TECHNIQUES AND APPLICATIONS IN INTERVENTIONAL CARDIOLOGY

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Techniques and Applications in Interventional Cardiology

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FOREWORD

Interventional cardiology has revolutionized the diagnosis and treatment for large segments of the patient population with diseases affecting the cardiovascular system. Part of the reduced age-adjusted mortality from cardiovascular disease is due to the development and subsequent widespread use of more sophisticated diagnostic and therapeutic techniques. Advances in interventional cardiology have been numerous and rapid, and important future technologies likely will further reduce morbidity and mortality for cardiac patients.

This textbook by Drs. Kulick and Rahimtoola provides the reader with a scholarly overview of the current status of interventional cardiology and includes narratives by 59 experts in various aspects of the field, who provide well-referenced and superbly illustrated state-of-the art commentaries on the usefulness and limitations of each technique.

Following a detailed discussion of the techniques of vascular access, this book is composed logically into four main sections. The first of these concerns intracoronary and peripheral vascular interventions and contains 10 chapters dealing with specialized techniques applicable to patients with coronary and/or peripheral vascular diseases, including detailed discussions of vascular angioplasty, laser therapy, and the use of stents.

The second section contains three chapters by well-recognized experts in the use of balloon commissurotomy, valvuloplasty, or dilation for the treatment of stenotic valvular and nonvalvular lesions. Part III comprises five chapters describing the use of several devices for the interventional treatment of arrhythmias, and includes important discussions on cardiac pacing, implantable cardioverters, and catheter albation for tachyarrhythmias. In the final section of this comprehensive textbook, expert discussions are included on the common procedures of endomyocardial biopsy and pericardiocentesis.

Drs. Kulick and Rahimtoola have done a superb job in organizing and integrating discussions by highly selected experts on the rapidly growing field of interventional cardiology. This text will be of great use not only to interventional cardiologists but even more so to the many physicians who refer patients for these worthwhile additons to our diagnostic and therapeutic armamentarium.

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PREFACE

Techniques and Applications in Interventional Cardiology is a current overview of the rapidly expanding field of interventional cardiology that highlights the practical applications of interventional techniques and emphasizes correct selection of appropriate patients and equipment, detailed instruction in the safe and proper performance of the various procedures, expected results, and guidelines for minimizing and managing any complications that might occur. Interventional cardiology is a broad discipline, encompassing management of coronary and peripheral vascular disease, valvular heart disease, cardiac dysrhythmias, and myocardial and pericardial disorders. In a rapidly evolving field such as this, production of a textbook containing the most up-to-date information is a formidable task; the reader will want to use this volume as a basis for integration of future developments in the field.

While we have attempted to present as current and complete a review as possible, the emphasis necessarily has been on those procedures already in widespread clinical practice or those anticipated to be widely available soon. We believe the vast majority of procedures likely to be performed by the practicing interventionalist is adequately addressed in this text. Our contributors were carefully selected for their acknowledged expertise in their respective fields as well as their extensive experience in the performance of the procedures described.

Techniques and Applications in Interventional Cardiology is intended as a practical reference emphasizing the performance of interventional techniques. Thus it will supplement standard textbooks of cardiac catheterization and more encyclopedic references in the field. We hope the book will prove useful to practicing interventional cardiologists, cardiovascular house staff in training, primary care physicians involved in the care and referral of patients requiring interventional cardiovascular therapy, and allied health professionals helping to care for such patients.

We gratefully acknowledge the excellent and timely contributions of our many expert authors, and the secretarial support staff at Los Angeles County–University of Southern California Medical Center.

Daniel L. Kulick, M.D.
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1

Technique of Vascular Access

Abraham Gonzalez, M.D.

Shahbudin H. Rahimtoola, M.B., F.R.C.P.

Daniel L. Kulick, M.D.

Correct methods of obtaining vascular access are extremely important in performance of diagnostic and therapeutic cardiac catheterization. Selection of the site for vascular access should take into consideration several factors: (1) type of procedure to be performed (i.e., diagnostic or therapeutic); (2) patient comfort; (3) risk of complications; (4) anatomic factors including presence and severity of peripheral vascular disease, prior vascular prosthesis placement, etc.; and (5) operator experience. The active interventional cardiologist should be experienced with as many vascular access site approaches as possible.

