SURGERY FOR ACQUIRED CARDIOVASCULAR DISEASE

THE ATHEROSCLEROTIC AORTA AT AORTIC VALVE REPLACEMENT: SURGICAL STRATEGIES AND RESULTS

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Background: Aortic valve replacement in patients with severe atherosclerosis of the ascending aorta poses technical challenges. The purpose of this study was to examine operative strategies and results of aortic valve replacement in patients with a severely atherosclerotic ascending aorta that could not be safely crossclamped.

Patients and methods: From January 1990 to December 1998, 4983 patients had aortic valve surgery; of these, 62 (1.2%) patients had a severely atherosclerotic ascending aorta and required hypothermic circulatory arrest to facilitate aortic valve replacement. They form the study group.

Results: All patients had hypothermic circulatory arrest, but several different strategies were used to manage the ascending aorta. These techniques included aortic valve replacement with the use of hypothermic circulatory arrest (39%), ascending aortic endarterectomy (26%), ascending aortic replacement (19%), aortic inspection and crossclamping during hypothermic circulatory arrest (10%), and balloon occlusion of the ascending aorta (6%). Duration of hypothermic circulatory arrest was substantially longer for patients having aortic valve replacement with hypothermic circulatory arrest than for all other strategies. Hospital mortality was 14%, and 10% of patients had strokes. Increasing New York Heart Association functional class and impaired left ventricular function were risk factors for hospital mortality. Choice of operative technique did not influence patient outcome; however, no patient who underwent replacement of the ascending aorta had a stroke.

Conclusions: Aortic valve replacement in patients with severe atherosclerosis of the ascending aorta is associated with increased operative morbidity and mortality. Complete aortic valve replacement during hypothermic circulatory arrest, the "no-touch" technique, requires a prolonged period of circulatory arrest. Ascending aortic replacement is a preferred technique, as it requires a short period of hypothermic circulatory arrest and results in comparable mortality with a low risk of stroke. (J Thorac Cardiovasc Surg 2000;120:957-65)

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Aortic atherosclerosis and calcification complicate cardiac surgery. In patients with severe atherosclerosis of the ascending aorta, coronary artery bypass grafting (CABG) can be done without cardiopulmonary bypass (CPB) and mitral and tricuspid valve surgery can be performed without aortic clamping. Unfortunately, no such options are available for patients who require aortic valve surgery. Therefore, aortic valve surgery in the patient with severe atherosclerosis of the ascending aorta requires modifications of techniques for CPB and cardiac arrest. The optimal approach for aortic valve surgery in such patients is unknown. The purpose of this study was to examine operative strategies and results of aortic valve replacement (AVR) in patients with a severely atherosclerotic ascending aorta that could not be safely crossclamped.

Patients and methods

Patients. From January 1990 to December 1998, 4983 patients had aortic valve surgery at The Cleveland Clinic Foundation. Operative reports were reviewed to identify those patients in whom hypothermic circulatory arrest (HCA) was used to manage a severely atherosclerotic ascending aorta at AVR. Sixty-two such patients (1.2%) were identified, and they form the study group. Patients with ascending aortic dissection or aortic aneurysm were excluded. Similarly, patients (not specifically identified) who had ascending aortic atherosclerosis and who did not have HCA were not part of the study.

Mean age was 72 ± 8 years (range 37-87 years); 55% were male. Forty-five percent had pure aortic stenosis, and 55% had mixed aortic stenosis and aortic regurgitation. Eighty-two percent of patients had coronary artery disease, and 43% had other valvular heart lesions. Left ventricular function was normal in 45%, mildly depressed in 16%, moderately depressed in 14%, moderately to severely depressed in 13%, and severely depressed in 10%; in 1 patient, left ventricular function could not be determined. Twenty-five (40%) patients had previous cardiac surgery, including CABG in 18. Three patients had 2 previous cardiac operations, and 3 patients had median sternotomy and an aborted procedure when aortic calcification was recognized. Eight patients had a history of mediastinal irradiation. Comorbid conditions are listed in Table I.

Aortic atherosclerosis was suspected preoperatively in only 50% of patients. All patients had preoperative chest radiographs, cardiac catheterization, and transthoracic echocardiograms. Additional preoperative studies included transesophageal echocardiography (5 patients), chest computed tomographic scan (7 patients), and thoracic magnetic resonance imaging (2 patients).

