Safety of Minimally Invasive Mitral Valve Surgery Without Aortic Cross-Clamp

Ramanan Umakanthan, MD, Marzia Leacche, MD, Michael R. Petracek, MD, Sathappan Kumar, MD, Nataliya V. Solenkova, MD, Clayton A. Kaiser, BSE, James P. Greelish, MD, Jorge M. Balaguer, MD, Rashid M. Ahmad, MD, Stephen K. Ball, MD, Steven J. Hoff, MD, Tarek S. Absi, MD, Betty S. Kim, MD, and John G. Byrne, MD

Vanderbilt Heart and Vascular Institute, Nashville, Tennessee

Background. **We developed a technique for open heart surgery through a small (5 cm) right-anterolateral thoracotomy without aortic cross-clamp.**

Methods. **One hundred and ninety-five consecutive patients (103 male and 92 female), age 69 ± 8 years, underwent surgery between January 2006 and July 2007. Mean preoperative New York Heart Association function class was 2.2 ± 0.7. Thirty-five patients (18%) had an ejection fraction 0.35 or less. Cardiopulmonary bypass was instituted through femoral (176 of 195, 90%), axillary (18 of 195, 9%), or direct aortic (1 of 195, 0.5%) cannulation. Under cold fibrillatory arrest (mean temperature 28.2°C) without aortic cross-clamp, mitral valve repair (72 of 195, 37%), mitral valve replacement (117 of 195, 60%), or other (6 of 195, 3%) procedures were performed. Concomitant procedures included maze (45 of 195, 23%), patent foramen ovale closure (42 of 195, 22%) and tricuspid valve repair (16 of 195, 8%), or replacement (4 of 195, 2%).**

Results. **Thirty-day mortality was 3% (6 of 195). Duration of fibrillatory arrest, cardiopulmonary bypass, and "skin to skin" surgery were 88 ± 32, 118 ± 52, and 280 ± 78 minutes, respectively. Ten patients (5%) underwent reexploration for bleeding and 44% did not receive any blood transfusions. Six patients (3%) sustained a postoperative stroke, eight (4%) developed low cardiac output syndrome, and two (1%) developed renal failure requiring hemodialysis. Mean length of hospital stay was 7 ± 4.8 days.**

Conclusions. **This simplified technique of minimally invasive open heart surgery is safe and easily reproducible. Fibrillatory arrest without aortic cross-clamping, with coronary perfusion against an intact aortic valve, does not increase the risk of stroke or low cardiac output. It may be particularly useful in higher risk patients in whom sternotomy with aortic clamping is less desirable.**

(Ann Thorac Surg 2008;85:1544–50)

Alternative approaches to sternotomy for mitral and or tricuspid valve surgery have been advocated to reduce mortality and morbidity and improve recovery and cosmetics. These approaches include partial sternotomies [1–3], and minithoracotomies with port access and robotic assistance [4–9]. Techniques include those performed using conventional instruments with smaller retractors as well as a variety of newer technologies, some of which are complex, expensive, and with a steep learning curve [7–11].

The aforementioned techniques, however, require the application of port access endoaortic balloon clamp [12] or a transthoracic direct aortic cross-clamp (applied through intercostal spaces with video assistance) [6, 13] and a cardioplegia delivery system [14]. One senior author (MRP) began a program of minimally invasive heart surgery using the original "Heart Port" platform in 1998. Over time, it evolved to a more simple and cost-effective approach by avoidance of cross-clamping and cardioplegic myocardial arrest using a small (5 cm) right anterolateral incision. This approach to the mitral and tricuspid valves, as well as other heart procedures performed through the right and left atrium, such as closure of atrial septal defect or removal of tumors or foreign bodies, has been used at Vanderbilt since January 2006.

Material and Methods

Institutional Review Board approval was obtained to review the medical records of patients who underwent minimally invasive open-heart surgery. The Institutional Review Board waived individual consent for the study. Between January 2006 and July 2007, 195 consecutive patients, age 69.3 ± 8.1 years (103 male and 92 female), underwent minimally invasive open-heart surgery. Minimally invasive surgery was defined as open-heart surgery performed with a 5-cm right anterolateral thoracotomy through the fourth intercostal space using a right submammary incision. The data were collected using the definitions in the Appendix.

Accepted for publication Jan 28, 2008.

Presented at the Fifty-fourth Annual Meeting of the Southern Thoracic Surgical Association, Bonita Springs, FL, Nov 7–10, 2007.

