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Port-Access–Assisted Aortic Valve Replacement: A Comparison of Minimally Invasive and Conventional Techniques

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ABSTRACT

Background. A hybrid Port-Access (PA) approach to aortic valve surgery (MPAVR) was designed as a less invasive aortic valve operation. The approach combines components of Port-Access technology with conventional cardiac surgical techniques via a limited sternal incision. This technique is compared to conventional aortic vale replacement (CAVR) for safety and efficacy.

Methods. One hundred eighty patients had aortic valve surgery between January 1, 2000, and June 30, 2004. Fifty-eight patients (32%) had primary isolated aortic valve replacement, 22 of those 58 patients (38%) underwent MPAVR procedures consisting of a limited inverted-T sternotomy, direct aortic cannulation, a percutaneous PA endocoronary sinus cardioplegia catheter, an endovent pulmonary artery catheter, and a percutaneous femoral endovenous return catheter. Thirty-six patients (62%) had aortic valve replacement by sternotomy and standard cardiopulmonary bypass techniques. The MPAVR and CAVR groups were compared for demographics and intraoperative and postoperative outcomes.

Results. Age, obesity, diabetes, New York Heart Association classification, ejection fraction, and other patient characteristics were not significantly different between the groups. MPAVR patients had lower Society of Thoracic Surgery risk scores (3.1 versus 3.9; $P = .277$). MPAVR patients were more likely to receive a stentless valve (36% versus 11%; $P = .042$) and required longer operative times (237 min versus 189 min; $P < .001$). Postoperative complications were minimal and equivalent. A single mortality in the CAVR group resulted in an overall mortality of 1.7%.

Conclusion. This hybrid, less invasive PA-assisted approach to aortic valve surgery is safe and effective. A total sternotomy can be avoided in selected aortic valve patients. Results equivalent to CAVR can be expected with this minimal access operation.

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INTRODUCTION

Minimally invasive cardiac surgery is a rapidly evolving field. New procedures combining limited incisions with evolving technology facilitate "minimally invasive" approaches to cardiac surgery procedures. Carpentier and associates were the first to describe a minimally invasive approach to mitral valve surgery by performing a mitral valve repair through a minithoracotomy with thoracoscopic assistance [Carpentier 1996]. The first minimally invasive aortic valve operation was described by Cosgrove and associates using a right parasternal incision and peripheral cardiopulmonary bypass techniques [Cosgrove 1996]. Since this initial procedure, a variety of incisions and newer technologies have been applied to minimally invasive aortic valve surgery [Cohn 1997; Gillinov 1997; Svensson 1997; Aris 1999; Machler 1999].

The Port-Access (PA) method (CardioVations, Johnson & Johnson, Somerville, NJ, USA) was originally developed as a catheter-based method to facilitate cardiopulmonary bypass and cardioplegic arrest for minimally invasive coronary artery bypass grafting (CABG) [Stevens 1996]. The PA endopulmonary vent catheter provides cardiac decompression, enabling surgeons to apply PA technology to valvular heart disease. The PA approach has been used primarily in minimally invasive mitral valve surgery [Pompli 1996; Glower 1998]. Although less common, PA techniques have been utilized for aortic valve surgery [Kort 2001; Wheatley 2004]. In this report, we review our experience with a minimally invasive approach to aortic valve replacement (AVR) that combines PA technology with direct aortic cannulation and external aortic cross clamping. To evaluate the safety and efficacy of this procedure, we compared our clinical outcomes with the outcomes of patients undergoing conventional primary AVR through a complete median sternotomy at our institution during the same time period.

