Pediatric Angiography

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Editor

with the assistance of
John H. Miller, M.D.

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Foreword

With the rapid advancement of technology in diagnostic imaging, the role of angiography is changing. However, angiography, whether by percutaneous arterial catheterization or digital subtraction methods, is still an important modality for indicated diagnostic and therapeutic purposes in the pediatric patient.

This book provides comprehensive coverage of pediatric arteriography and venography (excluding neuroradiology and intracardiac angiography) from the neonate through adolescence. Comparisons and relationships of the noninvasive techniques of nuclear radiology, ultrasonography, and CT scanning to angiography are placed in the proper perspective.

Throughout the text, Dr. Stanley and his collaborators have provided discussions as to the indications for angiography, the technique required, embryological development as indicated, anatomy of the pediatric vascular system, potential complications of the procedure, therapeutic uses and diagnostic criteria. The book contains extensive numbers of illustrations of the various lesions and a large list of pertinent references for each subject.

All of the authors are experienced pediatric angiographers and in this text are sharing their experience for others to use to improve the care of the pediatric patient. This should be a reference book for all radiologists doing vascular work, as well as pediatricians, surgeons, and others who are involved in the care of children.

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Preface

Pediatric angiography is a specialty undergoing a change in the everdeveloping field of pediatric radiology. Intravascular catheter techniques may be used both for the purpose of diagnosis and therapy. With the development of noninvasive studies (nuclear medicine, ultrasound, and computerized tomography), the role of catheter angiography for diagnosis has diminished, although there are well established criteria for the use of diagnostic angiography. In some circumstances angiography is the primary investigation of choice, whereas in other situations angiography is used to complement noninvasive studies, particularly when the latter investigations have been nonconclusive. There has recently been tremendous development in the role of therapeutic uses of catheter angiography in children for embolization, arterial infusion, and balloon dilatation. This book is designed to define the role of angiography for diagnosis and therapy in this changing world and enable the examination to be performed as safely and expeditiously as possible to give the maximum information. The case material has been culled in the main from the angiographic files of the Childrens Hospital of Los Angeles—the largest pediatric facility on the West Coast. It is designed to appeal to all doctors who look after children, and especially to radiologists who perform vascular procedures on children.

To a certain extent, part of the title is a misnomer. Angio is a Roman transliteration from the Greek $\alpha'\gamma\gamma\epsilon\tilde{\iota}o$, meaning vessel or receptacle. Angiography is usually taken to include lymph vessels as well as arteries and veins. The lymphatic system has not been included in this text. This book also does not cover pediatric neuroradiology or intracardiac pathology, because there are excellent texts for these regions. All other regions are covered comprehensively and new advances described. There are two main reasons why the actual catheter techniques are discussed in one chapter and not at the start of each section: first, to avoid repetition; and second, with the development of digital subtraction angiography the technique of percutaneous arterial catheterization will be of diminishing importance as a new expanded role of intravenous arteriography will be established.

Acknowledgments

From the onset of this project to its completion, my radiological colleagues at the Childrens Hospital of Los Angeles have been most supportive, not only in encouraging the various applications of angiography, but allowing more than my fair share of secretarial time and photographic services for the production of the book. The radiographic mastery of Frank Valadez and his technical team has provided the excellent angiograms. This book would not have been possible without the tireless patience and secretarial skill of Melody Kennemer, who along with Carolyn Eya typed the manuscript. No praise would be too high for their efforts. The photographic prints were produced either by Darryl Davis or by Joel Schulman, and much of the art work was produced by Elfriede Hutado. Our thanks are due to their untiring efforts. Finally, I would like to thank Ms. Ruby Richardson and Ms. Alice Reid of Williams & Wilkins, who along with Mike Treadway guided this book through the various stages of production. Their help and encouragement smoothed the difficult pathway from inception to final production.

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CHAPTER ONE

Angiographic Procedure

Patient Preparation

GENERAL PRINCIPLES

Arteriography is an invasive procedure which in capable experienced hands can be performed safely and expeditiously. In the correct clinical setting together with preliminary investigations angiography will give information unobtainable by any other investigation or will add important knowledge to an incomplete diagnostic scenario. Arteriography should only be undertaken if the result is going to influence the clinical management of the patient.

