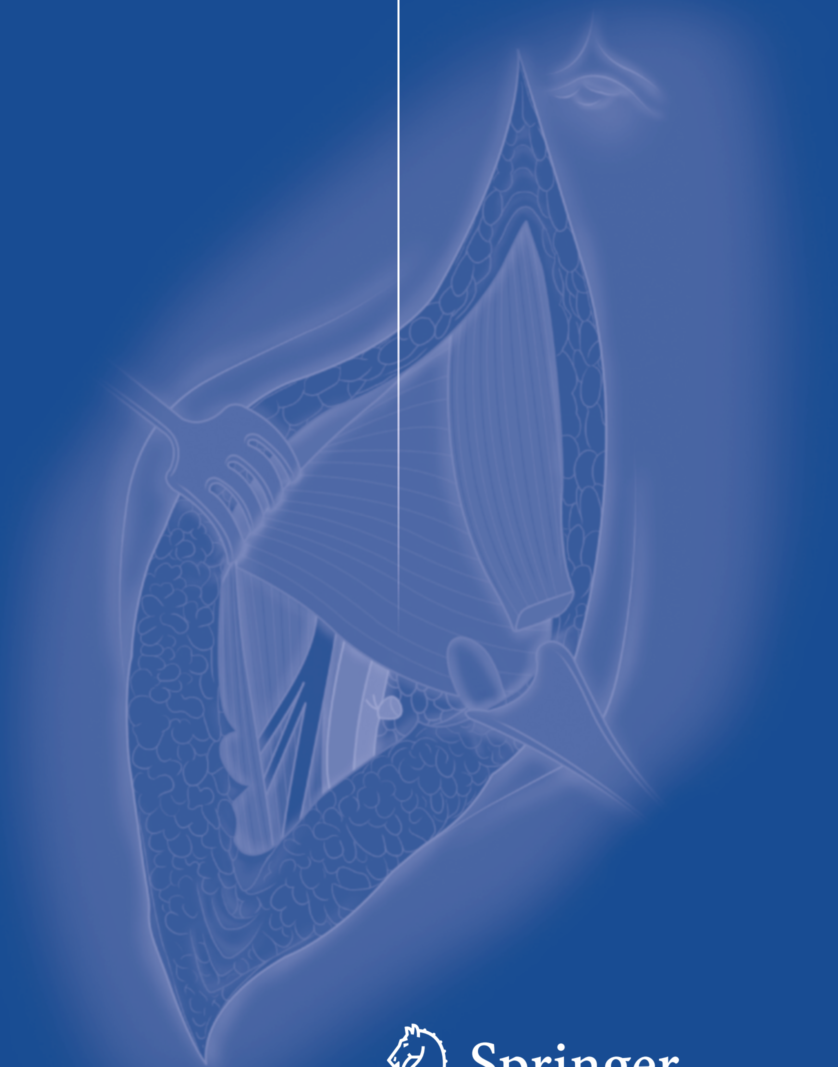
Constantine P. Karakousis

Atlas of Operative Procedures in Surgical Oncology



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To my wife Nitsa, our children, and our grandchildren

Preface

It has been 30 years since the publication of the *Atlas of Operations for Soft Tissue Tumors*. Additional information has been collected on the various procedures described in the first atlas, and several new chapters have been added. The discussion, as it befits the title of the book, is restricted in most chapters to the presentation of the surgical technique and the immediate effects on resection of tumor and postoperative complications.

Considering the extent of some of the operations illustrated in this book, a contemporary surgeon might regard them as too "radical," perhaps even an anachronism in the current era of progressively less extensive surgery for locoregional control of various tumors in combination with other modalities. Melanoma and breast are but just two examples where historically "aggressive" surgeries for the treatment of primary localized or regionally metastatic tumors have been replaced by less radical and less morbid approaches.

However, an operation with a large specimen and a long incision is not necessarily "radical" from a biologic viewpoint. The surgical margin of these large specimens, as in resection of retroperitoneal tumors or major amputations, is frequently in the range of a few millimeters between the infiltrating edge of the tumor and the surface of the specimen. Although the narrow surgical margin may concern a rather small area of the specimen surface, it is an important prognostic and etiological factor predictive of local recurrence. Such operations may be anatomically extensive but in reality are biologically conservative as the resections of retroperitoneal sarcomas clearly show with their high local recurrence rates. Many of the operations described in this book are "extensive" but hardly are "radical" in the sense that the desire for a wide surgical margin is always moderated by consideration of the effects of the extra margin in the function or cosmetic appearance of the involved area or in surgical complications. Radical resection carries the connotation of unnecessary removal of excessive uninvolved normal tissue without a concern for functional implications or without prior clear demonstration of therapeutic benefit to this more aggressive approach. Again, this is not what procedures demonstrated in this atlas entail. This principle is clearly manifest in the case of sarcomas of the extremities where the goal of limb preservation with adequate function is optimally combined with the pursuit of an adequate surgical margin. This requires knowledge of the functional anatomy of the extremity as there is considerable functional reserve available for the extremes of action whose removal does not affect routine activity.

