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Ascending Aortic Atherosclerosis – A Complex and Challenging Problem for the Cardiac Surgeon

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ABSTRACT

Ascending aortic atherosclerosis is an increasingly recognized problem in cardiac surgery. It is the most important risk factor for perioperative stroke and seems to be in part responsible for postoperative neurobehavioral changes. Patients exhibiting ascending aortic atherosclerosis have a significantly reduced survival rate and are at considerable risk for spontaneous embolic stroke during the long-term postoperative course. Preoperative noninvasive diagnosis and intraoperative assessment by inspection or palpation of the aorta are insensitive. Intraoperative epiaortic ultrasound scanning has emerged as a most helpful tool for the diagnosis of ascending aortic atherosclerosis and has revealed major insights into the nature and distribution of this disease. Management strategies range from minimally invasive aortic "no touch" techniques to maximally invasive procedures, including application of deep hypothermic circulatory arrest. Operative modifications in coronary artery bypass grafting include avoidance of aortic crossclamping, alternative methods of aortic crossclamping and placement of all arterial in situ bypass conduits, Y-grafts or extra-anatomical bypass grafts. Other operative strategies include modifications of the arterial cannulation site, replacement of the ascending aorta or ascending aortic endarterectomy. One of the most recently developed methods is embolic capture by intraaortic filters. Increased awareness of ascending aortic atherosclerosis is critical in order to prevent the devastating complications it can cause during cardiac surgery.

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INTRODUCTION

Crossclamping of the ascending aorta is an essential part of most operations in cardiac surgery. It is routinely carried out after institution of cardiopulmonary bypass in order to interrupt blood flow to the coronary arteries; thereby achieving ischemic ventricular fibrillation or cardioplegia supported cardiac arrest. As long as the vascular wall of the ascending aorta is non-diseased, the crossclamp can basically be applied without fear. However, increased attention to this maneuver should be paid once ascending aortic atherosclerosis (AAAS) is diagnosed. Why so?

Importance, Incidence and Distribution of the Disease. During the last few years there has been a clear upward trend towards increasing age of the surgical cardiac patients [Weintraub 1991, Clark 1994]. The incidence of atherosclerotic disease is high in these older patients, leading to a higher overall risk of atheroembolic events during heart surgery. Atherosclerosis of the ascending aorta has been demonstrated to be the most important risk factor for stroke in coronary artery bypass grafting [Roach 1996] and several papers have demonstrated ascending aortic atherosclerosis to be an independent risk factor for adverse postoperative events [Lynn 1992, Davila Roman 1994, Moshkovitz 1997]. Various surgeons and institutions have increasingly recognized the problem of ascending aortic atherosclerosis after experiencing complications associated with the disease [Mills 1991]. Figures 1 and 2 show autopsy specimens from a routine CABG patient that died from multicentric embolic strokes. Massive plaque formation, ulceration, and intimal mobile thrombi are seen in the aortic arch surrounding the origins of the cephalic vessels (Figure 1) and throughout the entire arch and descending aorta (Figure 2). This form of severe intimal plaque disease is likely to liberate particulates upon manipulation of any kind, especially perfusion cannula jets or clamping.

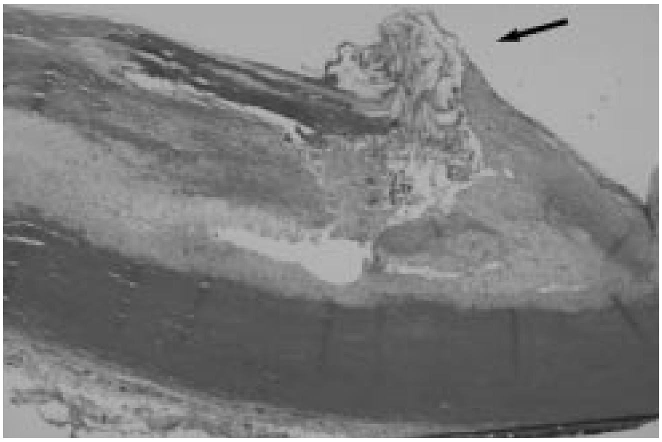

Figure. 3. Histologic view of a severely atherosclerotic ascending aorta. Note the extensive intimal thickening of the aortic wall caused by an atheromatose, partly ulcerating plaque. Protruding atheroma prone to embolization is marked by an arrow.

