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Cannulation of the Axillary Artery for Cardiopulmonary Bypass: Safeguards and Pitfalls

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Background. **The ascending aorta is the customary site for arterial cannulation for cardiopulmonary bypass. Favorable experience at our institution and elsewhere using axillary artery cannulation in treating type A aortic dissections has caused us to broaden our indications for using this site for arterial cannulation for cardiopulmonary bypass.**

Methods. **Medical records, operative notes, and perfusion records were reviewed in all patients in whom the axillary artery was cannulated directly or by a graft for cardiopulmonary bypass from January 1, 2000 through August 30, 2002.**

Results. **Seventy-five patients underwent axillary artery cannulation during the 32-month interval. Eleven patients had ascending aortic dissections, 20 had extensively diseased ascending aortas, and 44 were individuals undergoing repeat cardiac procedures. The right axillary artery was used in 72 patients and the left in 3. In 16 patients the artery was cannulated directly, and in 59 the arterial cannula was inserted into a prosthetic graft that had been anastomosed to the axillary artery. Axillary artery cannulation was satisfactory in 95% (71 of 75) of the cases in which it was used.**

Conclusions. **Cannulation of the axillary artery for cardiopulmonary bypass is a dependable approach for procedures including reoperations, aortic dissections, and extensively diseased ascending aortas.**

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The ascending aorta is the standard site for arterial cannulation for cardiopulmonary bypass. Alternative sites for arterial cannulation are the transverse arch of the aorta, the descending aorta, the femoral artery, the iliac artery, and the axillary and subclavian arteries. Favorable experience at our institution [1] and elsewhere using axillary artery cannulation in treating type A aortic dissections [2, 3] has caused us to broaden our indications for using this site for arterial cannulation for cardiopulmonary bypass.

Material and Methods

Medical records, operative notes, and perfusion records were reviewed in all patients in whom the axillary artery was cannulated either directly or by means of a graft for cardiopulmonary bypass; this review occurred at the Lehigh Valley Hospital from January 1, 2000 through August 30, 2002.

No preoperative evaluation of the arch vessels is performed on any patient except for measurement of bilateral upper extremity blood pressure. An infraclavicular incision is made, and the pectoralis major muscle is split in the direction of the fibers. The pectoralis minor is retracted laterally. Rarely, it is necessary to detach the head of the pectoralis minor from the coracoid process of the scapula. The axillary artery is mobilized by sharp dissection, taking care to avoid injuring the brachial plexus. Because the axillary artery lies deep to the axillary vein, it is usually necessary to mobilize and retract the vein. The patient is systemically anticoagulated with heparin. If the artery is to be directly cannulated, it is opened through a transverse arteriotomy and the cannula is inserted. A vascular clamp is left in place on the artery distally until the arteriotomy is repaired at the conclusion of the operation. If a graft is to be used, a woven, double velour graft (Hemashield Gold™ [Boston Scientific Medi-tech, Wayne, NJ]) is anastomosed to a longitudinal arteriotomy with 6-0 polypropylene suture (Fig 1). The vascular clamps are removed from the artery, restoring flow to the arm. A 22F open-end arterial cannula is inserted into the graft and secured with heavy ligatures. If the chest is open, venous cannulation is performed in the routine manner. If the intention is to institute cardiopulmonary bypass before sternotomy, central venous cannulation is performed through a femoral vein using transesophageal echocardiographic guidance to position the cannula in the right atrium. An arterial pressure monitoring line is inserted in the opposite radial artery or a femoral artery inasmuch as systemic pressure will not be reflected reliably by an arterial catheter in the extremity on the side being perfused. If direct cannulation of the axillary artery is performed, the transverse arteriotomy is closed in the usual manner after cardiopulmonary bypass is terminated. If a graft is used, the graft is amputated 1 or 2 cm from the anasto-

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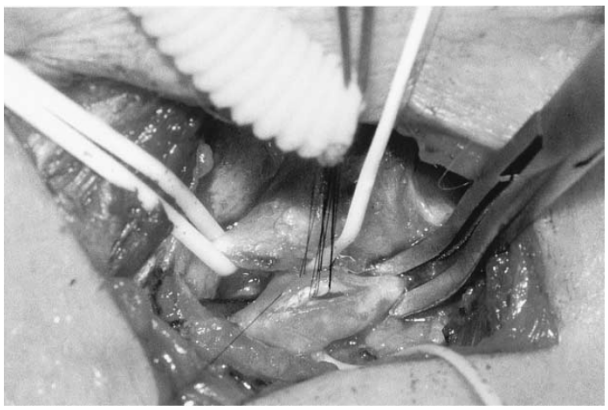

Fig 1. A woven, double velour graft (Hemashield Gold™) is anastomosed to a longitudinal arteriotomy with 6-0 polypropylene suture.

mosis to the axillary artery and oversewn with polypropylene suture or stapled with a vascular stapler.

