Is There a Role for the Left Ventricle Apical-Aortic Conduit for Acquired Aortic Stenosis?

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Background and aim of the study: **Aortic valve replacement (AVR) in patients with a heavily calcified ascending aorta and aortic root, or with conditions that preclude a median sternotomy, poses a formidable challenge. A left ventricle apical-aortic conduit (AAC) is an alternative in these situations. Herein, the authors' experience with AAC in adult patients with acquired aortic stenosis is reported.**

Methods: **Between 1995 and 2003, 13 patients (mean age 71 years) underwent AAC for severe symptomatic aortic stenosis (mean valve area 0.65 ± 0.02 cm^2). Indications for AAC were heavily calcified ascending aorta and aortic root (n = 5), patent retrosternal mammary grafts (n = 4), calcified ascending aorta and aortic root plus patent retrosternal mammary graft (n = 1), retrosternal colonic interposition (n = 1) and multiple previous sternotomies (n = 2). Seven patients had previous coronary artery bypass grafting (CABG). The mean preoperative left ventricular ejection fraction was 50 ± 4%.**

Results: **AAC were performed under cardiopulmonary bypass through a left thoracotomy (n = 10), median sternotomy (n = 2) or bilateral thoracotomy (n = 1). Hearts were kept beating (n = 5) or fibrillated (n = 7). Circulatory arrest was used in one patient. Composite Dacron conduits with biological (n = 6), mechanical (n = 4) or homograft (n = 2) valves were used. Distal anastomoses were performed in the descending thoracic aorta (n = 12) or in the left iliac artery (n = 1). Two patients underwent simultaneous CABG. Three patients died in-hospital from ventricular failure (n = 1), intravascular thrombosis (n = 1) and multi-organ failure (n = 1). The mean hospital stay was 26 days. Complications included respiratory failure requiring tracheostomy (n = 2), stroke (n = 1) and re-exploration for bleeding (n = 2). At a mean follow up of 2.1 years, there have been four late deaths; causes of death were congestive heart failure (n = 2), ischemic cardiomyopathy (n = 1) and cancer (n = 1).**

Conclusion: **AAC provides an acceptable alternative to AVR in selected patients who are at exceedingly high risk for the standard procedure.**

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Aortic valve replacement (AVR) in patients with a heavily calcified ascending aorta and aortic root (porcelain aorta), or with conditions that preclude a median sternotomy, pose a formidable challenge. The left ventricle apical-aortic conduit (AAC) has been used successfully in the past for the relief of neonatal aortic stenosis (1). The technique was initially explored conceptually by Alexis Carrel in 1910, and used clinically in the 1950s (2). Enthusiasm for the procedure peaked in the 1970s and early 1980s (3-6). The development of alternative techniques of left ventricular outflow tract (LVOT) enlargement, such as the Konno-Rastan approach, led to a decline in the frequency of AAC use (7,8).

There is, however, a group of adult patients with acquired aortic stenosis who would clearly benefit from this procedure (9). These include patients with porcelain ascending aorta and aortic root in which cross-clamping of the aorta poses a prohibitively high risk, and where the valve would also be exceedingly difficult to place secondarily to aortic root calcium. Another group of patients would be those who have undergone multiple previous cardiac operations that preclude the safe performance of a redo sternotomy. A left ventricle AAC represents an alternative approach in all of these situations.

The study aim was to examine the present authors' experience with AAC in adult patients with acquired aortic stenosis.

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Clinical material and methods

Patients

The surgical database of the Division of Cardiovascular Surgery of the Mayo Clinic Rochester, Minnesota was reviewed for adult patients who underwent left ventricle AAC for aortic stenosis. Between January 1995 and May 2003, 13 patients (mean age 71 ± 4 years; range: 35 to 86 years) underwent AAC for severe symptomatic aortic stenosis. Seven procedures were performed by one surgeon (HVS), while two surgeons each performed two procedures, and one surgeon performed one procedure. The patients' charts, operative reports, echocardiographic and cardiac catheterization files were reviewed. Patients and/or their physician were contacted for follow up.

This study was approved by the Mayo Clinic Internal Review Board, and informed consent was obtained from the participants.

The indications for AAC, demographic characteristics of the patients and their echocardiographic evaluations are listed in Table I. Data were expressed as mean (± SEM). All patients had severe aortic stenosis with a mean aortic valve area of 0.65 ± 0.02 cm^2. The mean aortic valve gradient was 42 ± 4 mmHg, and the mean left ventricular ejection fraction 50 ± 4%.