Most recently, the importance of embolic showers caused by microemboli from moderately or even non-diseased ascending aortas has been addressed. Increasing attention is being paid to neurobehavioral changes after heart surgery [Breuer 1983, Shaw 1987] and a clear association with cerebral microembolism, partly originating from the ascending aorta, has been demonstrated [Hammon 1997]

Ascending aortic atherosclerosis is a common disease, reaching an incidence of up to 89% in the current CABG population [Ohteki 1990]. Data on the distribution of atherosclerotic plaque within the ascending aorta are delineated in a pathologic study carried out by Tobler in 1988 [Tobler 1988] and from papers on epiaortic ultrasound [Marshall 1989, Ohteki 1990]. According to Tobler's findings, the overall prevalence of atherosclerotic plaque amounts to 38%, with the right side of the ascending aorta being more commonly involved than the left. Involvement of the innominate and subclavian arteries seems to correlate with significant ascending aortic atherosclerosis. In the lower parts of the aorta, atherosclerotic plaques are predominately located on the anterior right portion of the vessel, whereas in the upper parts they are more evenly distributed. Tobler and coworkers speculated that the stream of left ventricular ejection might in part contribute to this distribution of plaque. Slightly different distribution patterns of the atherosclerotic process, however, have been found with intraoperative epiaortic scanning [Marshall 1989, Ohteki 1990]. AAAS is often associated with atherosclerotic lesions of the abdominal aorta [Mills 1991] or the descending aorta [Choudhary 1997]. Nevertheless, it has to be kept in mind that of all aortic segments, the ascending aorta is the least involved with atherosclerosis [Tobler 1988], while the descending and abdominal aorta are frequently affected.

Pathomechnisms involved with aortic crossclamping:

Mechanical force can lead to cracking or rupture of an atherosclerotic plaque (Figure 3 ◎) and release of atheromatous debris from the plaque, with embolization into the peripheral circulation, ischemic damage to the brain (Figure 4 ◎) and other vitally important organs including, the heart itself. Macro- as well as microemboli (particles of less than 200 micrometers in diameter), may be washed away by the arterial blood stream. During CABG they are most notably detected during application and release of the aortic crossclamp [Mills 1991]. Side wall or partial (tangential) clamping for performance of the proximal anastomoses is a specially recognized situation involving mobilization and consequently detectable embolization of atheromatous debris [Mills 1993]. In a cadaver study, Stefaniszyn and coworkers detected indentations in the intima, partial intimal tearing, as well as distortion of the aortic valve and the right coronary ostium after application of a partial occluding clamp to the ascending aorta [Stefaniszyn 1984]. These facts clearly call for increased attention to this significant trauma to the ascending aorta.

Figure. 4. Cerebral CT scan of a patient with a massive stroke caused by crossclamping a severely atherosclerotic ascending aorta. Note the extensive ischemic areas in both hemispheres.

Atheroembolism is a common event in cardiac surgery and the ascending aorta apparently is the major source of embolism. In a paper by Blauth, atheroembolism was detected in 21.7% of patients undergoing autopsy after cardiac surgery and was found in multiple organs primarily the brain, spleen, and kidney [Blauth 1992]. According to a multivariate analysis, in this study, peripheral vascular disease and ascending aortic atherosclerosis were highly significant predictors of peripheral embolism.

An exact figure on stroke caused by crossclamping a severely diseased ascending aorta has been reported by Lynn [Lynn 1992], who, after crossclamping experienced a stroke rate of 19% in 57 patients exhibiting aortic calcification. The immense danger of clamping a severely athero-

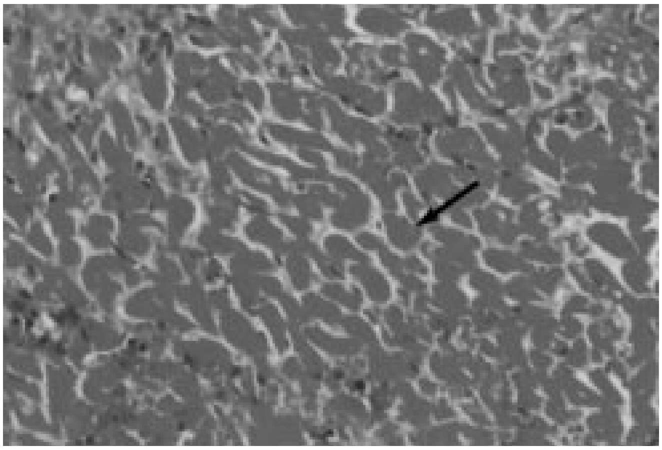

Figure 5. Myocardial infarction (autopsy specimen) in a patient who was operated on using the single crossclamp technique in the presence of a heavily atherosclerotic ascending aorta. For this situation the term "trash heart" has been created. Myocardial infarction occurred despite the use of single aortic crossclamping. Note the loss of nuclei and cross striation of myocytes (Arrow).