FEMORAL VASCULAR ACCESS

The availability of preformed diagnostic and guiding catheters has made the femoral technique developed by Judkins the most commonly used method for diagnostic as well as therapeutic cardiac catheterization. After preparation of the patient, the femoral artery is located by palpating in the area of the inguinal crease, midway between the anterior superior iliac spine and the symphysis pubis *below* the inguinal ligament. Care should always be taken to identify the course of the inguinal ligament, as the skin crease may be variable in position. Vascular puncture should be performed below this structure (Fig 1–1). The mnemonic *NAVEL* is useful in remembering the relation of structures in the femoral canal; from lateral to medial, structures are situated as follows: femoral *n*erve, femoral *a*rtery, femoral *v*ein, and most medial, *l*ymphatic vessels. Arterial and venous entry should be 3 to 5 cm below the inguinal ligament (Fig 1–2). This will avoid puncture of noncompressible vascular segments, which may predispose to hemorrhage into the thigh or peritoneal cavity or pseudoaneurysm formation. Furthermore, more caudal cannulation of the femoral artery in the region of origin of the profunda femoris artery (approximately 5 cm below the inguinal ligament) may complicate or prevent wire passage into the common femoral artery. External hip rotation as well as adduction helps to fixate vascular structures, especially the common femoral artery, facilitating vascular entry. Local anesthesia of the site of puncture is accomplished with 5 to 10 mL of 1% lidocaine (without epinephrine), initially infiltrated subcutaneously, using a 25-gauge needle in a quantity sufficient to raise a wheal, and then with an 18- or 20-gauge needle to infiltrate deeper tissues. A scalpel (no. 11) is used to incise the skin transversely (0.5 cm). The femoral venous cannulation site should be at least

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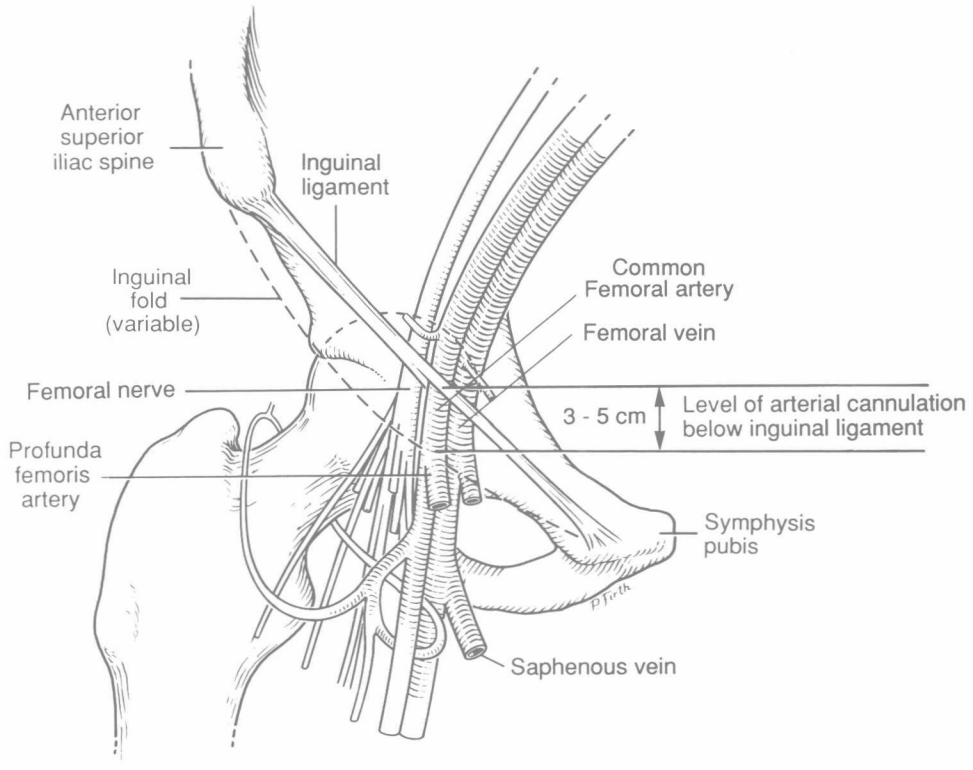

FIG 1–1.
Inguinal region anatomy, with suggested guidelines for correct vascular cannulation.

