Management of Arterial Injuries Related to Cardiac Catheterization in Children and Young Adults

By Peter B. Mansfield, M.D., Alan B. Gazzaniga, M.D., and S. Bert Litwin, M.D.

SUMMARY

Retrograde arterial catheterization in children and young adults carries a risk of vessel damage and occlusion. The management of 29 such injuries is presented. The first patient in this series died after amputation of his lower extremity for gangrene. In all patients in whom distal pulses were absent 8 hours after catheterization arterial obstruction was complete. Claudication developed in the two patients who were not operated upon. Twenty-seven patients had arterial exploration and repair. The indications for exploration and the surgical technics evolved during the series are presented. In 24 patients pulses and perfusion returned to normal after operation, and two patients had residual arterial obstruction without symptoms.

Additional Indexing Words:
Arterial catheterization Arteriotomy

CARDIAC diagnostic investigation in children or young adults requiring arterial catheterization carries a risk of local vessel injury and loss of distal perfusion. Although the reported incidence of vessel injury after catheterization in these patients is said to be low, serious problems can arise as a result of such injury. The Cardiovascular Surgical Service at the Children’s Hospital Medical Center in Boston has adopted an intensive approach to the treatment of arterial injuries resulting from such diagnostic procedures. As a result of this experience, an effective technic for the management of these complications has emerged.

Methods

Clinical Material

Before November 1969, 29 children and young adults had been evaluated for arterial injuries resulting from diagnostic procedures. Age, sex,

diagnosis, site of vessel injury, and type of repair are listed in table 1. There were eight injuries of the brachial artery, four injuries of the axillary artery, and 17 injuries of the superficial femoral artery. Twenty-six of the 29 patients were seen within 72 hr after catheterization. Two of the 29 patients were evaluated 3 weeks and 4 weeks after vessel injury and were observed only. One patient was seen a week after catheterization and underwent thrombectomy at that time. Three injuries occurred after the vessel had been exposed and entered multiple times with a Teflon-coated needle. All other injuries occurred after exposure of the vessel and arteriotomy with insertion of an angiographic catheter.

In most patients pulses were absent distal to the injury. In five patients with proven complete superficial femoral obstruction, a very faint delayed but palpable dorsalis pedis pulse was noted by several examiners; this pulse attested to the flow brought in by collateral channels. The posterior tibial pulse, however, was absent in all our patients with femoral arterial block, and all limbs were paler and cooler than those on the opposite side. Capillary filling was usually delayed. Severe ischemia with changes in sensation was rarely seen, in contrast to the experience with adult arteriosclerotic limbs after arterial occlusion.

Several types of arterial lesions were encountered. The most common type was tear and

From the Department of Cardiovascular Surgery, Children’s Hospital Medical Center, and the Department of Surgery, Harvard Medical School, Boston, Massachusetts.

Received January 16, 1970; revision accepted for publication April 30, 1970.