Definitions. *Stroke* was defined as a permanent neurologic deficit not present preoperatively and persisting at the time of hospital discharge. *Perioperative myocardial infarction* was defined as the appearance of new Q waves on the electrocardiogram or elevation of cardiac enzymes. *Postoperative ventilatory insufficiency* was defined as the need for mechanical ventilation for more than 48 hours after the operation.

Data analysis. The Fisher exact test and univariate logistic regression analyses were performed to detect predictors of operative mortality or stroke because the number of events was too small for multivariable analyses to be performed. The Kruskal-Wallis test was used to compare the operative techniques with respect to durations of HCA and CPB. All statistical testing was conducted with the use of 2-sided alternatives with a type I error level of .05. Unless otherwise specified, all values are expressed as mean ± standard deviation.

Results

Intraoperative evaluation of the aorta included palpation (100%), transesophageal echocardiography (79%), and epiaortic echocardiography (13%). In each case the surgeon judged that the aorta could not be safely crossclamped. The pathology of the ascending aorta was classified as an "eggshell" or "porcelain" aorta in 18%, diffuse calcification in 66%, and noncalcified atheromata in 14%.

Although the ascending aorta or aortic arch was cannulated in 34%, the majority of patients had alternate sites of arterial cannulation; these included the femoral artery (34%), the axillary artery (24%), and the innominate artery (8%). All patients had AVR, and the aortic prostheses implanted included the following: Carpentier-Edwards bioprostheses (79%, Baxter Healthcare Corp, Newport Beach, Calif), St Jude Medical mechanical prostheses (18%, St Jude Medical, Inc, St Paul, Minn), and allograft aortic root (3%, CryoLife, Inc, Kennesaw, Ga). Fifty-eight percent of patients had concomitant procedures (Table II). A period of HCA was used in each case to facilitate AVR. Five different strategies were used in conjunction with HCA (Table III). The most common approach included excision of the native aortic valve and prosthetic valve replacement during a prolonged period of HCA (24 patients, 39%). Strategies that included definitive treatment of ascending aortic atherosclerosis were aortic endarterectomy (16 patients) and ascending aortic replacement (12 patients) (Fig 1). In 6 patients, inspection of the aorta during HCA revealed a safe spot for aortic clamping. In 4 patients, a Foley catheter was introduced through the aortotomy during a brief period of HCA; the balloon was then inflated, CPB resumed, and AVR performed during rewarming.

Mean duration of HCA for the entire group was 28 ± 24 minutes, with a range of 1 to 100 minutes. The duration of HCA was greatest in patients having AVR with HCA (Table III). Mean duration of CPB was 159 ± 64 minutes; the differences in CPB times among groups were no greater than expected by chance (*P* = .64). Mean nasopharyngeal and core temperatures at the ini-

Table I. *Comorbid conditions in 62 patients with ascending aortic atherosclerosis*

*Condition**	*No.*	*%*
Peripheral vascular disease	35	56
Carotid stenosis	22	35
Previous stroke	7	11
Hypertension	29	47
Chronic obstructive pulmonary disease	18	29
Diabetes mellitus	14	22
Chronic renal insufficiency	9	14
Mediastinal radiation therapy	8	13

*Conditions are not mutually exclusive.

Table II. *Concomitant procedures in patients having AVR*

Procedure	*No.*
CABG	27
CABG and carotid endarterectomy	3
CABG and MVR	1
CABG and aortic root enlargement	3
Myectomy and aortic root enlargement	1
Mitral valve debridement	1

AVR, Aortic valve replacement; *CABG*, coronary artery bypass grafting; *MVR*, mitral valve replacement.

Table III. *Management of the ascending aorta during HCA*

Variable	*AVR during HCA*	*Aortic endarterectomy*	*Ascending aortic tube graft*	*Inspect and crossclamp*	*Balloon occlusion*
No.	24	16	12	6	4
HCA (min)	54 ± 18*	13 ± 6	17 ± 6	4 ± 5	5 ± 4
Stroke†	4 (17%; 9%-28%)	2 (12%; 4%-27%)	0 (0%; 0%-15%)	0 (0%; 0%-27%)	0 (0%; 0%-38%)
Mortality†	3 (12%; 6%-24%)	3 (19%; 8%-34%)	3 (25%; 11%-44%)	0 (0%; 0%-27%)	0 (0%; 0%-38%)

HCA, Hypothermic circulatory arrest; *AVR*, aortic valve replacement.
*$P < .001$ versus other techniques.
†Presented as number, percent, and 70% confidence limits.

tiation of HCA were 18°C ± 3°C and 21°C ± 4°C, respectively; the differences among groups were no greater than expected by chance ($P = .69$). Retrograde cerebral perfusion during HCA was used in 38 patients (61%). Cardioplegia techniques included retrograde cardioplegia (76%), retrograde and antegrade cardioplegia (13%), antegrade cardioplegia (3%), and no cardioplegia (8%).

