Appendix A: Abdominoinguinal Incision for the Resection of Pelvic Tumors

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OVERVIEW

The abdominoinguinal incision allows a vast improvement in the exposure and resectability of tumors in the lower abdomen with fixation to the pelvic side wall. A midline abdominal incision is connected to a longitudinal inguinal incision across the inguinal ligament. The pelvic side wall is directly exposed by detachment of the rectus muscle from its origin on the pubic crest and by division of the inguinal canal along the spermatic cord. This exposure allows safe resections along the iliac vessels without tumor spillage. The abdominoinguinal incision should be part of the armamentarium of every surgeon willing to accept responsibility for pelvic and pelvic side wall malignancy.
INTRODUCTION

Pelvic tumors with lateral fixation present difficulties in their resection, primarily due to inadequate exposure through conventional abdominal incisions. The difficulty arises especially with tumors in the lower parts of the pelvis where the anterior abdominal wall converges with the retroperitoneal structures (e.g. iliopsoas muscle, iliac vessels). In this area the inguinal ligament spanning between the anterior superior iliac spine and the pubic tubercle provides an obstacle to unhindered exposure.

A midline, paramedian, or oblique abdominal incision often does not provide adequate exposure for these tumors. These incisions render sufficient exposure for the dissection and control of the common iliac vessels proximally, below the bifurcation of the aorta, but do not afford exposure of the terminal portion of the external iliac vessels because the presence of tumor hinders further visibility. Often these tumors are considered unresectable or are managed with hemipelvectomy.

Queral and Elias reported a two-stage procedure for removal of a sarcoma localized in the right iliac fossa with involvement of the iliac vessels. In the first operation a femorofemoral bypass was performed from the left side to the right, and the common femoral artery was proximally ligated and divided. In the second operation, through an abdominal incision the mass was resected with en-bloc resection of a segment of the right iliac vessels, which were ligated and divided proximally. This example provides a solution to the distal control of the iliac vessels, but it requires two operations, and exposure at the time of resection of the tumor mass through an abdominal incision remains suboptimal.

What is needed for the resection of these tumors is an incision that would simultaneously provide an incontinuity in exposure of the abdominal cavity and one or both groins so that both iliac and femoral vessels would be exposed in one field. For this incision an abdominal component would be needed and an incontinuity inguinal component, i.e. an abdominoinguinal incision. The inguinal ligament would have to be divided to allow uninterrupted exposure and control of the iliofemoral vessels.

A lower midline incision provides good exposure of the intrapelvic structures. An inguinal incision exposes the femoral vessels. A transverse incision connecting the two, by dividing the origin of the rectus abdominis from the pubic crest and the insertion of the inguinal ligament to the pubic tubercle, provides the necessary link that allows a single incontinuity field and optimizes exposure. Although in the preceding discussion we arrived at the abdominoinguinal incision deductively, in reality I stumbled upon variations of it in the first few cases in the process of designing an incision for a specific tumor. Later I realized that this could be developed into a formal incision for exposure in the lower quadrants of the abdomen. The abdominoinguinal incision may function much in the same way that the thoracoabdominal incision is used for the upper quadrants of the abdomen.

INDICATIONS

The indications for the abdominoinguinal incision are: (1) abdominal or pelvic tumors extending over the iliac vessels, (2) tumors in the iliac fossa (Figure A1), (3) primary tumors, possibly involving the iliac vessels or large iliac lymph node metastases, (4) tumors with fixation to the wall of the true pelvis or large obturator nodes, (5) tumors involving the pubic bone with or without extension to the pelvis or adductor group of muscles, and (6) tumors of the groin when they involve the vessels of the lower abdominal wall or extend in the retroperitoneal area.
**Figure A1** Position and incision. With the patient in the supine position, a lower midline abdominal incision is outlined from just above the umbilicus to the pubic symphysis. The peritoneal cavity is entered, and exploration is carried out to assess the extent of disease. Preliminary dissection between the tumor mass and midline pelvic structures may be carried out. Involvement of the latter does not necessarily mean unresectability, of course, since they can often be removed en-bloc with the tumor. When there is a question of involvement of the iliac vessels distally, the common iliac vessels are dissected free and vessel loops are passed around them.