Circulation, Volume XLII, September 1970
### Table 1

**Summary of Patients with Arterial Injuries Related to Cardiac Catheterization**

<table>
<thead>
<tr>
<th>Patient</th>
<th>Sex</th>
<th>Age (yr)</th>
<th>Diagnosis</th>
<th>Site of injury (artery)</th>
<th>Type of repair</th>
<th>Result*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M</td>
<td>9</td>
<td>Tetralogy of Fallot</td>
<td>Superficial femoral</td>
<td>Embolectomy and closure</td>
<td>Amputation below knee: died</td>
</tr>
<tr>
<td>2</td>
<td>M</td>
<td>14</td>
<td>Aortic stenosis</td>
<td>Superficial femoral</td>
<td>Thrombectomy and wedge resection</td>
<td>Excellent</td>
</tr>
<tr>
<td>3</td>
<td>M</td>
<td>9</td>
<td>Aortic stenosis</td>
<td>Brachial</td>
<td>Thrombectomy and closure</td>
<td>Fair</td>
</tr>
<tr>
<td>4</td>
<td>M</td>
<td>4†</td>
<td>Ventricular septal defect</td>
<td>Superficial femoral</td>
<td>Thrombectomy and closure</td>
<td>Excellent</td>
</tr>
<tr>
<td>5</td>
<td>M</td>
<td>25</td>
<td>Mitral insufficiency</td>
<td>Superficial femoral</td>
<td>Thrombectomy and resection</td>
<td>Excellent</td>
</tr>
<tr>
<td>6</td>
<td>M</td>
<td>12</td>
<td>Aortic stenosis</td>
<td>Superficial femoral</td>
<td>Observed</td>
<td>Claudication: lower leg</td>
</tr>
<tr>
<td>7</td>
<td>F</td>
<td>16</td>
<td>Tricuspid stenosis</td>
<td>Superficial femoral</td>
<td>Thrombectomy, resection, vein graft</td>
<td>Excellent</td>
</tr>
<tr>
<td>8</td>
<td>M</td>
<td>23</td>
<td>Aortic stenosis</td>
<td>Axillary</td>
<td>Observed</td>
<td>Claudication: arm and hand</td>
</tr>
<tr>
<td>9</td>
<td>F</td>
<td>23</td>
<td>Aortic stenosis</td>
<td>Superficial femoral</td>
<td>Thrombectomy and resection</td>
<td>Excellent</td>
</tr>
<tr>
<td>10</td>
<td>M</td>
<td>19</td>
<td>Mitral stenosis</td>
<td>Brachial</td>
<td>Thrombectomy and closure</td>
<td>Excellent</td>
</tr>
<tr>
<td>11</td>
<td>M</td>
<td>18</td>
<td>Aortic stenosis</td>
<td>Axillary</td>
<td>Thrombectomy and resection</td>
<td>Excellent</td>
</tr>
<tr>
<td>12</td>
<td>F</td>
<td>6</td>
<td>Pulmonary stenosis</td>
<td>Superficial femoral</td>
<td>Thrombectomy and closure</td>
<td>Excellent</td>
</tr>
<tr>
<td>13</td>
<td>F</td>
<td>10</td>
<td>Truncus arteriosus</td>
<td>Superficial femoral</td>
<td>Thrombectomy and closure</td>
<td>Failure</td>
</tr>
<tr>
<td>14</td>
<td>M</td>
<td>13</td>
<td>Ebstein's anomaly</td>
<td>Brachial</td>
<td>Thrombectomy and closure</td>
<td>Excellent</td>
</tr>
<tr>
<td>15</td>
<td>M</td>
<td>6</td>
<td>A-V block</td>
<td>Superficial femoral</td>
<td>Thrombectomy and closure</td>
<td>Excellent</td>
</tr>
<tr>
<td>16</td>
<td>M</td>
<td>18</td>
<td>Ventricular septal defect</td>
<td>Axillary</td>
<td>Thrombectomy and resection</td>
<td>Excellent</td>
</tr>
<tr>
<td>17</td>
<td>M</td>
<td>6</td>
<td>Double outlet right ventricle</td>
<td>Brachial</td>
<td>Thrombectomy and closure</td>
<td>Failure</td>
</tr>
<tr>
<td>18</td>
<td>F</td>
<td>3</td>
<td>Aortic stenosis</td>
<td>Superficial femoral</td>
<td>Thrombectomy and closure</td>
<td>Excellent</td>
</tr>
<tr>
<td>19</td>
<td>M</td>
<td>10</td>
<td>Aortic stenosis</td>
<td>Superficial femoral</td>
<td>Thrombectomy and resection</td>
<td>Excellent</td>
</tr>
<tr>
<td>20</td>
<td>F</td>
<td>11</td>
<td>Aortic stenosis</td>
<td>Superficial femoral</td>
<td>Thrombectomy and resection</td>
<td>Excellent</td>
</tr>
<tr>
<td>21</td>
<td>M</td>
<td>12</td>
<td>Aortic stenosis</td>
<td>Brachial</td>
<td>Thrombectomy and resection</td>
<td>Excellent</td>
</tr>
<tr>
<td>22</td>
<td>M</td>
<td>9</td>
<td>Aberrant (L) coronary</td>
<td>Brachial</td>
<td>Thrombectomy and resection</td>
<td>Excellent</td>
</tr>
<tr>
<td>23</td>
<td>M</td>
<td>2</td>
<td>Aortic stenosis</td>
<td>Axillary</td>
<td>Thrombectomy and wedge resection</td>
<td>Excellent</td>
</tr>
<tr>
<td>24</td>
<td>F</td>
<td>19</td>
<td>S/P ostium primum repair</td>
<td>Brachial</td>
<td>Thrombectomy and resection</td>
<td>Excellent</td>
</tr>
<tr>
<td>25</td>
<td>M</td>
<td>13</td>
<td>Aortic stenosis</td>
<td>Superficial femoral</td>
<td>Thrombectomy and resection</td>
<td>Excellent</td>
</tr>
<tr>
<td>26</td>
<td>M</td>
<td>19</td>
<td>Ventricular septal defect</td>
<td>Brachial</td>
<td>Thrombectomy and resection</td>
<td>Excellent</td>
</tr>
<tr>
<td>27</td>
<td>M</td>
<td>10</td>
<td>Ventricular septal defect</td>
<td>Superficial femoral</td>
<td>Thrombectomy and resection</td>
<td>Excellent</td>
</tr>
<tr>
<td>28</td>
<td>M</td>
<td>2</td>
<td>Ventricular septal defect</td>
<td>Superficial femoral</td>
<td>Thrombectomy and wedge resection</td>
<td>Excellent</td>
</tr>
<tr>
<td>29</td>
<td>M</td>
<td>6</td>
<td>Patent ductus</td>
<td>Superficial femoral</td>
<td>Thrombectomy and resection</td>
<td>Excellent</td>
</tr>
</tbody>
</table>