In addition to the description of procedures according to anatomic or organ-based consideration, a thematic approach according to the surgical technique is also presented. This results in some repetition of information and redundancy of style, but it is believed that looking at the same thing from different points of view produces a deeper understanding and reveals the unity in surgical technique that permeates several groups of procedures. Ligation and division of the inferior epigastric vessels provides exposure in continuity of the iliac and femoral vessels and surrounding space. This is an essential surgical step in a radical groin dissection (with in-continuity dissection of the inguinal and deep nodes), the abdominoinguinal incision, and the internal hemipelvectomy. Preservation of these vessels also provides the main blood supply for rectus abdominis flap mobilized to provide coverage for a defect in the contralateral lower abdominal wall and groin. Mastering the technique of dissection in the bowel mesentery is a sine qua non in resecting tumors involving the bowel, in colon esophageal bypass, in peritoneolysis used during construction of a Roux-en-Y loop, and in ileal loop bladder.

The description of extensive procedures described in this volume provides not only evidence of their feasibility but also information on how they can be done with a minimum of complications. Such procedures are applied in patients with locally or regionally advanced tumor with a favorable outlook. Patients more likely to respond to the surgical treatment are those with a small number (1–3) of discrete tumor masses and a long duration of persistent disease without rapid progression. It is possible that cancer therapy may go through a stage where systemic treatment may be highly effective in destroying microscopic disease or small metastatic nodules but unable to eradicate large metastatic masses calling in this case for their surgical extirpation.

In the context of ever-increasing research discoveries in the medical treatment of cancers, some surgeons may view this atlas or portions thereof to be of historical interest. I actually believe that the surgeon's role will not diminish, at least in the foreseeable future, and perhaps may even become more important as part of a multidisciplinary team. A sound knowledge of the gamut of surgical techniques in oncology enables the surgeon to be at the forefront of treatment for these patients and to offer the best opportunities for palliation or cure. I sincerely hope that my experience, what I've learned—the successes and the failures—over the past 40 years can help young surgeons to continue improving the lives of cancer patients. I am confident that the future generations will continue to refine surgical techniques and better understand the applications of these techniques in the context of multimodality therapies.

I would like to express my gratitude to the late E. D. Holyoke, MD, and H. O. Douglass Jr., MD, for their unflagging support in the early steps of my career; and Nicholas Petrelli, MD, in providing an example of unparalleled devotion to the mentorship of Fellows and his emphasis on biologic research and participation in prospective randomized trials. From the younger attendings who served in the Soft-tissue Melanoma Service, R. N. Nambisan, MD, R. Lopez, MD, and M. Vezeridis, MD, distinguished themselves with their excellent clinical work.

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Contents

1 Surgical Technique in Cancer Surgery

The therapeutic intervention of a surgical oncologist in dealing with solid tumors is usually performed through procedures aimed at complete extirpation of the tumor and preservation of functional anatomy as much as it is feasible.

Integration of Modalities

It is imperative, however, that the surgical oncologist be familiar with the applications and relative effectiveness of the other modalities of treatment, such as chemotherapy, radiation, and possibly immunotherapy. In some cases, such as rhabdomyosarcoma and osteogenic or Ewing sarcoma of the bone, neoadjuvant therapy is indicated initially in order to first shrink the tumor, thereby making the operation easier and improving survival. This therapy also allows assessment of the degree of necrosis of the tumor and of the effectiveness of the chemotherapy used, aiding the decision about continuing with the same protocol postoperatively. Although the main function of the surgical oncologist is to evaluate the resectability of a solid tumor and the possible benefit to the patient of resection, it is also appropriate to consider, based on the known literature, whether it may be best to abstain from operating on a patient who would not be likely to benefit because of the nature or stage of the tumor. Another alternative may be to delay the operation until other treatment modalities have had a chance to produce an effect. Nevertheless, the chief therapeutic modality of the surgical oncologist is the performance of a surgical procedure.

Goals for the surgical technique should be safety, oncological soundness (providing for a satisfactory margin and yet preserving functionally important structures), and a minimum of complications. A preoperative determination is made as to whether the surgical procedure could be potentially curative, or whether it would only be palliative. This distinction is often simple and obvious. Operating on a patient with limited expectations of improving his or her condition increases the surgeon's responsibility to perform the procedure with a minimum of complications and a brief hospital stay. One should weigh the possible benefit of the contemplated operation for the patient versus the possible risk.