MATERIALS AND METHODS

A retrospective review of the computerized cardiac surgery database at The Bryn Mawr Hospital identified 180 patients who underwent aortic valve surgery between January 1, 2000, and June 30, 2004. Fifty-eight (32%) of these patients had primary isolated AVR. These patients were divided into 2 groups based on their method of AVR. Twenty-two patients underwent minimally invasive Port-Access–assisted AVR (MPAVR) through a ministernotomy. These patients were compared to 6 patients who underwent

Table 1. Preoperative Demographic Data*

	CAVR, n = 36	MPAVR, n = 22	*P*
Sex, M:F	19:17	16:6	.264
Age, y	69 ± 14 (range, 41-89)	69 ± 10 (range, 50-84)	.644
≤64	12 (33%)	8 (42%)	.495
65-74	9 (25%)	8 (31%)	.582
≥75	15 (42%)	6 (27%)	.463
BMI	29 ± 6 (range, 20-45)	29 ± 4 (range, 20-37)	.847
Diabetes	9 (25%)	6 (29%)	.766
Obesity	12 (33%)	5 (23%)	.554
Renal failure	0	1 (5%)	.379
Hypertension	24 (67%)	11 (50%)	.272
Cerebrovascular disease	4 (11%)	1 (5%)	.640
Cerebral vascular accident	4 (11%)	0	.287
COPD	4 (11%)	5 (23%)	.278
SBE	3 (8%)	0	.281
Peripheral vascular disease	3 (8%)	2 (9%)	1.00
Congestive heart failure	15 (42%)	7 (32%)	.580
NYHA classification			.071
I	0	3 (14%)	
II	9 (25%)	8 (36%)	
III	15 (42%)	8 (36%)	
IV	11 (31%)	3 (14%)	
STS risk score	3.9 ± 2.5	3.1 ± 2.7	.277

*Values are mean ± standard deviation. CAVR indicates conventional aortic valve replacement; MPAVR, minimally invasive Port-Access–assisted aortic valve replacement; BMI, body mass index; COPD, chronic obstructive pulmonary disease; SBE, subacute bacterial endocarditis; NYHA, New York Heart Association; STS, Society of Thoracic Surgery.

conventional AVR (CAVR) through a complete median sternotomy with standard cardiopulmonary bypass techniques.

Table 1 lists the preoperative demographic data for both groups. Routine preoperative evaluation included electrocardiography, chest x-ray, bilateral carotid artery ultrasonography, echocardiography, peripheral vascular screening via ankle-brachial indices, and coronary angiography. The 2 groups were well matched with regards to demographics and risk factors. The mean age of each group was similar (69 ± 10 years versus 69 ± 14 years; $P = .644$), although the CAVR group contained a greater percentage of patients over the age of 75 (42% versus 27%; $P = .463$). The CAVR group also had a higher percentage of women (44% versus 27%; $P = .264$). Both cohorts had similar rates of preoperative risk factors such as diabetes, hypertension, chronic obstructive pulmonary disease, obesity (body mass index >30), and peripheral vascular disease. The CAVR group contained patients with a higher incidence of congestive heart failure (42% versus 32%; $P = .580$) and New York Heart Association (NYHA) classification scores of III or IV (73% versus 50%; $P = .071$). CAVR patients also had higher Society of Thoracic Surgery (STS) risk scores (3.9 ± 2 versus 3.1 ± 2.6; $P = .277$). A single patient in the MPAVR group had preoperative renal failure, defined as a creatinine level >2.0 mg/dL.

Based on the NYHA classification, all of the patients in the CAVR group and the majority of patients in the MPAVR group underwent AVR for symptomatic aortic valve disease. Three patients in the MPAVR group were asymptomatic and underwent AVR because of severe aortic stenosis and the presence of 1 of the following sequelae: a mean systolic peak gradient >100 mmHg, cardiomegaly, left ventricular end diastolic diameter >5.5 cm, or depressed left ventricular function. Three patients in the CAVR group underwent surgery for bacterial endocarditis. A single patient required conversion from mini to complete sternotomy. In this patient, exposure of the proximal aorta from the ministernotomy was inadequate because of extensive pericardial adhesions from prior mediastinal radiation. None of the procedures in either group were redo sternotomies because repeat operations were excluded from this review.

