

Beating-Heart Valve Surgery in Patients with Renal Failure Requiring Hemodialysis

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Background and aim of the study: The safety and efficacy of beating-heart valve surgery as a myocardial protection strategy was evaluated in patients with renal failure requiring hemodialysis.

Methods: This was a retrospective review of nine patients (four males, five females; mean age 46.7 years; mean duration of hemodialysis 47 ± 49 months) who underwent beating-heart valve surgery at the present authors' institution between April 2000 and September 2002.

Results: The mean cardiopulmonary bypass time was 77.2 ± 8 min. Perioperatively, two patients died (one from sepsis; one from complication of anticoagulation). There were no deaths in the follow up since discharge, with average follow up 18.3 months (range: 9-27 months). Other complications included

reintubation for <24 h (one case), AV graft thrombosis (one patient) and stroke (one patient, as mentioned above). There were no new cardiac (including arrhythmia and low cardiac output syndrome) or metabolic complications (including hyperkalemia and fluid overload).

Conclusion: This is the first report of beating-heart valve surgery using simultaneous antegrade and retrograde perfusion with normothermic blood. Despite being small in size, the study demonstrated the safety of this approach in a high-risk population with renal failure requiring hemodialysis. The results suggested a low incidence of complications, and short ICU and hospital stays.

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Patients with renal failure are at an increased risk of morbidity and mortality (13-77% and 8-31%, respectively) during cardiac surgery (1-4). Over 50% of this morbidity is due to cardiac causes (arrhythmias and low cardiac output syndrome). Pulmonary, metabolic (hyperkalemia) and hematologic (coagulopathy) complications have also had a significant impact on outcome after cardiac surgery in these patients. Traditionally, cardiopulmonary bypass (CPB) has been used in coronary as well as valvular surgery. While some of the complications could be attributed to the metabolic and hematologic effects of CPB, some of them (including arrhythmias, hyperkalemia, low cardiac output syndrome) are also due to suboptimal myocardial protection, the administration of cardio-

plegia, and reperfusion injury (5). Following the success of beating-heart coronary surgery, a review was conducted of the potential benefits of beating-heart valve surgery. While retrograde coronary sinus perfusion of the heart has been described for beating-heart valve operations (5), in the present study simultaneous antegrade and retrograde perfusion was used as described previously (6). This is the first report describing the technique in patients with end-stage renal disease requiring hemodialysis.

Clinical material and methods

Patients

Between April 2000 and September 2002, nine patients with renal failure requiring hemodialysis (four males, five females; mean age 46.7 years) underwent beating-heart valve surgery. The etiology was infectious endocarditis in four patients and degenerative disease in five. Procedures included mitral valve replacement (MVR) in four patients, MVR/coronary artery bypass grafting (CABG) in one patient, aortic valve replacement (AVR) in one patient, AVR/MVR in one patient, AVR/CABG in one patient, and combined

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mitral and tricuspid valve repair in one patient. Hypertension was present in eight patients, while four had diabetes. Other comorbidities and risk factors are shown in Table I. All patients received aprotinin (2×10^6 units bolus, then 0.5×10^6 units/h). An additional 2×10^6 units were added to the CPB circuit. All patients underwent hemodialysis 12-24 h prior to and 16-24 h after surgery. Postoperatively, patient management included radial artery and pulmonary artery pressure monitoring, with its attendant calculations of cardiac output, vascular resistance and other hemodynamic parameters. All patients were extubated within 0-24 h after the procedure.

Surgical technique

Aortic valve surgery

Standard cannulation of the ascending aorta and right atrium ('two-stage' single venous cannula) was performed and CPB initiated at normothermia (35-37°C). The coronary sinus was cannulated for retrograde, high-flow continuous perfusion with normothermic oxygenated blood. To prevent catheter dislodgment, an additional 4-0 Prolene stitch was placed around the coronary sinus free wall as described previously. A left ventricular venting catheter was then introduced through the right superior pulmonary vein to avoid distension of the left ventricle and to improve visibility in the field. (This step was subsequently omitted from the surgical routine, and the heart is now vented through the aortic root only.) As experience was gained with this technique, visibility did not become a major issue, despite the absence of a left ventricular vent. The aorta was then