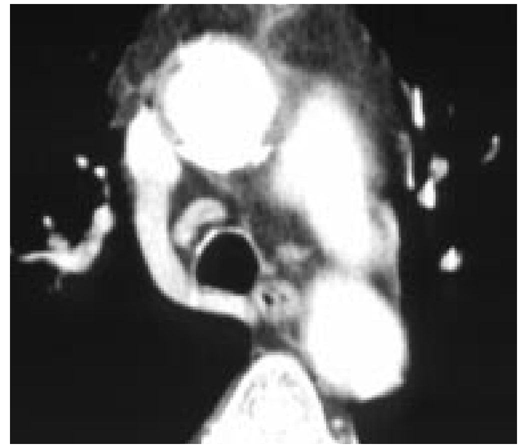

Figure 6. Thoracic CT scan showing calcification of the ascending aorta which interrupts the continuity of the aortic wall. In this patient epiaortic scanning and palpation also revealed heavy ascending aortic atherosclerosis. An aortic "no touch" technique was used with an IMA in situ graft to the LAD and an axillocoronary vein graft to the RCA on the beating heart.

sclerotic ascending aorta is also underlined by data from Mills and Everson, who reported 4 fatal and 5 nonfatal strokes in 20 such patients [Mills 1991]. The jeopardy to the heart and the rate of myocardial infarction (MI) after crossclamping a diseased aorta is often underestimated, and for severe embolic injury to the heart, the term "trash heart" has been created [Salerno 1982, Mills 1991]. A histologic view of myocardial infarction most probably caused by embolism from AAAS after crossclamping is shown in Figure 5

Despite the fact that manipulation of the ascending aorta with the crossclamp is the most important factor in ascending aorta born embolism, palpation and cannulation [Marshall 1989] may cause embolism as well and must be carried out with the same level of precaution as crossclamping.

Acute aortic dissection may be a further damaging effect caused by aortic crossclamp application on an atherosclerotic ascending aorta. In an autopsy study by Lam [Lam 1977] AAAS was detected in 2 out of 7 autopsy cases exhibiting aortic dissection after CABG. Chronic dissections following coronary artery bypass grafting are an increasingly recognized problem as well.

Natural Course of the Disease:

Few data in the literature are available on the natural course of ascending aortic atherosclerosis. In a selected group of beating heart CABG patients Moshkovitz and coworkers reported a 3 year survival rate of slightly greater than 50% for patients exhibiting ascending aortic atherosclerosis and an 85% survival rate for patients without the disease [Moshkovitz 1997]. It is well known that emboli from a severely atherosclerotic ascending aorta can be a cause of stroke during the long-term postoperative course [Vogt 1999, Wareing 1992].

DIAGNOSIS

I) Preoperative diagnosis.

As AAAS often requires complicated modifications of procedures in cardiac surgery, accurate preoperative assessment, at least in high-risk patients, is highly desirable. An adequate preoperative noninvasive diagnostic method, however, is not available at present.

History, risk profile, physical examination:

Patient history and physical examination may already reveal useful hints that should alert the cardiac surgeon. Known factors associated with ascending aortic atherosclerosis are listed in Table 1( ).

Chest X-ray:

On the chest roentgenogram, ring shaped calcifications of the aortic knob may be detected in the range of 7% [Choudhary 1997] in the CABG population, but these calcifications usually do not reflect the type of atherosclerosis on the ascending aorta. [Wareing 1992]. Only the most severe cases of ascending aortic atherosclerosis are detected on chest x-ray or during coronary angiography [Mills 1991, Culliford 1994].

CT scans:

On thoracic CT scans calcification of the ascending aorta can be appreciated [Ohteki 1990], but widespread use

Table 1. Risk factors for the presence of ascending aortic atherosclerosis according to literaure.

Risk factor	*Listed in citation*
Older age	[Wareing 1993]
Hypertension	[Wareing 1992]
Smoking History	[Davila Roman 1994]
Extensive coronary artery disease	[Choudary 1997]
Peripheral vascular disease	[Davila Roman 1994]
Cerebrovascular disease	[Brener 1984, Landymore 1981]

of CT exams before cardiac surgery has not gained popularity and soft atheromatous debris cannot be detected. A representative scan is shown in Figure. 6 (◎).

MRI:

The possibility of diagnosing atherosclerosis of the thoracic aorta by magnetic resonance imaging has already been explored in early studies [White 1986] and the noninvasive nature of the method as well as the avoidance of contrast media clearly speak in favor of this preoperative diagnostic approach. Patients with permanent pacemakers, however, need to be excluded from the examination and dynamic assessment of the aorta is more difficult than with ultrasound examinations [White 1986].

Transesophageal echocardiography (TEE):

Although transesophageal echocardiography is often advocated as an adequate diagnostic tool, its sensitivity and specificity in detecting ascending aortic atherosclerosis is rather low. In particular, the distal portion of the ascending aorta, which is usually the site of cross clamping, is poorly visualized [Seward 1990, Culliford 1994]. Advances in technology, however, seem to enhance the diagnostic value of TEE [Ribakove 1992].

Transthoracic echocardiography:

It has been recently stated [Liel-Cohen 1998] that transthoracic echocardiography can identify patients free of ascending aortic atherosclerosis and may reduce the need for transesophageal echocardiography in these patients. Nevertheless, accurate preoperative assessment of the application site for the crossclamp or the arterial cannula remains rather difficult.

Angiography:

Calcifications in the ascending aorta may be detected during translumination for coronary angiography (Figure. 7 ◎) and reduced elasticity of ascending aortic pulsations can in some cases serve as an indirect sign for ascending aortic atherosclerosis. Careful inspection of the angiogram has been recommended for proper planning of the operation [Mills 1993].