Results

Seventy-five patients underwent axillary artery cannulation during the 32-month interval. These 75 patients represented 2.7% (75 of 2,771) of the patients undergoing cardiac surgical procedures at Lehigh Valley Hospital during that period. There were three groups of patients in whom axillary artery cannulation was used (Table 1). Eleven patients had ascending aortic dissections, 20 had extensively diseased ascending aortas, and 44 were individuals undergoing repeat cardiac procedures. The right axillary artery was used in 72 patients and the left in 3. In 16 patients the artery was cannulated directly, and in the remaining 59 the arterial cannula was inserted into a prosthetic graft that had been anastomosed to the axillary artery (Table 2). Direct cannulation was more common in the early months of this study period, but the use of an attached graft has become routine (Fig 2).

Eleven (14.7%) of the 75 patients died. The causes of death are shown in Table 3. Thirteen additional patients had a total of 32 complications as shown in Table 4. Three patients could not be adequately perfused including one who died of bleeding on the third postoperative day. Three major nonfatal neurologic problems (two cases of paraplegia and one stroke) were present on arrival in the emergency room. Ten complications necessitated return to the operating room for additional procedures. There were no dissections or other injuries to the perfused axillary arteries. No patients suffered a brachial plexus injury nor were there any wound hematomas or infections.

Table 1. Indications for Axillary Artery Cannulation

Ascending aortic dissection	11
Extensively diseased ascending aorta	20
Reoperation	44
Total	75

Table 2. Method of Axillary Artery Cannulation

Direct	16
Side graft	59
Total	75

Comment

None of the deaths could be attributed to axillary artery cannulation. It is possible that intraoperative malperfusion or embolization contributed to fatal and nonfatal neurologic events and multisystem failure but that seems unlikely as adequate flows were delivered through relatively normal axillary arteries. Admittedly there could have been some washout of mobile atheromatous debris from the ascending aorta.

The four intraoperative complications related to axillary artery cannulation represent important pitfalls that can be avoided (Table 5). Patient A had repeat myocardial revascularization through sternotomy without cardiopulmonary bypass (off-pump coronary artery bypass grafting). A complex vein graft had been brought from the left axillary artery to the right coronary artery and left anterior descending artery. The left internal mammary artery was not available because it had been used at the first operation several years earlier. The ascending aorta was severely diseased and not considered suitable for either cannulation or construction of a proximal anastomosis. In the early postoperative period he was returned to the operating room for revision of the occluded limb of the graft to the left anterior descending artery. The decision was made to perform the graft revision with cardiopulmonary bypass. The right axillary artery was exposed and found to be relatively small for the size of the patient, but it was nonetheless cannulated directly. Adequate inflow could not be achieved despite multiple manipulations of the cannula. The operation was converted from on-pump to off-pump, and the graft was revised without incident. The transverse arteriotomy in the axillary artery was repaired in the standard fashion. There was no evidence of dissection of the artery, and there was no vascular compromise to the patient's arm. The inability to perfuse the patient was related to direct cannulation of a relatively small axillary artery. Perfusion

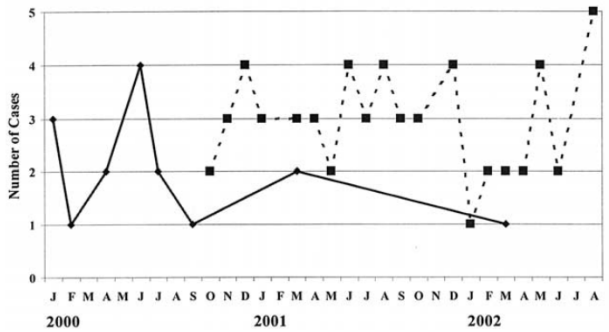

*Fig 2. Direct cannulation (*solid line*) versus use of an attached graft (*dotted line*). (*Letters = *months of the year.)*

Table 3. Mortality

Stroke	5
Postoperative bleeding	1
Myocardial infarction	2
Adult respiratory distress syndrome	1
Multisystem failure	2
Total	11

would probably have been satisfactory if the cannula had been placed in a graft anastomosed to the axillary artery.

In Patient B, axillary artery cannulation and central venous cannulation (through a femoral vein with transesophageal echocardiographic guidance) were performed before sternotomy because of concern about the proximity of the right ventricle to the posterior surface of the sternum. The axillary artery was cannulated directly and occluded distally with a vascular clamp. The chest was opened without incident, and cardiopulmonary bypass was discontinued for 60 minutes while adhesions were divided and the heart was mobilized. Cardiopulmonary bypass was reinstituted, and the operation was completed with some difficulty after another 3 hours 20 minutes of bypass. Approximately 12 hours postoperatively the patient was found to have a compartment syndrome involving the right forearm. A fasciotomy was required, and the patient was left with some sensory deficit although motor function is intact. The compartment syndrome, caused by prolonged arm ischemia secondary to clamping the axillary artery distal to the cannulation site, could have been prevented by cannulating a graft attached to the artery.

