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Abdominal Wall Tumors and Their Reconstruction

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Introduction

Abdominal Wall Tumor Resection and Reconstruction

The abdominal wall protects and contains the abdominal viscera, and serves to position and stabilize the thorax and upper body in space during movement. Components of the abdominal wall may be completely replaced if needed. The internal protective function of the abdominal wall can be replaced with synthetic meshes, fascial flaps, or grafts. External skin can usually be replaced with advancement of adjacent skin or regional thigh flaps. The loss of muscle function of the abdominal wall is generally well tolerated and can be adjusted to with time.

Repair of abdominal wall defects is limited only by the creativity of the reconstructive surgeon. One approach to abdominal wall reconstruction after tumor resection is to separate the two independent but related problems—how to reconstruct the internal abdominal wall, and how to replace the overlying skin.

This chapter begins with a discussion of tumor types that can involve the abdominal wall. The anatomy and physiology of the abdominal wall as it relates to abdominal wall reconstruction is then discussed. In the final section of the chapter, an algorithm for abdominal wall reconstruction is proposed, based on the need to replace the internal abdominal wall, the abdominal skin, or both following tumor removal.

Neoplasms of the Abdominal Wall

A wide variety of neoplasms can involve the abdominal wall. The abdominal wall is defined as the soft tissues and bony structures that contain the abdominal viscera, excluding the retroperitoneal structures and the musculature of the back. Various skin tumors including basal cell carcinoma, squamous cell carcinoma, and melanoma can occur in the abdominal skin. These tumors tend to be easily managed, superficial, and without involvement of deeper structures. Within the abdominal wall, sarcomas such as rhabdomyosarcoma, malignant fibrous histiocytoma (pleomorphic sarcoma), leiomyosarcoma, malignant nerve tumors, and liposarcomas can occur *(1)*. Masses found on physical examination are confirmed radiographically, usually with a contrast-enhanced computed tomography (CT) scan or magnetic resonance imaging (MRI). Needle biopsy often yields the diagnosis of the tumor type, though the lack of a definitive tissue diagnosis may not obviate the need for surgical excision. Intra-abdominal tumors such as colon and cervical cancer can invade the abdominal wall by direct extension, sometimes requiring a full-thickness abdominal wall resection. A more recently recognized cause of abdominal wall neoplasms is direct tumor implantation at the time of laparoscopy *(2)*, needle aspirations of the viscera *(3)*, and percutaneous gastrostomy tube placement for patients with head and neck cancer *(4)*. Finally, urachal carcinoma represents the neoplastic transformation of embryologic remnants within the abdominal wall *(5)*.

One tumor that is relatively common in the abdominal wall compared to other sites in the body is the desmoid tumor, or deep fibromatosis *(6)*. This is in contradistinction to the superficial fibromatoses, including Dupuytren's disease of the hand and Peyronie's disease of the penis, which share some properties such as local recurrence, but with a markedly decreased intensity of disease. The desmoid tumors are considered to be low-grade malignancies, roughly one-half occur in the abdominal wall, but they can occur elsewhere in the body, including the shoulder girdle and the chest wall. The tumors generally do not metastasize, but frequently re-occur locally and cause significant morbidity from their mass effect or their infiltration into adjacent normal tissues and viscera. During tumor resection, desmoid tumors grossly have poorly defined margins without a pseudocapsule. Histologically, the mass is comprised predominately of bland-appearing fibroblasts. Secondary pathologic criteria of mitotic figures or nuclear pleomorphism are rare. The tumors are associated with increased estrogen levels of pregnancy and the tumors in women occur during or following pregnancy. Abdominal wall desmoids are also a part of the clinical diagnosis of Gardner's intestinal polyposis syndrome. Finally, trauma, including the tissue injury of surgery, is associated with the development of desmoid tumors. Patients undergoing laparotomy for intestinal polyposis have also been known to develop desmoid tumors at their incision sites.