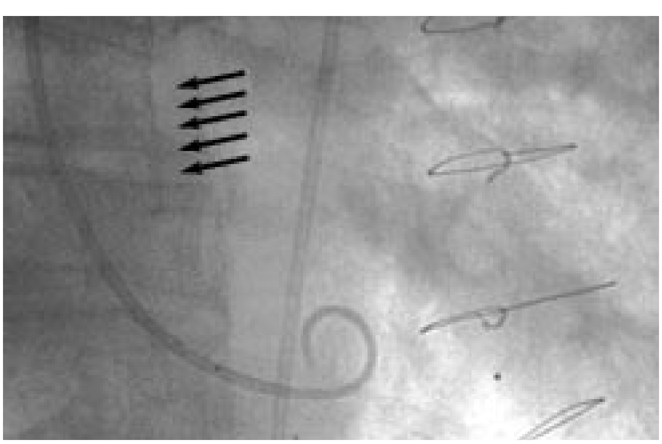

Figure 7. Calcification (arrows) of in the ascending aorta on the coronary angiogram enabled preoperative diagnosis of a severely diseased ascending aorta in this patient.

Intravascular ultrasound (IVUS):

Intravascular ultrasound would be an ideal tool to diagnose the disease and could be performed during coronary angiography [Blauth 1992]. The technique has, to our knowledge, not been tested for this purpose in larger studies. Its application is limited by the high costs of the IVUS catheters and by the potential dislodging of atheromatous debris during the examination.

II) Intraoperative diagnosis.

Inspection palpation.

Inspection of the ascending aorta is insensitive in the diagnosis of ascending aortic atherosclerosis, although occasionally plaque or slight inflammatory changes may be noted on the aortic wall. Adherence of the adventitia to the ascending aortic wall but not pericardial adhesions speak for the presence of the disease [Mills 1991]. In some cases, a pale or leather appearance of the ascending aorta can be noted [Mills 1991].

Palpation is quite insensitive as well [Kouchoukos 1994, Roach 1996]. The probability of detecting disease by palpation lies in the 25% range [Marshall 1989, Ohteki 1990]. It must be emphasized that, in any case, the ascending aorta should be palpated with caution as manipulation may cause dislodgment of atheromatous debris. Recommendations have been made regarding lowering of blood pressure [Bar El 1992] or decreasing pump flow before palpating the vessel. Little bleeding during scalpel puncture of the ascending aorta for cannulation seems to be a very reliable intraoperative diagnostic sign [Mills 1991]. Incomplete occlusion by the aortic cross clamp may be caused by severe AAAS.

Epiaortic ultrasound:

The introduction of epiaortic scanning has led to major advances in the understanding of this disease. It is carried out using high frequency linear ultrasound scanners [Marshall 1989, Wareing 1992] packed in a sterile plastic bag and should be performed before opening of the retrosternal fat tissue. In some cases, additional signal amplifiers such as saline solution poured into the anterior mediastinum or the pericardial sac must support visualization. Using epiaortic ultrasound, rates of ascending aortic atherosclerosis lie in the 58% [Marshall 1989] to 89% [Ohteki 1990] range, and moderate to severe atherosclerosis has been detected at a rate of 19.3% in a large series published by Wareing [Wareing 1993]. A major advantage of this technique is its quick and noninvasive nature. Despite its

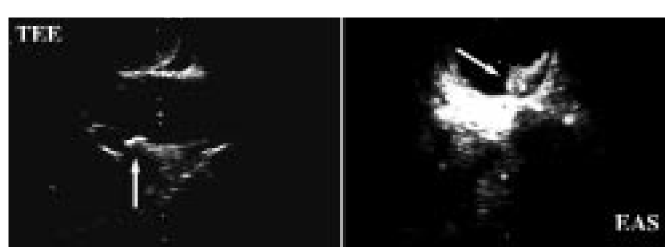

Figure 8. An atherosclerotic plaque in the posterior wall of the ascending aorta (arrows) visualized by transesophageal echo (TEE) and epiaortic scanning (EAS).

Table 2. Classifications of AAAS:

Author, Classification, Citation	Description
Inspection, palpation:	
Landymore [Landymore 1981]	
A	Single or multiple atherosclerotic plaques interposed between areas of normal aorta
B	Generalized degenerative changes of the media.
C	Aorta grossly thickened as a result of medial degeneration and calcification
Mills Everson [Mills 1991]	
I	"Porcelain aorta", Circumferential calcification
II	"Ragged, friable", may be detected by irregularity of the normally smooth lining of the ascending aorta on the left ventricular angiogram
III	"Liquid intramural disease", Intraluminal liquid debris, pale appearance of the aorta, adherence of the adventitia
Ultrasonic assessment:	
Epiaortic scanning:	
Wareing [Wareing 1993]	
Mild	Local thickening < 3mm
Moderate	Intimal thickening 3-5 mm
Severe	Thickening > 5mm, presence of marked calcification, protruding, mobile atheroma, ulcerated plaque, thrombi, circumferential involvement of all of the ascending aorta
Transesophageal Echo:	
Ribakove [Ribakove 1992]	
I	Minimal intimal thickening
II	Extensive intimal thickening
III	Sessile atheroma
IV	Protruding atheroma
V	Mobile Atheroma

extraordinary usefulness, difficulties exist as to distinguishing between soft friable and calcified fibrotic plaque [Wareing 1993]. An intraoperative view of AAAS by epiaortic ultrasound and by TEE is shown in Figure 8 ().

