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Choosing an Appropriate Implantable Device for Long-term Venous Access

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Abstract—*A variety of devices is now available for venous access in patients requiring long-term infusions of chemotherapeutic agents, hyperalimentation solutions, blood products or antibiotics. All have advantages and disadvantages which may make the selection of one type of device appropriate under a given set of circumstances but inappropriate in another. Experience has shown that patients needing intensive therapy for hematologic malignancies are best served by lines that require minimal dissection for insertion, such as the Hickman catheter. Patients who are unlikely to hemorrhage at the time of insertion and who need only intermittent therapy can take advantage of the greater convenience and cosmetic appearance of a totally implantable port. Peripheral vein cannulation by means of fine silicone rubber catheters can be performed by trained intravenous nurses to provide access of intermediate duration without the expense and inconvenience of surgical insertion in an operating room.*

INTRODUCTION

WHENEVER mankind has ventured into remote or hostile regions, the success of the undertaking has largely depended upon the procurement and maintenance of vital supply routes. Logistics are equally important for the successful treatment of a variety of malignancies, where the supply route depends on the adequacy of access to the venous system. Reliable entry into large central veins is essential for continued infusion of chemotherapeutic drugs, blood products, hyperalimentation solutions, fluids and electrolytes. Central venous access also provides a means of obtaining frequent blood samples to follow the parameters used to evaluate the effect of therapy.

The first experience with vascular access dates back to the 17th century, when the English architect Christopher Wren suggested utilizing hollowed quills for infusion of fluids into veins [1]. Unfortunately, medical knowledge had not advanced sufficiently by the mid-17th century to make appropriate use of this innovation. The first attempts at fluid infusion consisted of animal blood transfusion as a treatment of psychiatric disorders. The adverse results of this ill-conceived undertaking led to the abandonment of intravenous therapy for the next two hundred years.

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During the course of the 20th century, venous access has become routine. The simplest form of venous access is by means of stainless steel needles or polyethylene catheters. This form of venous access provides an adequate route for most patients who need only short-term therapy. When highly toxic chemicals are to be delivered, local inflammatory reactions and the danger of tissue loss from extravasation limit the usefulness of these standard devices. Percutaneously placed central venous lines reduce the problems with the local inflammation and extravasation but introduce a separate set of complication, such as pneumothorax, hemothorax, and vascular injury. Polyethylene catheters must also be replaced every 7–10 days, increasing further the risk of vascular or pleural injury [2].

Arteriovenous fistulae have provided satisfactory long-term vascular access for hemodialysis but require too much time to mature to be useful for most chemotherapy needs [3]. The venous damage produced by cytotoxic drugs may also limit the availability of veins to form such fistulae by the time the need for long-term access is appreciated. Approximately 75% of arteriovenous fistulae will function if patients have received less than 4 weeks of chemotherapy prior to the time of fistula creation. This rate falls to 30% for those patients who have received more than 4 weeks of chemotherapy prior to fistula formation [4].

Long-term venous access for chemotherapy that is consistently available for immediate use was

introduced in the mid 1970s with the development of implantable silicone rubber central venous catheters. Catheter function of as long as 34 months has been obtained for total parenteral nutrition utilizing the Broviac catheter [5]. The Hickman catheter, a larger diameter version of the Broviac catheter which permits blood withdrawal as well as drug infusion, has provided equivalent duration of function for patients receiving chemotherapy [6]. Both these catheters create a permanent opening in the skin at the exit site. For this reason infections are a common complication with this type of device. Totally implantable ports, which do not require violation of the skin barrier except at the time of access, have gained popularity as a substitute for the Hickman/Broviac catheter [7]. Since these ports contain no permanent transcutaneous components, they should theoretically promote infectious complications less frequently. Newer catheter materials now permit even the peripherally placed lines to be used for longer periods of time [8]. Patients requiring access of intermediate duration, for 45–90 days for example, may not need to undergo implantation of a permanent device at all.