The MPAVR procedure is a hybrid approach to AVR, combining PA endocardiac technology with direct minimally invasive techniques. After intubation with a single lumen endotracheal tube and initiation of general anesthesia, a transesophageal echoardigraphy (TEE) probe is inserted. Under echocardiographic guidance, the PA endocoronary sinus and endopulmonary artery catheters are percutaneously placed through the internal jugular vein by the cardiac anesthesiologist. The final position of the endocoronary sinus catheter is confirmed by dye injection under fluoroscopy. Next, a 5- to 6-cm skin incision is made, and an inverted-T sternotomy through the third intercostal space is performed. This incision provides excellent exposure of the proximal aorta and preserves both internal thoracic arteries. A pediatric rib retractor is inserted and the pericardium is incised. A pericardial cradle is fashioned, elevating the ascending aorta into the operative field. The ascending aorta is directly cannulated with a conventional aortic cannula (Medtronic-DLP, Minneapolis, MN, USA). The venous

Table 2. Intraoperative Data*

	CAVR, n = 36	MPAVR, n = 22	*P*
Total OR time, min	190 ± 35	237 ± 47†	<.001
CPB, min	114 ± 26	136 ± 29‡	.003
Cross clamp, min	93 ± 24	112 ± 26‡	.003
Prosthetic valve type			
Mechanical	7 (19%)	4 (18%)	.750
Stentless bioprosthetic	4 (11%)	8 (36%)§	.104

*Values are mean ± standard deviation. CAVR indicates conventional aortic valve replacement; MPAVR, minimally invasive Port-Access–assisted aortic valve replacement; OR, operating room; CPB, cardiopulmonary bypass.

†$P < .001$.

‡$P < .01$.

§$P < .05$.

Table 3. Postoperative Data*

	CAVR, n = 36	MPAVR, n = 22	*P*
Transfusion	17 (47%)	8 (37%)	.585
Reoperation			
Bleeding	1 (3%)	0	1.00
Other	4 (11%)	0	.12
Renal failure	2 (6%)	0	.497
Dialysis	1(3%)	0	1.00
Neurologic events	1 (3%)	0	1.00
Heart block	3 (8%)	0	.245
Length of stay, d			
ICU	5 ± 17	2 ± 3	.572
Time to discharge	13 ± 23	10 ± 16	.820

*Values are mean ± standard deviation. CAVR indicates conventional aortic valve replacement; MPAVR, minimally invasive Port-Access–assisted aortic valve replacement; ICU, intensive care unit.

cannula (CardioVations) is percutaneously introduced into the femoral vein and positioned into the right atrium under echocardiographic guidance.

After the initiation of cardiopulmonary bypass, the aorta is directly cross clamped with a conventional hydro-grip aortic cross clamp. Myocardial protection is achieved by a combination of retrograde (via the endocoronary sinus catheter) and antegrade cardioplegia infusion. After aortotomy, the aortic root is easily visualized and a clear operative field is effectively maintained by the endopulmonary artery vent catheter. The diseased native valve is excised and the annulus is suspended by commissural sutures, which further facilitate valve replacement. Following implantation of the prosthetic valve, the aortotomy is closed and the heart is de-aired by flooding the operative field with CO_2 and inserting an aortic root needle. The aortic cross clamp is removed, and cardiopulmonary bypass is terminated. Prior to heparin reversal, the femoral venous cannula is removed with the application of a single cutaneous stitch and a 5 lb sand bag is placed over the cannulation site until the procedure is complete. After removal of the aortic cannula, a single mediastinal Blake drainage tube is placed and the incision is closed.

Patients in the CAVR group underwent AVR through a 20- to 25-cm skin incision and a complete sternotomy from the sternal notch through the xiphoid process. Standard cardiopulmonary bypass techniques were employed including cannulation of the right atrium with a 2-stage venous cannula (Medtronic-DLP) and insertion of an outflow cannula into the ascending aorta. Similar to the MPAVR procedure, myocardial protection was achieved with a combination of retrograde and antegrade cardioplegia infusion.

All data are presented as mean ± standard deviation. Nominal data was compared between the 2 groups by the Fisher exact test. The Wilcoxon rank sum test was used to compare continuous data between the 2 groups. A *P* value <.05 was considered significant.