III) Classification of the disease.

Different authors reporting on the topic have used several classifications of ascending aortic atherosclerosis. They are listed in Table 2 (). It seems, in our opinion, reasonable to use one of the classifications developed by ultrasound, as they represent the more accurate diagnostic assessment of the disease.

MANAGEMENT

The surgical solutions suggested for management of the severely atherosclerotic ascending aorta range from minimally invasive to maximally invasive procedures. During the early 1980's, if significant ascending aortic atherosclerosis was encountered, abandonment of the cardiac surgery procedure and closure of the sternum was seriously considered [Reid 1983], and sometimes performed. Some of these patients were later reoperated on successfully [Peigh 1991].

I) General strategies.

Alternative cannulation for cardiopulmonary bypass:

Choice of an adequate, non-diseased arterial cannulation site is of critical importance. A femoral approach has been advocated by several authors but should be performed with caution as patients exhibiting generalized severe atherosclerosis (usually those who show AAAS) are at increased risk of retrograde aortic dissection [Lam 1977, Eugene 1981]. In addition retrograde embolization into the cererbral circulation might occur by a sand blast effect of the arterial cardiopulmonary bypass stream. A soft spot on the ascending aorta or on the proximal aortic arch can often be detected and used for insertion of the arterial cannula. Newer high flow ultrathin walled small diameter arterial cannulas are now marketed (Research Medical, Biomedicus) which can be inserted in between plates of calcium using a needle-dilator-guidewire (Seldinger) technique. These cannulae allow the surgeon to perfuse anterograde from the mid or distal arch and avoid the atheroemboli and peripheral vascular complications typical of femoral cannulation. These cannulae take advantage of the natural elasticity of the normal aorta in the region between plates of calcium by enlarging a small needle hole into a sizable cannulation site using graduated dilators.

The axillary artery has been described as a very attractive cannulation site in redo cardiac surgery and thoracic aortic surgery [Bichell 1997, Sabik 1995]. It can, therefore, also be chosen for aortic no touch techniques in cases of severe ascending aortic atherosclerosis. Nevertheless, freedom from significant subclavian artery stenoses must be carefully evaluated before application of this method.

Modifications of the aortic cross clamp:

Few modifications of the aortic cross clamp itself have been described in the literature. Culliford reported the use of a Fogarty atraumatic hydrogrip clamp with Teflon inserts for occluding the ascending aorta after endarterectomy [Culliford 1994]; Rousou advocated a modified Fogarty clamp for the diseased aorta [Rousou 1981]. To our knowledge, no comparative studies are available which focus on differences in embolic rates after application of different crossclamping devices.

Balloon occlusion:

As an alternative to crossclamping of an atherosclerotic ascending aorta, intraluminal balloon occlusion has been advocated. Foley catheters were used for this purpose in the 1980's [Erath 1983], but placement and pressure controlled positioning were major problems. The advent of the Heartport™ endoclamp for minimally invasive heart surgery and the availability of transesophageal echocardiography for intraoperative visualization of the balloon, have offered advances with this technique [Liddicoat 1998, Schultze 1999]. Liddicoat and coworkers placed the endoclamp via a pursestring suture at the origin of the brachiocephalic artery or on the aortic arch thus achieving pressure controlled occlusion of the ascending aortic lumen.

Mobilization of atheromatous material, however, might occur during placement of the balloon and dislocation of an intraaortic balloon may lead to obstruction of the head vessels causing cerebral ischemia. Aortic dissection has been encountered during performance of minimally invasive heart surgery using the Heartport™ endoclamp. Retrograde femoral perfusion as well as damage to the aortic wall by advancing the balloon catheter are the most probable causes leading to this complication.

Embolic capture:

Snaring or clamping of the supra-aortic vessels: Snaring or clamping the supra-aortic vessels for prevention of supra-aortic embolism during aortic cannulation was described relatively early by Landymore [Landymore 1982]. This method is nowadays performed very rarely and carries the risk of embolism from the supra-aortic arteries themselves, which are often involved in the atherosclerotic process.