cross-clamped and retrograde perfusion with oxygenated blood immediately commenced. The goal was to deliver between 300-350 ml/min at a mean coronary sinus pressure of <55 mmHg. The aorta was immediately opened after cross-clamping and suctioned out. The coronary ostia were inspected, and at least one coronary artery was cannulated. Simultaneous antegrade and retrograde perfusion of normothermic oxygenated blood was maintained to achieve a total flow of 350-400 ml/min. The non-cannulated ostium was inspected to ensure adequate return of effluent from the coronary circulation. Surgery on the aortic valve was then performed while the heart was kept normothermic and beating-empty. The electrocardiogram was monitored throughout the procedure. Normal sinus rhythm was frequently observed during the procedure, and was an indication of adequate myocardial protection. Upon completion, the aorta was closed as the coronary artery cannula was withdrawn. A vent was inserted into the ascending aorta and the heart deaired completely. The aorta was then declamped and the retrograde coronary sinus catheter removed.

Mitral valve surgery

Standard aortic and bicaval cannulation was performed and a de-airing catheter inserted into the aortic root, which was kept at low suction throughout surgery. CPB was initiated and normothermia maintained. When using the transeptal approach to the mitral valve, it was necessary to encircle the superior vena cava and inferior vena cava with caval tapes to completely exclude the venous return from the right atrium. Once the atrium was opened, a floppy car-

Table I. Preoperative and intraoperative variables.

Patient no./gender	Risks factor*	Duration of hemodialysis (months)	Pathology	Cause	Serum creatinine (mg/dl)	CPB time (min)	Procedure
30M	T,H,I	84	MR	Degen.	11.2	75	MVR
59M	H,D	5	MR	Degen.	6.9	80	MVR
55F	H,D	Unknown	MR	Infection	5.3	90	MVR
50M	T,H	144	AI	Degen.	10.1	74	AVR/CAB
25M	T,S	24	AI	Infection	3.8	66	AVR
52F	H,D,Tx	60	MR/ASD	Infection	4	90	MVR/ASD
35F	H,HN	26	AI/M Endo	Infection	11.8	75	MVR/AVR
61F	H,D	24	MR/TR	Degen.	4.1	79	MVP/TR
54F	T,H,I	24	MV/CAD	Degen.	8.7	66	MVR/CAB
Mean	-	47.28	-	-	7.32	77.22	-
SD	-	49.27	-	-	3.21	8.72	-

*Risk Factors: T: Tobacco smoking; H: Hypertension; D: Diabetes mellitus; I: HIV-positive; HN: Hydronephrosis; Tx: Failed kidney transplant.

AI: Aortic insufficiency; ASD: Atrial septal defect; AVR: Aortic valve replacement; CAB: Coronary artery bypass; CAD: Coronary artery disease; CPB: Cardiopulmonary bypass; Degen.: Degenerative; M Endo: Mitral valve endocarditis; MR: Mitral regurgitation; MVP: Mitral valve re-replacement; MVR: Mitral valve replacement; TR: Tricuspid regurgitation.

diotomy sucker was introduced into the coronary sinus to collect the coronary effluent and improve visibility. Various approaches were utilized in order to avoid air embolism: (i) the patient was maintained in the Trendelenberg position; (ii) the aortic root vent was maintained at low suction; (iii) the perfusion pressures were kept at 80-90 mmHg during CPB; and (iv) a short period of fibrillatory arrest was used while opening the left atrium if the mitral valve was competent. A vent was introduced into the left ventricle via the mitral valve immediately upon opening the left atrium in order to prevent left ventricular distension and air embolism. When using the above precautions, no adverse neurologic outcomes attributable to air embolism were encountered. When the left atrium was entered, the retractor was placed to achieve adequate exposure of the mitral valve. It was important at the time to prevent the induction of aortic insufficiency due to retraction. Mitral valve replacement or repair could then be performed. Ultimately, a floppy cardiotomy sucker was left inside the left ventricle across the mitral orifice as the left atrium was closed. The left ventricular vent was later removed and heart de-aired completely through the aortic root vent. Surgery was then completed in the usual fashion. The presence of severe aortic regurgitation would compromise coronary perfusion as well as visibility of the mitral valve, making beating-heart surgery impossible. In such a situation, the same strategy was used as described below for combined aortic/mitral valve operations on a beating-empty heart.

