Introduction

In many nutrition studies, chronic, long-term intravascular or lymphatic catheterization of animals frequently is desirable to facilitate blood and lymph sampling, pressure recording, and infusions with minimal disturbance of the animal. Numerous procedures for catheterization have been described. These procedures range from simple percutaneous catheterization of vessels close to the body surface to extensive surgical techniques for the catheterization of deep vessels that require special precautions in exteriorization and stabilization of the catheters. All are subject to a number of technical difficulties, especially if long-term stability and patency of the catheters is important.

Selection of a Catheterization Procedure

A number of factors are considered in the selection of a catheterization procedure. A principal factor is the relative size and accessibility of the vessel to be cannulated. There are a number of other factors, however, to consider. Some of these are the size of samples and the frequency and rapidity of collecting them, anatomical differences between species, problems involving maintenance of the catheters and, where infusions of materials are involved, whether the site of infusion is important.

The size of the vessel to be cannulated and the catheter must be consistent with the collection or infusion requirements. Snow and Tyner (54) have emphasized the importance of limiting the catheter diameter to one-third or less the lumen diameter of the intact vessel to preserve the flow of blood around the catheter and prevent spasm, constriction, and occlusive clotting. Thus, restrictions inherently are placed on the use of small vessels if large blood samples are required in a short time.

A given procedure is not universally suitable for all species because of anatomical differences. The aorta, for example, is not easily catheterized via the carotid artery in sheep (54) without producing a sharp bend in the catheter, but it can be accomplished readily in guinea pigs (52).

The post-surgical maintenance of catheters is a most important consideration. There is nothing more discouraging to the researcher than to spend considerable time in animal preparation only to have the catheter rubbed out, pulled out, or bitten off because the catheter is in the wrong place. Selection should be so that the exteriorized catheter is as inaccessible as possible to the animal.

Procedures to establish catheters for the infusion of materials into the circulation are dictated by the type of study. Certainly, if metabolism of a substance by a specific organ were being studied, it would be inappropriate to establish a catheter to introduce the material systemically unless it were known that the material was not metabolized by tissues other than that organ.

Materials for Catheters

Although a wide variety of synthetic polymers have been used in catheterization procedures, the basic requirements they must meet are the same. These are: a) no adverse effects on the tissue or of the tissue on the material, b) suitable physical properties, c) fabricable, and d) sterilizable. At present, though some polymers meet these requirements closely enough for their use, the ideal material has not been developed. Synthetic polymers for intravascular or intralymphatic implantation, without exception, have been associated with undesirable degrees of thrombogenicity and a significant number of occlusive complications (20, 33, 36). Thus, apart from the consideration of thrombogenicity, selection of catheter material is based primarily on its physical properties. The properties required will differ widely for a given procedure, depending upon such factors as the species of animal and its behavior, the vessel to be catheterized, the method of stabilization and
exteriorization, and the length of time the catheter is intended to remain functional.

Of the different polymers for long-term implantation, polyethylene, polyvinyl, Teflon®, and silicone rubber have been used most extensively. Polyethylene tubing is widely used in percutaneous catheterization procedures where relatively short lengths of tubing are involved. However, it is notoriously susceptible to kinking, loses tensile strength with time implanted, and has limited implantation life (most thrombogenic of materials listed).

Polyvinyl tubing has excellent tensile strength, flexibility, and kink resistance but tends to become more stiff with time implanted due to leaching out of the plasticizer used in its formulation. Its implantation life also is limited, although it is superior to polyethylene. The implantation life of both polyethylene and polyvinyl can be extended somewhat by siliconization. A distinct problem with polyvinyl tubing is the wide variation in physical properties, such as flexibility, kink resistance, etc., among tubing from different sources.

Teflon has excellent tensile strength, dimensional stability, and implantation time, but it is more inflexible than the other materials, becomes more brittle with time implanted, and is susceptible to kinking. Its stiffness makes it especially unsuitable for most venous catheterization procedures because of resultant intimal damage, but it has some definite advantages in arterial procedures. Special precautions must be taken with Teflon to smooth any sharp edges formed in catheter fabrication.