*Excellent — restored pulses equal to normal pulses on opposite extremity. Fair — pulses present, but decreased compared to opposite limb. Failure — no return of pulses.

†Age in months.
disruption of the posterior wall of the artery, opposite the site of arteriotomy. This damage extended proximally for about 0.5 to 1.0 cm, rarely extended distally, and invariably required arterial resection and reanastomosis. The next most frequent type of lesion was narrowing of the vessel, secondary to the closure of the arterial incision. Purse-string sutures and sutures that dragged strands of adventitia into the vessel lumen were frequent causes of local thrombosis in these patients. Multiple needle insertions caused local intimal damage and local thrombotic occlusion in three patients.

**Indications and Techniques**

Surgery was performed as soon as possible after the diagnosis of arterial injury had been made. This diagnosis was made after a period of observation to be sure that loss of distal pulses was not related to arterial spasm. When pulses had not returned within 8 h after catheterization, a diagnosis of vessel injury and occlusion was almost certain. In every instance in which pulses were not palpable 8 h after catheterization, there was complete arterial obstruction. When extensive injuries were recognized in the catheterization laboratory and pulses could not be obtained with closure, the patient was transported directly to the operating room where repair was undertaken with the aid of more adequate lighting and anesthesia.

In children general anesthesia was always used; endotracheal intubation was seldom necessary. In young adults with brachial lesions, local anesthesia and sedation with morphine were usually used. Intravenous administration of antibiotics, usually penicillin or oxacillin, was employed preoperatively and was continued in high dosage for 7 to 10 days postoperatively. The entire extremity was prepared for surgery, including the axilla and shoulder when an arm vessel was involved. The artery was adequately exposed for repair by extension of the previous cutdown incision parallel to the artery. The vessel was usually pulseless distally, with a blue-to-black clot visible through the site of injury. The artery was gently dissected free proximally and distally, and heavy silk ligatures or umbilical tapes were passed about it for improvement of exposure of the vessel. An intravenous anticoagulating dose of heparin (200 units/kg) was given, and the vessel was clamped below and above the arteriotomy. The previous arterial sutures were removed, the local thrombus was removed, and the arterial lumen was irrigated and inspected for damage. The proximal portion of the vessel was cleared with a Fogarty arterial balloon catheter of appropriate size (usually a no. 3 or no. 4). The distal vessel was cleared of clot by passage of the Fogarty catheter as far distally as possible. When brachial injuries were being repaired, the catheter was passed down both the ulnar and radial arteries. Either vessel could be selectively entered, depending on whether the forearm was held in pronation or supination. Accurate placement of the catheter could be assessed by palpation of the catheter within the artery at the wrist. Passes were made until no further thrombus was recovered and adequate back bleeding was established. If back bleeding did not occur, retrograde flushing from the wrist or ankle was used. Alternatively, the extremity was wrapped, beginning distally, with a tight elastic bandage (Esmarch) and clots were milked out in a retrograde fashion. The distal portion of the vessel was then flushed with a heparin-saline solution through an irrigating catheter. In the arm particularly, the patency of each distal artery could be demonstrated by this flush; the tissue was blanched in the area of distribution of the patent arteries.