**Figure A2** Incision through inguinal canal. If the decision is made to proceed with the resection the lower end of the incision is extended transversely to the midinguinal point and then vertically, over the course of the femoral vessels, for a few centimeters. The vertical portion of the incision is deepened to expose the common femoral vessels.
Figure A3 Dissection of inguinal nodes. When the operation is performed for large iliac and/or obturator nodes, or if there is clinical or potential microscopic involvement of the inguinal nodes, the vertical portion of the incision is made to extend to the apex of the femoral triangle, flaps are raised as in a groin dissection, and the nodes are mobilized off the femoral vessels, but their proximal continuity with the deep nodes is preserved.

Figure A4 Division of rectus abdominis muscle. The transverse portion of the incision is deepened to the surface of the anterior rectus sheath, which is divided, and the rectus abdominis muscle is transected a few millimeters from its origin on the pubic crest. This incision is through its tendinous portion.

Figure A5 (right) Incising the floor of the inguinal canal. The inguinal canal floor is divided in the same direction up to and including the medial border of the internal inguinal ring. In so doing, the spermatic cord is displaced medially. Alternatively, after division of the medial crus the inguinal floor may be incised from inside and the cord exposed from within the abdomen and extracted from the inguinal canal for medial displacement. Deep to the internal inguinal ring the structures of the cord deviate, the vas deferens coursing medially, and the internal spermatic vessels toward a lateral and cephalad direction. Depending on the location of the tumor, the internal spermatic vessels may have to be divided at this level; this maneuver usually leaves a viable ipsilateral testis. Division of the cord at the level of the external inguinal ring does not require ipsilateral orchietomy but will be accompanied by testicular atrophy.
Exposure of the pelvic side wall. The inguinal ligament is then divided at the pubic tubercle and dissection carried on its undersurface until the inferior deep epigastric vein and artery are encountered, ligated, and divided. The lateral third of the inguinal ligament is then detached off the iliac fascia. This allows the completion of the abdominoinguinal incision and provides wide exposure of abdomen and pelvis.

Further dissection depends on the location of the tumor. If the tumor is simply a pelvic mass extending over and obscuring the iliac vessels, the improved exposure now makes easy the dissection of the mass off the vessels and safe ligation of any tumor feeding branches. For large nodes the dissection is carried on the surface of the iliac vessels which are skeletonized. For a tumor located in the iliac fossa, the femoral nerve is located lateral to the femoral artery, immediately posterior to the continuation of the iliac fascia. A vessel loop is passed around it. Further cautious dissection along this nerve determines its relation to the tumor and whether it can be saved. If the tumor involves the vessels, proximal and distal control are secured and the dissection completed around the tumor mass, with any involved organs removed en-bloc. When the specimen is held only by the attachment to the vessels, the patient is heparinized, vascular clamps are placed proximally and distally, the specimen is removed, and vascular reconstruction is performed.

When the iliofemoral vessels are to be resected, the profunda femoris branches may have to be divided at a distance from the tumor in order to allow the mobilization of the specimen.

For tumors attached to the wall of the lesser pelvis or the obturator fossa, the improved exposure usually allows their resection. For tumors involving the pubic bone, following the completion of the abdominoinguinal incision, the adductor muscles are divided off the pubic bone at an appropriate distance from the tumor and the anterior and posterior pubic rami are exposed: the former just medial to the acetabulum and the latter medial to the ischial tuberosity. With the help of a right-angle clamp a Gigli saw is passed around the pubic symphysis, which is divided along with the anterior and posterior pubic rami. The obturator nerve and vessels have to be divided proximally because they course through the obturator foramen. The defect may be replaced with a polypropylene mesh.