PREANGIOGRAPHIC EVALUATION

The case together with the current noninvasive study should be reviewed with the referring physician, and it should be determined whether angiography is indicated and whether it will give the information required. The parents should be interviewed by the radiologist and the potential benefits and risks realistically explained with particular concentration on the potential complications of arterial puncture. If the child is old enough to understand and the parents are agreeable, this can take place in the patient's presence. An informed consent has to be taken and witnessed. The examination cannot be performed if the parents or guardian refuse consent. The patient's general health should be checked and inquiries made regarding allergies and bleeding tendencies. The patient's hemoglobin should be measured and the examination should not be performed if the hemoglobin is below 11 gm/100 ml, unless it is an emergency. Clotting studies are not routinely performed unless there is a clinical history of easy bruisability and bleeding tendencies or the patient's illness or treatment is likely to depress the clotting factors. If there is a depression of these factors, then these should be corrected prior to angiography by infusion of fresh plasma. Hemophilia is a relative contraindication, although arteriography can be performed with the assistance of a hematologist giving antihemophilia globulin. If there is a history of reaction to prior intravenous contrast agents then further details should be obtained. If the reaction was mild (*e.g.*, sneezing or hives), then premedication with diphenhydramine (Benadryl) (5 mg/kg IM injected 30 minutes prior to the exam with a maximum of 50 mg) is usually sufficient to prevent recurrence of the mild allergic response. With a more severe reaction the case should be discussed with the clinician to be certain that arteriography is essential. If arteriography is to be performed then steroids should be given for three

days prior to the study. Prednisone at a dose of 2 mg/kg is given daily, and diphenhydramine (Benadryl) is given as a premedication. The patient should be continuously monitored during the procedure and have the referring physician in attendance. There should be an open intravenous line and epinephrine 1:1000 and 1:10,000 drawn up ready to be given by either intramuscular or intravenous route along with hydrocortisone sodium succinate (Solu-Cortef, 10 mg/kg). It should be noted, however, that reaction to contrast agents given intraarterially is much less common than when given intravenously and that children react far less frequently when compared with adults.

Whereas arteriography is frequently performed on an emergency basis, it is never undertaken in a patient with unstable vital signs. Should the patient be hypertensive, the diastolic pressure is brought below 100 mm Hg with medication prior to the study to minimize hemorrhage at the puncture site, particularly upon withdrawal of the catheter.

Patients with pseudoxanthoma elasticum, Ehlers-Danlos syndrome, and homocystinuria have an increased risk with angiography (see Chapter 13), and this examination is only performed after close consultation with the referring physician.

As a general rule the patient spends the night of the arteriogram in hospital except for minor studies in older cooperative patients with responsible parents.

SEDATION

The majority of patients are given basal sedation which is all that is required to provide a cooperative patient in whom a diagnostic study can be obtained with the minimum of risk. The most common sedation is D.P.T. (Demerol, 25.0 mg; Phenergan, 6.25 mg; Thorazine, 6.25 mg/ml*). The sedation is given in the equivalent of 1 ml/10 kg by intramuscular injection about 20–30 minutes before the patient comes to the angiography suite. The dose should not exceed 2 ml in normal circumstances. If the patient is very uncooperative then the Thorazine and Phenergan doses may be increased to 12.5 mg or even 25 mg/ml. For patients with potential respiratory compromise fentanyl-droperidol† (Innovar) (0.02 ml/kg IM injected with a maximum dose of 1.5 ml given 30 minutes before the examination) is used. In a sick newborn chloral hydrate, 75 mg/kg given orally 30 minutes before the examination, is the sedation of choice and sometimes no sedation is required; the patient sucks on a sugar-coated nipple. For further sedation, diazepam (Valium) is given in small aliquots of 1 mg intravenously. The cardiovascular status and respiration as well as the level of consciousness should be carefully monitored before giving further doses (IV diazepam is slightly irritating to the vein. This can be minimized by diluting Valium with the patient's own blood).

* Demerol is the trade name for meperidine hydrochloride, Phenergan for promethazine, and Thorazine for chlorpromazine.

† Janssen Pharmaceutical, Inc., NJ.

For arch studies in teenagers, atropine, 0.01 mg/kg, is given to prevent possible excessive vagal slowing of the heart.

If a patient is mentally retarded or very uncooperative then general anesthesia is required. For splenoportography general anesthesia is always used.

FOOD AND FLUID RESTRICTION

The majority of studies at this hospital are performed at approximately 8 A.M. All oral intake is forbidden after midnight except for children under two years of age who are more susceptible to dehydration and irritability with fluid deprivation. In these circumstances clear fluids are allowed from midnight to 4 A.M. and then nothing further by mouth.

