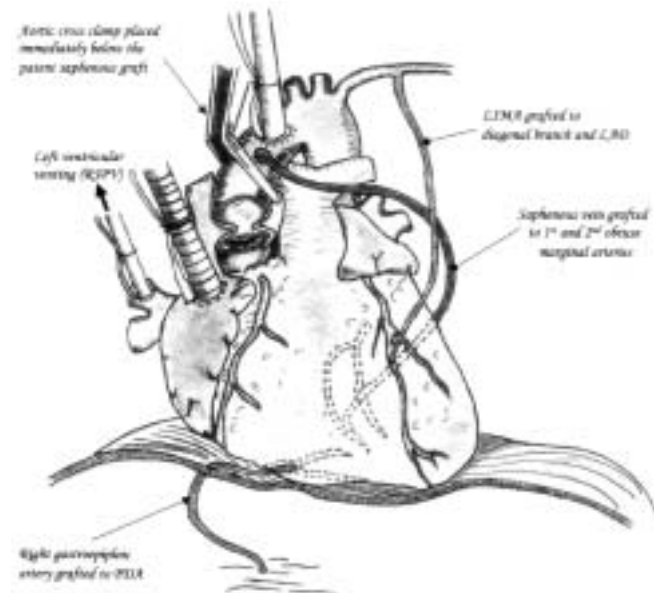


Figure 2: Beating heart aortic valve replacement without retrograde coronary sinus (CS) perfusion. Myocardial perfusion is achieved by patent in-situ left internal mammary artery (LIMA), right gastroepiploic artery and saphenous vein conduit respectively grafted to the left anterior descending artery (LAD) and diagonal, posterior descending artery (PDA) and obtuse marginal branches (1st and 2nd). The aortic cross-clamp is placed immediately below the patent venous graft. RSPV: Right superior pulmonary vein.

Echocardiographic evaluation at discharge confirmed a normally functioning prosthetic valve with no paravalvular leakage in all patients.

Follow up was complete in all patients, and ranged from six to 12 months. The mean NYHA class was improved, from III preoperatively to II postoperatively.

## Discussion

Aortic valve replacement in patients with a patent coronary artery bypass remains a surgical challenge, due mainly to the risk of inadvertent injury to the patent graft during dissection to gain proximal control. Furthermore, the issue of inadequate myocardial protection related to coronary artery disease, as well as to frequent myocardial hypertrophy, increases this risk.

When considering myocardial protection, several options are available, depending mainly on the surgical access. A minimally invasive approach, such as thoracotomy or partial sternotomy, might be possible in order to avoid extensive dissection and partly to reduce postoperative pain. Unfortunately, due to a

need to achieve myocardial protection, this specific approach involves cooling the patient and performing surgery with fibrillation, and a somewhat difficult venting of the left ventricle through the aortotomy.

As previously reported by Lucas et al. (1), and more recently by Dunning and colleagues (2), ventricular fibrillation does not result in reliable protection of the myocardium, since the resultant ventricular distension impairs the subendocardial blood flow and consequently increases ischemia and hinders the recovery of ventricular performance. Because of the severely impaired ventricular functions, ventricular fibrillation was considered to be hazardous, and not seen as the optimal solution for protecting the myocardium. The main challenge of the present study was to provide optimal myocardial protection, as these patients were considered high risk, with hypertrophic myocardium, coronary artery disease and impaired left ventricular ejection fraction (LVEF).

Both, cardioplegic arrest and a beating heart with continuous coronary perfusion through the coronary sinus and patent coronary bypass, have specific limitations for a minimal access. Optimal protection with cardioplegia involves the proximal control of patent in-situ arterial conduits (LIMA/RIMA/RGEA) and aortocoronary bypasses, which can be both tedious and time-consuming. In addition, despite reported procedures reducing the risk of graft injury (3,4), a great degree of surgical skill is required.