0.5 to 1.0 cm below and 1 cm medial to the arterial site in order to facilitate vascular compression and hemostasis following the procedure, and avoid the potential creation of an arteriovenous fistula. Moreover, it is important to recognize that the needle and catheters enter the vessel at approximately a 45-degree angle. Therefore, the skin incision will be caudal to the vascular entry site; this must be considered in order to ensure that the vascular puncture site is beneath the inguinal ligament.

Femoral Vein Cannulation

Femoral vein puncture and cannulation is generally performed before arterial puncture. This is done to minimize the duration of arterial catheterization as well as to allow vascular access for prompt administration of fluids or medications if needed. An 18-gauge Cook needle is the preferred entry device for venous cannulation. A 10-mL syringe is attached to the needle which is inserted into the venous incision at a 45-degree angle from the horizontal with the tip pointing cephalad in the sagittal plane. The needle is advanced in a plane 1 cm medial to the palpable femoral artery using continuous aspiration with the needle bevel up until the vein is cannulated as manifested by free aspiration of blood. Once cannulated, the needle is stabilized using the left hand and a short 0.035 to 0.038-in. J-tipped guidewire is advanced into the needle after the syringe is removed. The guidewire is advanced gently without using excessive force. Its position may be confirmed fluoroscopically if resistance is met. After withdrawal of the needle, a sheath

