AXILLARY ARTERY: AN ALTERNATIVE SITE OF ARTERIAL CANNULATION FOR PATIENTS WITH EXTENSIVE AORTIC AND PERIPHERAL VASCULAR DISEASE

The increasing number of patients with extensive aortic and peripheral vascular atherosclerosis or aneurysms who are undergoing cardiac operations present difficult decisions as to the optimal site of arterial cannulation for cardiopulmonary bypass. Femoral artery cannulation is the most common alternative to ascending aortic cannulation, but severe iliofemoral disease or the danger of atheroemboli caused by retrograde perfusion through an atherosclerotic or aneurysmal descending aorta may make this approach impossible or undesirable. We have used axillary artery cannulation for cardiac operations in 35 patients for indications including severe aortic atherosclerosis ($n = 16$), extensive aortic aneurysms ($n = 11$), and aortic dissection ($n = 8$). The cardiac operations performed were coronary artery bypass grafting ($n = 9$) aortic valve replacement ($n = 1$), aortic valve replacement and coronary artery bypass grafting ($n = 5$), repair of mitral valve periprosthetic leak ($n = 1$), and resection of ascending and/or aortic arch ($n = 19$). Deep hypothermia with circulatory arrest was used in 26 patients and retrograde cerebral perfusion in 18. All patients awoke from the operation and no patient had a cerebrovascular accident. One patient required axillary artery thrombectomy and one patient had a mild ipsilateral brachial plexus paresis after the operation. Four patients died in the hospital. We conclude that axillary artery cannulation is a safe and effective means of providing antegrade arterial flow during cardiopulmonary bypass in patients with severe atherosclerotic or aneurysmal disease. This strategy may lower the prevalence of stroke associated with cardiopulmonary bypass in these patients. (J Thorac Cardiovasc Surg 1995;109:885-91)

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Although the ascending aorta is the most common site of arterial cannulation for cardiopulmonary bypass, the presence of ascending aortic aneurysms, dissections, or atherosclerosis may make ascending aortic cannulation dangerous. The femoral artery is the most common alternative site of arterial cannulation in these situations. However, concomitant peripheral vascular disease, the risk of retrograde embolization, and extension of the aortic dissection into the femoral artery may make this approach undesirable.

We cannulated the axillary artery in 35 patients with extensive vascular disease in whom ascending aortic and femoral artery cannulation was impossible or undesirable because of severe arterial vascular disease. This study reviews our experience with this technique of arterial cannulation.

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Indications and surgical techniques

Axillary artery cannulation was undertaken in patients with ascending aortic aneurysms, dissections, or atherosclerosis that prevented ascending aortic cannulation and in patients with thoracoabdominal aortic and/or iliofemoral vascular disease that made femoral artery cannulation impossible or associated with a perceived risk of retrograde embolization of thrombus or atherosclerotic debris (Fig. 1). Aortic atherosclerotic and aneurysmal disease was identified and evaluated before the operation by echocardiography, computed tomography, arteriography, or magnetic resonance imaging (or a combination thereof) and during the operation by transesophageal or epiaortic echocardiography. No specific arteriographic visualization of the axillary artery was obtained before the operation.

The axillary artery is exposed for cannulation through an 8 to 10 cm incision below and parallel to the lateral two thirds of the clavicle (Fig. 2). The pectoralis major muscle is divided in the direction of its fibers, and the clavipectoral fascia is incised, exposing the pectoralis minor muscle. The pectoralis minor is divided or retracted laterally. The axillary artery is identified superior to the

Fig. 1. Chest x-ray films (**A** and **B**) and magnetic resonance imaging scans (**C** and **D**) of a patient with diffuse aortic aneurysmal disease. Note atheromatous debris in lumen of aneurysmal descending thoracic aorta.

axillary vein and by palpation. By means of sharp dissection the connective tissue and brachial plexus are dissected from the first part of the axillary artery. Proximal and distal control of the artery is gained by passing a shoestring tie around the artery proximally and distally. A single 4-0 Prolene pursestring suture (Ethicon, Inc., Somerville, N.J.) is placed in the anterior wall of the artery and passed through a tourniquet. The site of cannulation is proximal to the lateral thoracic artery.