INTRAVENOUS FLUIDS

Except for short cases an intravenous infusion is most helpful. Not only is dehydration prevented but drugs can be given easily in an emergency or for further sedation. The fluid solution of choice is 0.20 N NaCl/5% dextrose (or just 5% dextrose) with a flow rate adjusted sufficient to keep the intravenous line open. The intravenous infusion should be set up one hour before the patient comes to the department.

ANTIBIOTICS

Although there is a low incidence of bacteremia[1] during catheterization, prophylactic penicillin is given in cardiac patients at risk.[2]

TRANSPORTATION

The patient should be transported to and from the x-ray department on a trolley with the sides up and accompanied by a nurse.

GROIN SHAVE

For teenages a limited groin shave is usually required.

PERIPHERAL PULSES

In the ward before the patient comes to the angiography suite the site and amplitude of the peripheral foot pulses on both sides should be recorded. Also the femoral pulses should be located. Coincidental coarctation and peripheral embolic disease have been discovered prior to angiography, as has thrombosis of the femoral artery secondary to an attempted arteriogram at another institution. If the groins are infected the examination should not be performed.

PATIENT MONITORING

After placing the patient on the angiographic table, the electrocardiographic leads are connected. Visual

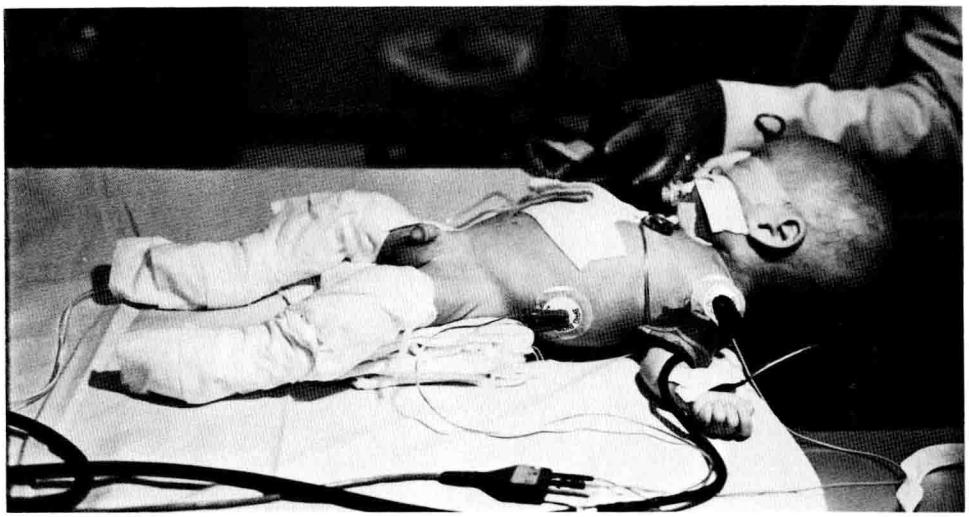

Figure 1.1 A four-month-old infant with webroll around the lower extremities to prevent heat loss.

and auditory documentation of cardiac rate abnormalities allows for early detection and rapid correction. A crash cart with all the equipment necessary to treat a cardiopulmonary arrest is kept permanently in the angiographic suite.

Children under the age of two are very susceptible to temperature change, particularly cooling. For this reason, the patients in this age group have their temperatures monitored using axillary probe. The temperature should be kept at between 36° and 38°C. There are several ways of keeping the infants warm. The ambient temperature of the room is raised to 29° or 30°C. A warm mattress is helpful along with limb wrapping with soft orthopedic bandage (Webroll‡ or a similar product) (Fig. 1.1). Overhead heating lamps are effective but have to be used with caution, and the correct distance between the lamps and the patient should be maintained using the lamp ruler. If the patient does become cool a rapid way to warm him is to fill a rubber glove with warm water, knot the wrist end, and place the glove acting as a hot water bottle next to him. More recently we have had a radiant heat warmer mounted beneath the overhead image intensifier (Fig. 1.2). The intensity of the radiant heat warmer is adjusted to keep the patient's temperature around 37°. This more than any other technique has proved very effective in maintaining the patient's temperature.

In small children four years and under the buttocks are elevated by folded towels and the legs slightly abducted and externally rotated which makes the femoral vessel puncture easier. The legs and arms are restrained (Fig. 1.3). The groin is cleaned with antiseptic and the drapes applied.