METHODS

Hickman catheter

The Hickman catheter consists of a 90 cm, 1.0 mm bore barium impregnated silicone rubber modification of the smaller indwelling right atrial (Broviac) parenteral nutrition catheter (Fig. 1). This larger diameter was designed to permit easier blood withdrawal. Recent modifications have included the addition of a second lumen to permit simultaneous infusion of more than one medication (Fig. 2). The external end of the catheter is equipped with a threaded plastic connector (Luer-Lok) adaptor that can be sealed with a plastic cap. A small dacron cuff envelopes the catheter 30 cm from the external end. This cuff plugs the subcutaneous tunnel and incites the ingrowth of fibrous tissue, thereby sealing

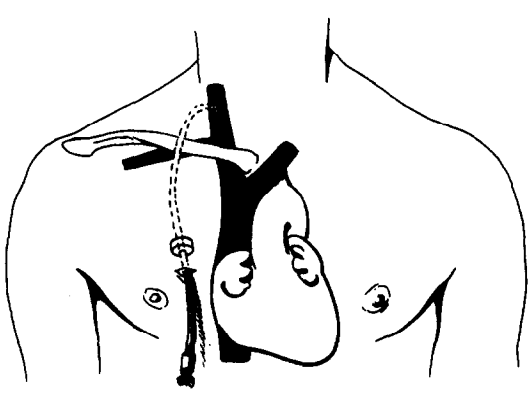

Fig. 1. Hickman catheter in preferred location.

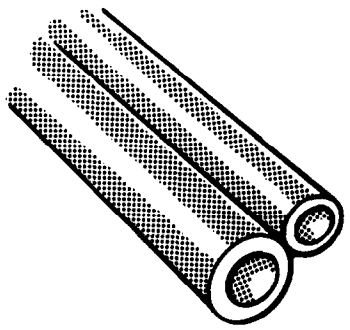

Fig. 2. Grooved configuration of the double lumen catheter in use from 1980 to 1986.

the catheter tract from the exit site wound and lessening the chance of accidental dislodgement.

The preferred operative procedure for insertion of the catheter is by cutdown via the cephalic or jugular venous system performed under local anesthesia [9]. Since the cephalic vein can be stenotic in patients who have previously received chemotherapy, we now routinely choose the external jugular vein for Hickman insertion. In those cases where the external jugular vein is of insufficient size for insertion of the catheter, the internal jugular vein can be isolated through the same incision and cannulated through a purse string suture. Once an adequate vein is identified, a tunnel is developed from the incision utilized for vein exposure to an exit site on the anterior chest wall. A variety of tunnelers is now available which minimize the tissue disruption and discomfort of this maneuver. A small exit site is created just lateral to the sternal border where the skin is relatively firmly attached to underlying fascia. The Hickman catheter is then threaded from the exit site into the operative incision by means of the tunneling passer (Fig. 3). The catheter is drawn into the cervical incision until the dacron cuff comes to lie within the subcutaneous tunnel, approximately 4–5 cm internal to the skin exit site . After its lumen is filled with saline, the catheter is trimmed to a length which will bring its tip to lie at the junction of the superior vena cava with the right atrium, once it has been inserted into the vein selected for cannulation. A small venotomy is then made in the isolated vein, and the catheter is threaded centrally into the superior vena cava. Usually the catheter will easily pass into the proper position, but on occasion fluoroscopy will be necessary to guide its insertion. In either case, radiologic confirmation of its position is obtained before the patient is allowed to leave the operating room. Before securing the catheter place, it is important to test its function, especially on blood withdrawal. If the catheter tip is lying against the endocardium, it will be difficult to obtain a steady stream on blood removal. Any such hesitancy requires repositioning

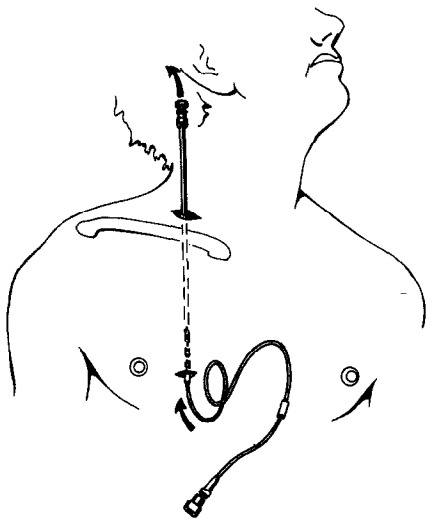

Fig. 3. Hickman catheter insertion. Development of subcutaneous tunnel with shunt passer.