Address correspondence to Dr Byrne, Vanderbilt University Medical Center, Department of Cardiac Surgery, 1215 21st Avenue South, Nashville, TN 37232-8802; e-mail: john.byrne@vanderbilt.edu.

Published by Elsevier Inc

0003-4975/08/$34.00
doi:10.1016/j.athoracsur.2008.01.099

Table 1. Demographic Data

Characteristics	Patients (n = 195)
Mean age (years)	69.3 ± 8.1
Gender:	
Male	103 (53%)
Female	92 (47%)
Atrial fibrillation	62 (32%)
Mean NYHA class	2.2 ± 0.7
Mean ejection fraction	0.49 ± 0.148
Previous MI	46 (24%)
CAD	60 (31%)
CHF	117 (60%)
Previous stroke	22 (11%)
Hypertension	110 (56%)
Diabetes	49 (25%)
Carotid disease	12 (6%)
Acute MI	4 (2%)
COPD	60 (31%)
Creatinine ≥ 1.5 mg/dL	36 (18%)
Hemodialysis	6 (3%)
Previous cardiac procedures	65 (33%)
Valve surgery	26 (13%)
CABG	48 (25%)
PCI	48 (25%)
Etiology:	
Myxomatous mitral valve disease	86 (44%)
Ischemic mitral valve disease	41 (21%)
Rheumatic mitral valve disease	34 (17%)
Endocarditis	7 (4%)
Other	27 (14%)

CABG = coronary artery bypass graft; CAD = coronary artery disease; CHF = congestive heart failure; COPD = chronic obstructive pulmonary disease; MI = myocardial infarction; NYHA = New York Heart Association; PCI = percutaneous coronary intervention.

One hundred eighty-nine mitral valve procedures were performed. Concomitant procedures included tricuspid valve surgery (n = 19), maze procedure (n = 45), and atrial septal defect or patent foramen ovale (PFO) closure (n = 42). In addition, six other nonmitral valve minimally invasive open-heart procedures were performed. No patients underwent concomitant coronary artery bypass surgery. Fourteen patients underwent planned "one-stop" concomitant percutaneous coronary intervention (immediately prior to the open surgery) in the hybrid catheterization lab-operating room. Among the 60 patients with concomitant coronary disease, 14 had critical lesions that required coronary intervention at the time of the surgery. Demographic data are listed in Table 1.

Technique

After appropriate anesthesia, a single lumen endotracheal intubation was used and a pacing Swan-Ganz pulmonary artery catheter was placed. A transesophageal echocardiogram (TEE) was performed. Patients were positioned in a supine position with the right side of the chest slightly elevated. They were prepped and draped in a standard fashion with an external defibrillator (ZOLL Medical Corporation, Chelmsford, MA). The aorta was screened for atheromas with TEE. A 5-cm right anterolateral thoracotomy was performed through the fourth intercostal space (Fig 1A). The femoral vessels were exposed using a transverse incision and the femoral artery was cannulated (n = 176) using an 18 or 16 French straight cannula (Edwards Life Sciences, Irvine, CA). In patients with grade 4-5 atherosclerotic aortic disease or suspected aortoiliac disease, axillary cannulation (n = 18) or direct aortic cannulation (n = 1) was performed. The femoral vein was cannulated with a 28 French venous return cannulae (Cardioversion, Inc., CA) In patients undergoing tricuspid valve surgery or right heart procedures, the superior vena cava was also cannulated to improve venous drainage (n = 14).

After systemic heparinization, patients were placed on cardiopulmonary bypass (CPB) with vacuum-assisted drainage. Patients were cooled to a mean temperature of 28.2 ± 1.6 degrees centigrade to induce fibrillatory arrest. If simple cooling did not induce fibrillatory arrest, the pacing Swan was used to induce fibrillation with rapid pacing. The left atrium was then immediately opened in the atrioventricular groove. In patients undergoing mitral valve procedures, the left atrial incision was extended and the mitral valve was exposed using a specially designed hand held atrial retractor, inserted through the left atrial opening (Fig 1B). The mitral valve repair (MVP) or replacement (MVR) was performed under direct vision using Cardiovations instruments (Cardiovations, Inc, Somerville, NJ). Concomitant maze using a Cryocath (Montreal, Quebec, Canada) catheter and PFO closure were performed if necessary.