PERSONNEL

In order to obtain a diagnostic angiographic study safely with the minimum of contrast injected and radiation exposure, the angiography team must be well trained and disciplined. At Childrens Hospital of Los Angeles the team consists of a radiologist, nursing assistant, and a technician. Each member of the team must have confidence in the other person's capabilities, with the radiologist being obviously in charge and personally checking the injector settings and syringe safety stop before each run is taken.

‡ Kendall Orthopedic Products, Boston, MA.

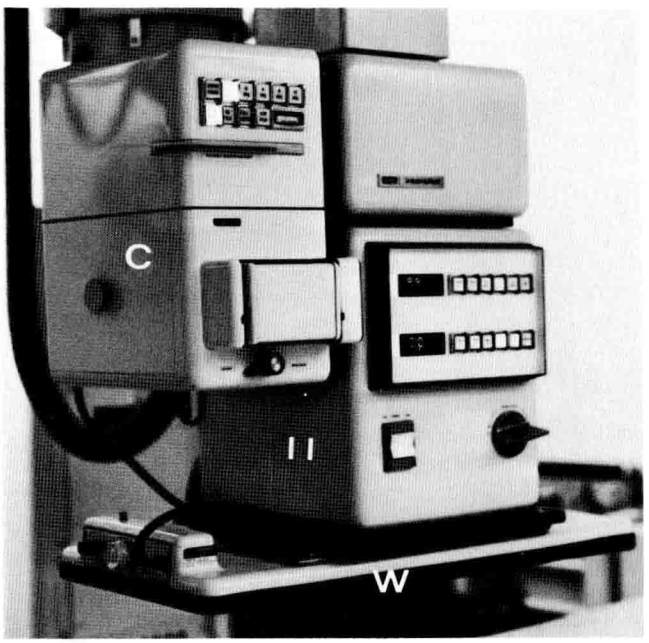

Figure 1.2 Photograph showing the position of the radiant heat warmer (*W*) situated below the image intensifier (*II*). The 105-mm camera (*C*) is seen adjacent to the image intensifier.

NEEDLES, CATHETERS, DILATORS AND GUIDE WIRES

Every angiographer has their own particular preference for needle-wire-catheter combinations. The

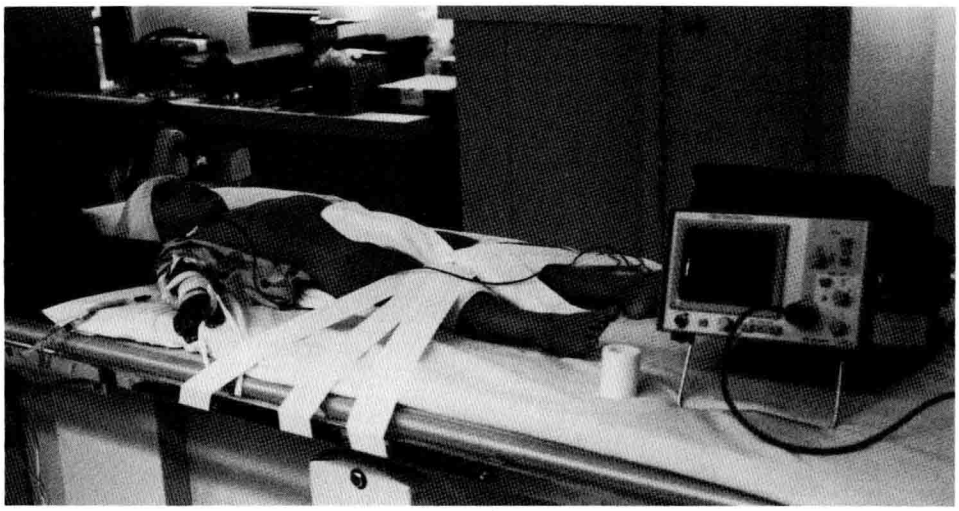

Figure 1.3 Photograph demonstrates the restraints over the knees and around the forearms to keep the patient still. Note also the padding under the buttocks to facilitate the arterial puncture.