After heparin is administered, femoral artery clamps are used proximal and distal to the cannulation site. A longitudinal incision is made in the center of the pursestring suture and the axillary artery is cannulated with either a No. 20 or 22 right-angled arterial cannula. The tourniquet is fastened down and the cannula is tied to the tourniquet and sutured to the skin. Flow is evaluated through the cannula by back bleeding.

Venous cannulation was performed with either a single double-stage right atrial cannula or direct cannulation of both the superior vena cava and inferior vena cava. Occasionally a long venous cannula was inserted via a femoral vein and passed into the proximal inferior vena cava instead of direct inferior vena cava cannulation. The superior vena cava was directly cannulated in several patients to allow for retrograde cerebral perfusion during periods of circulatory arrest.

Cardiopulmonary bypass was begun and flows with cardiac indices of 2.0 to 2.5 L/min per square meter were easily obtained with axillary artery cannulation. After the patient was weaned from cardiopulmonary bypass and the cannulas were removed, the axillary artery was closed longitudinally with an interrupted or running suture technique depending on the size of the artery.

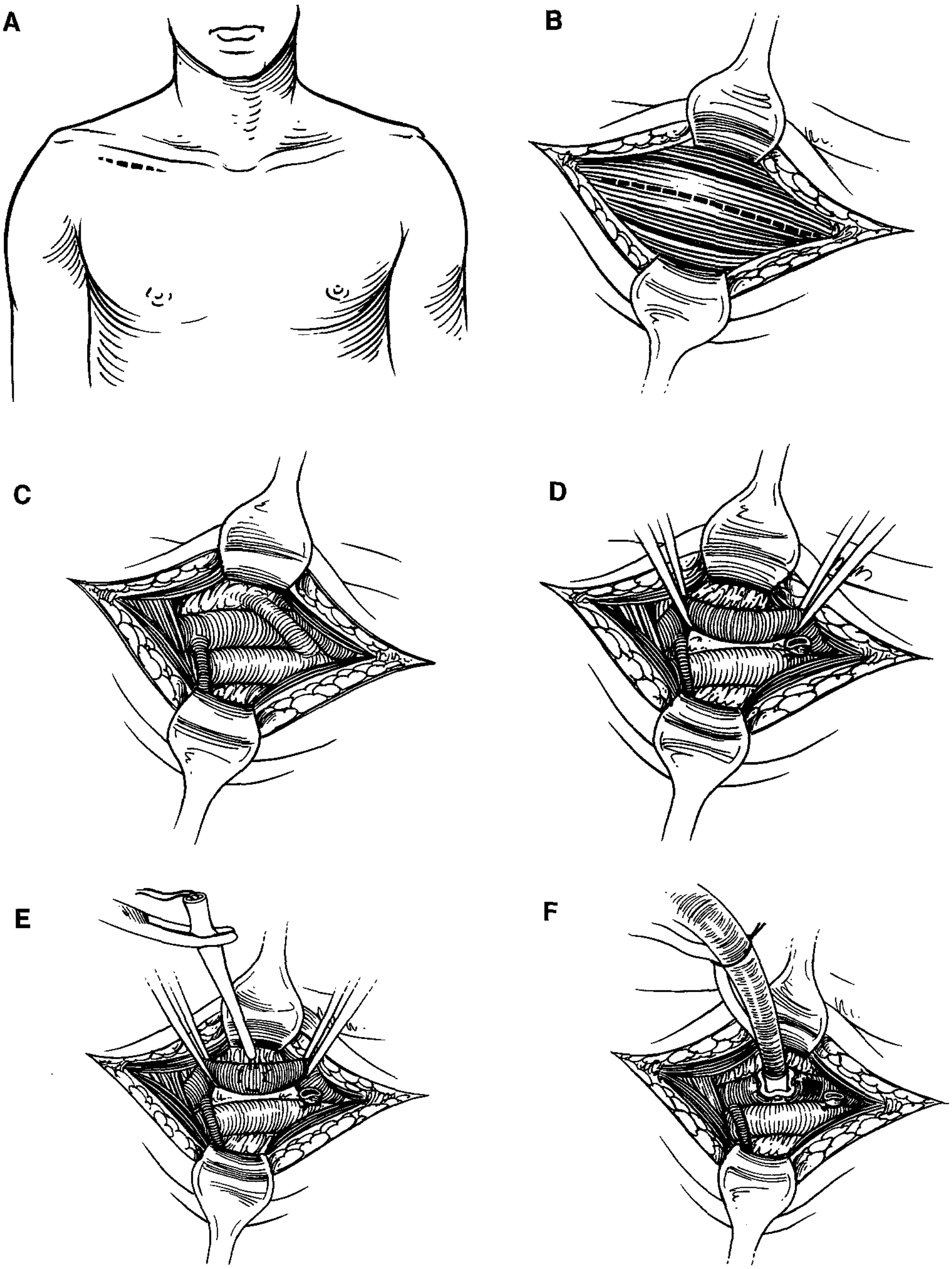

Fig. 2. Surgical technique of axillary artery cannulation. **A,** Site of incision below and parallel to clavicle. **B,** After incision of skin and subcutaneous tissue, before division of pectoralis major muscle in the direction of its fibers. **C,** After the clavipectoral fascia is incised and the pectoralis minor muscle is retracted laterally, the axillary artery is identified above the axillary vein. **D,** Crossing vein is divided and proximal and distal control of subclavian artery is obtained. **E,** Placement of pursestring suture and tourniquet. **F,** Cannulation of axillary artery with right-angled cannula.

Patient population and results

From March 26, 1991, to April 15, 1994, 35 patients, aged 35 to 82 years (mean 66 years) underwent axillary artery cannulation for cardiopulmonary bypass. Twenty-three patients (65.7%) were male. The indications for axillary artery cannulation are listed in Table I, and the operations performed are listed in Tables II and III. Deep hypothermia

Table I. *Indications for axillary artery cannulation*

Indication	*No. of patients*
Severe atherosclerosis	16
Aortic aneurysmal disease	11
Aortic dissection	8
Total	35

Table II. *Operations and number of operations performed with circulatory arrest and retrograde cerebral perfusion*