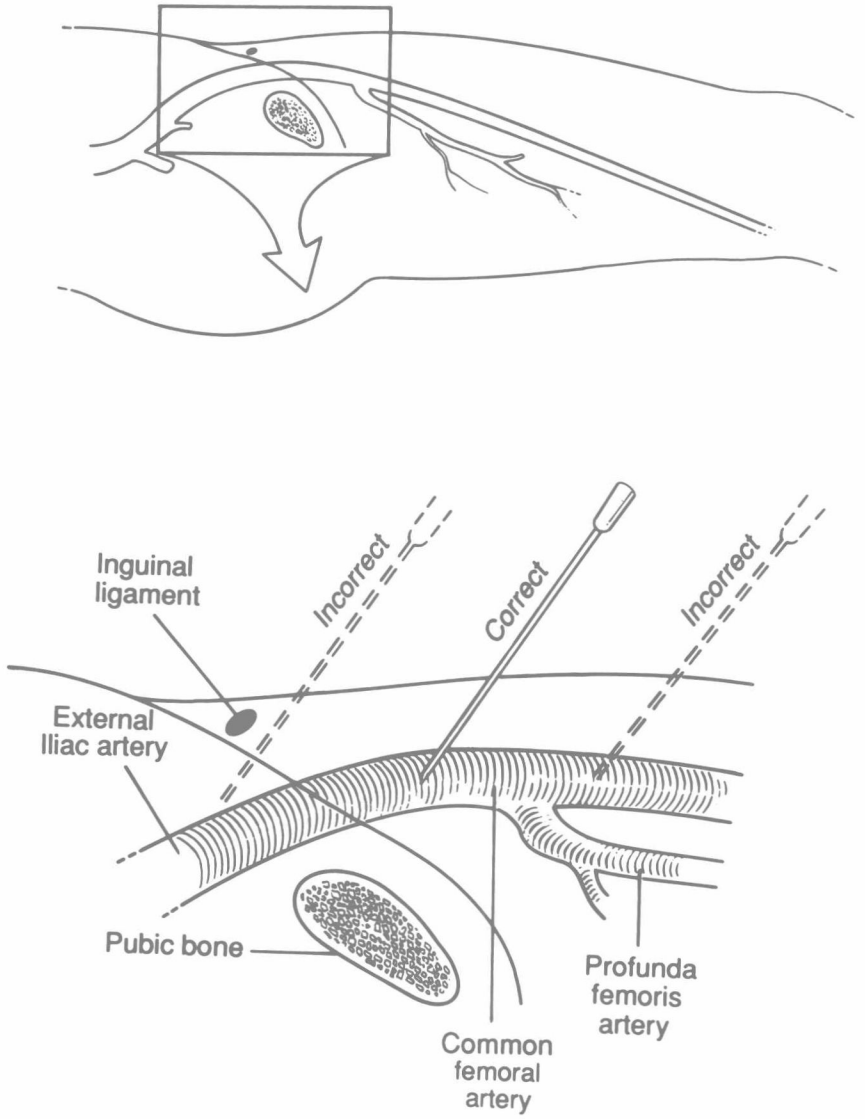

FIG 1–2.
Parasagittal section of the upper thigh and inguinal region at the level of the femoral artery showing correct and incorrect level of femoral arterial cannulation.

and dilator assembly is advanced into the vein by gently rotating it over the wire, and the wire and dilator are then removed. Once the sheath has been placed, the desired catheter can be inserted. Complications of femoral venous puncture include infection, femoral vein thrombosis, and iliac thromboses. Thrombosis is believed to occur more frequently in the pediatric population.

Femoral Artery Cannulation

After appropriate local anesthesia, cannulation of the femoral artery is performed using either a Seldinger needle, or if single-

wall puncture is desired, a Cook or Potts-Cournand needle (a Seldinger-type needle with hollow obturator). If the Seldinger needle is used, it is inserted at a 45-degree angle to the horizontal along the axis of the femoral artery as palpated by the left hand (Fig 1–3). It is advanced until resistance by the periosteum is felt. Care should be taken not to advance the needle harshly into the periosteum, as this may be quite painful. If desired, additional local anesthesia may be administered to the periosteum by removing the stylet and administering additional lidocaine; care must be taken not to infuse lidocaine intravascularly. After removal of the stylet, the needle is withdrawn slowly until the orifice of the needle is within the arterial lumen. This is confirmed when *vigorous* pulsatile arterial flashback from the Seldinger needle is obtained. At this point, a 145-cm 0.035- to 0.038-in. guidewire is advanced into the arterial lumen and the tip is positioned under fluoroscopic guidance in the descending aorta. Care must be taken not to traumatize the vascular endothelium. Less-than-vigorous backbleeding may represent a subintimal position or abrupt contact with the arterial wall. Gentle manipulation and altering the angle of entry often result in improved backbleeding through the needle.