Preoperatively, all patients were symptomatic, with five in NYHA functional class IV, five in class III, and three class II. Six patients had angina.

Indications for AAC

A heavily calcified ascending aorta and aortic root (porcelain aorta) was the indication in five patients. One patient had a retrosternal colonic interposition after a failed Ivor-Lewis esophagectomy for Barrett's esophagus with high-grade dysplasia. Seven patients had previous CABG operations (six patients had one

Table I: Indications for apical aortic conduit.

Patient	Age (years)	Sex	AVA (cm^2)	AV mean gradient (mmHg)	Indications for AAC procedures	Previous cardiac surgery no. n	Procedure(s)
1	76	M	0.6	43	Calcified ascending aorta	0	
2	75	F	0.8	63	Calcified ascending aorta	0	
3	86	M	0.6	33	Calcified ascending aorta	0	
4	77	M	0.73	26	Open coronary grafts behind sternum	1	CABG
5	71	M	-	45	Open coronary grafts behind sternum. 4th sternotomy.	3	CABG
6	64	M	0.81	37	Retrosternal colonic interposition	0	
7	66	F	0.48	56	Calcified ascending aorta	0	
8	77	M	0.7	45	Calcified ascending aorta	1	CABG-Attempted AVR
9	80	F	0.9	30	Open coronary grafts behind sternum	1	CABG
10	35	F	0.4	30	Recurrent subaortic stenosis 5th sternotomy.	4	1. Partial AV Canal repair. SAS resection. 2. MVR. SAS resection. 3. Aortic valvotomy. SAS resection. 4. MVR/AVR. SAS resection
11	56	M	0.57	43	Open coronary grafts behind sternum. Graft-dependent coronary circulation. Mediastinal radiation therapy	1	CABG-Pericardiectomy
12	69	F	0.75	30	Mediastinal radiation therapy. Radiation ulcer to anterior chest wall. Previous attempted AVR via median sternotomy.	2	1. CABG 2. Attempted AVR
13	85	F	0.48	72	Open coronary grafts behind sternum. Graft-dependent coronary circulation. Calcified ascending aorta	1	CABG

AV Canal: Atrioventricular canal defect; AVR: Aortic valve replacement; CABG: Coronary artery bypass graft; MVR: Mitral valve replacement;
SAS: Subaortic stenosis.

CABG, and one had three previous CABGs). A previous AVR had been attempted in two patients. In one of these cases, surgery was aborted due to heavily ascending aortic calcification, and in the other due to dense adhesions secondary to previous mediastinal radiation. In five patients the position of the patent grafts immediately behind the sternum made redo sternotomy highly risky. Therefore, the decision was taken to perform a left thoracotomy approach. Two patients had mediastinal radiation therapy, one for breast cancer and one for lymphoma; one of these patients had severe radiation ulcers on the anterior chest wall. Severe aortic stenosis was discovered in one patient whilst undergoing reoperation for CABG through a left thoracotomy. One patient had both a heavily calcified aorta as well as a retrosternal patent mammary graft. One patient had undergone seven previous sternotomies secondary to her atrioventricular canal defect and subaortic stenosis.

Surgical technique

A left thoracotomy was performed in 10 patients, through either the 4th or 5th intercostal space. A median sternotomy was performed in two patients, and a bilateral clamshell thoracotomy through the 4th intercostal space in one patient.

All procedures were performed under cardiopulmonary bypass (CPB). The hearts were kept beating in five patients, and fibrillated in seven. Circulatory arrest was used in one patient.

Arterial cannulation was performed in the femoral artery in six patients, descending thoracic aorta in five, the right axillary artery in one patient, and the distal ascending aorta in one patient. The venous cannula was inserted in the right atrium in four patients, and in the femoral vein in nine.

Conduits used

Composite woven Dacron conduits were used with either biological valves (Hancock; Medtronic Inc., Minneapolis, MN; n = 5; Carpentier-Edwards, Edwards Lifesciences, Irvine, CA; n = 1), mechanical valves (St. Jude Medical, Minneapolis, MN; n = 4; Carbo-Seal, CarboMedics, Austin, TX; n = 1) or homograft valves (Cryolife, Inc., Marietta, GA; n = 2).

A distal anastomosis was performed first with a partial occluding clamp, usually with the patient on partial CPB. The anastomosis was performed in the descending thoracic aorta in 12 patients, and in the left iliac artery in one patient. This last patient had extensive calcification of the descending thoracic and abdominal aorta that precluded the performance of an anastomosis there. Rather, the graft was tunneled retroperitoneally.