Nine postoperative deaths occurred, a hospital mortality of 14%. This compares with a hospital mortality of 0.5% for isolated AVR in our institution. Causes of death included myocardial infarction (5 patients), pneumonia (2 patients), prosthetic valve endocarditis (1 patient), and atheroembolic shower (1 patient). Increasing New York Heart Association functional class ($P = .02$), impaired left ventricular function ($P = .02$), and history of abdominal aortic aneurysm ($P = .05$) were risk factors for hospital mortality. Choice of operative technique did not influence hospital mortality ($P = .70$). There was a trend toward increased hospital mortality in patients with a porcelain or eggshell aorta ($P = .08$).

Hospital morbidity is detailed in Table IV. Six (10%) patients had perioperative strokes, and 3 died. These included embolic strokes identified by computed tomographic scan in 5 patients and a diffuse anoxic insult in 1 patient. Risk factors for stroke included abdominal aortic aneurysm ($P = .02$) and porcelain aorta ($P = .07$). Although 4 of the 6 strokes occurred in patients having femoral arterial cannulation, the site of arterial access did not emerge as a risk factor for stroke ($P = .4$) or death ($P = .9$). Although strokes were limited to patients having AVR with HCA and aortic endarterectomy, statistical analysis revealed that the risk of stroke was independent of procedure-related variables. Nine (14%) patients had transient confusion that cleared by the time of hospital discharge. The most common complication was postoperative ventilatory insufficiency, which occurred in 19 patients (31%); 2 of these patients required tracheostomy.

As noted previously, 11 patients (18%) had a circumferentially calcified eggshell or porcelain aorta. Management strategies varied in these patients and included AVR with HCA (4 patients), aortic endarterectomy (2 patients), ascending aortic tube graft (3 patients), balloon occlusion (1 patient), and inspection followed by crossclamp application distal to the calcium (1 patient). In general, a localized endarterectomy was necessary to facilitate the aortic suture line. Patients with a porcelain aorta had a particularly high morbidity and mortality, with 3 of 11 dying in the hospital and 3 having strokes.