Combined aortic/mitral valve surgery

In patients without aortic insufficiency, the mitral valve was replaced/repared first as described above. When this had been completed, retrograde perfusion

was begun through the coronary sinus. The aorta was cross-clamped and the aortic root opened. Simultaneous antegrade and retrograde perfusion was begun and the aortic operation completed as described above.

In patients with aortic insufficiency, simultaneous antegrade/retrograde perfusion was established as for an aortic operation. The left atrium was then opened and mitral valve surgery performed. The left atrium was closed as described for a mitral valve operation. The aortic valve was approached next, and the operation completed as described above for the aortic valve operation.

Combined valve surgery/CABG

CABG was routinely performed on a beating heart, without CPB. Next, CPB was instituted and valve surgery performed. In patients requiring AVR/CABG, the distal anastomoses were performed first, after which the grafts and native coronary vessels were used for antegrade perfusion. Once the valve had been replaced and the aortic root closed, the proximal anastomoses of the coronary grafts were constructed. Only rarely was any deterioration of hemodynamic parameters observed during the performance of off-pump CABG, necessitating revascularization on a beating-empty heart after institution of CPB.

Results

Patient demographics and comorbidities are listed in Table I, while the intraoperative and postoperative courses are summarized in Table II. All patients had good left ventricular function with a mean ejection fraction of 39±4%. Transesophageal echocardiography performed on completion of surgery revealed a pre-

Table II. Postoperative course of patients with beating-heart valve surgery.

Patient no./gender	Follow up (months)	Chest drain (ml)	Inotrope use	Complications	LOS in ICU (days)	Postoperative LOS (days)
30M	18	960	No	AV graft thrombosis	4	9
59M	27	900	No	Reintubation	4	7
55F	-	400	Yes	Sepsis/death	79	79
50M	19	600	No	None	1	4
25M	-	650	No	ICH/death	6	6
52F	20	340	No	None	1	10
35F	18	880	No	None	2	7
61F	17	1,580	No	None	3	5
54F	9	550	No	Seizure	3	7
Mean	18.28	762.22	-	-	12.37	14.88
SD	5.25	376.52	-	-	26.97	24.11

AV:Arteriovenous; ICH: Intracranial hemorrhage; ICU: Intensive care unit; LOS: Length of stay.

served ejection fraction in all cases. The mean follow up was 18.3 months (range: 9 to 27 months). The preoperative and intraoperative descriptions of these patients are listed in Table I, while the postoperative course is depicted in Table II. All patients were extubated within 0-24 h postoperatively.

The postoperative serum levels of electrolytes did not show any significant change when compared with preoperative levels. The postoperative coagulation profile did have a tendency towards coagulopathy, but this did not reach statistical significance (preoperative versus postoperative prothrombin time (PT) = 12.6 versus 15 s; partial thromboplastin time (PTT) = 33 versus 41 s; platelet count = 174,000 versus 109,000/ml; $p > 0.05$). The mean postoperative chest drainage was 762 ± 376 ml. Inotropes were needed in only one patient, who was receiving inotropes preoperatively and was in septic shock (patient 55F).

Postoperative complications included reintubation for less than 24 h, arteriovenous graft (for hemodialysis) thrombosis and stroke (the same patient mentioned above, who died). There were no new cardiac (including arrhythmia and low cardiac output syndrome) or metabolic complications (including hyperkalemia, fluid overload). Likewise, there were no reoperations for bleeding.

Two patients died during the perioperative period, but none died after discharge (mean follow up 18.83 months; range: 9 to 27 months). One of these patients (55F) was admitted to the medical service ICU with severe sepsis for two weeks preoperatively and required inotropes preoperatively. This woman died on the 79th postoperative day from uncontrolled yeast and bacterial sepsis and multi-organ failure. The other patient died from a major hemorrhagic stroke during anticoagulation on the sixth postoperative day; his prothrombin time was 70 s, and INR could not be measured.

The mean length of ICU stay for all patients was 12.37 ± 26.97 days, and hospital stay 14.88 ± 24.11 days. However, for survivors, the average length of ICU stay was 2.8 ± 1.7 days and postoperative hospital stay 6.8 ± 1.96 days.