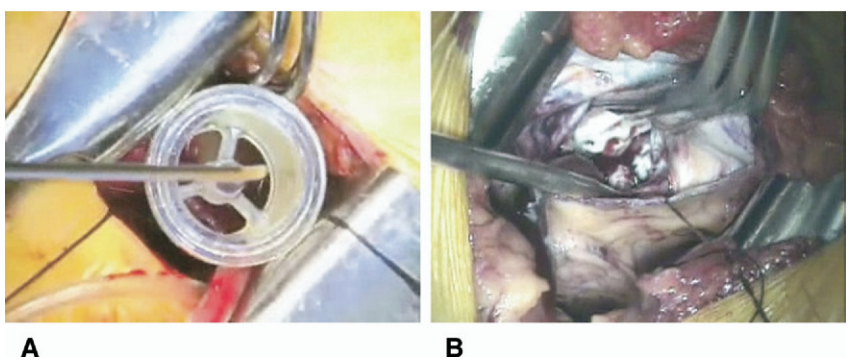

Fig 1. (A) Right anterolateral thoracotomy (5 cm). A prosthetic valve is held up next to the thoracotomy to show how small it actually is. (B) Operative situs and exposure of the mitral valve utilizing an atrial retractor.

Table 2. Operative Data

Variables	Patients (n = 195)
Mitral valve replacement	117 (60%)
Mechanical valves	17 (15%)
Biological valves	100 (85%)
Mitral valve repair	72 (37%)
Leaflet resection	39 (54%)
Folding valvuloplasty	27 (38%)
Sliding valvuloplasty	4 (6%)
Goretex chordae implantation	4 (6%)
Other procedure	6 (3%)
Concomitant procedure:	
Maze procedure	45 (23%)
PFO closure	42 (22%)
Tricuspid valve repair	16 (8%)
Tricuspid valve replacement	3 (2%)
PCI	14 (7%)
Operative duration (min):	
Fibrillatory arrest	88 ± 32
Cardiopulmonary bypass	118 ± 52
Total operation	280 ± 78

PCI = percutaneous coronary intervention; PFO = patent foramen ovale.

Mitral valve replacement with a bioprosthesis was typically performed with a porcine Mosaic valve (Medtronic Inc, Minneapolis, MN) because of its retractable posts. Carbon dioxide was continuously insufflated into the chest throughout the procedure to displace intracardiac air and a left atrial pump sucker was used to maintain a clear operative field. Upon completion of the open-heart procedure, insufflating the lungs further performed air removal and the left atrium was closed.

Because the incision is more lateral, the visualization of the mitral valve is excellent and minimal retraction of the heart is needed, avoiding aortic valve distortion. This minimizes aortic insufficiency, enabling a reasonably bloodless field. In the event of more significant aortic insufficiency, flows on CPB can be decreased for 1 to 2 minute intervals intermittently provided the systemic pressure does not fall below 30 mm Hg. Keeping the aortic pressure greater than 30 mm Hg keeps the aortic valve closed, and prevents air in the left ventricle from entering the ascending aorta. If aortic insufficiency is greater than 2+ this approach may be contraindicated.

Rewarming and cardioversion with the external Zoll pads (ZOLL Medical Corporation) were performed and patients were weaned off CPB. Post pump TEE was performed to confirm proper valve and ventricular function and to ensure complete removal of air. The arterial and venous cannulae were removed and the vessels were repaired. A chest tube was placed in the right pleural chest and a 9/9 Blake drain in the pericardial space. The thoracotomy was closed in a standard fashion.

Table 3. Valve Pathology Versus Type of Valve Procedure (Repair vs Replacement)

Valve Pathology	Total N = 195
Myxomatous valves:	86/195 (44%)
MV repair	57/86 (66%)
MVR	29/86 (34%)
Ischemic valves:	41/195 (21%)
MV repair	5/41 (12%)
MVR	36/41 (88%)
Rheumatic valves:	34/195 (17%)
MV repair	2/34 (6%)
MVR	32/34 (94%)
Other (7 endocarditic and 21 other):	28/195 (14%)
MV repair	8/28 (29%)
MVR	20/28 (71%)
Other patients not having any mitral surgery	6/195 (3%)

MV repair = mitral valve repair; MVR = mitral valve replacement.