Operation	*No. of patients*	*Circulatory arrest*	*Retrograde cerebral perfusion*
CABG	9	7	1
AVR	1	1	1
AVR and CABG	5	2	2
Repair MV periopros-thetic leak	1	0	0
Repair ascending aortic pseudoaneurysm	1	0	0
Aortic repair			
Dissection	7	6	6
Aneurysm	11	10	8
Total	35	26	18

CABG, Coronary artery bypass grafting; *AVR,* aortic valve replacement; *MV,* mitral valve.

Table III. *Aortic replacement operations*

Operations	*No. of patients*
Dissection	
AV repair, AA replacement	1
AV repair, AA replacement, CABG	1
Bentall procedure	1
AV repair, AA and Arch replacement	1
Arch replacement (elephant trunk procedure)	1
AA and arch replacement, CABG	1
AAA replacement	1
Aneurysm	
AVR, AA replacement	3
AVR, AA replacement, CABG	2
AVR, AA and arch replacement	1
Bentall	1
Bentall, arch and proximal DA replacement	1
Elephant trunk procedure	1
Arch replacement	1
AA, arch, and DA replacement	1
Total	19

AV, Aortic valve; *AA,* ascending aorta; *CABG,* coronary artery bypass grafting; *AAA,* ascending aortic aneurysm; *DA,* descending aorta.

with circulatory arrest was used in 26 patients and retrograde cerebral perfusion in 18 of the 26 who underwent circulatory arrest (Table II). In nine patients the cardiac operation included aortic arch resection and replacement.

Axillary artery cannulation was performed in all patients in whom it was attempted. In 34 patients right axillary artery cannulation was performed, and in one patient with severe atherosclerotic disease of the innominate artery we elected to cannulate the left axillary artery. This patient had diffuse severe atherosclerosis and underwent coronary artery bypass grafting. All patients were able to be adequately perfused via the axillary artery cannula.

Postoperative complications are listed in Table IV. There was one axillary artery thrombosis and one brachial plexus injury. A patient with Marfan's disease, chronic aortic dissection, and three previous cardiac operations underwent axillary artery cannulation for repair of a mitral valve periprosthetic leak. In the operating room the axillary artery was noted to be small. Immediately after the operation there was an excellent radial pulse, but several hours later the pulse had diminished and it was necessary to explore the artery, perform a thrombectomy, and reconstruct the artery with a vein patch. The patient did well without any further axillary artery complications. One patient had mild hand weakness and numbness on the same side as cannulation. This was believed to be due to a brachial plexus traction injury. The weakness quickly resolved, but the patient has some mild residual numbness in that hand.