Tumor Biopsy

Before a surgical procedure is performed, one should have clear knowledge of the history of the tumor and the stage of the disease. To determine the histology of the tumor, a preoperative biopsy is needed. Fine needle aspiration (FNA) may provide information as to whether the cells are malignant, but it may be difficult for the pathologist to make a definitive diagnosis when the structure of the tissue is lacking. Diagnosis is made easier by knowing the organ from which the FNA was taken. Therefore, FNA is usually employed only in specific circumstances, such as a cold thyroid nodule or a mass in the head of the pancreas. More often, a core biopsy is preferred, in which a small stab-wound incision is made with a #11 blade under local anesthesia over the most protuberant part of the tumor (provided it is not close to major vessels or nerves), allowing the passage of a tru-cut needle several times into the tumor mass and the removal of tumor tissue for pathologic evaluation. Obviously, it is preferable to make several passes in different directions and to remove several cylindrical pieces of tissue in order to have sufficient diagnostic tissue for the pathologist to evaluate. The stab-wound incision may have to be away from the center of the tumor mass so that the needle avoids major blood vessels. For tumors located in areas relatively inaccessible to inspection and palpation, a guided percutaneous biopsy by an interventional radiologist may be preferable. In every biopsy, consideration should be given to the feasibility of including the biopsy tract in the definitive operation.

Another method of biopsy is the open biopsy, which usually can be done under local anesthesia with or without intravenous sedation. The incision for the open biopsy should be in conformity with the expected orientation of the

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definitive incision for tumor removal. In the extremities, the biopsy incision usually is a vertical, longitudinal incision along the long axis of the extremity; this type of incision provides versatility in its length for the exposure and resection of the tumor mass when the definitive incision is made.

It is preferable, however, for the biopsy incision to be at or close to the most protuberant part of the tumor, easily circumscribed with an elliptical incision in the definitive operation so that the flaps created for the two sides will share equally the degree of their development around the tumor, thus minimizing the incidence of flap necrosis.

The technique of open biopsy involves an incision that goes vertically through the subcutaneous fat to the fascia and then into the tumor mass. It is important to obtain an adequate portion of the tumor mass in order to have diagnostic tissue. Before the biopsy, the surgeon should study the available CT scans or MRIs that show the tumor, its extent, and its location and distance from the skin surface, in order to become aware of the necessary depth of the biopsy and to determine the length of the biopsy incision. For most sarcomas lying deep below the fascia, the fascia is opened and then one proceeds to cut down to the surface of the tumor and obtain a generous specimen. One should be careful not to take specimens only from very close to the surface of the tumor mass, as this may be simply reactive tissue from the periphery of the tumor mass, which is not diagnostic. Therefore, if there is any question as to the diagnostic adequacy of the removed tissue, a deeper biopsy should be attempted, provided that there is no evidence of any major vessels or nerves nearby. It is a good idea to submit the specimen to frozen section to make sure the pathologist has sufficient tissue for diagnosis. Ample tissue samples should be provided to the pathologist so that both frozen section and the appropriate permanent studies may be made. The advantage of having the pathologist do frozen section is that he or she may alert the surgeon about not having diagnostic tissue if the biopsy was not obtained from areas deep into the tumor, or conversely, that it contained only necrotic tissue in which the characteristic features of the tissue of origin are occasionally lost. The tissue obtained in the biopsy therefore should be taken from both peripheral and deeper areas of tumor.

Good hemostasis is important at the biopsy site, achieved by cauterizing the smaller bleeders, ligating or suture-ligating the larger vessels, and finally using figure-of-eight sutures to control vessels retracted within the wall of the biopsy cavity or the subcutaneous fat. Surgicel or other hemostatic material may be used, followed by closure in layers of the periphery of the tumor and the subcutaneous fat, starting from the deep layers of subcutaneous fat adjacent to the fascia and then the more superficial layers. Finally, a few interrupted, absorbable sutures can be placed in the deep dermis of each edge and tied to take away the tension from the closure of the skin itself, which can be done with a running, subcuticular suture of 4.0 or 3.0 monofilament absorbable suture or continuous over-and-over skin suture of monofilament nylon.

The reason for extra care with hemostasis and the closure in layers of the wound is to avoid extravasation and infiltration into the surrounding tissues of blood from the biopsy site, which may carry tumor cells with it and therefore cause local dissemination of the tumor. The other reason for the layer closure of the biopsy track is to prevent seepage of fluid carrying tumor cells to the skin surface of the incision. This risk is more likely to materialize when the definitive operation immediately follows the frozen section report. The use of a drain to drain the biopsy cavity is best avoided; if it must be used (as in the rare case of a deep axillary sentinel node biopsy, which requires extensive dissection), the drain track and its exit point should be placed adjacent to and in line with the biopsy incision, so that the drain and biopsy incision can be easily encompassed by the definitive incision, if the sentinel node turns out to be positive.