Table 4. Valve Procedure in Myxomatous Valves

Total Patients	N = 195
Myxomatous valves	86/195 (44% of total patients)
MV repair	57/86 (66% of myxomatous)
Posterior leaflet disease	48/57 (84% of repairs)
Anterior leaflet disease	2/57 (4% of repairs)
Bileaflet disease	7/57 (12% of repairs)
MVR	29/86 (34% of myxomatous)
Posterior leaflet disease	2/29 (7% of MVR's)
Anterior leaflet disease	1/29 (3% of MVR's)
Bileaflet disease	26/29 (90% of MVR's)

MV repair = mitral valve repair; MVR = mitral valve replacement.

Data Analysis

Data are presented as mean values ± standard deviation or percentage. The statistical data analysis was performed using the STATA (College Station, Texas) 9.0 software package for Windows.

Table 5. Perioperative Data

Variables	Patients (n = 195)
Mean length of hospital stay (days)	7 ± 4.8
Median time to extubation (hours)	10 (range, 4.5–252)
Mean chest tube drainage (total mL)	1,224 ± 103
Mean PRBC transfusion (48 hours)	2 ± 3
Postoperative complications:	
Reoperation for bleeding	10 (5%)
MI	0 (0%)
LCOS	8 (4%)
Stroke	6 (3%)
TIA	2 (1%)
Renal failure	6 (3%)
Hemodialysis	2 (1%)
Respiratory failure/tracheostomy	8 (4%)
Operative mortality	6 (3%)

LCOS = low cardiac output syndrome; MI = myocardial infarction; PRBC = packed red blood cells; TIA = transient ischemic attack.

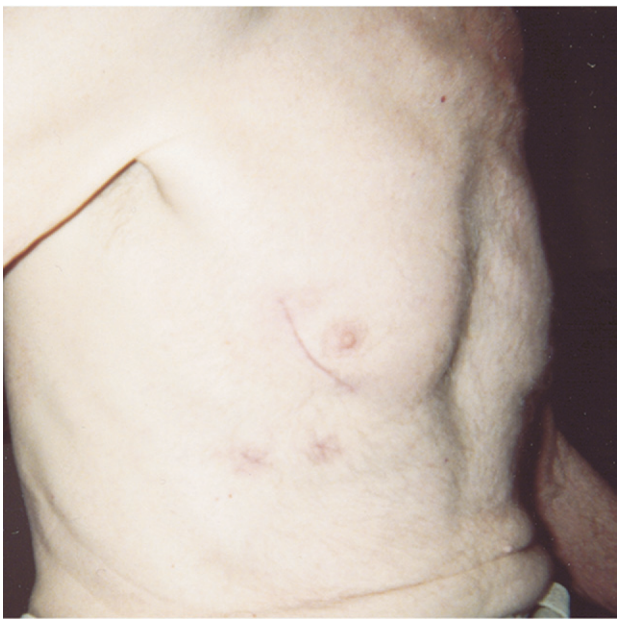

Fig 2. Excellent postoperative cosmetic results.

Results

Elective surgery was performed in 150 (77%) patients, urgent surgery was performed in 40 (20%) patients, and emergent surgery was performed in 5 (3%) patients. Mitral valve repair was performed in 72 (37%) patients, while mitral valve replacement in 117 (60%) patients. Fourteen patients with concomitant coronary artery disease underwent simultaneous ("one stop") percutaneous coronary intervention followed immediately by surgery in our hybrid operating room-catheterization lab. Surgical procedures and operative data are summarized in Table 2.

Etiology of valve pathology versus type of valve surgery is listed in Table 3, while details of MVP for myxomatous valves are outlined in Table 4. Sixty-six percent of myxomatous valves were successfully repaired, while 88% and 94% of ischemic and rheumatic valves, respectively, were replaced. Intraoperative TEE showed satisfactory valve function in all except one patient, in whom conversion to MVR was necessary due to residual mitral regurgitation.

Postoperative complications are summarized in Table 5. Six (3%) patients sustained postoperative stroke: two patients improved over time. Etiology of stroke included ischemic stroke (n = 3) and watershed stroke (n = 3). Two patients (1%) had postoperative transient ischemic attacks. Thirty-day mortality was 3% (n = 6). Causes of death included stroke (n = 3), multiorgan failure system (n = 1), sepsis (n = 1), and respiratory failure (n = 1).