Resistance in advancing the wire

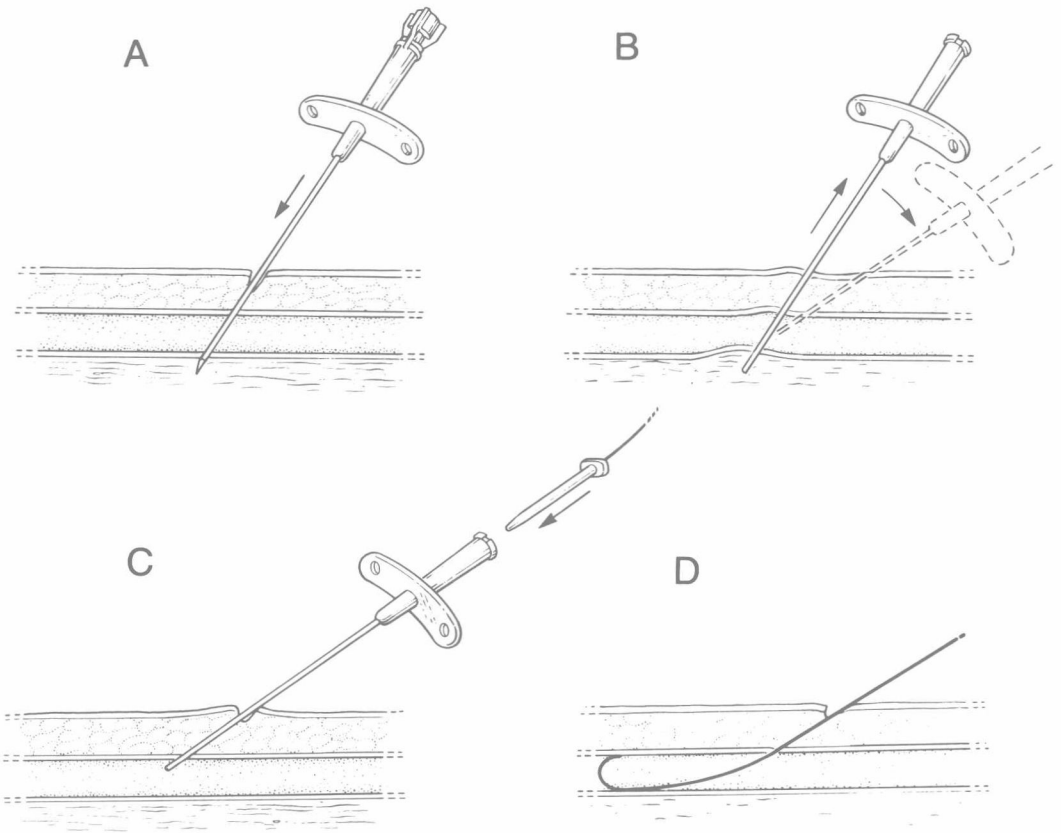

FIG 1–3.
Technique of arterial cannulation using the Seldinger needle. **A,** the needle with stylet is advanced into and through the femoral artery. **B,** the stylet is removed, and the needle is slowly withdrawn until brisk pulsatile blood return is obtained from the needle. The angle of the needle is then decreased. **C,** the guidewire is advanced gently into the artery through the needle. **D,** after the guidewire is positioned, the needle is removed. (Modified from Seldinger SI: *Acta Radiol* 1953; 39:368–376.[1])

through the needle and into the vessel may be secondary to needle orifice impingement against the posterior wall of the common femoral artery and may be resolved by simply decreasing the angle of the needle to at least 30 degrees and withdrawing the needle another 1 to 2 mm if necessary; this generally facilitates wire passage. Difficulty in advancing the wire beyond the common femoral artery should be investigated with an intravascular injection of angiographic contrast. This may be performed through the Seldinger needle itself or a small-gauge dilator (e.g., 5F or 6F) exchanged for the needle over a wire. Dilators should *never* be passed beyond a point of resistance.

If vessel tortuosity, but not obstruction, is confirmed, guidewire passage can be safely accomplished using one of the following techniques. If a fixed-core J wire cannot negotiate certain vascular segments, a flexible Benson wire or Wholey wire (ACS) may be very useful in some cases. Movable-core J wires that have variable core lengths which alter the degree of tip flexibility may be helpful. Caution is indicated when using this guidewire; once the core is withdrawn from the guidewire to any degree, it should *never* be reinserted against resistance or within tortuous vascular segments within the guidewire, as the shaft core may pierce the side of the guidewire and perforate the vessel wall. Another useful technique in negotiating tortuous vessel segments involves using a right coronary Judkins catheter inserted over a J-tipped guidewire. This catheter is used to steer the guidewire through the tortuosity. It can be guided by angiographic contrast injections. Again, this must be performed *very gently* so as not to dissect the vessel; *force should never be used to overcome resistance*. An alternative site of vascular access may be indicated in cases of extreme vessel tortuosity or stenosis, as the risk of vascular complications is significantly increased in these cases. Additionally, catheter control and maneuverability may also be compromised by extreme vessel tortuosity. If a peripheral vascular stenosis is documented angiographically, ad hoc peripheral angioplasty may be considered; this topic is discussed elsewhere in this monograph.