Treatment of desmoid tumors is initially surgical, and based on the local growth characteristics and symptoms caused by the mass. Resection to microscopic tumor-free margins is the goal *(7)*, with gross surgical margins of several centimeters recommended. Patients with negative microscopic margins have tumor recurrence rates of 33% at 10 years. Functional outcome of the abdominal wall should be preserved whenever possible, because negative histologic margins have not been shown to be a guarantee for local tumor control. Some studies have even shown no association between negative margins and recurrence rates *(8)*. Tumor recurrences typically occur within 2 years of the initial desmoid excision.

Non-surgical treatments including radiation therapy, chemotherapy, and estrogen deprivation have occasionally been effective at controlling the increase in tumor size. Radiation is occasionally used to help control

tumors that would be difficult to resect or for recurrent tumor. The association of desmoids with pregnancy has led to trials of anti-estrogens for patients with these neoplasms. Non-steroidal anti-inflammatory drugs (NSAIDs) have also occasionally been effective in reducing the size of tumors. Patients who have failed surgery, radiation, anti-estrogens, and NSAIDS often have been treated with chemotherapy such as doxorubicin. One issue that must be factored into the long-term studies of desmoid tumors is the occasional occurrence of "growth arrest," whereby the tumor spontaneously stops enlarging and becomes more quiescent.

Anatomy and Physiology of the Abdominal Wall

The abdomen can be viewed as a pressurized closed cylinder. The top of the cylinder represents the diaphragm, the bottom of the cylinder is the bony pelvis, and the sidewalls consist of the retroperitoneum posteriorly and the abdominal wall muscles laterally and anteriorly. Neoplastic processes that involve the posterior aspect of the abdominal wall are better characterized as retroperitoneal tumors and will not be discussed in this chapter.

The layers of the abdominal wall are consistent and important in the planning of tumor excisions. Adjacent to the intestines and abdominal viscera is the peritoneum, a thin filmy piece of tissue that lines the inner aspect of the abdominal wall. The next layers to be found laterally and anterolaterally on the abdominal wall are the transversalis fascia and the transversus abdominis muscle. The transversus abdominis muscle is typically tightly attached to the next most superficial muscle of the lateral and anterolateral abdominal wall, the internal oblique muscle. The fibers of the internal oblique are classically described as running in the same orientation as if one's fingers were placed fully extended into one's back pants pockets. The internal oblique muscle is thinnest as it follows the curves of the rib cage as the fibers approach the anterior rectus fascia, whereas the muscle is thickest near the iliac crest. The motor and sensory nerves to the abdominal wall run in the plane between the transversus abdominis and internal oblique muscles.

A natural dissection plane exists between the internal oblique and the external oblique muscles. The external oblique muscle and fascia, in contradistinction to the internal oblique, has fibers running in an orientation as if one's extended fingers are in one's front pants pockets. Like the internal oblique muscle, the external oblique acts to rotate the upper trunk around a fixed pelvis. The muscle has its blood flow entering segmentally along the imaginary mid-axillary line. Multiple small perforating blood vessels enter the muscle via the rib segmental vessels, and much larger blood vessels enter near the superolateral aspect of the iliac crest. A lack of connections between the external oblique and internal oblique muscles therefore allows for a surgical plane of dissection along the abdominal wall, from the semilunar line anteriorly (the insertion of the lateral abdominal wall musculature into the rectus abdominis fascia) to the mid-axillary line posteriorly. The external oblique muscle and fascia can act as an excellent surgical plane for excisions of tumors of the subcutaneous tissues. The three lateral abdominal muscles insert onto the lateral aspect of the paired rectus abdominis muscles. These two muscles, joined in the midline at the linea alba, are trunk flexors, with origins on the symphisis pubis and insertions along the rib cage and xyphoid. The segmental innervation by the intercostal nerves runs between the transversus abdominis and the internal oblique muscles. The blood supply to the rectus abdominis muscle is from the superior epigastric artery, the deep inferior epigastric artery, and laterally from smaller segmental vessels, which run with the motor nerves to the muscle.