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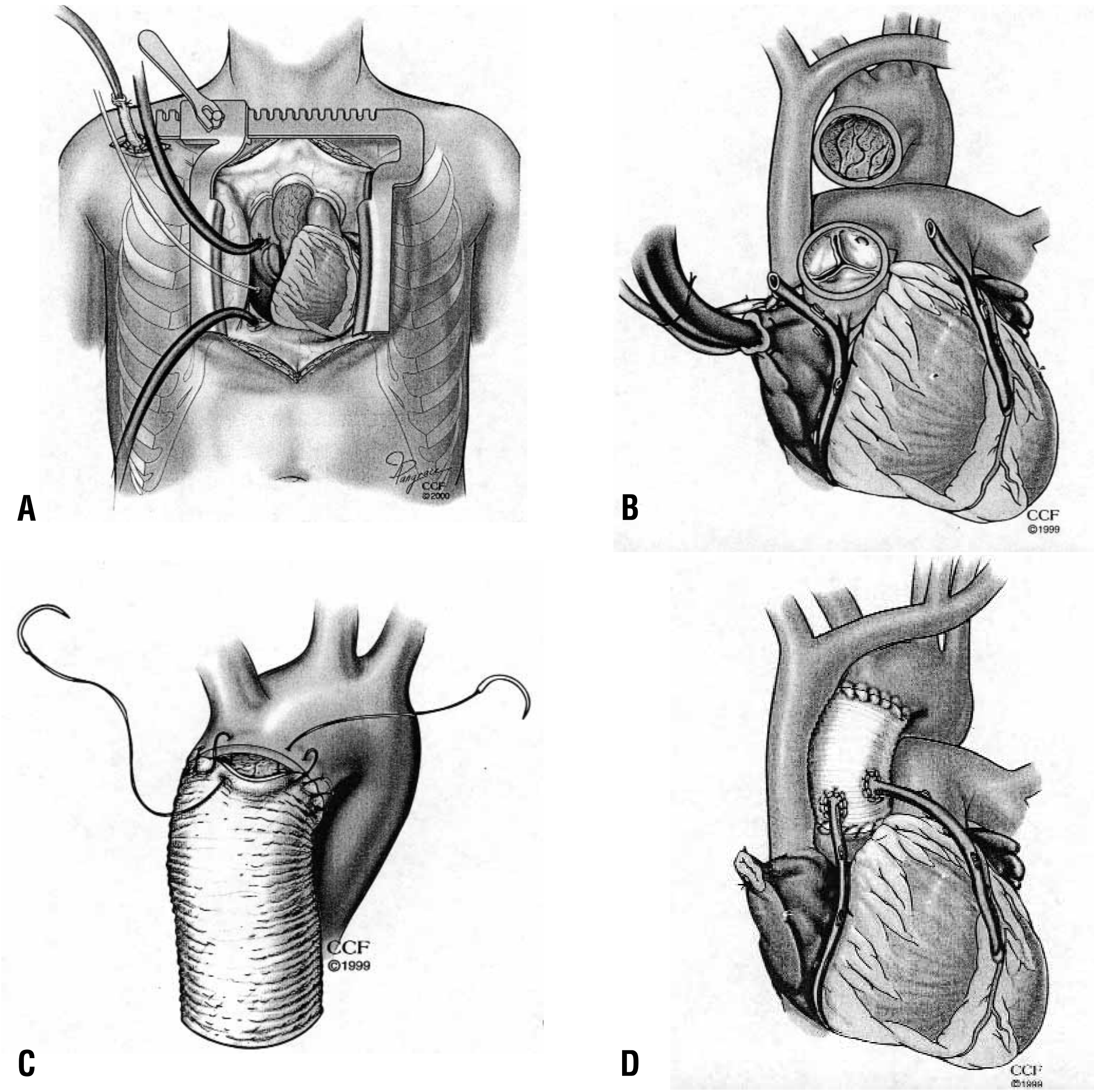

Fig 1. Technique for replacement of the ascending aorta with HCA. **A,** CPB is established via a cannula placed in a 6- or 8-mm Dacron graft sewn to the axillary artery and cannulas in the superior and inferior venae cavae. A retrograde cardioplegia catheter is placed through the right atrium. **B,** Distal coronary anastomoses are completed during systemic cooling. When the systemic temperature is 18°C, the circulation is arrested. Retrograde cerebral perfusion via the superior vena cava is at 200 to 400 mL/min. The diseased aorta is excised. **C,** The distal anastomosis is completed during HCA. Systemic perfusion is then reinstituted and the graft is clamped. **D,** The proximal aortic anastomosis and proximal coronary anastomosis are completed during rewarming.

Comment

Atherosclerosis of the ascending aorta and aortic arch is an important cause of embolic disease, and the presence of atherosclerotic plaques in the ascending aorta and proximal arch is a risk factor for ischemic stroke.[1-4] In a landmark study, Blauth and coworkers[1] demonstrated the importance of atheroembolism from the ascending aorta in patients having cardiac operations. Their review of autopsy findings in 221 patients having cardiac surgery revealed that 22% had atheroemboli, with the brain being the most commonly affected site. Of particular interest, atheroembolic events occurred in 37% of patients with severe disease of the ascending aorta but in only 2% of patients without important ascending aortic disease.

While Blauth and coworkers[1] have identified the importance of ascending aortic atherosclerosis in the patient having cardiac surgery, appropriate management of this condition is predicated on the surgeon's recognition of the aortic disease. Preoperative patient profiles are of limited utility in predicting the likelihood of ascending aortic atherosclerosis. Increased patient age is the most consistent risk factor for the condition.[1,5-7] One third of patients older than 80 years who undergo cardiac surgery have important ascending aortic atherosclerosis.[5] Other documented risk factors include carotid artery disease, abdominal aortic aneurysm, left main coronary artery disease, diabetes, hypertension, and history of cerebral emboli of unknown source.[1,6-10] Unfortunately, the majority of patients undergoing cardiac surgery have one or more of these conditions. On occasion, ascending aortic calcification may be recognized on the chest x-ray film or during cardiac catheterization[10]; however, these studies identify moderate to severe ascending aortic atherosclerosis in only one quarter of affected patients.[7,9] Gentle palpation of the ascending aorta is useful to detect extensive calcification. However, in a study of 500 patients, Wareing and associates[9] found palpation an insensitive technique, identifying significant atheromatous disease in only 38% of affected patients and underestimating its severity routinely. Although King and associates[11] demonstrated that chest computed tomographic scans were very accurate in predicting severe atheromatous disease and the need for HCA, it is impractical to obtain such scans in all patients at risk.