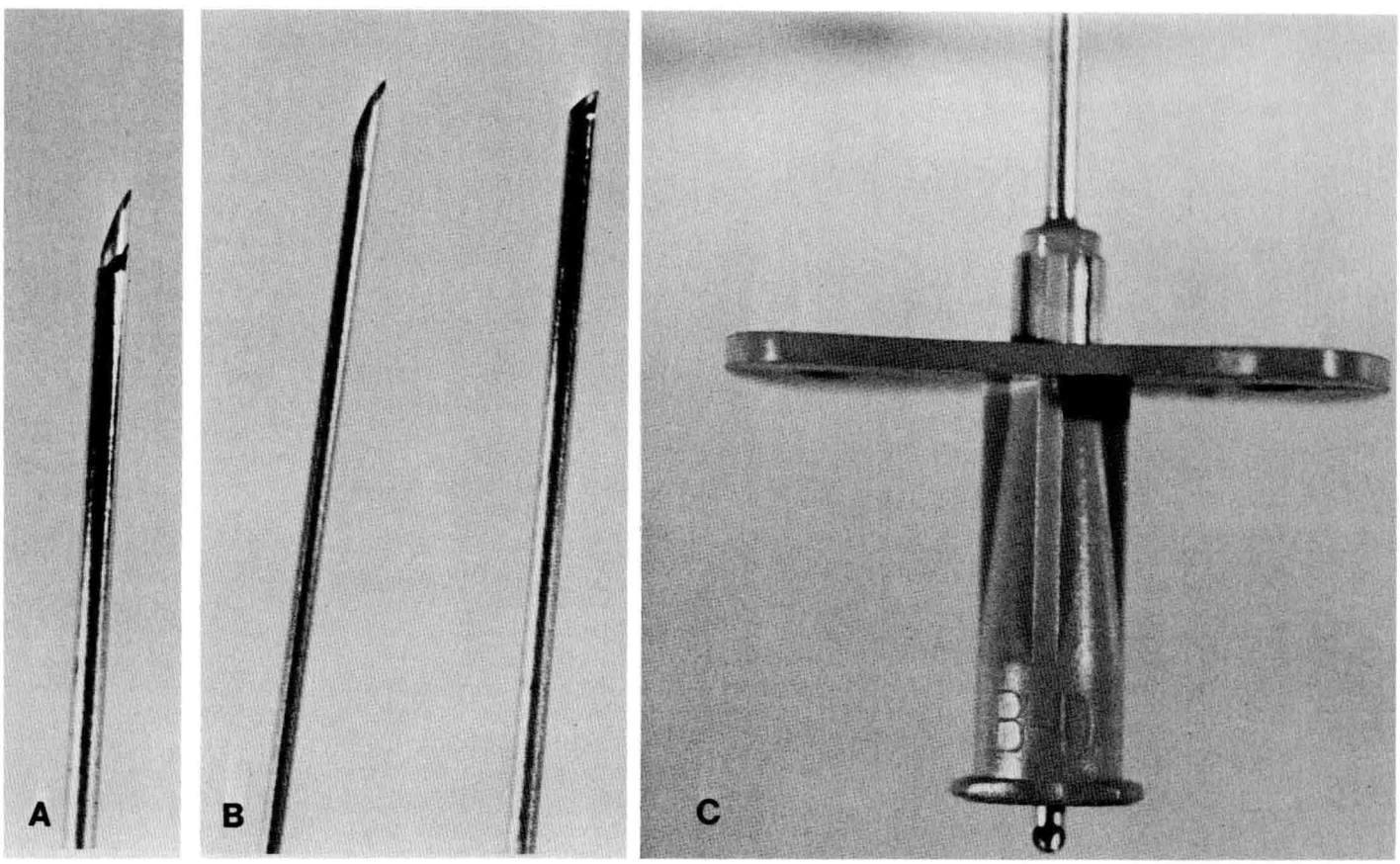

Figure 1.4 (*A*) Closeup photograph of the tip of the arterial puncture needle showing good fitting between the inner needle and outer cannula. (*B*) This demonstrates the bevel on both the needle and the cannula. (*C*) The extension of the cannula hub which facilitates entry of the guide wire is shown.

combination described below has been found to be safe and effective and has been used for over 1,000 pediatric catheterizations at this hospital. It should be noted that other needle-catheter-dilator and guidewire combinations have been reported.[3]

NEEDLES

The author's particular needle preference for the pediatric age group is the Potts-Cournand needle.§

§ Becton-Dickinson.