In these very challenging patients, the delivery of efficient cardioplegia to optimize myocardial protection was of prime necessity. Antegrade cardioplegia alone often results in a poor level of protection that depends on the inherent native coronary anatomy and the status of the coronary bypasses. In addition, retrograde cardioplegia may provide substantial benefits. In fact, optimal protection with cardioplegic arrest is generally obtained by a combination of both antegrade and retrograde techniques.

Ultimately, in the present patients AVR on a beating, perfused and vented heart remained the optimal theoretical choice. Continuous coronary perfusion through the coronary sinus and patent coronary bypasses preserves the myocardial physiology, and also avoids inadequate myocardial protection and the need to control patent grafts. Thus, although the procedure is greatly simplified, the need to dissect the right atrium and RSPV for respective access to the coronary sinus and left ventricular venting is mandatory, and this consequently limits the possibility of minimal access.

Few reports have been made using an antegrade perfusion through selective cannulation of both coronary ostia (5), and normothermic coronary perfusion is generally achieved with continuous retrograde oxygenated coronary sinus perfusion.

Due to native coronary artery disease, continuous antegrade coronary perfusion alone may result in sub-optimal protection and create an uncomfortable situation with ostial cannulation within the aortic root. Calcifications of the coronary ostia may also limit this approach. Continuous retrograde perfusion represents a good possibility, but depends on the surgeon being able to catheterize the coronary sinus in a redo configuration. However, the option of using a double venous cannulation with caval tourniquets and direct opening of right atrium may solve this problem (6).

Currently, guidelines for continuous retrograde coronary sinus perfusion are well established. For all patients, the ECG is continuously monitored and if any significant ST-elevation or idioventricular rhythm occurs, then the coronary sinus perfusion is increased, without exceeding a perfusion pressure of 60 mmHg (usually corresponding to a flow of 500 ml/min). In the hypertrophic left ventricle, an adequate coronary sinus flow may reach 500 ml/min. Ueda et al. (7) reported the need for a temporary increase in coronary sinus flow to 650 ml/min in order to recover a normal sinus rhythm from an idioventricular rhythm. This particular situation may result from an inadequate positioning of the catheter inside the coronary sinus. In addition, cardiac motion may displace the catheter; consequently, checking the position of the catheter is mandatory if any significant ECG changes occur. Thus, positioning and fixing the catheter under direct vision at the ostium of the coronary sinus, as described by Gersak (6), may be useful.

As patient #2 (see Table I) was operated on with a beating heart, there was no need to use either retrograde or antegrade coronary perfusion. In this patient, in-situ arterial and venous patent grafts provided adequate perfusion of all myocardial territories, and consequently the positioning of the aortic clamp below the implantation of the saphenous graft was mandatory to avoid the use of any retrograde coronary sinus perfusion.

Although, technically, AVR in the beating heart is similar to the 'normal' replacement technique, due to the continuous perfusion through the coronary sinus and patent coronary bypasses, some surgeons have expressed concern about retrograde coronary ostial blood flow, as this may compromise their visibility when excising a heavily calcified aortic valve. However, this problem is easily solved by using a gentle air blower, there being no risk of air embolism because of retrograde coronary flow. Nonetheless, extreme caution is recommended when calcifications are present, as these may migrate into the left ventricle during valve excision and annular decalcification. On the other hand, the risk of coronary embolization with calcifications is extremely limited because of the retrograde coronary flow.

### Study limitations

The main study limitation was the small number of patients, and a lack of control subjects, as no statistical conclusions may be drawn. However, the period of investigation was short and this specific subgroup of patients is generally limited within a usual cohort of operated patients. The primary aim was to assess technical solutions to simplify and reduce the operative risk of this challenging surgery, with optimal protection of the hypertrophic myocardium.

*In conclusion*, beating-heart AVR with patent coronary artery bypasses represents a reliable and effective option for reducing operative risk in reoperations. On the basis of these encouraging initial results and the technical simplicity involved, this surgical technique has become an elective procedure, and should be considered for lengthy and complex operations (8) with impaired LVEF.

### Acknowledgements

The authors thank Marie and David for their invaluable support in creating the figures.

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