Of the conventional polymers, silicone rubber is the most inert to tissue reaction and is the least thrombogenic. It has excellent elasticity and flexibility, which it does not lose even after prolonged implantation, and kink resistance in the thicker-walled tubing. Its major weakness seems to be its lower tensile and shear strength. Because of this and its elasticity, special care must be taken to prevent constriction of the lumen of the catheter during stabilization and exteriorization and to prevent nicking the catheter during implantation. The softness, flexibility, and antithrombogenic properties of silicone rubber make it particularly suitable for venous and lymphatic catheterization.

Because each material has inherent strengths and weaknesses, we have found it advantageous to fabricate catheters for specific procedures from a combination of materials. For example, our catheters for the femoral arterial procedure (58) are made from Teflon and silicone rubber. The Teflon is placed intrarterially where kinking is not a problem, but inertness and some stiffness are desirable. Silicone rubber is used for subcutaneous exteriorization because of the repeated flexion it will undergo during leg movement. A combination of silicone rubber and polyvinyl is advantageous for catheterization of vessels draining the gut, where a soft, most antithrombogenic, flexible catheter is required intravenously, but where a strong, flexible, highly kink-resistant material is needed for extravascular, subcutaneous exteriorization. A combination of silicone rubber and Teflon has been utilized for lymphatic catheters (16, 17, 22), thus utilizing the dimensional stability and fabricability of Teflon and the flexibility and inertness of silicone rubber. By using combinations of the different materials, the best features of each material can be exploited.

Because of the thrombogenicity of conventional polymers, there has been considerable interest in the development of polymers with thrombo-resistant surfaces. A number of these polymers have been prepared (19, 21, 26, 34, 35, 47, 57) with reasonable success, but none as yet is available for general use.

Catheterization Procedures

Arterial. Arterial catheterization procedures, although technically somewhat more difficult than most venous procedures, usually are more successful in terms of the functional life of the catheter. A number of factors affect the functional longevity of arterial catheters, the most important of which seems to be the rate of blood flow through the vessel catheterized. Available evidence strongly suggests that coagulation of blood is much less likely with rapid laminar flow and, as blood flow becomes slower or more turbulent, the chances of thrombosis and fibrin deposition increase markedly. Thus, it may be possible that even thrombogenic surfaces may not initiate coagulation if there is sufficient flow of blood past the catheter surface. Any reduction of lumen cross-section of a vessel by too large a catheter, by constriction and fibrosis, or by intimal damage with resultant endothelial proliferation and thrombus formation would promote catheter failure by restricting blood flow or creating excessive turbulence.

Procedures for catheterization of a number of different arteries in a variety of species have been described. By far the most popular is catheterization of the aorta, which has been
accomplished via the femoral (13, 31, 53, 58), a branch of the circumflex iliac (44), the carotid (52), and the umbilical (37) arteries and of the carotid artery via a direct approach (18, 40, 53, 54), the thyrolaryngeal (6), and the anterior auricular (1) arteries. These arteries undoubtedly are used because of their accessibility and size in relation to other available arteries.

In our experience with calves, the femoral procedure of Yelverton et al. (58) for aorta catheterization has proved consistently more successful than the circumflex iliac procedure of Olsen et al. (44). Although the circumflex iliac (branch) is much simpler to isolate, in about 50% of the cases the catheter would not negotiate a sharp caudal bend after being passed about 20 to 25 cm into the artery. This was probably the result of our using a large (1.5 mm id x 2.3 mm od), relative to the size of the vessel, Teflon catheter; when a smaller, more flexible catheter was used, successful cannulation usually was accomplished. In either procedure, we found it advisable to bathe the exposed artery with xylocaine to prevent constriction during cannulation. Because the circumflex iliac is smaller than the femoral, the use of sterile, lactate jelly as a catheter lubricant is a helpful adjunct to passage of the catheter into the aorta. It is not unusual for catheters placed in the aorta this way to remain functional for 6 months to 1 year or longer without sheath or thrombus formation provided that the requisite precautions are followed in catheter fabrication to prevent intimal damage and that adequate attention is paid to postoperative maintenance.

In very young calves (birth to 21 days), in which most of the arteries accessible to cannulation are comparatively small, the umbilical arteries provide a means of catheterizing the aorta with a relatively large catheter (37). Very long-term implantation cannot be expected, however, because it is difficult to accommodate the rapid growth that the animal undergoes. Leaving a loop of catheter in the abdominal cavity for this purpose may lead to intestinal strangulation.