In Patient C, cardiopulmonary bypass was also instituted before sternotomy. In this instance, a graft had been anastomosed to the axillary artery. Venous cannulation was accomplished as in patient B. After uneventful sternotomy, cardiopulmonary bypass was discontinued for 168 minutes while adhesions were divided and the left internal mammary artery was mobilized. When an attempt was made to reestablish cardiopulmonary bypass, there was excessive resistance in the arterial circuit. Close inspection revealed an apparent clot in the arterial filter despite the fact that the activated clotting time had been maintained at more than 480 seconds. The entire circuit (tubing, oxygenator, and filter) was changed. The arterial graft and cannula and the venous cannula were not changed. Cardiopulmonary bypass was reinstituted, and the operation was completed without incident. The problem was apparently caused by stasis in the extracorporeal circuit and could have been prevented by intermittent restoration of flow.

Table 4. Complications

Inadequate perfusion	3
Nonfatal stroke	3
Encephalopathy	4
Paraplegia	2
Pneumonia	2
Vocal cord paralysis	1
Thrombophlebitis	2
Clostridium difficile diarrhea	1
Pancreatitis	2
Dysphagia	1
Helicobacter pylori esophagitis	1
Postoperative bleeding	2
Sternal dehiscence	1
Infected vein harvest site	1
Perforated colon	1
Pericardial effusion	1
Right upper extremity compartment syndrome	1
Heart block requiring permanent pacemaker	1
Malignant ventricular tachycardia requiring implantable cardioverter defibrillator	3

Table 5. Pitfalls and Remedies With Axillary Cannulation

Pitfalls	Remedies
Patient A: Inability to perfuse adequately through small axillary artery with direct cannulation	Cannulate a graft anastomosed to the artery rather than the artery itself
Patient B: Compartment syndrome in the arm being perfused	Cannulate a graft anastomosed to the artery rather than the artery itself
Patient C: Clot in the arterial circuit	Intermittently circulate a small volume through the circuit
Patient D: Inability to achieve adequate arterial flow because of high resistance through cannula in side graft	Use a cannula with an open end rather than one with multiple side openings

The fourth problem also occurred in an individual (patient D) in whom cardiopulmonary bypass was performed early to facilitate safe repeat sternotomy. In this case also, the right axillary artery was cannulated by means of a graft, and central venous cannulation was performed as in the previous patients. Flow was limited to 2.2 L/min because of high pressure in the arterial circuit (280 mm Hg). Inspection revealed no apparent problems in the arterial circuit, and sternotomy was completed under partial bypass. Partial cardiopulmonary bypass was continued for 55 minutes while dissection was performed to allow central arterial (ascending aorta) and venous cannulation. Total bypass was then established, and the operation was completed without incident. On removal of the arterial cannula from the Dacron graft, it was apparent that the outflow from the cannula that had multiple side openings was compromised by the tight fit of the cannula in the graft. This problem would have been prevented by use of a cannula with an open end.

Cannulation of a graft attached to the axillary artery has several advantages over direct arterial cannulation. In addition to avoiding the pitfalls mentioned above, it greatly simplifies decannulation at the end of a prolonged operation. The only disadvantages appear to be the extra time required at the onset to anastomose the graft to the artery and the inevitable bleeding from the

suture line and "weeping" through the graft during cardiopulmonary bypass. Distal embolization from the stump of the graft left on the artery apparently does not occur. The axillary artery is the preferred site of cannulation for ascending aortic dissections (unless it is involved in the dissection) because it minimizes the risk of malperfusion, hypoperfusion, retrograde embolization, and retrograde dissections that might occur with femoral cannulation. This technique eliminates the need to move the cannula from the femoral artery to the newly inserted prosthetic graft to assure perfusion of the true lumen. It also facilitates antegrade cerebral perfusion, if desired, if the right axillary artery is used. The right carotid can be selectively perfused by simply occluding the innominate artery with a small vascular clamp.

Because the axillary arteries are usually relatively free of arteriosclerosis, they can often serve as a convenient site to cannulate for reoperations. The degree of iliofemoral arteriosclerosis in many patients with coronary artery disease precludes safe cannulation, and the extensive disease in the descending thoracic and abdominal aorta makes retrograde perfusion hazardous.

Finally, axillary artery cannulation is feasible in many patients with porcelain aortas, ascending aortas with protuberant atheromata, and ascending aortic aneurysms [4–6]. If the surgeon is uncomfortable or unable to perform off-pump bypass grafting in individuals with this type of aorta, on-pump beating heart bypass is feasible. Although there seems to be some risk of embolization from mobile atheroma of the arch or ascending aorta with axillary artery perfusion, we have not encountered this problem. One or both internal mammary arteries can be used as the inflow site for all grafts; we have used this technique in several patients. We have also used the contralateral axillary artery for a proximal anastomosis when there was doubt that the internal mammary could adequately supply the entire heart or the internal mammary artery was not available. In 95% of the patients (71 of 75) adequate perfusion was obtained with the techniques applied. If attention is paid to avoid the pitfalls mentioned above, axillary artery cannulation should be feasible and safe in nearly all patients.

Cannulation of the axillary artery for cardiopulmonary bypass is a safe and reliable procedure that is applicable to a variety of cardiac surgical procedures, including reoperations, aortic dissections, and extensively diseased ascending aortas.

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