The proximal anastomosis was performed in the left ventricular apex under full CPB in all cases. A core of left ventricle apex was removed. A rigid, right-angled connector (Medtronic Hancock Left Ventricular Connector; Medtronic Inc.) was used in 11 patients. Direct anastomosis of the graft to the left ventricle without a connector was used in two patients. Two patients underwent concomitant CABG.

Results

Morbidity and mortality

There were three early deaths. Two patients died during surgery. One of these had a previous CABG with the mammary artery graft running behind the sternum, and presented with symptomatic aortic stenosis (aortic valve area 0.9 cm^2, mean gradient 30

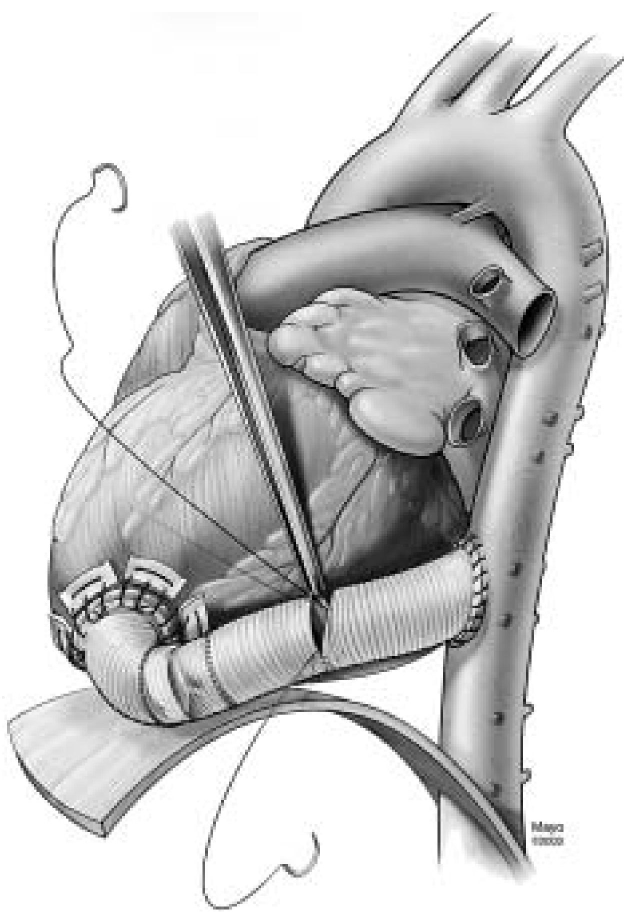

Figure 1: Apical aortic conduit technical considerations. The aortic anastomosis is constructed first. The left ventricular conduit anastomosis is constructed next. This anastomosis is made over large pledgeted sutures in the ventricular side to ensure hemostasis. No apical connector is used. The conduit valve is placed as close as possible to the ventricular apex to avoid unnecessary non-contractile space in the neo-left ventricle outflow tract. Finally, the two ends of the conduit are anastomosed together.

mmHg) and a left ventricular ejection fraction of 35%. This patient could not be weaned from CPB. The second patient was a 55-year-old male with previous mediastinal radiation and previous CABG with graft-dependent coronary circulation who was operated on for severe aortic stenosis (aortic valve area 0.57 cm^2). He underwent AAC and pericardiectomy, but developed massive intravascular thrombosis after the administration of protamine. Another patient developed heparin-induced thrombocytopenia with thrombosis of the iliac and femoral veins. He developed phlegmasia ceruleans dolens that required thrombectomy, subsequently developed sepsis, respiratory failure and multiple strokes, and died 16 days after surgery.

The mean duration of hospital stay was 26 ± 8 days. Morbidity included respiratory failure requiring tracheostomy in two patients, stroke in one patient, and re-exploration for bleeding in two patients.

Long-term follow up

Ten patients were discharged from hospital. The mean follow up was 2.1 ± 0.8 years. There were four late deaths; two occurred at four years, and one each at three years and six months after surgery. The causes of late death were heart failure (n = 2), ischemic cardiomyopathy (n = 1) and cancer (n = 1). Of the surviving patients, four were in NHYA class II, and two in class I. No hemorrhagic or thromboembolic complications related to the conduit were observed.

Echocardiograms were available in four patients after discharge. All conduits were seen to be patent, with no hemodynamically significant gradient across the valved conduit. No thrombosis of the native aortic valve was observed, although the gradient across the native aortic valve was decreased.