Venous. An almost infinite variety of venous catheterization procedures has been described. This probably results from the accessibility of many veins to percutaneous procedures or minor cut-down, the relatively large size of veins even in the extremities, and the suitability of venous blood for analytical purposes in most studies. Many of the procedures use similar approaches, with only minor modifications in materials, methods, and instrumentation. This is primarily a reflection of the idiosyncrasies of the one doing the surgery and is by no means a note of criticism, but only points out that one person may be more adept at performing skills a certain way than another. Many of the modifications, though minor, usually have been developed through trial and error and may be helpful to those wishing to adapt a procedure to their particular use.

Although short-term catheterization does not seem to present any particular problems, the long-term catheterization of veins has proved rather difficult. In general, catheters often are occluded soon after insertion into the vessel by thrombus formation at the tip or by the formation of a sheath that encloses the catheter and acts as a valve, permitting the injection of materials but preventing the withdrawal of blood samples. Sheath formation is the most common cause for failure. It is characterized by the deposition of a fibrous coat on the catheter that may occur within 30 min of insertion. This is subsequently followed by endothelial proliferation and medial hyperplasia and may be accompanied by a low-grade phlebitis.

The simplest and most widely used procedure for venous catheterization in most large animals is percutaneous catheterization of the external jugular vein. In our laboratory, we perform this either unilaterally or bilaterally, with or without local anesthesia, by tapping the vein with a hypodermic needle and threading an appropriate-sized catheter through the needle. The needle then is withdrawn, leaving the catheter, which is closed with a two-way valve and secured to the skin with stay sutures. The outer diameter of the catheter will determine the gauge of the needle. We routinely use siliconized polyvinyl catheters (1.5 mm id x 2.3 mm od) that remain functional about 10 days. If longer periods of patency are required, silicone rubber catheters should be used. We also use a minor cut-down procedure for inserting large (1.6 mm id x 3.2 mm od) silicone rubber catheters into the external jugular vein of calves (46). Similar procedures have been described for pigs (1, 9) and sheep (54).

Catheterization of the posterior vena cava has been accomplished in pigs, sheep, and cattle via the femoral (13, 31) and a branch of the circumflex iliac (12) vein or directly (27, 46). The femoral and circumflex iliac procedures are similar to those described for the corresponding arteries. Hull used an abdominal approach through the 12th rib in cattle and introduced a silicone rubber catheter (1.35 mm id x 2.3 mm od) that remains functional about 10 days. Many of the procedures described for the femoral approach also may be used for the jugular.
We also use this approach to catheterize the posterior vena cava when establishing the venous end of an intestinal lymph duct shunt in calves, but use a larger catheter (1.6 mm id x 3.2 mm od) and insert the catheter through the vein wall with a sharpened bone point (39, 46). Our experience has been that much less intimal damage results from the smooth puncture wound of the bone point than from the laceration caused by the cutting edge of a needle. Most catheters established in the posterior vena cava of calves by this procedure have been functional beyond 30 days.

Procedures for cannulation of the hepatic vein in the liver (23, 31) and for permanent occlusion and catheterization of the posterior vena cava to collect mixed hepatic venous blood (41) have been described for sheep. All procedures seemed relatively successful, with the catheters remaining functional for up to 150, 140 and 160 days, respectively.

Because of the widespread interest in studying the absorption of nutrients from the gut, considerable attention has been focused on catheterization procedures for obtaining blood from the major vessels draining the gastrointestinal tract of unanesthetized animals. The portal vein has received the most attention, procedures have been described for its catheterization via the mesenteric vein in man (14), dogs (30), chickens (43), sheep (2, 23, 41, 48), and cattle (11, 39, 55); via the right ruminal vein in cattle (45), via the umbilical vein in calves (37); and via a direct approach in sheep (4, 31) and cattle (7, 39). Procedures also have been described for catheterization of the mesenteric vein in cattle (11, 39), the right ruminal vein in cattle (45), and the gastroplenic vein in sheep (25) via their respective communicating branches. Although the functional life of the catheters is not always clearly detailed in these reports, one can conclude, in general, that the catheters remain patent for a limited time and that, even during their period of patency, blood samples cannot always reliably be obtained.

**Hydraulic needle.** In view of the technical problems associated with indwelling catheters, we developed a hydraulically operated needle and a procedure for its implantation on the portal vein (38). With its use, we have been able to obtain reliably repetitive blood samples with no evident discomfort or excitement of the animal over long periods (minimum, 84 days). We are currently experimenting with a smaller version of the needle that can be implanted on a branch of the anterior mesenteric vein for dye injection during blood flow and absorption studies.