of the tip if proper function is to be expected. If the cephalic vein or external jugular vein have been utilized for catheter insertion, simple vein ligation with an absorbable suture is utilized for hemostasis. Should the internal jugular vein be used for cannulation, a purse string suture is used to secure the vein wall around the catheter in order to preserve patency of the vessel. Persistence of the suture material at the site of vascular entry increases the chance of catheter shearing at the time of removal. For this reason, an absorbable suture is preferred. Once the catheter is in place and functioning properly, the wound is checked for hemastasis and closed with absorbable suture. We prefer a subcuticular closure of the dermis in order to avoid the need for later suture removal. A small suture can be utilized to secure the catheter at the exit site to reduce the dangers of early dislodgement. If such a suture is utilized, it should be removed in 7–10 days. Heparinized saline is then used to fill the lumen of the catheter and the cap is secured in place. Prophylactic antibodies are not routinely used, but a small amount of povidone iodine is placed around the exit site before dressing the wound.

To avoid the need for venous cutdown during Hickman insertion, a number of centers have adapted the Seldinger percutaneous method of catheter placement for insertion of these permanent lines [10]. This method relies on blind entry into the subclavian vein with a needle placed inferior to the clavicle. A wire is inserted through the needle into the subclavian vein to serve as a guide for the introduction of a vein dilator and split-sheath introducer. The catheter, which has been positioned within a subcutaneous tunnel by a method similar to that used with the cutdown technique, is then threaded through the introducer into the superior vena cava. This method may save time, but blind cannulation of the subclavian vein carries an inherent risk of injury to the subclavian artery and pleura, not seen with the cutdown technique. Experience with the Seldinger technique for Hickman placement has also introduced other unique complications. One of these consists of catheter breakage due to the shearing action of the clavical on the underlying rib [11]. When this happens, the central portion of the catheter is free to migrate into the pulmonary vasculature. Another unusual complication is that of drug extravasation along the fibrin sheath which may develop from the tip of the catheter back toward the venotomy site. When the venotomy has been secured with a tie at the time of catheter insertion, the route for drug extravasation is interrupted. When direct puncture of the vein has been utilized for catheter insertion and no tie has been used, drug is free to follow the route along the catheter into the subcutaneous tissue. Significant loss of soft tissue has been reported as a sequel to this type of extravasation [12]. For these reasons, and because the cutdown method is only marginally more time consuming in our hands, we have continued to prefer the cutdown over the percutaneous method for catheter placement.

Whichever method for catheter insertion is chosen, the catheter is available for immediate use, once the position of the tip has been confirmed radiologically. Currently all catheters are made of radio-opaque material. Consequently, it is not necessary to utilize contrast dye in order to identify the catheter on X-ray.

Postoperative care consists of daily cleansing of the exit site with hydrogen peroxide in order to remove any crusted material. It is best to keep an anti-bacterial ointment, such as povidone iodine, in contact with the exit site until healing occurs and the exit site suture can be removed. The incision utilized for cutdown can be uncovered the day following the operation. Redressing is only necessary in the occasional patient who develops prolonged oozing from the skin edges. Injection of the wound edges with lidocaine containing epinephrine and reapplication of a pressure dressing will usually suffice to control hemorrhage in these cases. We avoid the application of an occlusive dressing, such as Tegaderm or Op-site, feeling that this retains, rather than excludes, bacteria and moisture. When not in use the catheter must be flushed at least daily. Initially we utilized 2 ml per lumen of a saline solution containing 1000 units/ml of heparin. We now utilize a solution containing 100 units/ml, unless repeated catheter occlusion develops, in which case the more concentrated solution is again employed.