No patient had a cerebrovascular injury or evidence of an arterial embolic event. Four patients died, but none of them died of a complication of axillary artery cannulation or of an arterial embolic event. A patient with severe chronic obstructive lung disease who had a ruptured aortic arch aneurysm and chronic dissection died of complications of the lung disease. A patient who underwent replacement of the entire thoracic aorta for a ruptured aneurysm eventually died of complications of mediastinitis. A third patient, with preexisting severe ventricular dysfunction, died of progressive multisystem organ failure as a result of persistent low cardiac output. A patient who initially recovered from his operation uneventfully died of a perforated colon 3 weeks after the operation.

Discussion

Patients undergoing cardiac operations with extensive aortic, iliac, and femoral atherosclerotic or aneurysmal disease present difficult decisions as to the best site of arterial cannulation. We reviewed our experience with axillary artery cannulation in 35 patients undergoing cardiac operations with extensive arterial vascular disease. From our series we believe axillary artery cannulation to be a safe, easy, and effective way of arterial cannulation for cardiopulmonary bypass in these patients.

Two complications were related directly to axillary artery cannulation. One patient with a very small axillary artery required postoperative exploration of the cannulated artery for thrombosis. The patient had no sequela from this event. Vein patch closure of small axillary arteries may prevent this complication. Another patient early in our series had a mild brachial plexus traction injury. The patient has mild residual numbness in that hand but no disability related to the injury. Care in dissecting the artery around the brachial plexus should prevent this injury.

Atheroemboli generated during cardiac operations are a major source of morbidity and mortality.[1-9] They may result in stroke, severe visceral organ injury, or death.[1-9] During the operation atheroemboli may be generated in a number of ways: by simple external manipulation of an atherosclerotic or aneurysmal aorta; by cannulating or crossclamping an atherosclerotic aorta; by the "sandblasting" effect of the high-velocity jet of arterial blood exiting from present day aortic cannulas onto a diseased aortic wall; and by retrograde perfusion through a diseased aorta. Much work has been devoted both to detecting which patients are at risk of atheroemboli[10-15] and to developing new surgical techniques and cannulas to avoid the development of atheroemboli during cardiac operations.[14, 16-21]

Axillary artery cannulation may help prevent the development of atheroemboli during cardiac operations in patients with extensive aortic atherosclerotic and aneurysmal disease. Because the axillary artery is cannulated directly, there is no cannulation and less manipulation of an atherosclerotic ascending aorta. In addition, because the arterial high-velocity flow is away from the diseased ascending aorta and arch, there is no "sandblasting" effect during cardiopulmonary bypass. Also, arterial blood flow with axillary artery cannulation is antegrade, unlike with femoral artery cannulation, in which arterial flow is retrograde.

We believe the avoidance of retrograde blood flow through an atherosclerotic or aneurysmal aorta to be important in decreasing the occurrence of atheroemboli and stroke during cardiopulmonary bypass. Retrograde arterial perfusion through an atherosclerotic aorta has been shown to be associated with stroke and visceral organ injury resulting from atheroemboli.[4] Martin and Hashimoto reported the highest incidence of stroke occurred in their patients who underwent femoral artery cannulation for cardiopulmonary bypass.[8] In an autopsy series, Blauth and associates[1] demonstrated that all of their patients with significant ascending aortic atherosclerosis had severe abdominal atherosclerosis. For these reasons we have preferred axillary artery cannulation with antegrade arterial blood flow during cardiopulmonary bypass rather than femoral artery cannulation.

Table IV. *Postoperative complications*

Complication	*No. of patients*
Axillary artery thrombosis	1
Brachial plexus injury	1
Pericardial effusion	2
Sternal wound infection	3
Cardiac arrhythmia	
Atrial	11
Ventricular	2
Junctional	1
Congestive heart failure	2
Pericarditis	1
Prolonged ventilatory wean	4
Lower extremity deep venous thrombosis	1
Central venous line bacteremia	3
Urinary retention	1
Ischemic colon	1
Total	34

Despite these 35 patients being at high risk for stroke and visceral end-organ injury as a result of atheroemboli, none of our patients had a clinically demonstrable injury resulting from atheroemboli. We believe this finding to be due to the decreased potential of atheroemboli generation with axillary artery cannulation.