**Lymphatic.** Development of procedures for cannulating the thoracic lymph duct and various regional lymph ducts has advanced rapidly in the last 10 years. Most of the early procedures involved simple cannulations, with no provision made for the return of lymph to the body. As a result, an abnormal state of plasma protein and body fluid equilibrium occurred through a constant loss of lymph.

Brown and Hardenbergh (5) were the first to describe a technique for collecting thoracic duct lymph in unanesthetized animals for a period of days with minimal loss of lymph. They established a lymph shunt by connecting a thoracic duct cannula to a venous catheter outside the body. The thoracic duct was cannulated with polyvinyl tubing near the thoracic duct ampulla, and a return catheter was inserted into the left jugular vein. This general operative technique has been used to cannulate the thoracic duct of man (3, 16, 17), sheep (49), calves (8, 15, 16, 29, 50), goats (42) and cows (24).

Because it is often difficult to cannulate the thoracic duct near the ampulla, Cochrum, Okimoto, and Najarian (10) established a lymph reservoir in the left jugular vein of goats. A silicone rubber catheter was inserted into the reservoir and connected to a second catheter in the right jugular vein to complete the shunt.

Although cannulating the thoracic duct at the base of the neck has been the most popular approach, there are some major disadvantages of the technique. There are many accessory lymph ducts and aberrant communications between the thoracic and right lymphatic ducts in this region, thus making it difficult to cannulate the thoracic duct. It also is very difficult to fix catheters in position in the mobile neck area.

Because of these complications, Lascelles and Morris (32) chose to cannulate the thoracic duct of sheep via an approach through the 8th rib on the right side. The thoracic duct was easily located without dissection on the right dorsolateral surface of the aorta and cannulated with siliconized polyvinyl tubing. A paired duct was sometimes present on the left side of the aorta and was ligated. The shunt was completed by passing a second catheter into the right external jugular vein.

In our laboratory, we have established, using silicone rubber catheters, thoracic duct-
jugular vein shunts or thoracic duct-duct shunts in calves (46) by an approach similar to that described by Lascelles and Morris (32) for sheep. Both types of shunt remained patent for about the same length of time (34 to 38 days), but the duct-duct shunt had less tubing exteriorized and required considerably less maintenance. Failure of the thoracic duct-jugular vein shunts or thoracic duct-duct formation in the venous end of the shunt; failure of the duct-duct shunt was caused by clotting of lymph in the return catheter.

Lascelles and Morris (32) also have described a method for establishing intestinal lymph duct fistulae in sheep. No provision was made for returning lymph to the animal. Shannon and Lascelles (51) modified this technique to establish intestinal duct-jugular vein shunts in calves. By similar techniques, we established intestinal duct-jugular vein and intestinal duct-duct shunts in calves but found them unsatisfactory because of difficulty in maintaining the long length of tubing connecting the intestinal cannula to the jugular catheter and because lymph flow was slowed by poor aspiratory action in the return cannula of the duct-duct shunt. As a result, we modified the procedure to establish intestinal duct-posterior vena cava shunts in calves (46). The venous end of the shunt was inserted into the vein with a sharpened bone point (39) and positioned in the vein where there was maximum aspiratory action in the catheter. These shunts remained patent up to 33 days. They were easy to maintain because clotting in the return end of the shunt was never a serious problem, and only a short length of tubing was exteriorized. Eventual failure of the intestinal duct-vena cava shunts usually was attributable to clot formation in the collection end of the shunt.

Although the major difficulty in maintaining duct-venous or duct-duct shunts is clot formation either in the collection or return end of the shunt, there are a number of steps that can be taken to delay this event. Recent studies strongly indicate that silicone rubber is the catheter material of choice in long-term shunts. The use of a smooth Teflon tip (22) may be helpful in avoiding restriction of the cannula lumen when it is fixed in the duct, thereby preventing a reduction in lymph flow that might promote clotting. Irrigatable catheters (29) (McGilliard, unpublished data) that permit the infusion of heparin into the lymph as it first enters the shunt are effective in extending the patency of the shunt. Finally, the importance of good aspiratory action in the return end of the shunt cannot be overemphasized. This has been stressed by Wang, Caro, and Yamazaki (56) in their studies with hepatic duct-posterior vena cava shunts in dogs and has been observed by us in studies involving thoracic duct- and intestinal duct-posterior vena cava shunts in calves.