Comment

The principle findings in this series are that right anterolateral minithoracotomy for minimally invasive open heart surgery without aortic cross-clamping is: 1) safe with low complications rates and mortality (3%); 2) offers excellent visualization of the mitral and tricuspid valves; and 3) provides good cosmetic results (Fig 2). Minimally invasive techniques are more challenging and require a learning curve and possibly longer cardiopulmonary bypass times, once the surgeon is comfortable in this environment this technique is remarkably straightforward, is done under direct vision with standard surgical technique, albeit with special long instruments, and offers excellent exposure of the valve.

Conversely, robotic approach with or without port access methods, while comparable to conventional surgery in expert hands [15, 16], is associated with higher cost and the need for a steep learning curve of new sets of skills. Moreover, the topography of the valve differs from that observed in conventional sternotomy and thus the surgeon needs to be trained in this exposure. Simplification of the procedure is desirable in order to reduce the time of the operation and to address other drawbacks.

The common theme of previously reported minimally invasive heart surgery approaches is the need of aortic cross-clamping and a cardioplegia delivery system. The latter can be challenging because the advancement of a coronary sinus catheter for retrograde cardioplegia may not always be possible, and sometimes can lead to perforation of the coronary sinus [17]. Alternatively a new version of the aortic endovascular occluder, which provides for direct cannulation of the ascending aorta and antegrade perfusion, can obviate some problems seen in the early series of the Port access [5]. However, if the aortic endovascular occluder dislodges or does not achieve complete aortic occlusion, this can lead to poor myocardial protection or worse. The use of direct antegrade aortic cardioplegia also poses the risk of aortic dissection.

In order to simplify the technique and avoid aortic cross-clamping and cardioplegic ischemia, we have adopted cold fibrillatory arrest. The key principle for myocardial protection is to keep the heart completely decompressed by opening the left atrium immediately upon fibrillation. The left ventricle cannot be allowed to distend. Vacuum-assisted drainage also assists with heart decompression. The coronaries are perfused with oxygenated blood against an intact aortic valve. If the aortic valve is incompetent this technique may be contraindicated. Our low incidence of low cardiac output syndrome (4%), despite 18% (35 of 195) of our patients with an ejection fraction 0.35 or less, confirms that this method offers excellent myocardial protection. We believe this is because minimal retraction of the heart is needed because the surgeon can visualize the valve easily, thereby avoiding aortic valve distortion, aortic insufficiency, and coronary malperfusion. Most prior studies on fibrillatory arrest have evaluated intermittent cross-clamp for coronary artery bypass grafting [18] and some [19] have reported an increase in myocardial acidosis when hypothermic fibrillatory arrest was used in emergent coronary revascularization. Our technique is

different in that the myocardium never becomes ischemic and it is always decompressed.

Satisfactory removal of air in minimally invasive procedures may be difficult due to the limited access to the aorta or the apex of the heart [20]. Mohr and colleagues [21], in their series of Port access minimally invasive mitral valve surgery, have reported a higher rate of incomplete removal of air of the heart by transthoracic echo and a 17% rate of postoperative confusion. Grossi and colleagues [4] have used a right thoracotomy approach combined with endoaortic balloon occlusion and either peripheral or central cannulation, and in a large series of patients (714) reported 2.9% incidence of stroke. With the same approach Dogan and colleagues [5] have reported a 5% rate of transient ischemic attack, while Nifong and colleagues [22], in a large multicenter trial of robotic mitral valve surgery, have reported no stroke. Greelish and colleagues [3], using the lower hemisternotomy approach for mitral valve repair, have reported a 1.9% incidence of stroke. In a recent series from Svensson and colleagues [23], comparing the results of mitral valve reoperations done either through a redo-sternotomy versus a right thoracotomy approach, the incidence of stroke was 2.7% versus 7.5%, $p = 0.04$, respectively. In the right thoracotomy approach fibrillatory arrest was used in the majority of the patients (91%). Removal of air of the cardiac cavities was performed by the aortic root vent and a vent placed through the mitral valve. In our experience we had 3% stroke rate (none in the redo group). We attribute our low stroke rate to our adhering to four absolute precautions to decrease the risk of stroke: (1) the arterial perfusion pressure should never be allowed to go below 30 mm Hg (this keeps the aortic valve closed and prevents air from entering the ascending aorta); (2) in mitral valve repair, we do not test the repair by insufflating the left ventricle with a syringe of normal saline because this can push air or debris into the ventricle and aorta, but rather make the aortic valve incompetent to fill the left ventricle retrograde; (3) the use of carbon dioxide insufflation has markedly reduced the amount of air in the heart chambers and the air emboli; we flush carbon dioxide into the thoracic cavity at 5 liters per minute throughout the operation to prevent air; and finally (4) before the patient is cardioverted, we check for air by TEE; however, sometimes the patient converts on his own; the key aspect is to keep the mitral valve incompetent in order to avoid air emboli. In the case of valve replacement, we place a flexible pediatric vent or Foley catheter through the valve to keep it incompetent.