Echocardiography has emerged as a useful technology for detection of ascending aortic atherosclerosis. Transesophageal echocardiography is more sensitive than palpation for the detection of atheromatous disease of the ascending aorta.[12] Protruding atheromata detected by transesophageal echocardiography are a risk factor for stroke in elderly patients undergoing CPB.[12] However, even with multiplane transesophageal echocardiography, it is difficult to detect disease in the distal ascending aorta, the usual site for cannulation and aortic clamping.[6,9] Epiaortic echocardiography does not have this limitation, and this modality is the most sensitive technique for detecting ascending aortic atherosclerosis. In a study of 100 consecutive patients having cardiac surgery, Sylivris and colleagues[6] detected ascending aortic disease in 16% by palpation and in 90% by epiaortic ultrasonography. These authors also found that epiaortic ultrasonography was more sensitive than transesophageal echocardiography for examining the mid and distal ascending aorta. Davila-Roman,[7] Wareing,[8,9] and their associates from Washington University have the greatest experience with epiaortic ultrasonography and they report similar results. They recommend intraoperative ultrasound scanning in all patients 70 years of age or older undergoing cardiac operations. Ohteki and coworkers[13] have demonstrated that epiaortic ultrasound is more sensitive than preoperative computed tomographic scanning. Although infrequently used in the current series, epiaortic ultrasound is the technique of choice for detection of ascending aortic atherosclerosis.

Table IV. *Postoperative morbidity*

Morbidity	*No.*	*%*	*CL*
Stroke	6	10	6-15
Confusion	9	15	10-21
Ventilatory insufficiency	19	31	24-38
MI	5	8	5-13
Wound infection	5	8	5-13
Reoperation for bleeding	4	6	3-11
Renal failure	2	3	1-7
Ventricular tachycardia	1	2	0.2-5

CL, 70% confidence limits; *MI*, perioperative myocardial infarction.

When a severely atherosclerotic ascending aorta is recognized before institution of CPB, alteration of perfusion and crossclamping techniques decreases the risk of stroke. Wareing and associates[8] reported a 6% occurrence of stroke in patients with moderate to severe atherosclerosis of the ascending aorta who had minor modifications in operative technique; in contrast, similar patients who had ascending aortic replacement had no strokes. Patients who have ascending aortic atherosclerosis and require isolated CABG can be treated by a variety of techniques. Mills and Everson[10] have described CABG with CPB and without aortic clamping. They used the left internal thoracic artery for inflow with multiple T and Y grafts. Other approaches that use CPB include construction of proximal anastomoses during a brief period of HCA,[14] aortic endarterectomy,[15] and replacement of the ascending aorta with a tube graft.[16] All of these techniques entail aortic manipulation. In contrast, off-pump CABG with the internal thoracic arteries used for inflow avoids all aortic manipulation; therefore, this technique may be preferred when feasible.

Unlike coronary artery surgery, aortic valve procedures require both CPB and aortic manipulation. AVR in patients with severe atherosclerosis of the ascending aorta requires either aortic clamping or a period of HCA. Several reports describe techniques for managing aortic valve disease in limited numbers of these patients. Coselli and Crawford[17] and Byrne, Aranki, and Cohn[18] have described a "no-touch" technique for such patients. An alternate site for arterial cannulation is chosen, the patient is cooled, and AVR is performed during a period of HCA. Although this approach was successful in these 2 reports of small numbers of patients, the duration of HCA ranged from 38 to 65 minutes. Opting for a different strategy, Svensson and coworkers[19] reported successful aortic endarterectomy to facilitate AVR in 6 patients with a calcified ascending aorta. They and others have not observed aortic dilatation after aortic endarterectomy, but long-term follow-up is unavailable.[19,20] Wareing and colleagues[8] have reported excellent results with replacement of the ascending aorta in patients with aortic atherosclerosis who require AVR. Others, however, consider this too extensive a procedure[18] and have been unable to duplicate their results.[11] Cosgrove[21] reported balloon occlusion of the ascending aorta after performing an aortotomy with the aid of HCA; this requires a very brief period of HCA, but there may still be the risk of dislodging emboli.[18]