Resection of Extremity Sarcoma

Figure 1.1 shows the elliptical incision carried out around the biopsy incision of a soft tissue sarcoma of the anterior thigh, extending far enough proximally and distally to allow identification of the approximate location of the end of the tumor mass. Around the elliptical portion of the biopsy incision, one develops flaps 3–4 mm thick for a lateral distance of 1–2 in.—in other words, sufficient to get away from the biopsy plane—and then one proceeds with dissection on top of the fascia, which is incised after the palpable extent of the tumor is passed (Fig. 1.2), provided that the preoperative CT scan or MRI and the operative findings indicate that the tumor is deep to the fascia. When the tumor is partly subcutaneous, the elliptical incision around the biopsy should include a larger section of skin, so that the incision is made well away from the tumor. In this case, a skin graft or flap rotation may be required at the end of the procedure.

The portion of the incision proximal and distal to the elliptical incision is continued with a vertical dissection through the subcutaneous fat, using a scalpel and/or cautery all the way down to the fascia, given that one is already away from the area of the biopsy track and the tumor is known to be deep to the fascia. In other words, one does not have to make a flap thin all the way along the length of the flap; it is wiser to make the flap thin only in the area close to the tumor mass and/or the biopsy incision, and to make the flap thicker as one gets away from the area of the tumor. This policy considerably decreases the chance of flap necrosis and also diminishes the chances of excessive postoperative lymphorrhea and the incidence of lymphedema.

As soon as one feels that the flap development is slightly beyond the lateral extent of the tumor, the fascia is incised all the way around and longitudinally proximal and distal to the tumor to the corners of the incision, so that the anatomical structures (i.e., the underlying muscles beneath the fascia) are identified. Based on the preoperative x-ray studies and actual findings at the time of the operation, one should be able to tell which muscles need to be resected and begin to divide these muscles proximal and distal to the tumor. Figure 1.3 shows the division of the sartorius muscle, both proximally and distally. Dividing the involved muscles proximal and distal to the area of the tumor allows entry into a deeper plane, which, in combination with palpation of the exposed surface of the tumor mass, allows the determination of whether one needs to further develop the flap laterally. Absent this approach, the usual tendency is for unnecessarily wide flaps.

A principle of paramount importance is the preservation of the functional integrity of important anatomic structures in the vicinity of the tumor mass—or their deliberate, informed sacrifice, when necessary. Such structures are exposed well above and below the tumor mass so that their course can be traced to the greatest extent possible without risking contamination of the field with tumor cells through an incidental breach of the tumor surface. In the case presented, the structures at risk include the external iliac and common femoral vessels and the femoral nerve; these are dissected and surrounded by vessel loops for proximal control. To expose the external iliac vessels, the technique of radical groin dissection is utilized in getting into the deep retroperitoneal space by dividing the external oblique, internal oblique, and transversus abdominis muscles and the inguinal ligament lateral to the artery and then ligating and dividing the inferior epigastric vessels. This allows for exposure of external iliac vessels in continuity with the femoral vessels, as well as exposure of the obturator nerve in the pelvis coursing on the fascia of the obturator internus en route to the obturator foramen. Given the location of the tumor, the superficial femoral vessels may also be exposed (Fig. 1.3).

After division of the sartorius muscle, which overlies these vessels, and after incision of a layer of fascia, which spans between the adductor magnus and the vastus medialis distally, one enters Hunter's canal, and the superficial femoral vessels are dissected and encircled with vessel loops. At this level, they are just above the point where they go through the adductor hiatus in order to get in the popliteal fossa and become popliteal vessels. In some patients with tumors coming close to this region, one may have to actually divide the tendinous attachment of the adductor magnus at the adductor tubercle (i.e., the insertion of the musculotendinous portion of the adductor magnus, supplied by the sciatic nerve while the bulk of its muscular portion is supplied by the obturator nerve). The only other muscle in the adductor group that has a dual nerve supply and often receives it exclusively from the femoral nerve is the pectineus muscle; a branch goes behind the femoral artery and vein to supply this muscle. In the example cited, it is shown how important it is that one has control of the vessels proximal and distal to the area of involvement by the tumor. If there is provisional evidence that the vessels are skirting the periphery of the tumor and are not surrounded by it, one opens the vascular sheath at an area away from the tumor and starts very cautiously dissecting the vessels surrounded by loops off their sheath. The appearance of edema in the sheath indicates involvement by tumor at a close distance and the attempt to save the vessels should be abandoned in favor of resection of the vessels and immediate repair with grafts. First, one would have to dissect in a medial and lateral plane around the mass at a safe distance from the tumor in order to free circumferentially what is to become the specimen (Fig. 1.4).

Proximally and distally, one may have to divide the superficial layer of adductors such as pectineus and adductor longus, gracilis, and possibly adductor brevis and adductor magnus (Fig. 1.5). One may have to come around the surface of the tumor, and after the specimen to be has been freed all the way around with the tumor mass in the center encasing the femoral vessels, one may then heparinize the patient, apply vascular clamps proximally and distally, resect the specimen, and replace the resected vessels with vascular grafts (Fig. 1.6).