Venous access ports

Since all cuffed catheters leave a permanent break in the skin at the exit site and require daily flushes for patency, interest has focused on the development of an access device that can be totally implanted and requires less daily care. At the present time there are a number of venous access ports available. All of the port devices consist of a catheter similar to the Hickman attached to a reservoir equipped with a silicone rubber diaphragm (Fig. 4). Access to the port is established by plunging a needle through the skin and subcutaneous tissue into and through the silicone rubber diaphragm (Fig. 5). A special needle, called a Huber needle, must be used to avoid coring and removing portions of the diaphragm (Fig. 6). The Huber needle is beveled in such a way as to cut a slit rather than a core in the diaphragm, allowing more punctures without leakage (Fig. 7). The method of inserting these devices is similar to that utilized for Hickman insertion except that a pocket must be developed to hold the reservoir, rather than a subcutaneous tunnel and exit site. The ideal location of this pocket is on the anterior chest wall just below the clavicle. Since the cephalic vein can be exposed through the same incision utilized to develop the pocket, our preferred vein for port insertion is the cephalic vein. If the cephalic vein is of insufficient size to accept the catheter, a second incision is performed just above the clavicle to identify one of the jugular veins. Communication between the two incisions can be established by blunt dissection within the subcutaneous tissue overlying the clavicle. Once the catheter is in proper position as established by fluoroscopy, flow characteristics are determined by flushing and blood withdrawal through the port. The port must then be placed between the subcutaneous tissue and the pectoralis major fascia. The port is secured in position with at least three permanent sutures to prevent its turning over, an event which places the septum out of reach of the access needle. In obese patients it is best to place the pocket no deeper than 2 cm below the dermis. This sometimes requires a plane of dissection between layers of fat rather than between the fat and pectoralis major fascia. Once the catheter and port are in place, the subcutaneous tissue and dermis are closed with absorbable suture. A dry sterile pressure dressing is applied to the wound following completion of the skin closure. This can be removed the following day as in the case of Hickman insertion.

Access ports have the advantage of keeping all foreign material beneath the skin, theoretically reducing the exposure to bacteria. Ports also seem to require less frequent flushing to maintain patency. This may be due to the relatively rigid nature of the diaphragm which eliminates motion of the heparin solution in and out of the catheter tip. The disadvantage of ports is that a needle puncture is required to establish access. Needle puncture requires considerable skill, may be painful, and may itself introduce infection. If the needle becomes dislodged during the course of drug infusion, drug extravasation with severe tissue loss may result. Ports also require more tissue dissection for insertion, a potential disadvantage for patients with low platelet and white cell counts at the time of operation.

Peripheral silastic catheters

Recent improvements in the materials used in the manufacture of peripheral catheters has increased the longevity of these devises. With a duration of function of 45–90 days, a single line will often get a patient through the first course of chemotherapy. Peripheral placement at the bedside by a specially trained IV nurse avoids emergency use of the operating room to establish access in patients who arrive for treatment at awkward moments.

RESULTS

Between the years 1978 and 1987, 690 catheters were inserted for chemotherapy in 593 patients at the University of Maryland Cancer Center (Table 1). More than half of the patients (401) had acute leukemia. The rest had lymphomas or other solid tumors. Single lumen catheters were used 312 times, and double lumen catheters were placed 378 times. A single surgeon was responsible for placement in 490 cases. A rotating group of surgeons was responsible for the remaining 200 catheters.

The 690 catheters functioned for a total of 134,273 days for an average duration of 195 days per catheter. Single-lumen catheters lasted longer than double-lumen ones, reflecting, in part, the greater severity of illness for which double-lumen catheters were employed. Infectious complications developed on an average of 1.99 times per 1000 days of catheter use (Table 2). Non-infectious complications developed 3.26 times per 1000 days of catheter use. Fully 1/3 of catheters (231/690) functioned without complications for the entire period of use.

Most of the infectious complications consisted of bacteremias (397) and exit site infections (160) which, for the most part, could be treated with antibiotics without catheter removal. Tunnel infections, which occurred in 46 cases, always required removal of the catheter for cure.

Non-infectious complications consisted of hemorrhage at the time of catheter placement, thrombosis of the cannulated vein, migration of the catheter out of position with accidental loss, luminal fracture, and loss of function due to partial plugging of the lumen. Most of these problems could be corrected without catheter loss. The exceptions were