The preceding reports describe small numbers of patients having AVR in the setting of an atherosclerotic calcified aorta, and no larger series comparing different surgical strategies have been reported. The purpose of this study was to examine operative strategies and results in a large series of patients with ascending aortic atherosclerosis who required AVR. In this group of patients with aortic valve disease and severe ascending aortic atherosclerosis, operative morbidity and mortality were high. This may be attributed in part to the high proportion of reoperations and comorbid conditions, such as radiation heart disease. However, it is likely that ascending aortic and diffuse atherosclerosis coupled with the magnitude of the surgical procedures were the major causes for increased operative risk.

Although all patients had HCA, 5 different strategies were used to manage the ascending aorta. The most commonly used strategy was AVR during HCA with a "no-touch" technique as described by Coselli and Crawford[17] and Byrne, Aranki, and Cohn.[18] This approach required an HCA period far longer than for the other techniques. There was some success with aortic endarterectomy; however, this procedure may be associated with dislodgment of atherosclerotic debris, and the long-term fate of the thinned aorta is unknown.[20] In a few patients, inspection of the aorta during HCA revealed a safe spot for aortic clamping; this is a favorable situation, but it was uncommon in our experience. Balloon occlusion was also a successful strategy for the few patients in whom it was used.

Like Kouchoukos and associates,[16] we presently favor ascending aortic replacement with a tube graft in patients who require AVR and have a severely and diffusely atherosclerotic ascending aorta. Advantages of this technique include absence of aortic manipulation before HCA, resection of the diseased segment of aorta, and a relatively brief period of HCA. Although the differences in mortality and stroke between patients based on surgical technique could be due to chance, no patient with ascending aortic replacement had a stroke. Recent adjuncts, including axillary artery cannulation and retrograde cerebral perfusion, may further improve the results of this technique. In a series of 47 patients with coronary disease who had ascending aortic replacement, Kouchoukos and associates[16] reported a 4% mortality and no strokes. We believe that future study of larger numbers of patients having AVR with this technique is likely to demonstrate advantages to this approach.

Limitations

This is an observational clinical study examining patients in whom HCA was used to facilitate AVR in the setting of a severely atherosclerotic ascending aorta. Operative techniques were chosen by the surgeon in a nonrandomized fashion. Patients with severe ascending aortic atherosclerosis who did not have HCA were not identified; therefore, we cannot compare morbidity and mortality in such patients with those in patients who did have HCA. Although epiaortic echocardiography is now used routinely in the evaluation of patients with ascending aortic atherosclerosis, in the current series such patients were in the minority. The majority of patients had aortic calcification that was detectable by palpation, and it is likely that the severity and extent of ascending aortic atherosclerosis were underestimated. Patients with ascending aortic atherosclerosis who did not have HCA were not included in this report; thus, the impact of HCA in these patients cannot be analyzed. Finally, the relatively small number of patients in this report precluded multivariable analysis with adjustments for possible differences among the patients in various subgroups. Our ability to determine the superiority of one surgical technique over another was thereby limited.

Conclusion

AVR in patients with severe atherosclerosis of the ascending aorta is associated with increased operative morbidity and mortality. Complete AVR with HCA, the "no-touch" technique, requires a prolonged period of HCA and does not prevent strokes. Ascending aortic replacement is a preferred technique, as it requires a short period of HCA and results in comparable mortality with a low risk of stroke.

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Discussion

Dr Nicholas T. Kouchoukos *(St Louis, Mo).* In a retrospective analysis, Dr Lytle and his colleagues have identified 62 patients undergoing AVR in whom HCA was used for management of a severely atherosclerotic ascending aorta. The patients were elderly, had a high prevalence of coronary artery disease, and had a substantial prevalence of other valvular lesions, abnormal ventricular function, and previous cardiac operations. Although porcelain or calcified aortas were discussed, noncalcified atheromatous lesions were present in 14% of these patients. In our experience, these "soft" lesions are the most dangerous and can only be identified accurately by epiaortic scanning.