The cannula and needle fit snugly without any perceptible lip at the junction of the two which could damage the artery on entry. The needle is hollow and sharp, and the cannula has a satisfactory short bevel enabling easy passage of the wire from the needle into the artery (Fig. 1.4). The only slight disadvantage of the smaller needle is that the needle is unnecessarily long for small infants, which is not a disadvantage in itself but minor movements at the hub end can lever the cannula end out of the artery. These needles are disposable and come presterilized. After three attempts the needle is discarded, inasmuch as a progressively blunted needle is more likely to cause the femoral artery in an infant to go into spasm. It should be noted that experienced pediatric angiographers use other types of needles.[4] These include needles with a solid inner needle and an outer Teflon sheath. If the angiographer is not experienced it is relatively easy to advance the sheath subintimally. Also external pressure over the subcutaneous part of the sheath may be required to bring the tip parallel to the arterial lumen to enable the guide wire to pass easily. Another type of needle has the bevel in the needle facing upwards and that on the cannula downwards. (Some angiographers find that it is easier to advance the wire with the cannula bevel facing downwards.) Pencil tip needles are not used. Even when sharp, these tend to damage the artery, causing it to go into spasm. The size of the needle along with the guide wire-catheter combinations most suitable for the various age groups are shown in Table 1.1.

GUIDE WIRES

After successful puncture of the artery with the needle a straight guide wire is introduced. It is the author's particular preference to use a fixed core wire with a 3-cm flexible tip. It is the flexible tip end of the guide wire which is first introduced into the needle. The wires are heparin-coated to cut down on clot formation on the wire.[5] Systemic heparin is not routinely used (see later). The only other wires which are regularly used are the fixed core J wires with terminal curves of 3, 7.5, or 15 mm. All of the wires should have a central safety wire to contain the outer coil during manipulation, thus reducing the tendency to kink or separate. For pediatric use a wire of 125 cm has been found to be most satisfactory. Most manufacturers' guide wires come presterilized and should be discarded after one use.

CATHETERS

In the author's experience polyethylene is the most suitable material for pediatric angiography catheters. The polyethylene catheters have the right combination of flexibility and torque control and have an excellent memory. The polyethylene is made radiopaque by incorporating either lead or barium salts. We have experienced no thrombogenic complications using polyethylene catheters.

The majority of catheters used at this hospital are preshaped at the factory and come presterilized. If necessary, the catheter can be shaped with a steam kettle to create a terminal curve to suit the individual case. When shaping the catheter under steam the end of the catheter should be protected or else it will flare and cause difficulty in introducing the catheter tip into the artery. Also, sharp angulation of the catheter under steam should be avoided or the catheter may kink. A kink represents an area of potential weakness and possible fracture. Any catheter with a kink in it is discarded.

The catheters, although ordered in pediatric lengths, are usually too long and are therefore cut down so that the maximal flow rates can be utilized for the individual case. Even though the flow rate according to Poiseuille's law is directly proportional to the fourth power of the radius and indirectly proportional to the length, it is still worthwhile to make the catheter as short as possible to obtain maximal flow. After measuring the catheter against the patient or on the scout film the catheter is cut, and the sleeve and female end of the hub are placed over the cut end and slid along the catheter. The cut end is then flared with a match (Fig. 1.5*A*). The flared end is then rapidly cooled in saline, and the male end of the hub is connected onto the female end. The hub is tested for water tightness by injecting saline with a finger occluding the distal end of the catheter. Tension on the hub while the catheter is gently pulled will demonstrate the adequacy of the flare in holding the catheter within the hub (Fig. 1.5*B*).

Table 1.1
Size of Needle and Suitability of Guide Wire-Catheter Combinations with Respect to Age/Weight

Age	Weight (kg)	Needle	Wire	Dilator	Catheter[a]	Inner/Outer Diameter (inches)
0–2	0–10[b]	20	025[c]	4 F	4.1 F	037/054
2–5	10–20	20	025	5 F	5 F	042/066
5–12	20–40	18	035	5 F	5 F	042/066
12	>40	18	035	5 F	6 F[d]	047/079

[a] The catheter is tapered to the wire size.
[b] For patients below 2 kg use a 3.7-F catheter with 0.025 wire and 20-gauge needle.
[c] Not all 0.025 wires fit into a 20-gauge needle (Cook wires fit).
[d] Except cerebrals 5 F.