RESULTS

Operative times were significantly longer in MPAVR patients (237 ± 47 minutes versus 190 ± 35 minutes; $P < .001$). Cardiopulmonary bypass and cross-clamp times were also increased in this group (136 ± 29 minutes versus 114 ± 26 minutes and 112 ± 26 minutes versus 93 ± 24 minutes, respectively; $P < .01$). A single patient in the MPAVR required an intra-aortic balloon pump following termination of cardiopulmonary bypass. Fewer than 20% of all patients in the series received mechanical valves, and the majority of patients in both groups received stented bioprosthetic valves. Patients in the MPAVR group were more likely to receive a stentless bioprosthetic valve (36% versus 11%; $P < .05$; Table 2).

Postoperative complications were minimal in both groups. MPAVR patients were less likely to require a postoperative blood transfusion (37% versus 47%; $P = .585$). There was no incidence of perioperative myocardial infarction in either group. The incidence of postoperative bleeding, renal failure, or neurologic events was minimal in the CAVR group and absent in the MPAVR group (Table 3). Five patients, all from the CAVR group, required a second operation. Three patients developed heart block and required the insertion of a permanent pacemaker. One patient was taken back to the operating room for bleeding, and another patient required a sternal wound revision. There were no cases of postoperative prosthetic valve dysfunction in either group.

MPAVR patients spent less time in the intensive care unit (ICU) postoperatively (2 ± 3 days versus 5 ± 17 days; $P = .572$) and had shorter total hospital lengths of stay than their CAVR counterparts (10 ± 16 days versus 13 ± 23 days; $P = .820$). There were no complications from femoral cannulation in the MPAVR group. The lone mortality in this study came from the CAVR group and involved a protracted, complicated postoperative course which ultimately resulted in multisystem organ failure and death.

DISCUSSION

The primary objectives of minimally invasive surgical techniques are the reduction of incisional trauma and postoperative pain and the facilitation of rapid patient recovery. Secondary goals include shorter ICU and hospital lengths of stay, reduced hospital costs, improved cosmesis, and increased patient satisfaction with their operation. In the past decade, a

number of new minimally invasive procedures have evolved in the field of cardiac surgery. To gain acceptance, these novel procedures must produce outcomes which, at minimum, equal the results of their conventional, "gold standard" predecessors. In this report, we have proven the safety and efficacy of the MPAVR approach to AVR. This minimally invasive technique provides results that are equivalent to CAVR performed through a complete median sternotomy.

PA technology was originally developed as a catheter-based method for closed-chest cardiopulmonary bypass. The PA technique was described for minimally invasive CABG and mitral valve surgery, but its use has expanded to include aortic and tricuspid valve surgery, atrial sepal defect closure, combined valve/CABG procedures, anti-arrhythmia surgery, the removal of cardiac tumors, and redo valve surgery [Stevens 1996; Fann 1997; Galloway 1999; Schroeyers 2000; Citterio 2001; Onnasch 2002; Tripp 2002; Akpinar 2003; Wheatley 2004]. The safety of PA CABG and mitral valve surgery has been well documented. Initial reports have shown that PA procedures produce outcomes comparable to those done through a complete median sternotomy [Galloway 1999; McCreath 2003]. In addition to improved cosmesis, PA procedures have resulted in a reduction of postoperative transfusion requirements, length of stay, and septic complications [Grossi 2001]. One report cites a reduction in acute renal injury in patients undergoing PA mitral valve surgery, suggesting that this approach may be preferable to the conventional procedure in patients at high risk of renal complications [McCreath 2003].

PA technology has been combined with a variety of minimally invasive incisions to produce safe and effective results for AVR [Kauer 1998; Christiansen 1999; Kort 2001; Wheatley 2004]. Although there are anecdotal reports of the use of the endoaortic balloon catheter for aortic occlusion and cardioplegia delivery during PA AVR, most groups employ conventional proximal aortic cannulation and an external cross clamp [Glower 2000; Chitwood 2001]. Our MPAVR procedure combines a 5- to 6-cm ministernotomy with PA coronary sinus and endopulmonary artery vent catheters, percutaneous femoral venous and direct aortic cannulation for cardiopulmonary bypass, and external aortic cross clamping to provide an excellent exposure of the proximal aorta. The PA endopulmonary vent provides adequate left ventricular decompression and a clear operative field, enabling the implantation of a variety of different mechanical and bioprosthetic aortic valves. Furthermore, the smaller operative field does not limit the surgeon's options for prosthetic valve replacement, as evidenced by the use of stentless bioprosthetic implants in the MPAVR group in this study. We also feel that this is a versatile technique that can be employed for more complex procedures. This approach has been used for ascending aortic surgery, mitral valve surgery, and combined aortic and mitral valve operations.