The technique that Lytle and his colleagues used most frequently for management of these problems was AVR during a period of HCA. This was associated with the highest incidence of stroke, 17%, although the differences between this stroke rate and those observed with the other techniques were not statistically significant. A substantially longer period of HCA, which averaged 54 minutes, was required for this technique as compared with the other 4 techniques.

Because of this and because of the lower stroke rate with ascending aortic replacement (which was actually zero) and an early mortality comparable with the other 2 commonly used techniques, the authors recommend ascending aortic replacement as the method of choice for managing patients with severe atherosclerosis of the ascending aorta.

Unfortunately, or perhaps fortunately, because of the low prevalence of atherosclerotic disease in patients with aortic valvular disease or coronary disease, no single center has accumulated a large experience. In this series of almost 5000 cases of aortic valve surgery that Lytle and his colleagues reviewed, only 62 cases of severe atherosclerosis of the ascending aorta were identified.

In our own experience with epiaortic scanning, which began in 1987, we have identified only 84 patients over the age of 50 with severe aortic atherosclerosis from a cohort of 4200 patients who were scanned. This represents approximately 2% of the group. In our series, all but 1 of the patients underwent complete or partial ascending aortic replacement with HCA. All underwent CABG and a substantial percentage required valve replacement or other procedures, including carotid endarterectomy, an experience that is not dissimilar from that described by Dr Lytle. The 30-day mortality was 8% and the stroke rate was 3.6%.

I agree with Dr Lytle that these patients are at increased risk primarily because of the complexity of the procedures and the presence of comorbid conditions. Atherosclerosis of the ascending aorta has consistently been shown to be a marker for diffuse atherosclerosis.

So that the optimal strategy for management of such patients can be determined, a multicenter study involving large numbers of patients will be needed. I hope such a study can be designed and implemented in the near future.

I have 3 questions for Dr Lytle. If you are now using epiaortic scanning routinely, has the frequency with which a severely atherosclerotic aorta is detected increased or decreased? It is conceivable that the number of cases detected might increase, but at the same time the number of patients who required HCA might decrease because of the ability of epiaortic scanning to identify areas where cannulas and clamps can be safely placed on the ascending aorta.

Do you manage patients undergoing AVR with severely atherosclerotic aortas any differently from the way you manage patients undergoing CABG who also have severely atherosclerotic aortas and in whom attachment of grafts to the ascending aorta is necessary?

How do you manage the patient with a calcified ascending aorta who has severe aortic regurgitation during the period of cooling that is required to establish HCA?

Dr Lytle and his colleagues have addressed a very important and persisting problem in cardiac surgery that is likely to increase in frequency in the future, and they have identified a strategy for management, given the present state of knowledge, that I agree is the appropriate one.

Dr Lytle. Thank you very much, Dr Kouchoukos. First of all, I would remind the audience that all of these patients were undergoing AVR. The reason that we chose patients undergoing AVR to review is that we were forced to deal with the aorta and CPB. For patients who have isolated coronary artery disease, there are numerous strategies that can be used, including off-pump surgery and bringing grafts off of patent arterial grafts. Therefore, the options are many for patients with isolated coronary artery disease. We have occasionally used deep hypothermia, circulatory arrest, and AVR for patients undergoing isolated coronary surgery, usually in the face of this very soft atheromatous disease and in situations in which the patients had extensive coronary artery disease and needed numerous CABGs.

We do not routinely use epiaortic studies but almost routinely use transesophageal echocardiography. Transesophageal echocardiography does not always give us all the information we need, but it alerts us to the problem of ascending aortic atherosclerosis, and then we will do epiaortic echocardiography to look at the details of the distal ascending aorta and aortic arch. When the aorta is atherosclerotic, we commonly will cannulate the axillary or innominate artery.

The management of a patient with a very bad aorta who also has very severe aortic insufficiency is a major problem. What we will usually do is try to get the patient as cold as we can and use an atrioventricular vent to try to keep the left ventricle from becoming distended. At times we end up having to use circulatory arrest at a temperature that is not as low as I described. We may be able to cool to 25°C, for example, when the heart arrests and aortic insufficiency overwhelms the vent and forces circulatory arrest. Fortunately, the replacing the aorta at some point just proximal to the innominate artery usually does not take much time. During HCA, we use retrograde cerebral perfusion that is 14°C to 15°C, and with a short period of arrest that appears to work out with reasonable cerebral protection.