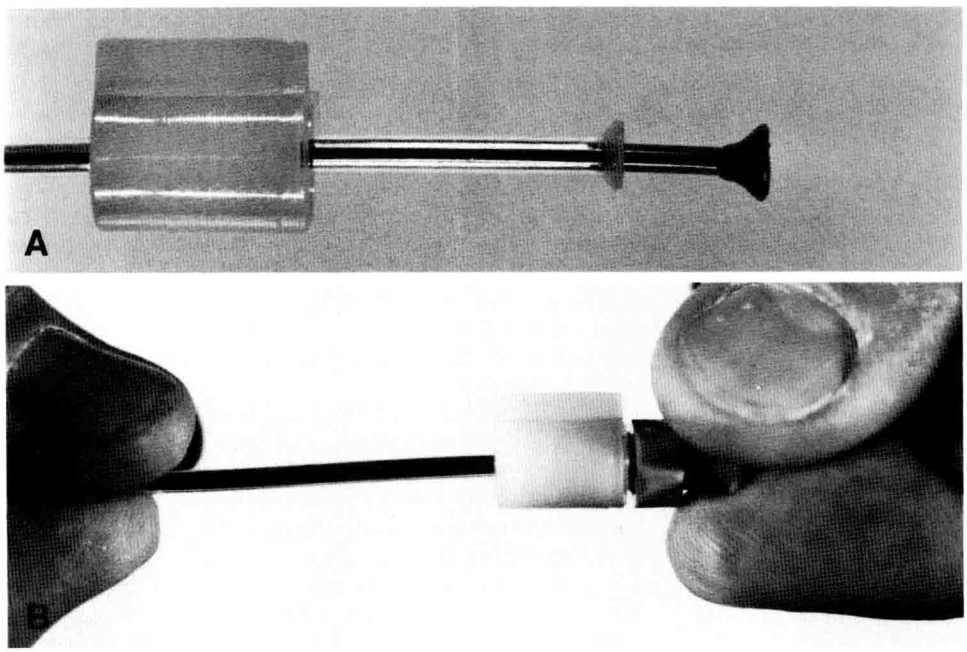

Figure 1.5 (*A*) The catheter has been shortened and a flare placed on the end with a match. The end is then reassembled. (*B*) Gentle pulling will determine the adequacy of the terminal flare.

DILATORS

A dilator is used in every patient. The authors have found that use of a dilator facilitates the passage of the catheter and prevents fraying of the catheter tip. The dilators which are made of Teflon can vary in quality, and it is important to choose one with a smooth even taper which fits snugly onto the guide wire (Fig. 1.6). This is particularly important in children in the three- to five-year age group who invariably have thick walled muscular arteries. In this group a 5-French (F) dilator is used over an 025 guide wire. Occasionally in this situation a 5-F dilator will not pass through the arterial wall, in which case a 4-F dilator is used followed by a new 5-F dilator. Like the catheters, the dilators are discarded after being used just once.

For some examinations (low inferior vena cavagrams and femoral arteriography) an adequate injection can be made through the dilator, and it is unnecessary to introduce a catheter.

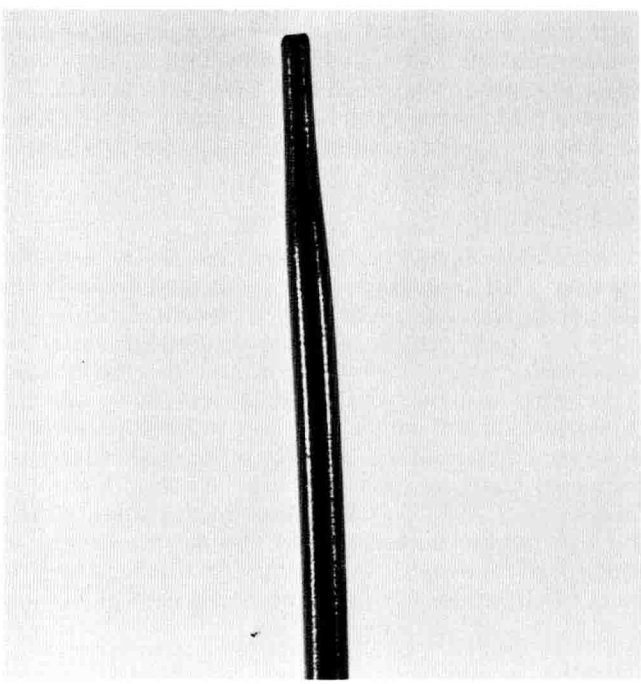

Figure 1.6 Closeup photograph of the dilator showing a smooth taper to its tip.

HEPARIN

Systemic heparin is not routinely used except for transluminal angioplasty and embolization procedures. The dose of heparin is 100 units/kg. We have never found bleeding at the end of the examination a problem, but if the effect of the heparin has to be reversed then it can easily be done with protamine (10 mg/1000 units heparin).

CONTRAST AGENTS

Water-soluble contrast agents used in present angiography are the organic salts of triiodobenzoic acid consisting of a positively charged cation and a negatively charged anion. The most common anion radicals are diatrizoate and iothalamate. The cations consist of either sodium or methylglucamine or a combination of the two. The contrast agent can be conveniently divided into low (group 1), medium (group 2), and high (group 3) concentrations. The individual contrast agents and their important physical and chemical

characteristics are shown in Table 1.2. Because of the unacceptable risks the high concentration agents are not used in pediatric practice and are therefore not represented in the table.