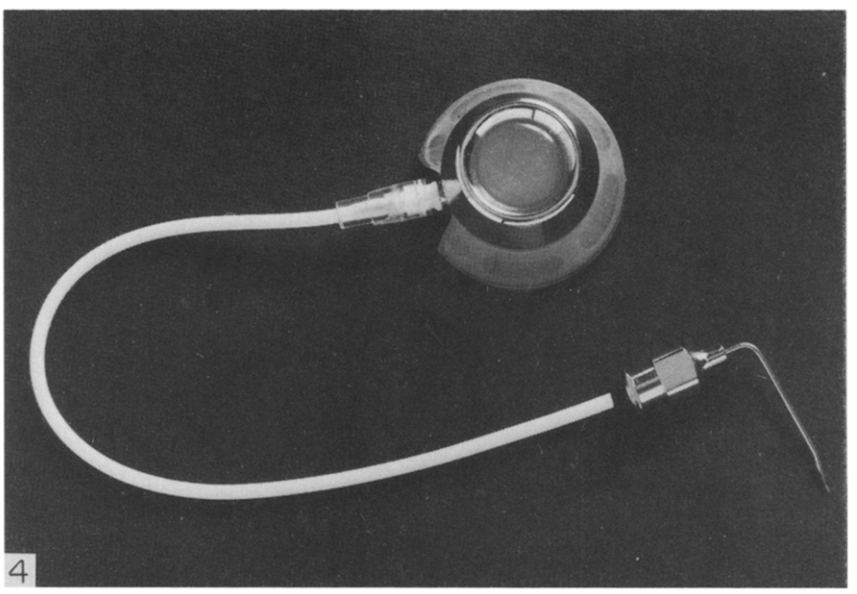

Fig. 4. *Venous access port with the flat beveled Huber needle used for port access.*

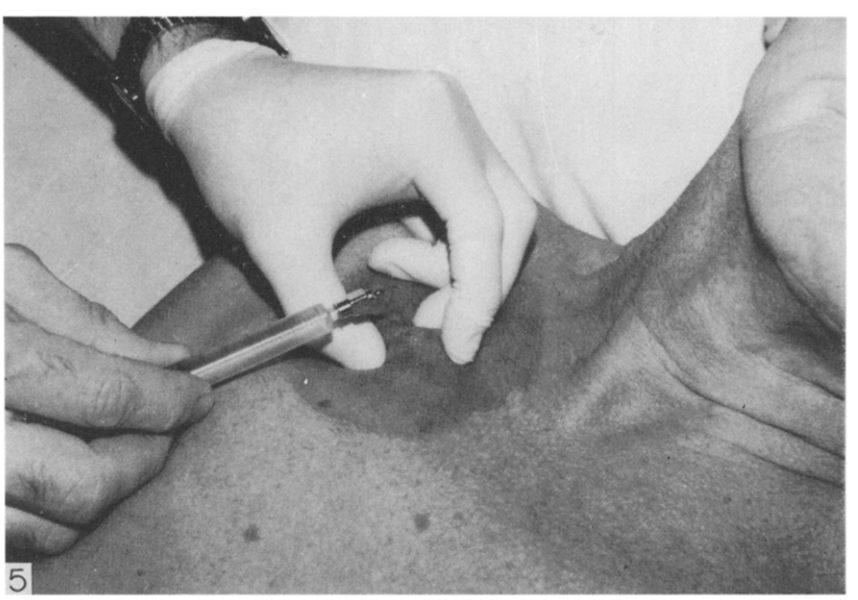

Fig. 5. *Huber-needle access of subcutaneous port. Septum location is identified by triagulation, using fingers placed around rim.*

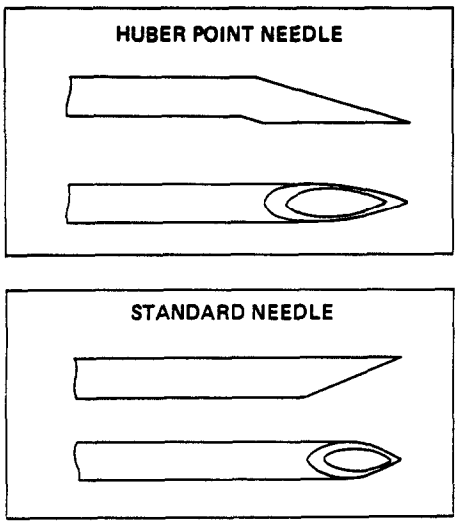

Fig. 6. Huber needle used for port access has a flat bevel which avoids coring the septum. Standard needle has angled bevel.

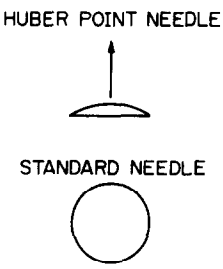

Fig. 7. Septum defect produced by a standard needle and a Huber needle.