The abdominal wall is important for movement and the prevention of hernias, but it is expendable. Logically, the less of the abdominal wall is lost, the less is the functional deficit. Loss of one entire rectus muscle is common for breast reconstruction, and is generally well tolerated. At 6 months, compensation for the loss of the muscle occurs, and women have similar exercise tolerances after surgery as they did before surgery *(9)*. Many women undergo removal of BOTH rectus muscles for bilateral breast reconstruction. These women often have functional alterations in their torsos, frequently not being able to perform a leg lift or sit up from a lying position without the use of their arms. However, the remaining abdominal muscles tend to compensate over time, rendering the muscle loss more tolerable. Tumor excisions of the flank have more variable outcomes. Loss of the full-thickness abdominal wall laterally by necessity also removes the nerves that run to more anterior musculature including the rectus muscle on that side. Generalized abdominal wall bulges can occur after flank tumor excisions. These bulges are almost impossible to restore to a mirror contour image of the unaffected side.

Reconstruction of the Abdominal Wall

Good communication between the surgical oncologist and the reconstructive surgeon is the first step in the reconstructive plan for the patient. Anticipation as to the size and depth of the surgical defect is critical for patient expectations as to the magnitude of the procedure, prepping and draping of the patient to include possible flap harvest sites, and the existence in the operating room of bioprosthetic and prosthetic meshes of adequate size and quantity. The reconstructive surgeon must devise strategies for solving two independent but related questions: How to close the internal abdominal wall, and how to close the skin.

The Planning of How to Close the Internal Abdominal Wall

Closure of the abdominal wall is critical to prevent evisceration, and needs to be performed whenever the abdominal cavity is entered. After tumor removal, the abdominal wall defects usually cannot be primarily sutured together. Rather, a replacement of the abdominal wall is needed, and the easiest manner to repair the abdominal wall is with a bioprosthetic or a synthetic mesh. Mesh selection is based on an analysis of the quality of the tissues both above and below the mesh. A strategy for abdominal wall reconstruction and choice of mesh will be presented in the next sections based on the quality of the local tissues.

Adequate soft tissues above and below the mesh

Prosthetic meshes are commonly used for abdominal wall reconstruction. They are durable, flexible, and available in numerous sizes. Polypropylene mesh is porous, allows for the egress of fluid collections and the ingrowth of fibrous tissue for improved incorporation into the tissues. Several studies have advocated intraperitoneal placement of polypropylene mesh, stating that bowel adhesions are minimized if the mesh is placed under tension to avoid wrinkles. There are generalized concerns by many surgeons, however, that adhesions between the synthetic mesh and the bowel can lead to bowel injury, fistulae, and bowel obstructions. For this reason, polypropylene mesh is placed intra-abdominally in clean surgical cases (those without bacterial contamination), when the viscera are not swollen (allowing the mesh to be placed tight and flat without wrinkles), and when there is a adequate vascularized tissue (such as greater omentum) to interpose between the mesh and the viscera to prevent direct contact of the mesh to bowel.

Adequate soft tissues above the mesh, clean wound, but inadequate soft tissues below

Patients who have undergone tumor excision with extensive bowel manipulation and with little or no available greater omentum to interpose between the mesh and the bowel have a greater risk of mesh-related bowel adhesions. For these patients, a less adhesogenic mesh is commonly chosen. Expanded polytetrafloroethylene mesh (ePTFE) can be placed against the bowel, and this smooth non-porous mesh does not tend to cause significant bowel adhesions. The lack of adhesions to the mesh is both its most favorable characteristic and its major drawback. The lack of incorporation to surrounding tissues (fascia, muscle, and subcutaneous fat) contributes to an extremely unlikely ability to salvage the mesh reconstruction without surgical removal in the event of an infection, and prevents its use in contaminated cases. Bioprosthetic mesh materials (derived from decellularized human or animal tissues) are also an option in these situations because they generally result in low adhesion formation and do incorporate into the surrounding tissues.