Dr Denton A. Cooley *(Houston, Tex).* A direct surgical approach can be used for most patients with calcific disease of the ascending aorta and arch. In some patients, however, an indirect approach may be used with success and without the complexity of HCA and the threat of cerebral complications. We have recently devised a simple technique of apicoaortic bypass through an anterolateral thoracotomy incision, entering the fifth intercostal space, for patients with severe and complex disease of the left ventricular outflow. I will attempt to describe what we have done.

In the first step, a valve-containing conduit is attached to the descending aorta and hemostasis is secured. We have used a St Jude Medical valve.

In the second step, CPB is begun with femoral venous and arterial cannulation. The apex of the left ventricle is exposed to allow attachment of a standard, rigid, right-angled fabric-covered conduit with an attached sewing ring. We have used the Medtronic left ventricular connector. Ventricular fibrillation is induced, the apex is cored, and the graft is attached with sutures.

In step 3, the 2 grafts are then anastomosed and ventricular function is restored, usually by means of a countershock.

Recently, we have used this simplified technique of apicoaortic bypass in 7 patients who had a variety of left ventricular outflow problems. The technique was used successfully to treat 2 patients with so-called porcelain aortas, densely calcified sinuses of Valsalva, and severe aortic stenosis. In both patients exploration had been done by highly competent surgeons in other institutions. The other 5 patients also had complex cases of outflow tract obstruction and numerous comorbidities, including previous mediastinal irradiation. All of the patients in the series had undergone previous cardiac surgery; most had undergone multiple conventional procedures for congenital and acquired outflow obstructions.

Recently, this simplified technique of apicoaortic bypass has also been adapted successfully for implantation of the Jarvik 2000 continuous-flow left ventricular assist device (CardioWest Technologies, Inc, Tucson, Ariz) without a contained valved conduit. In the future, I believe the technique will become standard for implantation of left ventricular assist devices.

Dr Lytle. Dr Cooley's concept of a left ventricular–descending aortic valved conduit is another interesting innovation from someone who is one of my idols. I am sure that this approach will be the right answer for some patients. At The Cleveland Clinic, we did this type of procedure a couple of times back in the late 1970s but have not repeated it since that time. In those early days, it did not seem to work out very well, probably because the technology of the left ventricular connection was not as far advanced as it is now. We now are in an era in which left ventricular assists are used a lot, and the left ventricular connection devices have improved. I do not doubt that a valved conduit can help some patients.

Dr Lars G. Svensson *(Burlington, Mass).* Several years ago we reported our experience doing endarterectomies for calcified aortas, excluding atheromas, with similar findings, namely, that patients who had had radiation, particularly CA breast radiation, seemed to be prone to the development of calcification. We have used techniques similar to yours, and we have also used Dr Cooley's technique.

In 2 of our patients the axillary arteries could not be used for CPB. They had had previous cardiac surgery and had aortic valve stenosis. We inserted apical-descending conduits without using CPB. On the basis of this experience, in a situation in which one is not able to use CPB, I think this technique is a good alternative.

I have a couple of questions. You seem to be advocating graft replacement now more than endarterectomy for aortic repair. What do you do when the aortic arch contains a lot of calcium and you are not able to drive your needle through the calcium? Do you endarterectomize the descending aorta, and what do you do with your end point in that situation? We have always been concerned about creating aortic dissection, although we have not seen it. However, the New York University group had that happen as a complication in one of their series of patients.

Second, what do you do postoperatively after endarterectomy when a lot of raw medial tissue is exposed? Do you prescribe clopidrogel (Plavix), aspirin, or heparin? We have prescribed warfarin sodium (Coumadin) in many patients, even though most of them have had biologic valves inserted.

Dr Lytle. Realistically, in a lot of these patients we sometimes have to do a local endarterectomy to sew the graft in. Where to end that endarterectomy is often a difficult question, but with time and experience I think I have been more effective in replacing the aorta and doing a localized endarterectomy than endarterectomizing the entire aorta and then reclamping it. We have not yet recognized a distal dissection caused by this technique, but we have worried about it.

I do want to mention that we are reluctant to replace the aorta with a Dacron graft in a patient who has had previous mediastinal radiation. These patients are at increased risk for wound complications and we would prefer not to have cloth in the field.