Intraaortic filtration: Most recently, intraaortic filters, which are introduced through the arterial cardiopulmonary bypass cannula for capture of atheromatous debris have been developed, and initial experience demonstrates a very high incidence of atheroma embolization [Reichenspurner 1998] even during routine crossclamping of normal appearing ascending aortas. At present, however, insufficient data is available concerning the benefit of these devices. The easy handling speaks for the application of the filter, but of concern can be the placement of such filters into an ascending aorta that is internally coated with mobile, protruding atheromatous debris. Despite its soft design, manipulation of the filter could in these cases theoretically cause embolization instead of preventing it. As embolization of atheromatous particles has been detected in the filters from patients with normal appearing ascending aortas [Reichenspurner 1998], the major field of application might be in routine heart surgery patients with absent or mild atherosclerosis on epiaortic echo.

Left ventricular and aortic root venting: By left ventricular venting, embolic material can be aspirated with the bloodstream and captured by a filter in the CPB circuit. It has to be kept in mind, however, that although venting is an accepted adjunct in the prevention of stroke caused by ascending aortic atherosclerosis, it can also be a cause of stroke by suction of air [Roach 1996].

Retrograde cardioplegia: Retrograde cardioplegia can be recommended if the single crossclamp technique is applied, and offers the advantage of retrograde washing out of atheromatous debris from the coronary circulation and capture by the aortic root suction.

Retrograde cerebral perfusion: This method can be applied for embolic dislodgement if deep hypothermic cardiocirculatory arrest is applied [Byrne 1998].

II) Management of AAAS in coronary artery bypass grafting.

Avoidance of aortic crossclamping, off pump coronary surgery, operations without aortic crossclamping:

Off pump coronary surgery: With the advances in beating heart techniques, revascularization off pump is a very reasonable approach to the problem [Moshkovitz 1997, Calafiore 1998]. It offers the major advantage that, in addition to not applying the aortic cross clamp, the damaging effects of cardiopulmonary bypass to the brain are avoided [Moshkovitz 1997].

Operations on pump with the heart beating or fibrillating:

If the patient does not tolerate off pump CABG, an on pump, beating heart or fibrillating heart concept would be the next step to be taken into consideration [Perrault 1997]. Cannulation is carried out as described above. If an on pump, fibrillating heart strategy is chosen special attention has to be paid to the presence of aortic valve regurgitation [Liddicoat 1998], which may cause left ventricular distention. In such cases, cooling the patient to 22°C and reduction of pump flow to achieve perfusion pressures of 20-30 mm HG has been successfully applied [Bar El 1992]. In the absence of aortic valve regurgitation, cooling to moderate hypothermia might, in certain cases, be sufficient [Mills 1993]. It must be emphasized, however, that mobilizing the heart for revascularization of the back wall can cause poor venous drainage and reduction of pump flow. Therefore, generous lowering of body temperature during these procedures can be recommended. At temperatures in the 20° to 22°, proximal anastomosis to the ascending aorta may be performed during a few minutes of circulatory arrest. If time problems arise the pump can be restarted for a few minutes with finger occlusion of the punch hole in the ascending aorta (Personal communcation: Mark Levinson, MD, Heart Surgery Forum Open-Heart-L listServ Feb. 6, 1999). Other grafts can be sewn to such a graft as a Y-graft during rewarming.

Modifications of aortic crossclamping:

Avoidance of the partial occluding clamp, single crossclamping: As placement of the partial occluding clamp is a major event causing micro- and macroembolism from the ascending aorta, placement of the proximal and distal anastomoses of an aortocoronary bypass graft during one single period of aortic crossclamping is an attractive approach. The method was originally described by Salerno [Salerno 1982], who observed low complication rates with this technique. Despite the fact that older and sicker patients were operated on, Aranki reported a significantly better outcome for these patients as compared with patients operated on using a partial occluding clamp [Aranki 1994]. In this retrospective comparative study, single aortic crossclamping resulted in lower mortality, lower rates of myocardial infarction and low cardiac output syndrome, lower creatine kinase MB release, and a lower stroke rate. Aranki firmly believes that reduced manipulation and trauma to the ascending aorta is the significant factor in the success of this method. Similarly good results were obtained by Weisel in a prospective randomized study, and the value of single aortic crossclamping was underlined by Loop and coworkers [Weisel 1983, Loop 1992].

At our institution, we regard the single aortic cross clamp technique as the method of choice in cases of moderate atherosclerosis of the ascending aorta. In more severe cases, we apply an aortic no touch strategy using arterial in situ or extraanatomical bypass grafts off pump whenever possible.

Alternative placement of the aortic crossclamp: In certain cases, very proximal placement of the aortic cross clamp and the side-biting clamp may be sufficient in managing AAAS [Wareing 1992]. However, in our experience, placement of the side biting clamp in the very proximal position can be difficult and care should be taken to avoid kinking or compression of the aortocoronary graft by the right atrial appendage.

Figure. 9. Axillary anastomosis of an axillocoronary bein graft which was performed in order to detour a severely atherosclerotic ascending aorta. The graft was brought to the target vessel via a transintercostal and transpleural course.