Inadequate soft tissues above and adequate soft tissues below the mesh

Thin atrophic skin above a tumor typically is resected, so patients with poor-quality tissues overlying the tumor can be reconstructed with synthetic meshes if local skin or tissue flaps from remote areas can be used to cover the mesh reconstruction site. Treatment of the skin in abdominal wall reconstruction surgery will be discussed in a subsequent section.

Inadequate soft tissues above and below the mesh, or a contaminated surgical field
Various biologic tissue or bioprosthetic mesh options exist for placement into a surgical field contaminated by a pre-existing wound or bowel surgery. Bioprosthetic mesh material including human acellular dermis are ideal for reconstruction of the fascia in a contaminated surgical site, because of their ability to become quickly vascularized, resist infection, and prevent adhesions to bowel *(10,11)*. Acellular dermis may result in a bulge at the surgical site in these contaminated cases, but allows for fascial closure in challenging wounds. Other bioprosthetic meshes include porcine submucosa and decellularized xenogenic dermis. Another option in these cases is the use of autologous fascia lata harvested from the patient's own lateral leg. A section of fascia lata 22 × 12 cm^2 in size can be harvested from a linear thigh incision. The local wound complications from taking the fascia lata from an ambulatory patient are common, including hematoma and seroma, but not overly problematic or functionally debilitating. The fascia lata is most easily used as a tissue graft, detaching the tissue, and transferring it to the abdominal wall for repair of the defect. For infra-umbilical defects, the fascia lata can remain attached to its blood supply (as a pedicled flap) attached the tensor fascia lata and/or rectus femoris muscle *(12)*. The use of vascularized tissue may improve the ability of the wound site to resist infection, but greatly increases the difficulty in transferring the tissue and insetting it into the abdominal wound defect (Figures 12.1 and 12.2).

The Planning of How to Close the Skin

Tumor resection often involves the creation of sizeable skin defects. The blood flow reaches the abdominal skin through numerous sites. The most important source is the peri-umbilical perforating blood vessel system that originates from the deep inferior epigastric artery and runs through the rectus abdominous muscle. Numerous other segmental vessels reach the abdominal skin from the superior epigastric, intercoastal, femoral, and superficial inferior epigastric arteries. The natural direction of blood to flow in the skin of the abdominal wall is along the nerve dermatomes—roughly parallel to a line drawn from the tip of the scapula to the umbilicus.

There is no substitute for close communication between the oncologic and reconstructive teams for the planning of the dimensions and orientation of these defects. When possible, incisions should be aligned along the dermatomes for two reasons. First, this allows for the undermining of skin above and below the defect, without compromising the skin blood flow (which enters the skin as described previously). Second, oblique skin incisions along dermatome lines cut the fewest peripheral skin nerves, and potentially limit nerve pain morbidity after the procedure. Finally, the patient can be placed with the center of the defect at the "break" of the operating room table. Skin closure for oblique and transverse incisions can be aided by flexing the patient on the operating room table, thereby taking tension off of the skin closure. The abdominal skin