Table 1. Hickman catheter: University of Maryland Cancer Center, 1978–1987

Catheters	690
Patients	593
Single surgeon	490
Acute leukemia	401
Double-lumen	378
Complication free	231
Total days 134,273	

Table 2. Hickman catheter complications: risk factors 1978–1987

	Infectious complications		Non-infectious complications	
Factor	Relative risk	*P* value	Relative risk	*P* value
Double lumen catheter	2.1	0.01	3.6	0.01
Single surgeon	—	—	0.77	0.01
Obesity (1.25 × IBW)	1.7	0.02	2.0	0.01
Neutropenia	1.6	0.02	—	NS
Complications per 1000 days	1.99		3.26	

thrombosis of the cannulated vessel and catheter migration with accidental loss.

In looking for risk factors leading to infectious and non-infectious complications, a number of associations were found. Infectious and non-infectious complications were significantly more common with the double-lumen Hickman catheter than with the single-lumen device (Table 2). Infectious and non-infectious complications were also more common in obese patients. Neutropenia was significantly more common in patients suffering infectious complications but had no relationship to the non-infectious complication rate. Relying on a single surgeon for catheter placement significantly reduced the rate of non-infectious complications.

Relatively little long-term data are available for venous access ports used for chemotherapy. A recently published experience with 329 devices in 300 patients show a cumulative port availability of nearly 70% at 3 years [7]. Complications developed in 39% of cases, including local infection and sepsis (16.4%), thrombosis (9.7%) and drug extravasation (6.4%). While this complication rate and longevity is superior to that seen with the Hickman catheter [13], the patient population in this study was also different. Only 21 of the 300 patients had leukemia. The remainder had solid tumors, or non-malignant conditions such as Crohn's disease, that would be expected to produce less profound alterations in the leukocyte and platelet counts and require a lower intensity of chemotherapy. It should be noted however that the port devices do not entirely eliminate the problem of infection and thrombosis. They do introduce the potential of drug extravasation that is not a problem with Hickman use.

DISCUSSION

Central venous access for chemotherapy has come a long way in the past 10 years. Catheters and ports are now available which can provide years of access with relatively few complications. None of the available devices is perfect, however. Each offers some advantages and disadvantages over the other available devices (Tables 3 and 4). In choosing the appropriate device for a given patient, one must consider a number of different factors. A patient with poor platelet and leukocyte counts, secondary to acute leukemia, will be better served by a double-lumen Hickman catheter than by a port. Less dissection and bleeding can be anticipated by avoiding the pocket required to accommodate the reservoir. The double-lumen catheter also allows more rapid infusion of blood products and is better adapted to continuous use over several weeks. In contrast, an active outpatient requiring only weekly or monthly doses of chemotherapy will find the port to be far more convenient.

Table 3

	Device		
	Hickman	Port	Peripheral silastic catheter
Preferred placement	Jugular vein	Cephalic vein	Basilic/cephalic vein
Indications	Long-term, continuous therapy	Long-term, intermittent therapy	Intermediate-term, continuous therapy
Advantages	Low insertion trauma, immediate, painless low skill access	Low maintenance, cosmetic, reduced infections	Ease of placement (nurse), saves central veins
Disadvantages	Infection, maintenance, cosmetic	More dissection for insertion, needle extravasation	Infection, thrombosis, shorter duration

Table 4

Catheter	Placement ease	Immediate use	Painless	Cosmetic	Skill to use	Infectious	Extra vasation	Breakage
Hickman	++	+++	+++	+	+	++	±	++
Port	+	+	+	+++	+++	+	++	±
Peripheral silastic	+++	+++	+++	+	+	+++	±	++

The experience with Hickman catheters over nearly a decade at the University of Maryland demonstrates the basic safety of these catheters for long-term use in severely ill leukemic patients. Although the surgical technique for catheter insertion is considered to be mundane, it is clear that reliance on a single interested surgeon will lower the rate of non-infectious complications. The infectious complications may be reduced in part by modifications in the design. The double-lumen catheter used from 1980 to 1986 was associated with a significant increase in the risk of infectious complications. This catheter also had an awkward grooved configuration (Fig. 2) that interfered with exit site healing. Double-lumen catheters that are now available have the same diameter and configuration as the original single lumen Hickman. These modifications should improve the rate of infection seen with this device, unless these infections have been related more to the disease process being treated by double-lumen catheters (leukemia) than to the device itself.

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