The artery was repaired by reclosure of the arteriotomy, transverse wedge resection of the damaged portion of vessel with a transverse evertong closure, or resection and either anastomosis or insertion of a vein graft. If there was no significant intimal damage and if thrombosis occurred because of: (1) narrowing, (2) a distal clot that had formed during prolonged catheterization, or (3) turning in of the adventitia at the arteriotomy site, wedge resection and closure with interrupted evertong horizontal mattress sutures usually sufficed. However, if posterior intimal damage was significant or if any doubt existed, we found resection and reanastomosis the most successful mode of repair. It is interesting that in the four patients in which a less than excellent result was obtained, thrombectomy and closure had been performed. The technic of resection and anastomosis provided excellent results whenever it was used. Since these patients were young and arterial growth was anticipated, less than half the arterial circumference was closed with running sutures, and interrupted evertong sutures were used for the remainder. A vein graft was used only once, early in this series.

For anastomosis the arterial ends were held together with vascular clamps; thus any tension on the suture line was avoided. Depending on the size of the vessel, 5-0, 6-0, or 7-0 silk or Dacron was used. Critically important to the success of the procedure was the removal of all the adventitia from the injury site for about 1.0 cm in each direction. This was circumferentially and painstakingly done. This step allowed precise intimal approximation and maximal anastomotic diameter and prevented adventitial strands from being pulled into the lumen with the suture. The resected vessel was closed by use of evertong...
Figure 1

(A) Femoral arteriogram of patient 6 at 15 months after retrograde cardiac catheterization via the right superficial femoral artery. (B) A line drawing of the x-ray findings shown in corresponding panels of A. Panel 1 shows good inflow via the external iliac and common femoral arteries. Panel 2 demonstrates enlarged collateral vessels around the femoral neck (upper two arrows).
mattress sutures at the corners of the closure. The back wall was closed with a continuous horizontal mattress or over-and-over suture, and the front row with interrupted everting mattress sutures. The wound was irrigated with local antibiotic solution (neomycin, polymyxin, and bacitracin), and the skin was loosely closed.

Intravenous postoperative heparinization was continued when direct closure without resection had been done, when there was poor back bleeding or a high hematocrit, secondary to cyanotic heart disease. Anticoagulating doses of heparin (100–200 units/kg every 4 hr) were continued from 2 to 5 days postoperatively. Posterior splints have been used for support of the arm in brachial artery injuries. All bandages were small and loosely applied.

**Results**

The results in patients undergoing surgical exploration for loss of distal pulses after diagnostic procedures are shown in table 2. There were no failures or complications in the three patients with axillary artery injuries.

Eight injuries of the brachial artery were treated surgically. Six of these patients had return of normal peripheral pulses. Patient 3 (table 1) had faint but definite peripheral pulses that improved markedly after an aortic valvotomy, and the repair is classified as a fair result. Patient 17 had an improperly closed arteriotomy, which led to subsequent loss of his peripheral pulses.

Of the 16 patients with injuries of the superficial femoral artery treated surgically, 14 recovered normal pulses; two did not (failures). Patient 12 had a thrombectomy immediately before cardiopulmonary bypass. Pulses were regained before bypass but were absent immediately after surgery. This patient has regained a dorsalis pedis pulse, but the posterior tibial and popliteal pulses are absent. It is of interest that patients 5, 16, and 27 had femoral artery reconstruction 24 to 48 hr before complete open heart repair but had no postoperative arterial difficulty.

Patient 1, the other failure in the femoral artery group, shows the devastating results of arterial insufficiency. He was a 9-year-old, with severe tetralogy of Fallot. After catheterization his hematocrit was 80%, and he had no pulses in the right leg below the groin. He underwent arterial thrombectomy at 5 days and again at 8 days after catheterization, and was heparinized for a prolonged interval. Arterial patency at the catheterization site was obtained, but small vessel obstruction distally led to dry gangrene, which necessitated guillotine amputation at the ankle. After definitive amputation below the knee 6 days later, he had several cyanotic spells and a terminal cardiac arrest.