Modification and avoidance of proximal anastomoses to the ascending aorta:

Aortic spoon-jaw clamp: Robicsek described a very simple method of a direct vein graft anastomosis to a diseased ascending aorta [Robicsek 1995]. With the help of a small device inserted into the ascending aortic lumen through a stab wound, a soft area of aortic wall can be isolated and one proximal anastomosis may be performed. One point of criticism might be the fact that the inner aortic wall is manipulated and that embolism could occur during problems with insertion of the device.

All arterial in situ bypass grafting: Following an aortic no touch concept, multiple arterial in situ bypass conduits can be placed in order to avoid proximal anastomoses to the ascending aorta. Beating heart, off pump or on pump techniques, as well as fibrillating heart strategies, can be used for performance of the distal anastomoses [Suma 1989]. Performing several arterial anastomoses on the beating heart, however, is technically quite demanding and maybe unnecessary in the often old and mulitmorbid CABG population exhibiting ascending aortic atherosclerosis.

T- or Y grafts: As an alternative to all arterial in situ bypass grafting, T- or Y-grafts originating from an IMA in situ graft or from an extraanatomical coronary bypass graft may be performed to detour an atherosclerotic ascending aorta. Arterial [Calafiore 1995] as well as venous bypass material [Peigh 1991] may be used for this purpose.

Extraanatomical bypass grafts: Already during the early phases of coronary artery bypass grafting, extraanatomical bypass conduits originating from arterial inflow sources other than the ascending aorta have been described. The innominate artery [Weinstein 1980, Suma 1996], the subclavian [Suma 1996] or axillary artery [Bonatti 1998], the internal mammary artery [Peigh 1991], and the right gastroepiploic artery [Mills 1991] have been used for the proximal anastomosis of coronary bypass grafts. Venous as well as arterial bypass material has been described for these bypass constructs. The advantage of the extraanatomical bypass approach using venous bypass material is its more straightforward conduct than with arterial bypass grafts.

The axillocoronary bypass graft concept for management of the severely atherosclerosis of the ascending aorta has been developed and described by our group, and several advantages over other methods mentioned in this review have been encountered. [Bonatti 1998]. A proximal anastomosis of a coronary vein graft originating from the axillary artery is shown in Figure 9 (◎). Indications for extra-anatomical bypass constructs are rare [Peigh 1991] and long-term patency rates of these bypass grafts is unknown.

Incomplete revascularization: The cardiac surgeon who encounters a severely atherosclerotic ascending aorta is often confronted with the question of incomplete revascularization. Difficulties may arise during revascularization of the circumflex artery and right coronary artery branches both during beating heart off pump surgery and beating/fibrillating heart revascularization on pump. In the former case despite new refined techniques of exposing the back wall of the heart [Calafiore 1998], tilting may

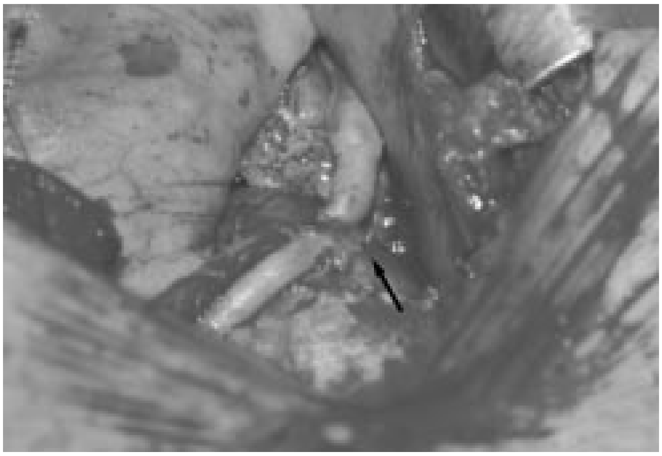

Figure. 10. Partial replacement of the ascending aorta. The anterior portion of the aortic wall was replaced by a pericardial patch (arrow) and proximal vein graft anastomoses were performed to the patch.

Figure. 11. Macroscopic view of a severely atherosclerotic ascending aorta exhibiting ulcerating plaque. The picture was taken from a pathological specimen of a patient suffering an extensive embolic stroke by aortic crossclamping in heart-lung transplantation.

not be tolerated. Lifting of the beating heart on pump can compromise venous drainage and thereby lead to low pump flows and venous congestion. In such cases, one might choose an incomplete revascularization strategy and leave the branches of the back wall of the heart ungrafted. Incomplete revascularization is a quite frequent problem in beating heart coronary surgery and has in fact been advocated for management of ascending aortic atherosclerosis [Reid 1983, Moshkovitz 1997]. Tackling the ungrafted vessels by percutaneous intervention is an option but may be limited by an increased risk of embolic events during catheter manipulation.

III) The role of ascending aortic endarterectomy and replacement.