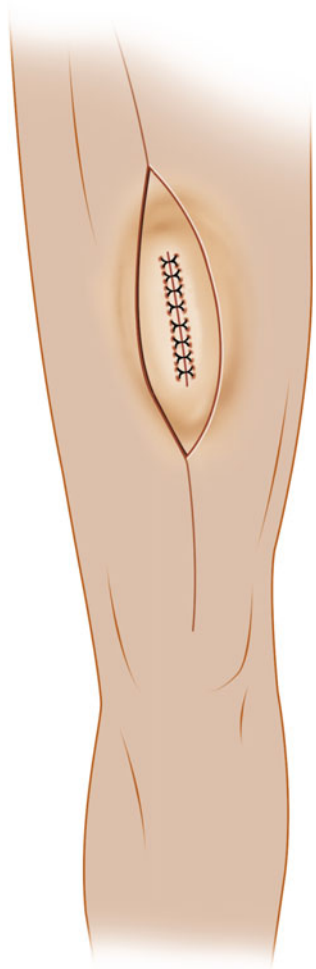


Fig. 1.1 Elliptical incision around the previous biopsy incision. It is extended proximally and distally for better exposure and control over the desired margin of resection

Fig. 1.2 Flaps have been developed medially and laterally around the biopsy incision

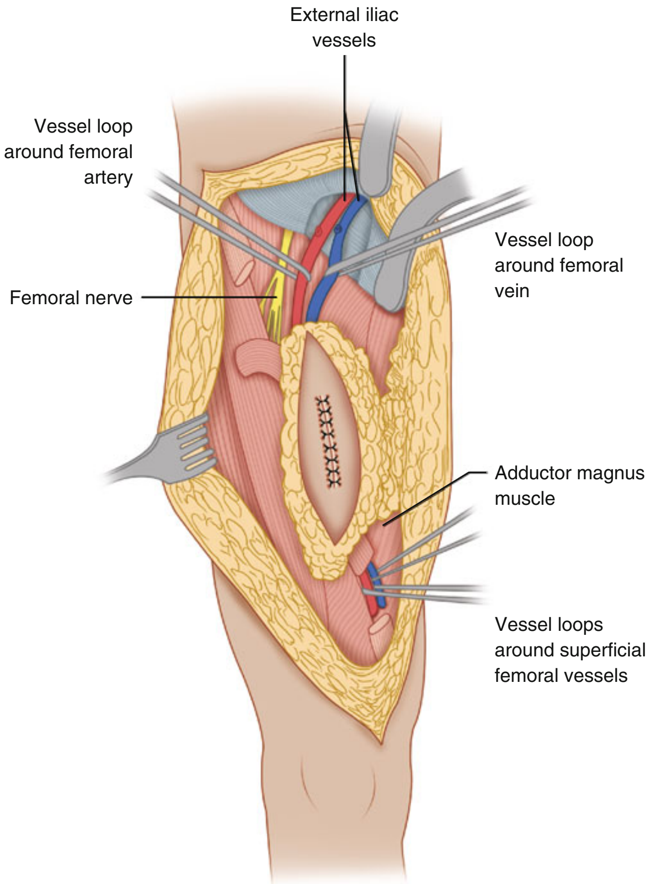


Fig. 1.3 The retroperitoneal space has been exposed for proximal vessel control, and the sartorius has been divided proximally and distally. The superficial femoral vessels have been dissected in Hunter's canal below the tumor

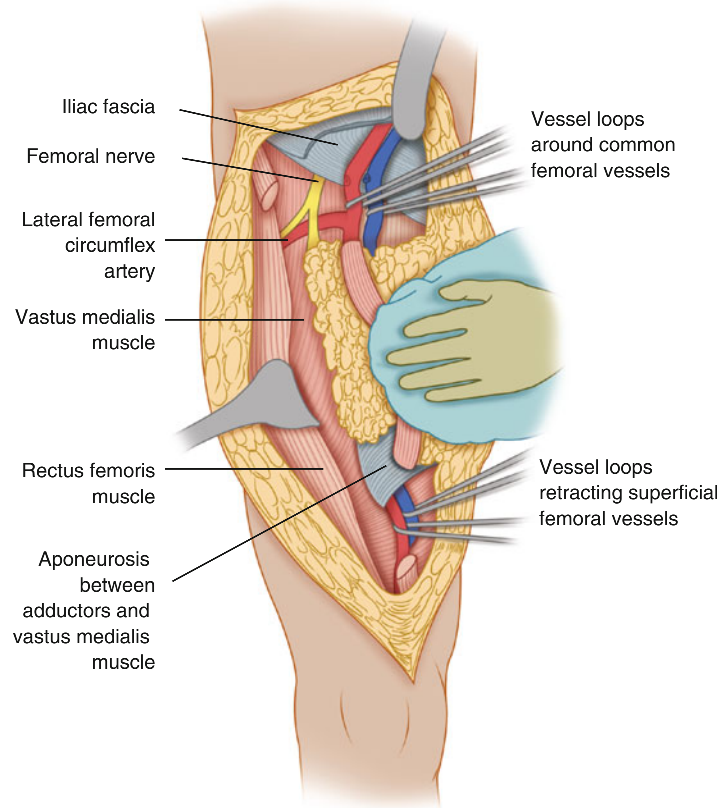


Fig. 1.4 The vastus medialis has been exposed laterally. The vastoadductor membrane is distally exposed. The lateral circumflex branches of the profunda vessels and the beginning of the superficial femoral vessels are dissected