Discussion

End-stage renal disease is an important risk factor for both morbidity and mortality after cardiac surgery conducted on CPB. The combined relative risk for death during a combined valve-CABG procedure has been reported to be as high as ten-fold that for an isolated CABG (2). Whilst this strategy in patients with poor left ventricular function has been reported previously (6), this is the first report on the use of simultaneous antegrade and retrograde continuous perfusion

for beating-heart valve surgery in patients with end-stage renal disease.

Although the present study was small, the results suggested low morbidity and mortality and short ICU and hospital stays. The mean length of stay in hospital for survivors in the present study was 6.8 ± 1.96 days, whereas Durmaz et al. (1) reported a mean hospital stay of 13.6 days for survivors of cardiac surgery who required hemodialysis for renal failure, though these authors used blood cardioplegia in either antegrade or retrograde fashion. The present results also compared favorably with those reported by Brinkman et al. (4) of 13.5 days using conventional cardioplegic arrest, though no mention was made by these authors of the composition of their cardioplegia solution.

In patients on hemodialysis, CPB-associated problems such as fluid and electrolyte imbalance, hemoglobin concentration and hemostasis necessitate aggressive postoperative management. Cardiac morbidity secondary to inadequate myocardial protection and ischemia-reperfusion injury, such as arrhythmias and low-cardiac output syndromes occur in up to 25% of the patients (1,2). The present authors believe that the beating-empty state of the heart during the procedure contributes to a better postoperative cardiac function, as evidenced by the lack of low cardiac output syndrome and arrhythmias. Only one patient who had been in chronic atrial fibrillation preoperatively, went back into atrial fibrillation on the first postoperative day. Postoperatively, all of the present patients who were not taking inotropes preoperatively, did not require inotropes postoperatively (except for patient 55F)

From a technical standpoint, there are certain advantages to the beating-heart approach. During repair of the mitral valve, the valve competence can be tested in a more physiological manner with a beating heart. Another advantage of this approach is in patients with aortic valve surgery. Because the heart is in sinus rhythm at all times, any heart blocks caused by injury to the conduction system will become immediately apparent when the sutures are being placed during valve replacement. It should be possible to replace those stitches during surgery rather than creating permanent heart block. In the present series the mean CPB time was 77 min, which again compared favorably with that reported elsewhere (6) of 144 ± 47 min (mean aortic cross-clamp time 92 ± 37 min). This was in large part due to minimal 'weaning' from CPB that was required in these cases and, again, was a reflection of the myocardial protection, because none of the patients required inotropes in order to be weaned off CPB. Gersak and Sutlic (7) have also reported similar reductions in CPB times when using beating-heart valve surgery.

During the present study there was one valve-related death, which was due to anticoagulation. This patient was doing well on the sixth postoperative day and undergoing anticoagulation when he suffered a massive hemorrhagic stroke and died; at that time his PT was 70 s and INR could not be measured. This was the only neurologic complication. The other patient who died should probably not have been operated upon at all, but valve surgery was performed at the behest of the family who wanted everything done for this relatively young patient. She had been admitted to the hospital for two weeks before any surgeon consultation. At that time, she was septic and in heart failure, and required inotropes to maintain blood pressure. Although her heart failure improved, she eventually died from severe fungal sepsis almost three months later whilst in the ICU.

Although others have reported beating-heart surgery using retrograde perfusion alone (5,7), the present authors believe that combined antegrade and retrograde perfusion provides the best myocardial protection possible for the entire heart, especially for longer procedures such as combined valve and valve/CABG surgery. For aortic valve operations, placement of a vent through the right superior pulmonary vein has been avoided; instead, a vent through aortotomy was used. In this way, the pulmonary vein vent could be used initially to improve exposure of the operative field, while using antegrade cannulas for coronary ostial cannulation. Another step which has not been found useful (though many surgeons might disagree) is to fibrillate the heart when making the aortotomy, thereby reducing uncontrolled splatter of blood due to the ejecting heart. As soon as the aorta is decompressed, the heart can be defibrillated into sinus rhythm, though if the pulmonary vein vent is being used, this step may not be necessary.

In conclusion, beating-heart valve surgery can be offered to patients with end-stage renal disease. Further research is needed to assess the value of this strategy of myocardial protection during valvular surgery in high-risk populations such as end-stage renal disease patients and those with poor left ventricular function.

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