Endarterectomy:

Culliford and coworkers are proponents of ascending aortic and aortic arch endarterectomy, which they reported in 13 patients with pedunculated or mobile atheroma [Culliford 1986, Culliford 1994]. The procedure was carried out in deep hypothermic cardiocirculatory arrest and was performed during a period of 3.5 to 12 min. The only neurologic deficit in their first series occurred in a patient whose disease was detected after placement of the aortic cross clamp. If endarterectomy is to be performed, the atheroma should be loosely adherent and mobile and not a protruding lesion, as aortic dissection may occur after manipulation of such pathologies. Most recently, Vogt and coworkers reported one perioperative death and two adverse neurologic events (one early, one late) in 22 patients with ascending aortic and aortic arch endarterectomy during CABG or aortic valve replacement [Vogt 1999]. Vogt stated that one advantage of the procedure was the elimination of protruding and mobile plaques that can cause stroke during the long-term postoperative course.

Replacement:

Partial replacement: During the early era of CABG, patch replacement of the anterior portion of the ascending aorta was advocated [Robicsek 1980]. We choose this variation of proximal anastomotic placement if the atherosclerotic process is confined to the anterior wall of the ascending aorta (Fig. 10 ◎). The advantage of this technique is that the proximal anastomosis is technically quite easy to perform; the disadvantage is a longer partial occluding time of the ascending aorta and the possibility of bleeding at the patch suture line.

Complete replacement: Complete replacement of the ascending aorta using deep hypothermic circulatory arrest for severe atherosclerosis is a very aggressive and controversial issue. It is the method of choice for Kouchoukos and coworkers, who observed a zero percent stroke rate in 47 patients and a perioperative mortality rate of 4.2% [Kouchoukos 1994]. The same group experienced a higher stroke rate in patients with moderate to severe ascending aortic atherosclerosis who underwent minor procedural modifications than in patients who underwent ascending aortic replacement [Wareing 1993]. Most recently, however, King and coworkers report a stroke rate of 3/17 and a perioperative mortality rate of 5/17 with ascending aortic replacement [King 1998]. These results have forced King's group to judge this method as a high-risk procedure. One argument speaking for complete replacement of a severely diseased ascending aorta is the fact that one source of atheromatous emboli is eliminated, which may prevent future embolic events.

IV) AAAS in valve procedures.

Replacement of the ascending aorta has been reported recently for cases of AAAS in aortic valve procedures. No strokes occurred in three such pilot procedures reported by a group from Harvard [Byrne 1998]. As the tolerated period of cardiocirculatory arrest is in the range of 45 to 60 min, implanting the prosthetic valve is possible, but little time reserve is available once problems occur. This year the Zurich group [Vogt 1999] advocated aortic endarterectomy for AAAS in aortic valve replacement.

V) AAAS in thoracic organ transplantation.

Little is reported on the problem of ascending aortic atherosclerosis in heart or heart-lung transplantation. We have at our institution experienced a single case of severe stroke after placement of the aortic crossclamp in heart-lung transplantation (Figure 11) and a case which required ascending aortic replacement during deep hypothermic circulatory arrest for dissection of a severely atherosclerotic ascending aorta during isolated heart transplantation. Awareness of the problem, especially in elderly patients with ischemic cardiomyopathy and accurate preoperative and intraoperative assessment of the disease in this population are key issues. If the ascending aorta is regarded as unclampable intraoperatively, synthetic graft replacement during deep hypothermic cardiocirculatory arrest and performance of the aortic anastomosis to that graft seems to be a realistic option.

CONCLUSION

In this review, we tried to outline the complexity of problem solving when an atherosclerotic ascending aorta is encountered during cardiac surgery. Increased attention to the problem, even if inspection and palpation cannot appreciate atherosclerosis, is absolutely mandatory. The ideal method for management of a severely atherosclerotic aorta, however, still needs to be evaluated and at present individualized strategies often must be created.

Regarding all the methods of management of AAAS the surgeon sometimes has to decide whether, for the sake of protection from cerebral embolism, less accurate methods of myocardial protection and revascularization need to be applied rather than operating on a crossclamped arrested heart. We ourselves would advocate such a "brain before heart" strategy because the spectrum of therapeutic options for postoperative cardiac problems is essentially wider than the spectrum of therapies available for postoperative stroke. In addition it has to be kept in mind that crossclamping a severely atherosclerotic ascending aorta is a danger to the heart itself. Adequate preoperative diagnostic tools for assessment of AAAS would be necessary in order to guarantee adequate surgical planning.

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REVIEW AND COMMENTARY

1. Editorial Board Member EK34 writes:

You state that CPB damages the brain, therefore off-pump is preferable. What about the data by Clark on emboli from simply manipulating the heart?

Author's Response by Johannes Bonatti, MD:

I certainly agree that simple manipulation of the heart can lead to generation of emboli especially if intraventricular clot is present. Manipulation of an atherosclerotic ascending aorta also creates a significant embolic load that can be avoided by the aortic "no touch" techniques described in the review. Off pump techniques using all arterial in situ or extraanatomical bypass grafts therefore seem to be a reasonable approach to the problem and offer the major advantage that in addition to not touching the ascending aortae damaging side effects of cardiopulmonary bypass (CPB) are avoided. As mentioned in the article, however, we would use CPB in any patient who does not tolerate off pump surgery.