Discussion

Left ventricle AAC is a useful technique to relieve aortic valve stenosis when standard techniques cannot be applied. The most common situation is that of porcelain aortic root, which is defined as massive calcification of the ascending aorta from the aortic valve to the arch, precluding aortic cannulation or cross-clamping (10). In these cases, aortic cross-clamping can be associated with a high risk of dissection, hemorrhage or systemic embolization (10), and the only alternative to the AAC would be a full aortic root replacement with a composite aortic graft using either axillary, innominate or femoral artery cannulation under deep hypothermic circulatory arrest (10-14). The 30-day mortality for this approach is 9%, and the three-year survival 40% (13). In the present series, none of the patients whose indication for AAC was a porcelain aorta died perioperatively. However, the long-term mortality is high - not due to the procedure itself, but to the generalized atherosclerotic disease (14).

The second most common indication in this series was the difficult or extremely risky redo sternotomy, either because of patent coronary grafts behind the sternum, multiple previous cardiac operations, or previous mediastinal radiation therapy. In the present series, four patients had undergone previous cardiac surgery with patent mammary grafts located directly behind the sternum. Damaging those grafts during re-entry poses an unacceptable risk to the patient. One of these patients had, in addition, undergone previous mediastinal radiation therapy. Patients requiring AVR after previous CABG surgery are particularly at risk because of older age and the presence of left ventricular hypertrophy and myocardial ischemia due to severe coronary artery disease, as well as graft disease. Additional problems include that of re-entry, the ability to deliver cardioplegia, and management of previously placed grafts. Re-entry problems have been reported in 16% of the patients, and damage of the previously placed grafts had occurred in up to half of these patients (15).

The spectrum of mediastinal radiation injury is broad, extending from minor fibrosis with little or no structural effects to heavy scarring and fusion of mediastinal structures with extensive pericardial, myocardial, vascular and valvular damage (16). Operative mortality was 12% in the present group of patients, but has been reported to be as high as 40% in patients with left ventricular dysfunction and constrictive pericarditis (17).

One patient in the present series had a previous retrosternal colonic interposition. Performing a median sternotomy may result in damage of the conduit or its blood supply with the consequent risk of ischemia to the conduit or contamination of the operative field. It seems logical that the best approach for this patient with severe aortic valve stenosis would be a left thoracotomy and AAC.

Another indication for which the left ventricular AAC has been used in the past is LVOT obstruction (valvular, subvalvular and or supravalvular) with severe hypoplasia of the aortic annulus of diffuse, tunnel-like subvalvular aortic stenosis (1,18-20). Currently, most of these patients are managed with a modified Kono-Rastan operation (7,8), though for patients with multiple unsuccessful previous operations for subaortic stenosis who are not candidates for this surgery (e.g. patient #10), the AAC offers a reasonable alternative to relieve the LVOT obstruction.

Several technical aspects should be considered during the insertion of an apical aortic conduit (Fig. 1):

1. The operation can be performed either through a

median sternotomy or via a left thoracotomy. For patients with no previous cardiac operation and with only a calcific ascending aorta, the median sternotomy approach is favored. However, for patients who are at exceedingly high risk for sternotomy (redo sternotomy with patent grafts, retrosternal colonic interposition, etc.), the left posterolateral thoracotomy is preferable.

2. The distal aortic anastomosis is performed first. The Hancock valve conduit or reconstructed mechanical valve conduit is sewn to the descending thoracic aorta. It is important to measure the length of the valve conduit so that the valve is as close to the left ventricular apical segment as possible. This reduces the length of the non-contractile, neo-LVOT. A side-biting clamp is used to allow distal aortic perfusion. Partial bypass through the femoral artery maybe preferable during this time to assure good distal aortic perfusion pressure and prevent spinal and visceral hypoperfusion. Once the anastomosis has been completed, the graft is clamped, the side-biting clamp removed, the graft deaired, and hemostasis established.

3. The ventricular anastomosis is constructed next. A full CPB is instituted. The pericardium is excised anterior to the phrenic nerve, and the heart is fibrillated. A ventriculotomy is made 1 cm to the left of the anterior descending artery, with the incision beginning at the apex and extending several centimeters proximally towards the base of the heart. Care should be taken not to injure the left anterior descending artery, nor the anterior papillary muscle of the mitral valve. The anastomosis is performed with interrupted stitches of 2-0 polypropylene or braided polyester reinforced with a large circular strip of felt on the epicardial side of the anastomosis to ensure hemostasis. Although in two recent cases, the left ventricular apical rigid connector was not used, its use has been advocated in the past (4) to prevent collapse of the graft during systole. The present authors have not experienced this problem, however.