Use of the Potts-Cournand or Cook needle is preferred when a single-wall arterial puncture is to be performed. This is most beneficial in fully anticoagulated patients, those recently given thrombolytic therapy, and in very obese patients. The Potts-Cournand needle is advanced just as the Seldinger, but more slowly, and the hollow obturator lumen is left unobstructed so as to permit blood return. Once blood return is observed from the obturator lumen, the angle of the needle may be reduced to about 30 degrees and the needle advanced another 2 to 3 mm to ensure that the needle as well as the obturator is within the vessel. The obturator is withdrawn and adequate backbleeding should be obtained prior to guidewire advancement into the vessel. The Cook needle is used in a manner similar to femoral venous cannulation. The Cook needle may be used with or without an attached syringe. Once the guidewire has been advanced to the descending aorta under fluoroscopic guidance, an arterial sheath-dilator may be inserted into the femoral artery over the wire; the sheath-dilator should be guided and stabilized with the left hand, and *gently* rotated and advanced with the right hand, without forcing or "crimping" the system. The wire and dilator are then removed, and the sheath manually aspirated and flushed.

Complications of Femoral Vessel Cannulation

Local complications of femoral arterial access include hemorrhage into the thigh with excessively low punctures, or pelvic bleeding with punctures of the distal external iliac artery above the inguinal ligament. Pseudoaneurysm formation may occur following puncture in noncompressible inferior segments of the femoral artery, or in patients with wide pulse pressures (e.g., se-

vere hypertension or aortic regurgitation). Additionally, hematoma formation may cause nerve compression or compartment syndromes.

Femoral thrombosis or uncontrolled femoral arterial bleeding must be managed aggressively, including obtaining vascular surgical consultation. Femoral arterial exploration can be performed relatively easily and should be performed as soon as possible to prevent prolonged limb ischemia or severe blood loss. Other complications of femoral artery catheterization include infection, which is quite rare, and arteriovenous fistula formation. This last complication can be minimized by increasing the distance between femoral venous and arterial punctures and achieving adequate hemostasis with manual compression after catheter withdrawal. We prefer sequential removal of arterial and venous sheaths with the latter being removed 5 to 10 minutes after the first in order to allow good hemostasis. Local femoral complication rates have ranged from 3% to 6% in past series with hemorrhage rates ranging from 0.3% to 2.0% and thrombosis rates ranging from 0.1% to 1.1%.[2–7] In a recent large series, vascular complications occurred in 0.5%, and significant hemorrhage in 0.1% of patients.[8] Wyman et al.[9] have reported a vascular complication rate of 2.6% following percutaneous transluminal coronary angioplasty and 15.1% following catheter balloon valvuloplasty.

BRACHIAL VASCULAR ACCESS

Venotomy and Arteriotomy

Brachial Vein Cannulation

This technique may be useful in patients who have coagulopathies or have received thrombolytic therapy, to allow for direct hemostasis. The arm is prepared in a sterile fashion and supported on a movable arm board.

The skin 0.5 to 1.0 cm above the flexor crease overlying the palpable brachial artery is anesthetized with 1% lidocaine. If concurrent left heart catheterization is planned, a wide (2–3 cm) incision above the antecubital fossa is made; if only right heart catheterization is planned, a smaller incision is made. If a basilic or median antecubital vein of adequate size is palpable, an incision over this vessel should be made. Cephalic veins should be avoided, as these vessels enter the subclavian vein at right angles, making catheter passage difficult in most patients. If basilic or median antecubital veins are unsuitable, then deeper dissection to the brachial arterial sheath will allow exposure of a brachial vein which is generally suitable for cannulation. One or two veins may accompany the brachial artery, and are virtually always adequate for cannulation (Fig 1–4,A). If both veins are suitable, the more medial vein is generally preferred as this most commonly empties into the basilic vein. A tourniquet placed high on the arm under the sterile drapes can help the operator identify and isolate the appropriate vein(s). Once an adequate vein is isolated, a 1.0- to 1.5-cm length of the vein is carefully cleaned of overlying fascia and nerves, and is tagged with 3–0 or 4–0 silk suture at both the proximal and distal ends (Fig 1–4,B). The exposed vein is supported with the 4–0 silk sutures or a small pair of forceps inserted in the open position under the vein in order to support the vessel and bring it to the surface. With a no. 11 scalpel held with the sharp edge up, a small nick is made in the vein and a vein "pick" or catheter introducer is inserted into the vessel (Fig 1–4,C and D). Under this, the catheter of choice is advanced through the nick and into the vein. If a tourniquet was used, it should be released at this time. The suture surrounding the distal vein should be tied in place (Fig 1–4,E). The proximal suture may be tied around the catheter after positioning, if the latter will be left in the patient for any significant period of time. If only a right heart catheterization is planned, the incision is sutured using 3–0 silk with interrupted inverted mattress sutures (Fig 1–4,F).