Our results show comparable short-term outcomes between 2 cohorts of patients undergoing AVR by 2 different methods. The MPAVR procedure required a significantly longer operating room time to complete compared to CAVR. Based on our experience, the majority of this additional time can be accounted for by the time required to place the PA catheters using TEE and fluoroscopy prior to incision. MPAVR patients also had significantly longer cardiopulmonary bypass and cross-clamp times. These prolonged times may be due to the higher incidence of stentless valve implants in this group. Nevertheless, these differences did not negatively impact patient outcomes, as ICU and total hospital lengths of stay tended to be shorter in MPAVR patients. Other series of PA AVR have reported similar trends in operative times and length of stay data [Wheatley 2004].

Limitations of this report are its retrospective nature and lack of power. Although the 2 cohorts have similar demographics, our results are subject to selection bias. Lower preoperative morbidity, as suggested by the reduced incidence of congestive heart failure and lower STS risk scores in the MPAVR group, could have contributed to the shorter ICU and hospital lengths of stay. Although we speculate that the increased operative time in the MPAVR group is the result of the time required to place the PA catheters prior to incision, we cannot definitively state this, as we did not measure this time separately from total operating room time. Finally, despite the excellent outcomes in the MPAVR group, our conclusions are based on a small number of patients. In review of our experience and the existing literature, it is likely that there will be continued expansion and utilization of this and other hybrid procedures. Close monitoring and constant evaluation of these techniques is warranted.

The MPAVR procedure adds to existing minimally invasive surgical options for AVR. In our series, patients undergoing the MPAVR procedure had equivalent outcomes, uneventful postoperative courses, and were free from major postoperative complications such as bleeding, renal failure, stroke, and valvular dysfunction. Additionally, there was a trend toward reduced transfusion requirements and shorter ICU and hospital lengths of stay. In summary, this report adds to the growing body of literature supporting the safety and efficacy of minimally invasive PA-assisted AVR.

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REVIEW AND COMMENTARY

Reviewer TM433 writes:

a) What kind of cardioplegia was used?

b) The operative setting chosen by the authors represents 1 opportunity to perform a minimally invasive aortic valve replacement. I would like to ask for a more detailed explanation about the motivation for using this setting and what are the main advantages against the direct cannulation of the right atrium, putting a vent directly into the pulmonary artery, and giving only antegrade cardioplegia, which also facilitates a minimally invasive aortic valve replacement (own experience).

c) It would also be interesting to know more about the costs of the instruments used.

Author's Response by Dr. Bradley G. Leshnower:

a) We used a cardioplegia solution composed of 65 meq K/L, 50 mg 1% lidocaine/L, 12.5 gm mannitol/L, and 25 cc of 7.5% NaHCO3 in a 4:1 crystalloid:blood mixture.

b) As opposed to direct cannulation of the right atrium and pulmonary artery, we feel that the use of the Port-Access coronary sinus and pulmonary artery catheters combined with a femoral venous catheter for cardiopulmonary bypass allows for an operative field that is clear and unobstructed. In our experience, the use of fewer cannulas in the operative field facilitated operating on the aortic root and ascending aorta through a small incision.

c) The costs of the instruments were $1195 for the endopulmonary artery vent catheter, $1750 for the coronary sinus catheter, and $416 for the femoral venous cannula. We obtained a mean total hospital cost for 2 "typical" patients in each group, based on age and total hospital length of stay. The mean costs were $35,911 for MPAVR versus $43,403 for CAVR.