Two patients in the series were seen 3 and 4 weeks after catheterization respectively and were not operated upon. Patient 8 became symptomatic, with arm fatigue and hand claudication. His symptoms have slowly improved over the subsequent 6 months and reconstructive surgery is not planned at this time. Patient 6 had catheterization of the superficial femoral artery. Three weeks after catheterization he had claudication after walking one block. He was observed, and 1 year later he had lost most of his claudication and had regained a faint, though delayed

<table>
<thead>
<tr>
<th>Artery</th>
<th>No. of patients</th>
<th>Excellent</th>
<th>Fair</th>
<th>Failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axillary</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Brachial</td>
<td>8</td>
<td>6</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Femoral</td>
<td>16</td>
<td>14</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

*See table 1 for definitions.*

and a greatly enlarged profunda femoris (lower arrow). These arteries provide blood to the muscles in the leg above the knee (note distal tapering) and normally have only small collateral communications with vessels in the lower leg. No superficial femoral artery is seen at this stage of peripheral flow. Panel 3 shows washout of the arteries seen in panel 2 and delayed retrograde filling of the superficial femoral artery beyond the area of occlusion (arrow). There is a 1 to 2 cm block at the origin of the superficial femoral artery with a patent distal vessel. Resection and reanastomosis will relieve this patient’s claudication.

*Circulation, Volume XLII, September 1970*
dorsalis pedis pulse. No popliteal or posterior tibial pulses were present. Arteriography (fig. 1) demonstrated complete superficial femoral obstruction and marked arterial collateral development. The profunda femoris was open and the distal superficial femoral artery was filled retrogradely via the geniculate arteries. Surgery has been scheduled for next summer.

**Discussion**

Complete arterial obstruction occurs in a significant number of young patients after retrograde arterial catheterization. In the past, concern over these injuries has been minimized since severe complications have been rare. However, in this series one patient died as a result of injury of the superficial femoral artery and two patients have had disabling limb claudication. In addition to these complications, there are additional reasons for adoption of an early and intensive emphasis on arterial reconstruction. Inadequate limb growth and claudication in adult life may occur.

If after subsequent open heart repair, low cardiac output occurs, the viability of the limb supplied only by collaterals may be in jeopardy. Furthermore, many patients need more than one catheterization, and preservation of available arteriotomy sites is essential. This is especially true when the brachial artery is used in patients with aortic stenosis. Subsequent studies through the arm have to be done at the axillary level, and axillary injuries can produce serious disability requiring extensive reconstructive surgery.

Our experience had taught us to reconstruct the injured artery surgically as soon as possible after the diagnosis is made. Although thrombi can successfully be removed as late as 7 to 10 days after thrombosis, the use of Fogarty catheters is more effective when clots are removed within 24 hr after the injury. The postoperative use of anticoagulants has been rare. In this age group runoff is usually excellent, and, providing the closure has been technically adequate and distal and all proximal clot has been completely removed, anticoagulants have been unnecessary. The postoperative use of heparin has been limited to those few patients who have demonstrated poor back flow, have had delayed explorations with fibrin layering, or have severe cyanotic heart disease and markedly elevated hematocrits. In the cyanotic group, erythropheresis at catheterization or at surgical exploration can be of significant benefit.

Many factors contribute to postcatheterization arterial obstruction. We suggest attention to the following preventive measures or operating procedures: (1) Adequate exposure and good lighting are necessary for nontraumatic handling of arterial vessels. In every patient we have extended the original cutdown incision to facilitate definitive repair. (2) Few surgeons do arterial manipulation without one or two assistants for help in exposure and stabilization; yet in many of these patients, closure was accomplished by a single operator. (3) The insertion of a catheter into a small artery may easily snowplow the posterior intima ahead of it. Better exposure and decrease of the angle of entry may help to diminish the incidence of this most common form of injury. (4) In children, closure of the vessel with an adventitia purse-string suture is hazardous. This suture narrows the size of the lumen and may infold intima and adventitia, leading to occlusion. Transverse arteriotomy, clearing away of the adventitia, and use of interrupted horizontal mattress sutures incorporating the intima are preferable. (5) We have found arterial repair to be greatly facilitated by the use of microvascular instruments and magnifying lenses. Most commonly, vision dictates the adequacy of fine suture placement; the hand has rarely been the limiting factor. (6) At the conclusion of arterial catheterization good forward and backward bleeding must be present before the vessel is closed. If they are not, Fogarty catheterization is indicated. Heparin should be given to such patients.

**References**

Management of Arterial Injuries Related to Cardiac Catheterization in Children and Young Adults

PETER B. MANSFIELD, ALAN B. GAZZANIGA and S. BERT LITWIN

doi: 10.1161/01.CIR.42.3.501

Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 1970 American Heart Association, Inc. All rights reserved.
Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circ.ahajournals.org/content/42/3/501

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Circulation can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Circulation is online at:
http://circ.ahajournals.org//subscriptions/