Stabilization and Exteriorization

The importance of proper fixation of the cannula in lymph ducts has been stressed by Artz et al. (3). We have found this is important with blood vessels as well. Moreover, when a length of tubing is left in the thoracic or abdominal cavity to accommodate for any change in position of the organs when the animal stands, subsequent growth, and changes in fill, care must be taken to orient and stabilize the tubing so that there will be no chance for it to kink. We usually glue with silicone rubber cement or tie with nonabsorbable sutures small bands of polyvinyl surgical sponge or dacron velour to the catheters at the point they exit from the vessel and at the point or points of attachment to supporting tissues. Definite care must be taken when tying the catheters in place at these points not to compress the tubing and reduce its internal diameter. These bands subsequently become infiltrated with connective tissue, thus firmly securing the catheter.

There are three important considerations in the exteriorization of a permanently indwelling catheter. (a) The way in which the catheter is exteriorized should provide maximum protection to the catheter from the animal and its surroundings. (b) The exteriorized end of the catheter should be placed where it is readily accessible, with minimal disturbance of the animal, to the person taking blood or lymph samples. (c) Orientation of the catheter should be such that only minimal maintenance is required to keep the area around the catheter free from contamination and infection. The subcutaneous procedure described by Dougherty et al. (13), Olsen et al. (44) and Yelverton et al. (58) provides an excellent means to exteriorize catheters, especially if long lengths of catheter are involved. This procedure completely encloses the catheter, except the immediate end that is exposed for closure with a valve. In calves, we (38, 39) routinely exteriorize our catheters, except those in the jugular vein, subcutaneously to the edge of the lumbar shelf with a long, eyed, stainless steel needle about the same diameter of the
largest catheter tubing. Parker et al. (45) have stressed the importance of exteriorizing the catheter ventrally to provide drainage and prevent ascending infections along the subcutaneous tract. All our catheters have been exteriorized dorsally, however, and no infections have been observed provided that the catheter is fixed to minimize movement of the catheter in and out of the skin and that the area around the skin exit is kept clipped, reasonably clean, and dusted with an antibiotic powder.

In preparations such as lymph shunts (46), subcutaneous exteriorization is contraindicated because the length of the shunt must be kept to a minimum. Thus, it is necessary to lead the catheters through the body wall via stab wounds or the original incision rather than to subcutaneously tunnel to a location inaccessible to the animal. With this type of exteriorization, provision must be made to anchor the catheters at their points of exit through the body wall to prevent any movement back and forth through the exit wound and to provide an impermeable seal around the tubing. Completion of the lymph shunt is made by butting the exteriorized ends of the catheters together in a short length of tubing that snugly fits the external diameter of the catheters. Small nylon bands are used to secure the union.

A number of different methods have been used for closing catheters after their exteriorization. A satisfactory closure should fulfill several requisites, the most important of which is the prevention of blood re-entering the catheter once it has been flushed and filled with anticoagulant solution. It should be such that it readily can be kept clean and aseptic insofar as is possible. It should be easily operable for taking blood samples or infusing solutions. We (38, 39), as well as a number of others (13, 31, 44, 45, 58), have found that a needle hub that snugly fits into the end of the catheter, a two-way valve with the handle removed to prevent accidental opening, and a male cap to prevent contamination of the open end of the valve is a highly satisfactory means of closure and fulfills all the requisites previously mentioned. A check of each hub and valve (as a unit) should be made before each use to make certain that it does not leak.

Stay sutures provide a simple means for anchoring vascular catheters and valves or lymphatic catheters to the skin of an animal (39, 46); however, they are not long-lasting and tend to slough out in about 7 to 10 days. Suture material threaded through a short length of polyvinyl tubing looped beneath about 4 cm of skin provides a somewhat longer-lasting preparation (44). Both preparations are subject to frequent replacement, and the open wounds caused by sloughing are subject to infection. Moreover, the valves are exposed to the environment of the barn. Repeated suturing and exposure of the valves, thus, presents a serious problem to long-term use. We have solved this problem by the use of a patch, made from cotton webbing and Velcro, which can be rather permanently cemented with branding cement to the animal and closed over the valves when blood samples are not being taken or when infusions are not being made (38). A simpler, unenclosed patch has been used for securing lymphatic shunts to the skin.