Fig. 1.5 The involved superficial layer of adductor muscles is divided off its origin from the pubic bone. This layer is also divided below the area of the tumor

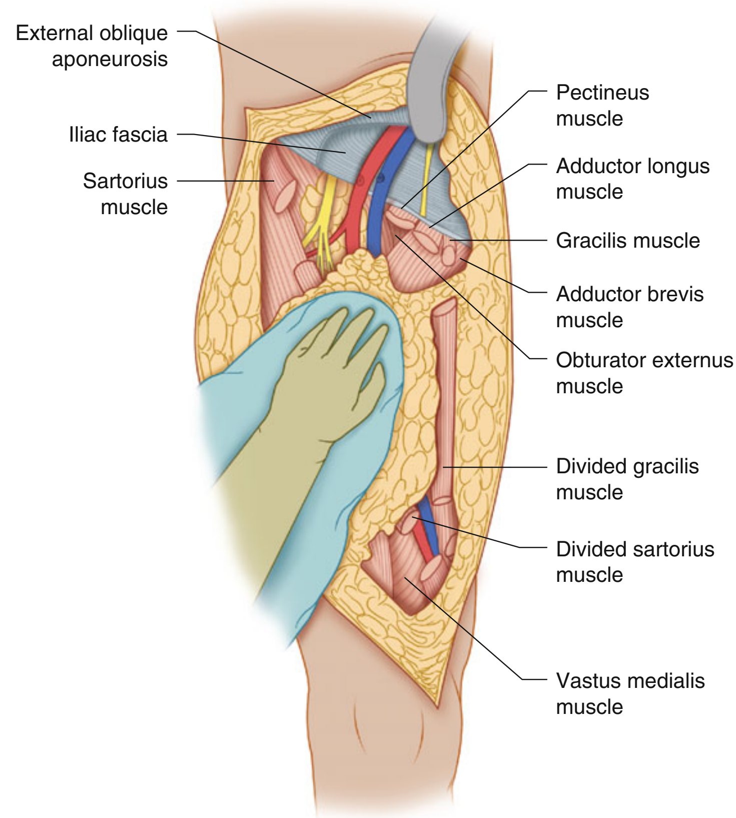
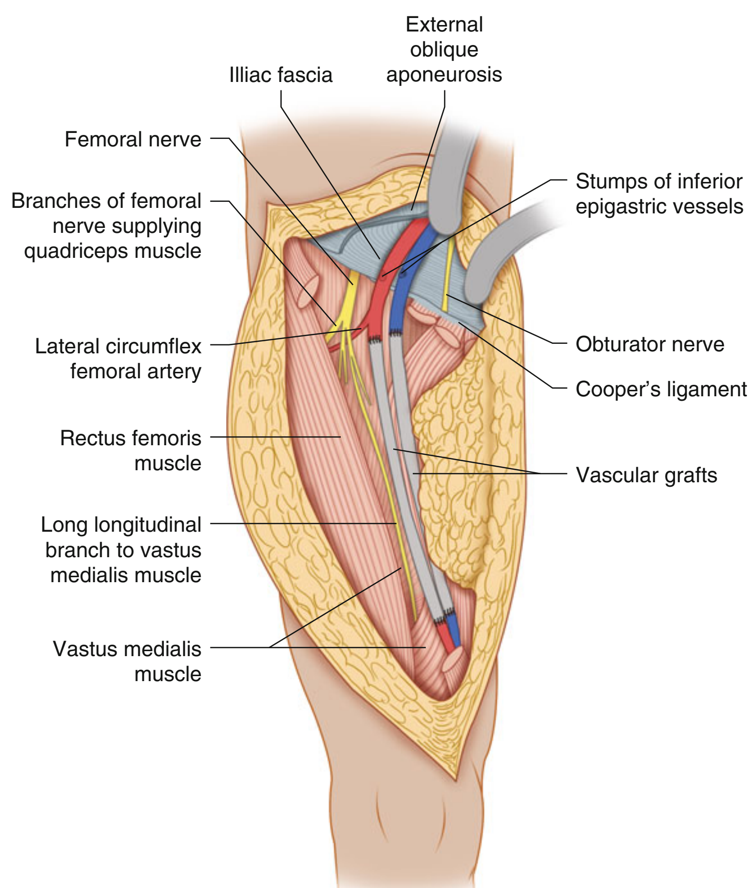


Fig. 1.6 The femoral vessels have been replaced with vascular grafts after removal of the tumor



Strategy of Operative Procedure

The strategy of operative procedure includes the positioning of the patient on the operating table so that during the performance of the operation, one works with gravity assisting and not opposing the surgical maneuvers. The positioning also should allow optimal incisions to be used in order to expose and resect the tumor mass.