We have commonly used axillary artery cannulation for patients who require extensive aortic arch reconstructions. In addition to avoiding retrograde perfusion of the descending thoracic aorta and arch, axillary artery cannulation provides the possibility of right carotid artery perfusion in conjunction with innominate artery occlusion. Whereas our standard methods for cerebral protection during circulatory arrest involve retrograde superior vena cava perfusion, in some reoperations superior vena cava control can be difficult to obtain, making effective perfusion difficult. In this situation antegrade low-level arterial perfusion via the axillary artery can provide effective cerebral protection.

In summary, we have found axillary artery cannulation to be an effective and safe method of arterial cannulation for cardiopulmonary bypass in patients with extensive arterial vascular disease. It may decrease the risk of stroke and visceral organ injury associated with cardiopulmonary bypass in this high-risk group of patients.

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Discussion

Dr. Walter P. Dembitsky *(San Diego, Calif.).* Early in the series, one patient had a brachial plexus injury. I assume the four patients who died were evaluated for plexus integrity. Because this complication appears to be the only major one encountered with the technique, would you elaborate on how to avoid it?

Dr. Sabik. All four patients who died awoke after surgery without any evidence of brachial plexus injury or cerebrovascular accident. The brachial plexus injury was in a patient early in the series. This injury consisted of mild ipsilateral hand weakness and numbness. At present the patient has mild residual numbness, but no weakness. This injury was believed to be due to traction on the brachial plexus. I believe the key to avoiding a brachial plexus injury is careful dissection and avoidance of unnecessary traction on the brachial plexus.

Dr. Dembitsky. Eight patients had aortic dissections. In our experience at least 10% of patients with dissections have separations that involve the innominate artery, possibly making them susceptible to false-channel perfusion using the right axillary cannulation route. Sixteen patients in your series had severe iliofemoral atherosclerosis, suggesting that they might have the same process in their upper extremities. In fact, one patient did have left axillary artery perfusion that was successful. How do you assure the safety of the axillary artery perfusion site, both in terms of initial selection and during conduct of the perfusion?

Dr. Sabik. We do several things to ensure the adequacy of the axillary artery as the site for arterial cannulation.

After cannulating the artery we visually inspect the backflow of blood through the cannula to ensure that it is brisk. After cannulation is performed we also slowly infuse 200 to 300 ml of perfusate and monitor the arterial line pressure. We also monitor systemic arterial pressure using a left brachial artery catheter to detect false channel perfusion. False channel perfusion, however, has not been a problem in our experience with axillary artery cannulation.

Dr. Dembitsky. The advantage of axillary artery cannulation for preventing central nervous system embolization seems evident. The technique also may provide a means for antegrade arterial perfusion of the brain during systemic hypothermic circulatory arrest. I noted that 26 patients had circulatory arrest and only 18 of those had retrograde superior vena caval perfusion. Although this is somewhat tangential to your main theme, how do you select whether to use antegrade, retrograde, or no perfusion for brain protection?

Dr. Sabik. We began cannulating the axillary artery for cardiopulmonary bypass before using retrograde cerebral perfusion. Patients early in our experience with axillary artery cannulation who underwent circulatory arrest therefore did not undergo retrograde cerebral perfusion. At present we routinely use retrograde cerebral perfusion during circulatory arrest.

We have employed antegrade cerebral perfusion using the axillary artery cannula during circulatory arrest in a patient with a persistent left superior vena cava. This patient did very well. However, for this technique of cerebral protection to be used, the innominate artery has to be clamped. Many of the patients in whom we use axillary artery cannulation for cardiopulmonary bypass have diffuse atherosclerosis, often involving the base of the innominate artery. This might preclude the safe application of an arterial clamp. However, in a patient without atherosclerosis of the base of the innominate artery, cerebral protection during circulatory arrest using antegrade perfusion via the axillary artery may be a valuable technique.