For a large tumor located in the groin, covering or involving the entire length of the common femoral vessels and possibly the lower abdominal wall, the abdominoinguinal incision provides incontinuity exposure of the iliofemoral vessels. In making the incision, flaps may have to be raised around the mass. If the lower abdominal wall and inguinal ligament are involved, following transection of the anterior rectus sheath and rectus abdominis muscle off the pubic crest, the incision is continued through the external oblique aponeurosis and internal oblique and transversus abdominis muscles at a sufficient distance from the tumor. The inguinal ligament is divided off the anterior superior iliac spine and the pubic tubercle, and thus the lower abdominal wall muscles and inguinal ligament are removed en-bloc with the tumor. The inferior epigastric vessels are divided at the point they proceed behind the rectus muscle.

In Figure A6 the lateral third of the inguinal ligament has not been detached off the iliac fascia, a step providing further exposure.
Figure A7  Deep closure. The closure of the abdominoguinal incision is uncomplicated. Lateral to the vessels the inguinal ligament is approximated to the iliac fascia and medial to the vessels to Cooper's ligament. The rectus sheath and muscle are approximated to their remnants on the pubic crest. A suction drain is placed in the inguinal portion of the incision. A subcutaneous layer of absorbable material may be used. The skin and the midline portion of the incision are closed in a routine fashion. The sartorius muscle may be detached from its origin on the anterior iliac spine and rotated to provide a nice muscle coverage of the exposed femoral triangle vessels and nerves.

Figure A8  Deep closure requiring mesh. When a defect in the fascia has been created, it may be covered with a plastic mesh, which also replaces the inguinal ligament. The mesh should not be in direct contact with the vessels. This can usually be done by dividing the sartorius muscle distally at the apex of the femoral triangle and mobilizing the distal end so that the vessels are covered, taking care to avoid devascularization of this muscle.

When the defect in the groin also involves the skin, we have used the contralateral rectus abdominis muscle which is divided proximally and rotated with the posterior sheath attached to it, its blood supply deriving from the inferior epigastric vessels. The muscle is sutured to the defect and skingrafted immediately.
Figure A9  Skin closure.
DISCUSSION

The abdominoinguinal incision has been used in over 50 patients with a variety of tumors, usually soft-tissue sarcomas. One of these patients had adenocarcinoma of the sigmoid fixed to the iliac fascia. This tumor was thought to be unresectable at another hospital, but was successfully removed through this incision. The majority of the patients had been operated on once or twice elsewhere, and were found to be unresectable or thought to need a hemipelvectomy.

All these tumors, presenting with fixation to the soft tissues of the wall of the pelvis, were resected with the abdominoinguinal incision, with the exception of two patients. They required hemipelvectomy due to extensive nerve involvement. One patient required an abdominobinguinal incision, i.e. bilateral extension of the abdominal inguinal midline incision to the groins. Tumors involving the innominate bone, with the exception of the medial portion of the pubic bone, are resected best with the use of the techniques of internal hemipelvectomy, and, if necessary, hemipelvectomy.

The abdominoinguinal incision heals well without complications. In the event of a previous transverse incision in the lower quadrant, which may have interrupted the connection to the superior epigastric vessels and the distal portion of intercostal and lumbar branches, a small area of necrosis at the junction of the midline and transverse portions of the incision may occur, since this incision divides the inferior epigastric vessels. In two patients with this condition a small area of ischemic necrosis developed, which, following debridement, healed by secondary intention.

There was one death 2 weeks postoperatively, which resulted from erosion and hemorrhage of a previously heavily radiated external iliac artery that was in contact with a mesh used to replace a fascial defect. It is important therefore to cover the vessels with the sartorius or rectus femoris muscle (by dividing its origin from the anterior inferior iliac spine and displacing it medially) when a mesh is placed adjacent to the vessels or when there is concern about pap necrosis. No instances of postoperative incisional hernia have been noted.

The abdominoinguinal incision renders resectable the majority of pelvic tumors with lateral fixation to the soft tissues of the pelvis and, through improvement in exposure, allows for a safe, deliberate dissection. It is the counterpart of the thoracoabdominal incision for the upper quadrants of the abdomen. The results from the use of this incision obviously depend on the histologic type and stage of the tumor and the expected margin of resection one can thus obtain. It should be used when appropriate and in the context of the biology of the tumor, the expected margin, and the possible use of adjuvant treatments.