Brachial Artery Cannulation

The brachial artery is the distal continuation of the axillary artery. It lies superficially in the arm, coursing between the biceps brachii and triceps muscles. In the antecubital fossa, the brachial artery courses underneath the bicipital aponeurosis (see Fig 1–4,A). Distal to this, it separates into the ulnar and radial arteries. The median nerve runs medial to the brachial artery in the lower arm. Care must be taken to avoid this structure during arteriotomy. If any question arises during dissection as to whether a structure might be a nerve, a small-gauge needle may be advanced into it and aspirated. This technique may avoid undesired trauma to the nerve. If the operator is positioned along the medial aspect of the arm by means of abducting the arm and supporting it on an arm board and stand, this facilitates identifying the bicipital aponeurosis and getting under it for cleaning the artery, and also helps avoid the median nerve.

After local anesthesia, a 2.0- to 2.5-cm-wide transverse incision is made 0.5 to 1.0 cm above the flexor crease overlying the palpable brachial artery. Gentle blunt dissection with a small curved Kelly clamp is used to expose a 1.0- to 1.5-cm length of the brachial artery, which is then cleared of overlying fascia and nerves and dissected free of the adjacent brachial vein(s). Care is taken to avoid the more medial median nerve. It is preferable to cannulate the brachial artery above the bicipital aponeurosis. Self-retracting retractors are useful in maintaining exposure of the artery. Moistened umbilical tape is wrapped around the proximal and distal exposed ends of the artery to stabilize the artery and control bleeding once the artery is incised. The ends of the tape are clamped with a small clamp. A no. 11 scalpel is used to incise the brachial artery transversely with the blade facing upward, taking care to incise only the upper portion of the artery and not transect it (Fig 1–5). Heparin, 3,000 to 5,000 units, is then administered into the distal brachial artery. Some operators prefer to insert a 6F or 7F sheath flushed with heparinized solution (5% dextrose or saline) in order to facilitate catheter exchanges. The catheter of choice is then carefully introduced into the brachial artery over a 0.035- 0.038-in. guidewire, and advanced through the brachial, axillary, and subclavian arteries. If no sheath is used, the exposed artery is allowed to bleed a small amount between catheter exchanges in order to minimize thrombus formation. During catheter insertion, tension on the proximal umbilical tapes is relaxed to facilitate passage of the catheter.

After completion of the procedure, the catheter is withdrawn and the artery is allowed to bleed momentarily to clear thrombi which might have accumulated around the catheter. Tension is placed on the proximal arterial tape to stop bleeding. At this point, tension on the distal arterial tape is released to allow backbleeding from the distal artery. If blood flow is not brisk from either the proximal or distal artery, a 3F or 4F Fogarty embolectomy catheter is advanced into the artery gently to a position distal to the presumed site of the thrombus. It is inflated with the indicated amount of saline and gently withdrawn. Resistance should not be overcome with force but rather with a decrease in volume infused into the balloon. The catheter is pulled out of the incision together with any thrombus. The procedure is repeated until adequate blood return is obtained from the distal artery. If distal blood return cannot be obtained despite these procedures, vascular surgical consultation should be obtained.

Arterial repair is performed using 6–0 TEVDEK suture with a running stitch beginning at the lateral edge of the arteriotomy. A double tie is used to secure each end of the suture. Care should be taken not to incorporate the posterior arterial wall with the sutures. Following arterial repair, the proximal and distal umbilical tapes are loosened and the radial pulse is checked. If this is adequate, skin closure is then performed using either interrupted mattress

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