Contraindications to perform this approach are the presence of 2+ or greater aortic regurgitation because it limits the visibility of the surgical field, and causes coronary malperfusion; and the presence of pectus excavatum because of the difficulty of left atrial exposure due to the pushing of the sternum on the cardiac chambers. The presence of concomitant coronary artery disease has been a classic contraindication for minimally invasive valve surgery. Because these approaches offer significant improvement in outcomes, the use of simultaneous percutaneous coronary intervention was used in 7% of the patients in our hybrid cath lab-operating room. The tradeoff is an increased amount of bleeding resulting from antiplatelet agents [24]. In our experience only one patient in this group required reoperation for bleeding.

Mitral valve repair was successful in 66% of myxomatous valves. The majority (90%) of MVRs for myxomatous diseases occurred when patients had complex bileaflet disease. Thus, bileaflet repair is challenging whether using conventional or minimally invasive approaches. For complex bileaflet disease, it is the preference of some surgeons to replace the mitral valve rather than performing complex mitral valve repair. Ischemic valves were replaced 88% of the time and this followed surgeon preference. Recent evidence suggests that ischemic patients fare just as well with MVR as with repair, and repair is often not durable [25]. Because ischemic mitral regurgitation is largely a ventricular problem, some surgeons feel that MVR is preferable so as to assure valve competence considering most patients with ischemic mitral regurgitation will not outlive a biologic MVR.

Limitations

This was an uncontrolled series and data were retrospectively collected. The surgical approach was determined by surgeon's preference. Later during the study, however, this has become our standard approach for mitral and tricuspid valve surgery if no concomitant aortic valve disease is present. If complex bileaflet valve repair is deemed likely, a sternotomy may be preferable in some cases. Obviously, late follow-up will be needed to determine whether valve repairs are durable.

Funding and technical support for this project were provided by the Vanderbilt Heart and Vascular Institute.

References

1. Cosgrove DM 3rd, Sabik JF. Minimally invasive approach for aortic valve operations. Ann Thorac Surg 1996;62:596–7.
2. Gundry SR, Shattuck OH, Razzouk AJ, del Rio MJ, Sardari FF, Bailey LL. Facile minimally invasive cardiac surgery via ministernotomy. Ann Thorac Surg 1998;65:1100–4.
3. Greelish JP, Cohn LH, Leacche M, et al. Minimally invasive mitral valve repair suggests earlier operations for mitral valve disease. J Thorac Cardiovasc Surg 2003;126:365–71.
4. Grossi EA, Galloway AC, LaPietra A, et al. Minimally invasive mitral valve surgery: a 6-year experience with 714 patients. Ann Thorac Surg 2002;74:660–4.
5. Dogan S, Aybek T, Risteski PS, et al. Minimally invasive port access versus conventional mitral valve surgery: prospective randomized study. Ann Thorac Surg 2005;79:492–8.
6. Chitwood WR Jr, Elbeery JR, Moran JM. Minimally invasive mitral valve repair using transthoracic aortic occlusion. Ann Thorac Surg 1997;63:1477–9.
7. Grossi EA, LaPietra A, Applebaum RM, et al. Case report of robotic instrument-enhanced mitral valve surgery. J Thorac Cardiovasc Surg 2000;120:1169–71.
8. Rodriguez E, Nifong LW, Chu MW, Wood W, Vos PW, Chitwood WR. Robotic mitral valve repair for anterior leaflet and bileaflet prolapse. Ann Thorac Surg 2008;85:438–44.