In many situations in which the tumor is not laterally fixed, but when it is large and distal and pressing against the obturator foramen(s) or the obturator areas, one can obtain sufficient exposure with a unilateral or bilateral use of the transverse portion of the full incision. In other words, the lower end of the midline incision is extended transversely from the pubic symphysis to the pubic tubercle, and the ipsilateral rectus sheath and muscle are divided off the pubic crest.

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Appendix B: Canine Osteosarcoma

Charles Kuntz
INTRODUCTION AND USE OF CANINE OSTEOSARCOMA AS A MODEL FOR HUMAN OSTEOSARCOMA (Figure B1A)

Osteosarcoma occurs commonly in the dog. It has been estimated that there are 8000 new cases per year in the United States alone. This high frequency makes it an excellent model for human osteosarcoma and it has frequently been used for this purpose. Similarities between canine and human osteosarcoma include metaphyseal occurrence, typical metastasis to lungs and other bones, and response to doxorubicin and platinum-based protocols. Canine osteosarcoma appears to be more malignant than human osteosarcoma in that, without treatment, death usually occurs within 4–5 months. This offers another advantage when considering it as a model for the human disease. Research protocols very rapidly demonstrate effectiveness of therapeutic attempts. Researchers can frequently demonstrate effectiveness within 2 years of beginning a therapeutic trial. Because financial incentives can be offered clients, identifying candidates has not been a problem. Necropsy compliance is usually very high. Alternatives for treatment can be attempted relatively easily if a therapeutic protocol can be logically justified based on experimental data in other species.

DEMOGRAPHICS AND PRESENTING CLINICAL SIGNS

Osteosarcoma is the most common malignant bone tumor in dogs. There is a biphasic prevalence age distribution curve for canine osteosarcoma, with peaks at 2 and 7 years. A male predominance has been shown in some studies, whereas others have shown no sex predilection. It most commonly occurs in metaphyseal bone. Commonly affected sites, in order of frequency, include the distal radius, proximal humerus, distal ulna, distal femur, proximal tibia, distal tibia, and diaphyseal ulna. Other affected sites include ribs, skull, vertebral bodies, scapula, metatarsal and metacarpal bones, lung, spleen, and mammary tissue. Primary soft-tissue occurrences are rare.

Most affected dogs present with lameness resulting from appendicular osteosarcoma. Usually, a painful swelling is identified over the affected region. Dogs with mandibular and orbital sites may present with dysphagia. Dogs with cranial or vertebral tumors will present with neurologic deficits. Dogs with pelvic masses may present with dyschezia. Some dogs will present with a history of acute exacerbation of clinical signs following trauma. This may mislead the clinician into suspecting a fracture or anterior cruciate ligament rupture. Radiographs of the affected region will usually confirm the diagnosis.

DIAGNOSTIC WORKUP (REGIONAL DISEASE)

Regional radiographs, in addition to predisposing factors such as large breed and advanced age, usually confirm the diagnosis of osteosarcoma and show the tumor’s extent in commonly affected anatomic sites. Typical lesions are a mixed pattern of cortical lysis and periosteal proliferation. Although a previous study suggested that radiographs underestimate the local extent of the tumor, a recent study showed that high-detail radiographs overestimate the local extent of the tumor. Nuclear scintigraphy also overestimates the local extent of the tumor, and to a greater degree than radiographs. Computed tomography is helpful in delineating skull and thoracic wall tumors. It can also be used for appendicular tumors to determine the extent of resection required to attain complete surgical margins. Determination of tumor volume and tumor length is of prognostic value in dogs with osteosarcoma in that large tumor size is associated with a poorer prognosis.

Biopsy may be performed, although it is usually not necessary to confirm the diagnosis. If performed, a Jamshidi biopsy needle should be used, and two samples taken, including the center and the periphery of the lesion. If this protocol is followed, a diagnostic accuracy of 90% can be achieved. Reactive bone may be identified, and this suggests that more aggressive biopsies are indicated.