4. Finally, the two grafts are de-aired and anastomosed together. Care should be taken to evacuate all residual air from the conduit before releasing the vascular clamps.

In summary, the AAC is a reasonable alternative to standard AVR for patients in whom conditions preclude a standard surgical approach.

References

1. DiDonato RM, Danielson GK, Driscoll DJ, et al. Left ventricle-aortic conduits in pediatric patients. J Thorac Cardiovasc Surg 1984;88:82-91
2. Salter DR, Wechsler AS. Apicoaortic shunts for left ventricular outflow obstruction. Ann Thorac Surg 1986;42:607
3. Brown JW, Kirsh MM, Salles CA. Extraanatomical bypass of the aortic root: An experimental technique. Ann Thorac Surg 1977;24:433-438
4. Brown JW, Brymer JF, Dunn JM, Kirsh MM. Simultaneous treatment of aortic stenosis and coarctation by left thoracotomy with apical aortic conduit. Ann Thorac Surg 1978;25:364-367
5. Cooper R, Ergin MA, Golinko R, Griepp RB, LaCorte M. Experience with left ventricular apicoaortic conduits for complicated left ventricular outflow obstruction in children and young adults. Ann Thorac Surg 1981;32:369-376
6. McGoon, Dwight C. Left ventricular and biventricular extracardiac conduits. J Thorac Cardiovasc Surg 1976;72:7-14
7. Konno S, Imai Y, Iida Y, et al. A new method for prosthetic valve replacement in congenital aortic stenosis associated with hypoplasia of the aortic valve ring. J Thorac Cardiovasc Surg 1975;70:909-917
8. Rastan H, Abu-Aishan N, Rastan D, et al. Results of aortoventriculoplasty in 21 consecutive patients with left ventricular outflow tract obstruction. J Thorac Cardiovasc Surg 1978;75:659-669
9. Absi TS, Cooley DA, Lopez RM. Apicoaortic conduit for left ventricular outflow tract obstruction: Revisited. Ann Thorac Surg 2000;69:1511-1514
10. Byrne JG, Aranki SF, Cohn LH. Aortic valve operations under deep hypothermic circulatory arrest for the porcelain aorta: 'No-touch' technique Ann Thorac Surg 1998;65:1313-1315
11. Banbury MK, Cosgrove DM, III. Arterial cannulation of the innominate artery. Ann Thorac Surg 2000;69:957.
12. Markowitz A. Utility of the full root bioprosthesis in surgery for complex aortic valve-ascending aortic disease. Semin Thorac Cardiovasc Surg 2001;13:12-15
13. Kouchoukos NT, Wareing TH, Daily BB, Murphy SF. Management of the severely atherosclerotic aorta during cardiac operations. J Cardiac Surg 1994;9:490-494
14. Rokkas CK, Kouchoukos NT. Surgical management of the severely atherosclerotic ascending aorta during cardiac operations. Semin Thorac Cardiovasc Surg 1998;10:240-246
15. Odell JA, Mullany CJ, Schaff HV, Orszulak TA, Daly RC, Morris JJ. Aortic valve replacement after previous coronary artery bypass grafting. Ann Thorac Surg 1996;62:1424-1430
16. Hancock SL, Tucker MA, Hoppe RT. Factors affecting late mortality from heart disease after treatment of Hodgkin's disease. JAMA 1993;270:1949-1955
17. Handa N, McGregor CG, Danielson GK, et al. Valvular heart operation in patients with previous

mediastinal radiation therapy. Ann Thorac Surg 2001;71:1880-1884
18. Van Son JA, Danielson GK, Puga FJ, et al. Supravalvular aortic stenosis. Long term results of surgical treatment. J Thorac Cardiovasc Surg 1994;107:103-115
19. Frommelt PC, Rocchini AP, Bove EL. Natural history of apical left ventricular to aortic conduits in pediatric patients. Circulation 1991:84(5 Suppl.):III-213-III-218
20. Bernhard WF, Poirier V, LaFarge CG. Relief of congenital obstruction to left ventricular outflow with a ventricular-aortic prosthesis. J Thorac Cardiovasc Surg 1975;69:223-229