The most important principle perhaps is what may be called the pursuit of "the path of least resistance." As one starts dissecting around the tumor mass, there is a tendency to deal first with important structures so as to demonstrate whether the tumor mass is resectable. For example, in the case of a retroperitoneal sarcoma approaching the midline, a seemingly logical approach might be to try to find out first if the tumor mass can be separated from the aorta on the left side or the inferior vena cava on the right side. If this can be done, then dissection becomes easier and the resectability of the tumor mass is established early in the operation. This undertaking may turn out to be dangerous, however, and sometimes the surgeon has to abandon the procedure of resection because of perceived difficulty or inability to control a bleeding branch from either of these two major vessels in the depths of the initial dissection while the bulk of the tumor is still adherent to the vessel. Therefore, it is always preferable to dissect along what we may call "the path of least resistance." Coming around the tumor mass, one can and should revise the plan of approach as considerations of safety and ease of exposure dictate. By doing the easy path of dissection around the tumor mass first, the tumor is mobilized sufficiently so that the other areas that previously appeared inaccessible or difficult to control become easier to manage and it is safer to continue with the dissection. For example, a retroperitoneal sarcoma of the upper quadrants is dissected first all the way around from its posterolateral attachments, mobilizing en bloc, if infiltrated, the parietal peritoneum and the involved layers of the anterolateral abdominal wall muscles, including if necessary the quadratus lumborum posteriorly and the diaphragm superiorly. The overlying colon (hepatic or splenic flexure) is dissected off the tumor mass when feasible, or it is divided above and below its area of involvement, including also the involved mesentery, which is separated at the base of the mesentery from the uninvolved part of the mesentery. The tumor is separated from the ipsilateral kidney if it is possible to do so without compromising the radicality of the procedure. Otherwise, one removes the kidney en bloc with the tumor mass by ligating the ureter distally, the renal artery posteriorly, and the renal vein anteriorly. Then it becomes easier, as the tumor has been mobilized, to pull it out of its location and create a space of a few millimeters between the tumor mass and the aorta, where one can proceed safely to dissect and divide the branches coming to the tumor mass from the aorta or the superior mesenteric artery. Therefore, the principle of the path of least resistance is an important one, which is justified on the basis of safety of dissection and at the same time increases the rate of resectability of the tumor.

Complete hemostasis is of utmost importance during the procedure because it allows for a dry field so that one can easily see the various structures; the prevention of excessive blood loss also often avoids the need for blood transfusion, with all its attendant risks. After removing the tumor mass, one carries out whatever repairs are required, such as re-anastomosis of bowel where a portion has been resected, or repair of a defect in the fascia or diaphragm. Usually it is wise in these extensive dissections to place one or two Jackson-Pratt (JP) drains in the operative field to monitor postoperative bleeding or other discharge, which would alert the surgeon as to the presence and severity of any problem. The drains also allow the removal of fluid oozing from the tissues, permitting them to come together and heal. At the time of closure of the incision, one should examine the flaps; if one of them is thin at the center of the incision, a narrow strip (e.g., 0.5–1.0 cm) is removed, provided that doing so will not unduly increase any tension at the closure line. The approximation of the skin is done with absorbable 3-0 sutures, taking bites through the deep dermis on either side with the knot on the inside to approximate the skin edges while excluding the deeper fat, so that the fat does not protrude through. Then an absorbable monofilament continuous 3-0 or 4-0 suture is applied for the superficial dermis to more accurately approximate the skin edges, or skin staples are used. Subcuticular closure is perhaps the least traumatic to the blood supply of the skin edges, followed by application of skin staples; the use of wide mattress or simple sutures, particularly when tied tight, may further compromise the tenuous circulation of the skin edges of the flaps, perhaps resulting in necrosis. (If necrosis involving a narrow strip of the skin edges becomes evident 2 or 3 days later, débridement is not usually required.) Gauze dressings are applied over the skin closure, and the JP drains are fastened with sutures at the point of their exit. Adhesive tape across (i.e., perpendicular to) the incision over the dressing alleviates any tension on the suture line, which may tend to obliterate small capillary vessels.

Use of Surgical Instruments

This section is mainly aimed at expediting the technical development of surgical residents, rather than at the mature surgeon. During residency, the surgical resident learns to use various surgical instruments in a way that is half conscious and learns to select the appropriate instrument for each step of common surgical procedures. Lack of full awareness of the proper application of the various instruments and their expected effectiveness will be apparent in areas where the surgeon has not operated often enough, or in the performance of an operation that must be designed according to the location and size of the tumor mass, as in most cases of soft tissue sarcomas.