DIAGNOSTIC WORKUP (METASTATIC DISEASE)

Approximately 10% of dogs will show gross evidence of distant metastasis at the time of diagnosis. Sixty percent will metastasize to lung and 40% will metastasize to other musculoskeletal sites. Thoracic radiographs, including right and left lateral and anterior/posterior, views are performed. Thoracic radiographs are limited in that they delineate only lesions which are greater than 6 mm in diameter. Computed tomography can also be used to screen for thoracic metastasis, but is not widely used. When available, nuclear scintigraphy is also performed, and will show occult bony metastasis in 10% of cases.

TREATMENT OPTIONS

Cure is achieved in less than 15% of dogs diagnosed with osteosarcoma. Treatment is directed at palliating or eliminating locoregional disease and preventing distant metastasis. Preventing of distant metastasis without eliminating the primary tumor offers no survival advantage. Analgesic therapy alone, using aspirin or piroxicam, has a median survival time of 90 days. It is most effective in dogs with relatively small tumors, in the absence of pathologic fractures. Most of these dogs
are euthanized because of pain and/or pathologic fracture of the affected bone. Palliative radiation therapy has also been attempted with coarsely fractionated radiation therapy (24–28 Gy in three or four dose increments). This does appear to reduce bone pain, but does not significantly improve survival. Patients with small tumors in the absence of pathologic fractures appear to have the best survival. The median survival time is 120 days. Most dogs are euthanized because of intractable pain and/or pathologic fracture.

Amputation offers significant improvement in survival over medical management in dogs with appendicular osteosarcoma. Amputation is well tolerated in almost all dogs in which it is performed, including those who are obese and those with neurological deficits. The author has performed approximately 300 amputations in dogs and has had only one, who had degenerative myelopathy, who had difficulty walking after surgery. This dog eventually was fully ambulatory 40 days after surgery. Most other dogs are fully ambulatory within 3 postoperative days. Regardless of the location of appendicular tumor, all amputations are performed using scapulectomy or coxofemoral disarticulation for front-limb and hindlimb lesions, respectively. Amputation by scapulectomy is associated with better function and cosmesis than amputation by scapulohumeral disarticulation or humeral–antebrachial disarticulation, and is technically less challenging. Coxofemoral disarticulation is also associated with better cosmesis and is also technically less challenging than amputation by midfemoral osteotomy or femorotibial disarticulation. Preservation of the extremity in dogs is not beneficial because they do not tolerate prostheses, and they function well without them. In two surveys, function and client satisfaction were very good to excellent in 98% of pets. Dogs having amputation alone for the treatment of appendicular osteosarcoma have a median survival time of 5 months. These dogs usually die of metastasis.

Rib tumors are treated with thoracal wall resection and, when treated with adjuvant chemotherapy, patients have a median survival time of 1 year. Mandibular tumors are treated with hemimandibulectomy; maxillary tumors are treated with partial maxillectomy and/or orbitectomy. Spinal tumors are treated with decompression and rarely have long-term survival. Pelvic tumors are usually treated with amputation and hemipelvectomy, and these patients usually have excellent function.

Limb salvage surgery can be performed in some dogs with appendicular osteosarcoma (Figures B1A,B and B2A,B). Dogs with tumors of the scapula, diaphyseal and distal radius and ulna, metacarpus, metatarsus, diaphyseal humerus, femur and tibia and distal tibia treated with limb-salvage surgery are associated with good to excellent function. Allograft implantation is not required for tumors of the scapula, metatarsus, metacarpus or ulna (distal or diaphyseal). Most other diaphyseal tumors and tumors of the distal radius treated with limb-salvage surgery require allograft implantation and are associated with good function. Dogs tolerate removal of up to 90% of the scapula with good function. Dogs with tumors of the proximal humerus treated by scapulohumeral arthrodesis following allograft implantation have poor functional outcome. The median survival time in dogs treated with limb-salvage surgery for appendicular osteosarcoma and chemotherapy is equivalent to those treated with amputation and chemotherapy, and is approximately 1 year. There is a 25% local recurrence rate following limb-salvage surgery, and local recurrence does not appear to negatively affect survival. If local recurrence occurs, a second limb-salvage surgery can be attempted, or amputation can be performed.