Post-surgical Maintenance

From available evidence, there is little doubt that the most frequent cause of failure of vascular catheters is occlusion by fibrin deposition and sheath formation that encloses the catheter. This may be complicated further by thrombus formation at the tip. Jacobs, Klopp, and Gott (28) have presented evidence that these formations occur during the first 2 to 4 hr after implantation and are spontaneously removed or diminished during the succeeding 18 to 24 hr. Thus, it would seem that the first 24 to 48 hr after surgery are the most critical period for maintaining catheter patency. In our experience, we have found it most advantageous to flush the catheters with sterile physiological saline and then fill them with a heparin-saline solution at 8-hr intervals for the first 2 to 3 days after surgery, at 12-hr intervals for the next 4 to 5 days, and at 24-hr intervals thereafter. Similar maintenance procedures have been used by Moodie et al. (41), Carr and Jacobson (7) and Katz and Bergman (31) with relative success. There is no solid evidence that indicates extensive anticoagulant therapy of the animal with heparin or dicumeryl will effectively prevent sheath and thrombus formation beyond 48 hr after surgery, and even during that period, its effectiveness is questionable (4, 11, 55) (McCullard, unpublished data).

No consensus of opinion regarding the concentration of heparin in saline required to maintain catheter patency is evident from the literature. Concentrations as low as 100 units/ml and as high as 5,000 units/ml of saline have been used with apparent success, with higher concentrations being used in arterial catheters than in venous catheters in
some studies. With calves, we have found a concentration of 250 units heparin/ml physiological saline satisfactory in both arterial and venous catheters. In studies such as those on lipid metabolism, where the use of heparin is contraindicated, a 2.5% solution of sodium citrate may be used to fill the catheters.

Because complete asepsis of the exteriorized catheters and valves is not possible even under the best conditions, a further complication to the maintenance of catheter patency is the presence of a low-grade phlebitis at the catheter tip that may, in turn, accelerate thrombus formation. With sheep, Moodie et al. (41) found that giving 2,000,000 units of penicillin in the heparin-saline solution used to flush the catheters each day during the first week and 3 times weekly thereafter proved invaluable in eliminating phlebitis and maintaining catheter patency. We have obtained similar results in recent studies with calves by using 1,000,000 units penicillin/ml of the heparin-saline solution used to fill the catheters.

Because the hydraulic needle (38) is enclosed and not in contact with blood in the vessel to which it is attached except during sampling or infusion, little post-operative maintenance is required. The needle is not inserted until the 7th day after its establishment on the vein. This allows sufficient time for tissue to infiltrate the holes of the attaching disc and form a strong union with the vein wall so that it is not pushed away from the disc when the needle is inserted. After the needle has been inserted and blood withdrawn, the sampling tube is flushed with saline, filled with anticoagulant, and the needle withdrawn. The residual fluid in the needle clears the needle point as it is withdrawn from the vein.

Lymph shunts require close observation (every 8 hr) and a daily check of flow rate because of the marked tendency for lymph to clot in the catheters under conditions of reduced flow. Thus, any factor such as sheath or thrombus formation on the venous return catheter, reduction of lumen diameter by fibrin deposition or compression, and adherence of small clots to the catheter wall that increases resistance to lymph flow requires immediate attention. Clots that form in the return end of the shunt generally can be removed by flushing with an anticoagulant solution, but clots in the collection end are difficult to remove. Gentle suction, applied to the cannula, is reasonably successful only when clot formation within the cannula is not extensive. Lymph duct cannulae with irrigatable tips allow easier removal of clots because they allow anticoagulant solution to be flushed through the tip while gentle suction is applied to the other end. Use of a fibrinolytic enzyme may also prove helpful in preventing or removing the buildup of fibrin on the internal wall of the shunt.

Summary

While this lucubration may have the dubious distinction of being original, it is not an exhaustive coverage of all the work that has been done in this field. Much of it is confined to studies with ruminants. Many of the techniques described are those in use at other laboratories. Many of them are our own, and in general, we have deemed it wiser to confine ourselves chiefly to those procedures with which we are most familiar. It is hoped that this paper will convey some knowledge of the various vascular and lymphatic catheterization procedures available and impart an appreciation of some of the problems that one might encounter in their use.

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