Meeting discussion

DR. DAVID BACH (Michigan, USA): You had one patient who died of cancer in late follow up, and one whose indication for surgery was a colonic interposition for esophageal cancer. Was it the same patient?
DR. KENTON J. ZEHR (Rochester, Minnesota, USA): No, it was not the same patient. The colonic interposition person is now at about two years' follow up, and is doing well.
DR. ROBERT W.M. FRATER (Bronx, New York, USA): Do you sometimes remove a porcelain aorta and put a conduit in?
DR. ZEHR: We have had variable luck with that procedure. Historically, Dr. Kouchoukos replaced porcelain aortas with a composite graft and subsequent coronary grafting. We have done this as well. The patients in this series were unique in the sense that some were redos as well as having a porcelain aorta. One 85-year-old woman had not only a porcelain aorta but also a right internal thoracic artery behind the sternum. Her left internal thoracic artery was also stuck to the sternum, and she had occluded natives. In a patient like that, few people would relish the thought of re-entering through a median sternotomy. That woman was actually quite easily treated through a left thoracotomy - she only stayed 10 days in hospital postoperatively.
DR. FRATER: Do you have a level of porcelain aorta that you will tackle in a conventional way?
DR. ZEHR: Absolutely. We only have done 13 patients over 10 years. This is our entire adult series of this type of a procedure. We have many aortas that we tackle in a standard fashion.
DR. JOSEPH M. FORBESS (Atlanta, Georgia, USA): In the LVAD world, when we have connected the left ventricular apex to the descending aorta, thrombus formation has occurred on top of the native aortic valve. Have you noticed any thrombus formation on top of the native aortic valve?
DR. ZEHR: No, we haven't - nor have we had any stroke problems. The conduit and valve are hard to image - it is right under the costochondral cartilages on the left side. Transthoracic imaging doesn't work well because you cannot window between the ribs. And with TEE, you're too far away to image the valve. You can image the outflow conduit nicely into the aorta, but you cannot image the valve very well - particularly if it's a mechanical valve.
DR. FORBESS: I was talking about the native aortic valves - presumably you had stenosis for the majority of these patients?
DR. ZEHR: Yes. I'm familiar with your referring to the Jarvik experience of putting it in the descending aorta - and getting a kind of a sludging in the ascending aorta. We haven't looked at that very closely.
DR. S. SZENTPETERY (USA): What was the reason for performing a mid-sternotomy on these patients, when you thought the operation was mainly for patients in whom you could **not** do a mid-sternotomy?
DR. ZEHR: I have to answer that on behalf of another surgeon. Those patients were the ones who had an absolute porcelain aorta, and the surgeon did not want to perform a composite replacement under circulatory arrest. So, they were operated on through a median sternotomy. The initial approach was in the standard fashion. A left apical-aortic conduit was carried out because of the degree of calcium in the aorta.
DR. GIDEON MERIN (Jerusalem, Israel): Your series is very small, and in two years' time, 50% of the patients will probably have died, considering the operative and postoperative mortalities. What do you tell such a patient if you consider AAC to be a valid option for surgery?
DR. ZEHR: We are operating on these cases in highly selected patients, but they are sick patients and usually hospitalized. Some are in congestive heart failure and are not going home without any surgery. So certainly, an argument can be made for not operating on some patients - there are more than 50% who will live long-term, and these are the ones who have usually seen various surgeons and been turned down several times. In highly selected patients, we have had good results.
DR. FRIEDRICH W. MOHR (Leipzig, Germany): I am interested in the hemodynamics. If you examine with echo, what is the transport function through the native aortic valve postoperatively, how much blood goes through the left ventricular outflow tract, and how does the left ventricular mass remodel or reduce after such an intervention compared with a standard aortic valve replacement? Do you have any idea? You had some very young patients, only 25 years old?
DR. ZEHR: I can't really answer about left ventricular remodeling, but I can say that we had variable degrees

of aortic stenosis, so native ejection occurred in some of the patients. We were very careful to exclude any patient with aortic regurgitation, so that was not a problem. But some of the patients had completely shut down the native valve postoperatively- we had a patient with a 0.4 square cm valve area who had no postoperative flow through her native aortic valve. But now, on echo it all comes up through the T in the descending thoracic aorta. The patient is alive and doing well. So these patients do manage. Certainly, with our left ventricular assist devices we can radically alter the flow of blood, even when it is brought to the ascending aorta. This method is certainly consistent with survival, but I have no data on whether left ventricular mass regression occurs, or the like.

DR. MOHR: In our LVAD patients, we have complete decompression, and we sometimes see valvular thrombosis at the aortic valve site. Does anything occur in your patients?

DR. ZEHR: We have not imaged them that closely to know. As mentioned, we have observed patients with no native aortic valve flow.