In going through compact tissue (tissue that is not transparent), the scalpel is the safest instrument for dissection (Fig. 1.7). With the appropriate amount of tension on the tissues on either side of the scalpel, the use of a sharp blade all the time, and the application of light pressure with the blade along the whole length of the incision, one can come within 1–2 mm of the surface of a major vessel or nerve without traumatizing it.

Similar dissection, although not as accurate, can be performed with the use of a cautery used lightly at all times (in other words, without pressure and controlling the depth of penetration by the cautery so that only a millimeter of tissue or less is being divided). Often residents are seen to use the cautery in strokes, but this is an unsafe technique. When the cautery is used to cut for 3 or 4 cm without control and acute awareness of what is being divided, this seemingly short space is long enough for something important to be divided. Therefore, the cautery should be used with constant application and a light touch on the tissues to be divided, with the tissues under tension. In this way, the division of tissues is controlled and the surgeon maintains an acute awareness of what is being divided at all times, as a potentially important structure may show up underneath. With vascular tissues, one applies the cautery continuously but moves more slowly so that the smaller branches are effectively cauterized. When a medium-size subcutaneous vein is encountered, which in the judgment of the surgeon can be cauterized, the tip of the cautery is applied at the middle of the vein and is left to cut through by cauterization; the two cauterized ends may have to be cauterized briefly again so that a definitive cauterization has taken place. The technique of cauterizing the vein by moving the tip of the cautery back and forth rapidly along the surface of the vein is less effective because it often causes bleeding before the two divided ends are cauterized. A better technique is to grasp each side of a vessel successively with a vascular forceps and apply the cautery on the forceps as needed.

Metzenbaum scissors are generally not safe for cutting through compact tissue, as one cannot see through these tissues; in order for the scissors to cut, one has to open their blades a few millimeters, which may be too much in the vicinity of a major nerve or vessel (Fig. 1.8). For instance, dissection in the popliteal space following the performance of the skin incision and then scalpel dissection of the subcutaneous fat down to and through the fascia reveals the common peroneal nerve in its course medial to the biceps femoris tendon. Use of scissors in this area would be inappropriate and could lead to damage of the common peroneal nerve.

Metzenbaum scissors can be used conveniently in lysing adhesions in the peritoneal cavity between loops of bowel, when the adhesions are soft and transparent. However, when a loop of bowel is densely adherent to the abdominal wall with scar tissue, the dissection should be done with the scalpel. Of course, in each case, including an extra thickness of the anterior abdominal wall is always preferable to cutting into the bowel. The Metzenbaum scissors also can be used to tease adipose tissue from the axillary vein, as in the apex of the axilla. Small venous tributaries or arterial branches can be visualized and clipped with hemoclips. Entering into the sheath of a major vessel or nerve and lengthwise incision of the sheath can also be carried out effectively with Metzenbaum scissors.

Graduating surgical residents are assumed to know how to tie well, and this is true in most cases. At times, however, they tie with the point being ligated under tension. This tension is not a problem if what is ligated is a sturdy anatomical structure, but when it is a fragile vein in the depths of the retroperitoneum, tension may disrupt this vein or of one of its tributaries and start serious bleeding. One should tie whatever structure is being ligated without moving the point of ligation at all during the process. In other words, one makes a throw and with one hand holds one string steady while the directing finger is brought to the lowest point the local anatomy permits. As the tie is tightened, the pull from the two opposed fingers is so balanced that the point being ligated is not moving at all. One should always use the dependent finger (i.e., the finger that will go the deepest into the wound) to allow a snug tie. Once this tie is applied tightly, the pulling is equally relaxed for the two hands so the point being ligated does not move; another throw of the tie is prepared and applied in the same direction (granny knot), which allows further tightening of the first knot. The third knot is made square (in the opposite direction) to avoid loosening of the knot later. For silk sutures, three knots in a tie are adequate to secure it, but monofilament sutures are slippery and require six to seven throws to avoid possible loosening of the tie later. A surgeon's knot (two sequential throws before the first knot is tightened) is helpful in avoiding loosening of the first tie while the next throw is prepared. When the second tie is a granny knot, tightening of a loosened first throw is often possible but is not guaranteed. The first technique—maintaining an equipotent tension between the two strands and tightening with the dependent finger—should be used at all times because it provides both a safe and secure tie. The second technique (a surgeon's knot) helps avoid loosening of the tie. A third technique, more easily applicable at the skin level when one uses simple interrupted sutures, also helps avoid loosening of the first throw while the second throw is prepared. In this technique, the first throw is completed and tightened to the desired degree; then the surgeon, holding the two strands under equal tension, rotates the two strands 90°. The strands now may be let loose, and while the first throw remains tight, the second throw is made and tightened.