Allograft implantation usually requires maintenance of a bone bank. Bones can either be harvested steriley and directly implanted, or harvested cleanly and secondarily sterilized prior to implantation. Transmission of infectious agents from the donor to the recipient has not been a significant problem. Infectious agents are usually introduced during the preparation of the graft, resulting in local infection. Methods for sterilization include steam sterilization, ethylene oxide sterilization and, more recently, low-temperature hydrogen peroxide plasma gas sterilization. Low-temperature hydrogen peroxide plasma gas sterilization does not cause deterioration of biomechanical properties of allograft bone. The author has performed limb-salvage surgery in two dogs using autograft bone which was autoclaved during the surgical procedure, and reimplanted in the tumor bed, with good results. This offers the advantage of no requirement for a bone bank. The allograft is filled with sterile methylmethacrylate prior to implantation. This has been shown to improve the biomechanical properties of the implant without negatively affecting bone incorporation. Limb-salvage surgery, where an allograft is implanted, is associated with a 50% infection rate. Interestingly, dogs who have a culture-positive infection are associated with a significant improvement in survival (median survival time of 600 days, compared with 290 days in dogs not having postoperative infection).

**ADJUVANT CHEMOTHERAPY**

Chemotherapy significantly improves survival in dogs with appendicular osteosarcoma when locoregional disease is eliminated using surgery. Protocols which have shown significant improvement in survival include doxorubicin, cisplatin, carboplatin, and to
The median survival times for the former three is approximately 1 year, and for the latter, 7 months. There has been no advantage to combination chemotherapy demonstrated. Dogs usually are euthanized because of the development of distant metastasis. Chemotherapy is well tolerated in most dogs. Eighty percent of dogs complete the course of chemotherapy without any significant side-effects. Eighteen percent have mild side-effects including bone marrow suppression, and gastrointestinal complications. Two percent have side-effects significant enough to require hospitalization.

Implantable cisplatin chemotherapy has been used to treat dogs with osteosarcoma, with encouraging results. Cisplatin is invested in a polylactic acid polymer which allows gradual release of the cisplatin over approximately 3 weeks. Peak levels, commonly associated with side-effects, are 10–30% of those attained with equivalent intravenous doses, but the area under the serum concentration curve (AUC) is seven to 22 times that attained with intravenous doses. Side-effects are rare but include nephrotoxicity (rare) and infection (common). Infection of the chemotherapy site appears to offer protection against metastasis, similar to that seen with infected limb-salvage allografts. The chemotherapy takes the form of a sponge which is implanted in the amputation stump or limb-salvage tumor bed, or of a gel which is a liquid at room temperature and becomes a solid at body temperature. Implantation of sponges in the limb-salvage tumor bed also reduces the incidence of local recurrence.

**PROGNOSIS**

Tumor size, calculated as the percentage of bone length affected by tumor, or as an actual tumor volume, has been found to be prognostic in dogs with osteosarcoma. Larger tumors have been found to have a poorer prognosis. Anatomic site is also prognostic in that appendicular osteosarcoma (radius, ulna, humerus, femur and tibia) is associated with a median survival
time of 1 year when treated with aggressive surgery and chemotherapy. Tumors of the mandible and scapula have a slightly better prognosis with a median survival time of about 15–18 months. Tumors of spine and skull have a poorer prognosis because of anatomic limitations on aggressive surgical resection. Extraskeletal osteosarcoma has a dismal prognosis with a median survival time of 73 days.3,20–25 The bone isoenzyme of alkaline phosphatase has been shown to be prognostic in that high levels before surgery are associated with a poorer prognosis. After the initial decrease following surgery, an increase helps predict impending gross metastasis. Quantification of metalloproteinases two and nine have shown some predictive value, and further studies are under way. Recent studies have suggested that tumor grade, characterized by degree of necrosis, mitotic rate and cell differentiation, is highly prognostic; further study is necessary.18
CONCLUSION

Osteosarcoma is a common tumor in the dog. It serves as an excellent model for human osteosarcoma studies. It is malignant, and affected patients usually die of their tumors. Aggressive surgery and chemotherapy have been shown to significantly improve survival.

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