9. Colvin SB, Galloway AC, Ribakove G, et al. Port-Access mitral valve surgery: summary of results. J Card Surg 1998; 13:286–9.
10. Chitwood WR Jr, Elbeery JR, Chapman WH, et al. Video-assisted minimally invasive mitral valve surgery: the "micro-mitral" operation. J Thorac Cardiovasc Surg 1997;113: 413–4.
11. Dogan S, Graubitz K, Aybek T, et al. How safe is the port access technique in minimally invasive coronary artery bypass grafting? Ann Thorac Surg 2002;74:1537–43.
12. Fann JI, Pompili MF, Stevens JH, et al. Port-access cardiac operations with cardioplegic arrest. Ann Thorac Surg 1997; 63(6 suppl):S35–9.
13. Reichenspurner H, Detter C, Deuse T, Boehm DH, Treede H, Reichart B. Video and robotic-assisted minimally invasive mitral valve surgery: a comparison of the port-access and transthoracic clamp techniques. Ann Thorac Surg 2005;79: 485–91.
14. Schwartz DS, Ribakove GH, Grossi EA, et al. Minimally invasive cardiopulmonary bypass with cardioplegic arrest: a closed chest technique with equivalent myocardial protection. J Thorac Cardiovasc Surg 1996;111:556–66.
15. Nifong L, Chitwood WR, Pappas PS, et al. Robotic mitral valve surgery: a United States multicenter trial. J Thorac Cardiovasc Surg 2005;129:1395–404.
16. Chitwood WR. Current status of endoscopic and robotic mitral valve surgery. Ann Thorac Surg 2005;79:2248–53.
17. Ryan WH, Dewey TM, Mack MJ, Herbert MA, Prince SL. Mitral valve surgery using the classical 'heartport' technique: the Dallas experience. J Heart Valve Dis 2005;14: 709–14.
18. Akins CW. Noncardioplegic myocardial preservation for coronary revascularization. J Thorac Cardiovasc Surg 1984; 88:174–81.
19. Greene PS, Cameron DE, Griffiths EM, DiNatale JM, Gardner TJ. Does hypothermic fibrillatory arrest improve myocardial protection during emergency revascularization? Ann Thorac Surg 1989;48:38–42.
20. Wimmer-Greinecker G, Matheis G, Dogan S, et al. Complications of port-access cardiac surgery. J Card Surg 1999;14: 240–5.
21. Mohr FW, Falk V, Diegeler A, Walther T, van Son JA, Autschbach R. Minimally invasive port-access mitral valve surgery. J Thorac Cardiovasc Surg 1998;115:567–76.
22. Nifong LW, Chitwood WR, Pappas PS, et al. Robotic mitral valve surgery: a United States multicenter trial. J Thorac Cardiovasc Surg 2005;129:1395–404.
23. Svensson LG, Gillinov AM, Blackstone EH, et al. Does right thoracotomy increase the risk of mitral valve reoperation? J Thorac Cardiovasc Surg 2007;134:677–82.
24. Byrne JG, Leacche M, Unic D, et al. Staged initial percutaneous coronary intervention followed by valve surgery ("hybrid approach") for patients with complex coronary and valve disease. J Am Coll Cardiol 2005;45:14–8.
25. Borger MA, Alam A, Murphy PM, Doenst T, David TE. Chronic ischemic mitral regurgitation: repair, replace, or rethink? Ann Thorac Surg 2006; 81:1153–61.

Appendix

Definitions

Hospital mortality: death for any reason occurring within 30 days after surgery or after 30 days occurring during the same hospitalization.

Congestive heart failure: presence within two weeks prior to procedure of paroxysmal nocturnal dyspnea or dyspnea on exertion because of heart failure or chest X-ray showing pulmonary congestion.

Myocardial infarction (MI): acute if present $\leq$ 7 days from the last documented MI or evolving, if, at the time of surgery, Q-waves or ST changes were present along with a creatinine kinase-MB (CK-MB) $>$ 5% of total CPK.

Urgent surgery: procedure required during the same hospitalization in order to minimize chance of further clinical deterioration, emergent if ischemic dysfunction (ongoing ischemia despite maximal medical treatment or IABP, acute/evolving MI, pulmonary edema requiring intubation) or shock.

Low cardiac output syndrome: was defined as a cardiac index $\leq$ 2.0 l/min/m^2, requiring triple inotropic support to maintain a systolic pressure greater than 90 mm Hg for at least 30 minutes, or placement of an intraaortic balloon pump (IABP).

Perioperative myocardial infarction: appearance of new Q waves and a CPK MB fraction $\geq$ 100 IU/L.

Bleeding: necessity of reexploration of the thorax for suspected bleeding during the postoperative period.

Stroke: evidence in the postoperative period of a new central neurologic deficit persisting for $>$72 hours, while if the neurologic deficit resolved in 72 hours it was considered a transient ischemic attack.

Acute renal failure: an increase in creatinine to twice the preoperative value.