According to Poiseuille's law the rate of delivery of a contrast agent is inversely proportional to the viscosity. The lower the viscosity, the greater the delivery rate. The viscosity is proportional to the size of the molecules injected. As the sodium molecules are smaller than the methylglucamine (meglumine) ones, agents containing sodium will be less viscous. However the sodium salts are more toxic than the purer methylglucamine. For selective cerebral arteriography, limb, bronchial and spinal arteriography, the purer meglumine salts are used. Our own particular preference is meglumine iothalamate (Conray 60), although meglumine diatrizoate (Hypaque 60) is preferred by others.[6] For aortography, iliac, selective celiac, hepatic, splenic, and renal arteriography, a more concentrated solution is used. In order to inject a high volume of concentrated contrast, the viscosity is reduced by combining meglumine and sodium salts. For aortic arch and pulmonary artery studies, meglumine (66%) and sodium (10%) diatrizoate (Renografin 76) is used. This contrast agent is tolerated best by the coronary arteries. For the other examinations, meglumine 52% and sodium 26% iothalamate (Vascoray) is used because of the higher iodine concentration. Because these solutions contain sodium and are more toxic, there is a danger of sodium overload, and in infants below the age of one year, the pure meglumine salt is used independent of the examination.

Contrast agents are acidic and hyperosmolar, which accounts for much of their toxicity. In children it is wise to wait at least ten minutes between each injection of contrast. With adequate hydration and normal renal function there should be little change in pH if the dose of contrast agent is kept to a maximum of 4 ml/kg. In the author's practice it has never been necessary to give bicarbonate to correct any decrease in pH associated with giving of contrast. The hyperosmolarity of the contrast agent can cause overhydration together with a falling hematocrit. With normally functioning kidneys this is usually rapidly corrected. However, it is important that the amount of perfusing fluid be kept to a minimum. In addition, the hyperosmolarity of the contrast agent will cause hemolysis of the red cells. It is therefore important that blood does not enter the barrel of the syringe of the mechanical injector.[7] Prolonged contact of red cells with the contrast agent will cause hemolysis and sludging.

Very occasionally, children will have an "allergic" response to the contrast. This reaction is less common with intraarterial injections compared with intravenous contrast. This reaction may be a true hypersensitivity[8-10] or be due to histimine release[11] or to chemotoxicity[12] or due to the activation of both the complement and coagulations systems.[13] In children these reactions are usually mild and can be prevented by prophylactic antihistimines before the examination. A history of a prior severe reaction will require steroids in addition to antihistimines, if it is deemed absolutely necessary that contrast be given again. (For details, see earlier under "Preangiographic Evaluation.")

Most angiographic examinations can be performed keeping the contrast level below the maximum of 4 ml/kg. However, occasionally it is necessary to exceed this dose. If the clinical and radiological circumstances dictate that this maximum be exceeded, then

Table 1.2
Physical Factors of Current Contrast Media[a]

Product	Anion	Cation(s)	Concentration (%)	Iodine (mg/ml)	Viscosity cps (at 37°C)	Sodium Content (mEq/ml · mg/ml)	
Group 1							
Hypaque 60% (Winthrop)	Diatrizoate	Meglumine	60	282	4.12	0.01	0.2
Conray 60 (Mallinkrodt)	Iothalamate	Meglumine	60	282	4.0	0.001	0.03
Renografin 60 (Squibb)	Diatrizoate	Meglumine (52%) Sodium (8%)	60	292.5	4.0	0.16	3.76
Reno-M-60 (Squibb)	Diatrizoate	Meglumine	60	282	4.2	0.04	0.91
Group 2							
Hypaque-M, 75% (Winthrop)	Diatrizoate	Meglumine (50%) Sodium (25%)	75	385	8.3	0.39	9
Renografin 76 (Squibb)	Diatrizoate	Meglumine (66%) Sodium (10%)	76	370	8.4	0.19	4.48
Conray 400[b] (Mallinkrodt)	Iothalamate	Sodium	66.8	400	4.5	1.05	24.2
Vascoray (Mallinkrodt)	Iothalamate	Meglumine (52%) Sodium (26%)	78	400	8.7–9.3	0.41	9.4

[a] After Winthrop.
[b] Rarely used because of high sodium content.