DISCUSSION

DR J. MICHAEL SMITH (Cincinnati, OH): Thank you for the invitation to be here today, and I would like to congratulate Dr Greelish on a nice presentation and a nice series. I think that it has become very obvious to me in the last few years of my practice that minimally invasive surgery is truly motivated by demand from the patients, and I think presenting a series like this is very important to present your data and consider this as we move to an era of percutaneous valve technology.

I think the three technical challenges to overcome when you are doing this is, number one, how are you going to safely perfuse the patient, and my first question is, do you do anything besides just the TEE to select patients for safety of thermal perfusion? The second thing is how do you occlude the aorta and protect the heart? And you have chosen to deal with that by not dealing with it. And the third issue is, how do you actually operate on the valve pathology once you get there, what kind of instruments?

The second question that I would like to ask is, your repair rate overall was only about 35%, and I would like to just clarify, are you compromising your ability to repair the valve because of this procedure? If you did those patients through a sternotomy, do you think you would have a higher repair rate? Thank you very much.

DR GREELISH: Thank you for your comments and questions, Dr Smith. Issues regarding who can safely be perfused with this technique center primarily on two areas, first the degree of atherosclerosis in the aorta and second the degree of left ventricular hypertrophy. You need to exercise caution in those patients with a heavy plaque burden in the descending aorta and arch as assessed by TEE. In patients with significant disease you should avoid retrograde perfusion from the groin for fear of dislodging embolic material. In this situation the axillary artery should be selected. Regarding patients with significant left

ventricular hypertrophy, I think you need to be aware of the vulnerability of the subendocardium and it's predilection for ischemia with low perfusion pressures with this technique. In these patients you have to keep the perfusion pressures high.

You are also correct in saying that we do not cross-clamp the aorta with our technique. It is always done under hypothermic fibrillatory arrest with high perfusion pressures to protect the heart. The techniques of repair or replacement are identical to the open technique, but as you have alluded to, special instruments are needed. We use Heartport-type graspers and needle drivers, and we have a custom handheld retractor as I have shown.

Regarding your second question about the distribution of mitral valve repair versus replacement in our series, overall there may be a slightly lower incidence of mitral valve repair than in some series. However, when you analyze the data, you see that the majority of the patients that underwent mitral valve replacement in the myxomatous category were those who had bileaflet disease. These patients are particularly challenging in most surgeons' hands and are associated with a much higher rate of failure if repair is attempted. In the ischemic group there was a tendency for more mitral valve replacements due surgeon preference issues and the current data on repair in this group. Dr Petracek who brought this procedure over from St. Thomas Hospital tends to perform more mitral valve replacements, especially in ischemics. This approach is now in vogue as we have learned that ischemic MR is really a ventricular problem rather than a valve problem and as data continues to come out that there is up to a 30% failure rate in ischemics undergoing mitral valve repair.

Online Discussion Forum

Each month, we select an article from the *The Annals of Thoracic Surgery* for discussion within the Surgeon's Forum of the CTSNet Discussion Forum Section. The articles chosen rotate among the six dilemma topics covered under the Surgeon's Forum, which include: General Thoracic Surgery, Adult Cardiac Surgery, Pediatric Cardiac Surgery, Cardiac Transplantation, Lung Transplantation, and Aortic and Vascular Surgery.

Once the article selected for discussion is published in the online version of *The Annals*, we will post a notice on the CTSNet home page (**http://www.ctsnet.org**) with a **FREE LINK** to the full-text article. Readers wishing to comment can post their own commentary in the discussion forum for that article, which will be informally moderated by *The Annals* Internet Editor. We encourage all surgeons to participate in this interesting exchange and to avail themselves of the other valuable features of the CTSNet Discussion Forum and Web site.

For May, the article chosen for discussion under the Adult Cardiac Surgery Dilemma Section of the Discussion forum is:

Endovascular Stenting for Traumatic Aortic Injury: An Emerging New Standard of Care

Sina L. Moainie, MD, David G. Neschis, MD, James S. Gammie, MD, James M. Brown, MD, Robert S. Poston, MD, Thomas M. Scalea, MD, and Bartley P. Griffith, MD

Tom R. Karl, MD
The Annals *Internet Editor*
UCSF Children's Hospital
Pediatric Cardiac Surgical Unit
505 Parnassus Ave, Room S-549
San Francisco, CA 94143-0118
Phone: (415) 476-3501
Fax: (212) 202-3622
e-mail: karlt@surgery.ucsf.edu