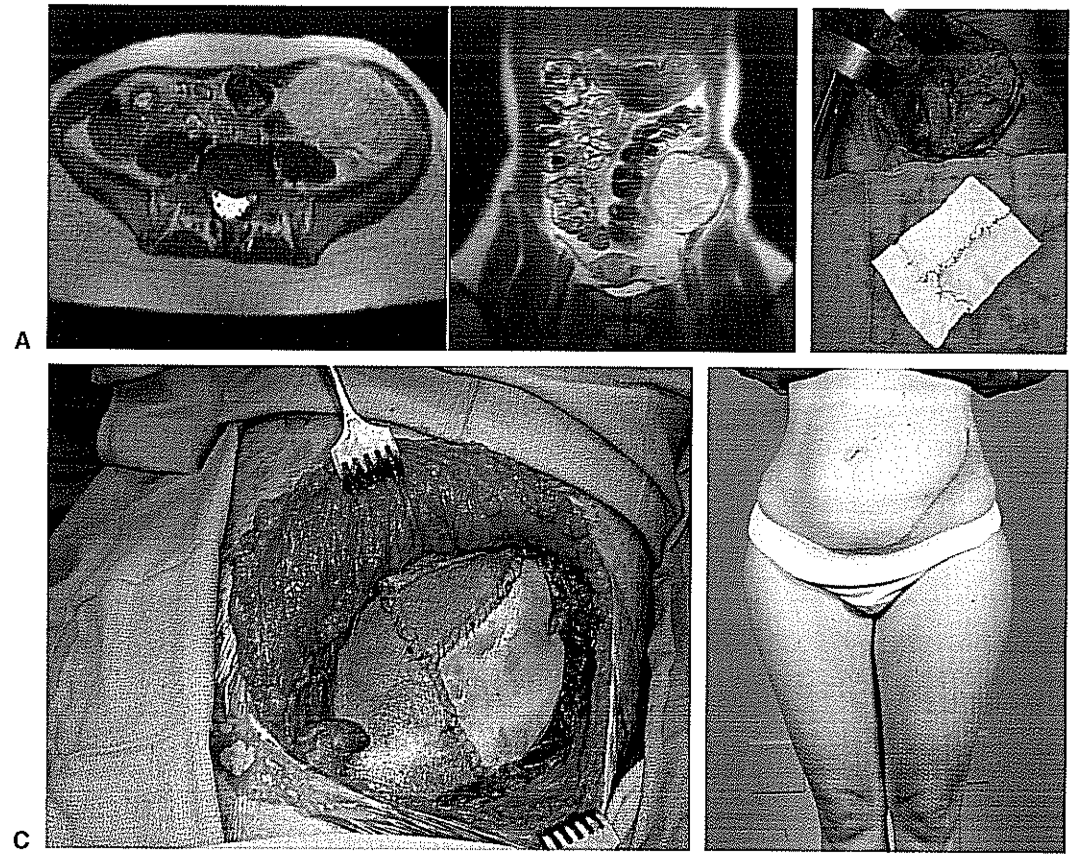

Figure 12.1. A 34-year-old woman with a desmoid tumor of left lower quadrant. There was adequate skin coverage, but without adequate greater omentum to interpose between synthetic prosthetic mesh and the bowel. (Case courtesy of Dr. Jeff Wayne). **(A)** CT scan shows the large tumor is attached to the left iliac crest. **(B)** Intraoperative photograph of the defect, with three sheets of acellular human dermis joined together with polypropylene sutures, which were used to reconstruct the muscle/fascia defect. **(C)** Intraoperative photograph of muscle/fascia reconstruction using human acellular dermis. **(D)** Appearance of reconstructed abdominal wall at 2-years follow-up.

stretches slowly in the post-operative period so the patient can eventually stand straight.

An example of good communication between the services is exemplified by the use of panniculectomy incisions for infra-umbilical abdominal wall tumors. Vertical incisions are problematic in obese patients, and performance of a panniculectomy for access to the abdominal wall has been shown to be efficacious in morbidly obese gynecology patients. The resulting incision is straightforward in its closure *(13)*.

All patients undergo the "pinch test" to assess the mobility of abdominal wall skin pre-operatively by the reconstructive team. This assessment of skin mobility is critical in planning if a direct skin closure over the defect is possible. Patient-specific factors such as obesity, previous incisions, previous weight loss, open wounds, stomas, and prior radiation therapy all are important factors in assessing pre-operatively if a patient can be closed with local tissue confidently. Cases exist when local tissues

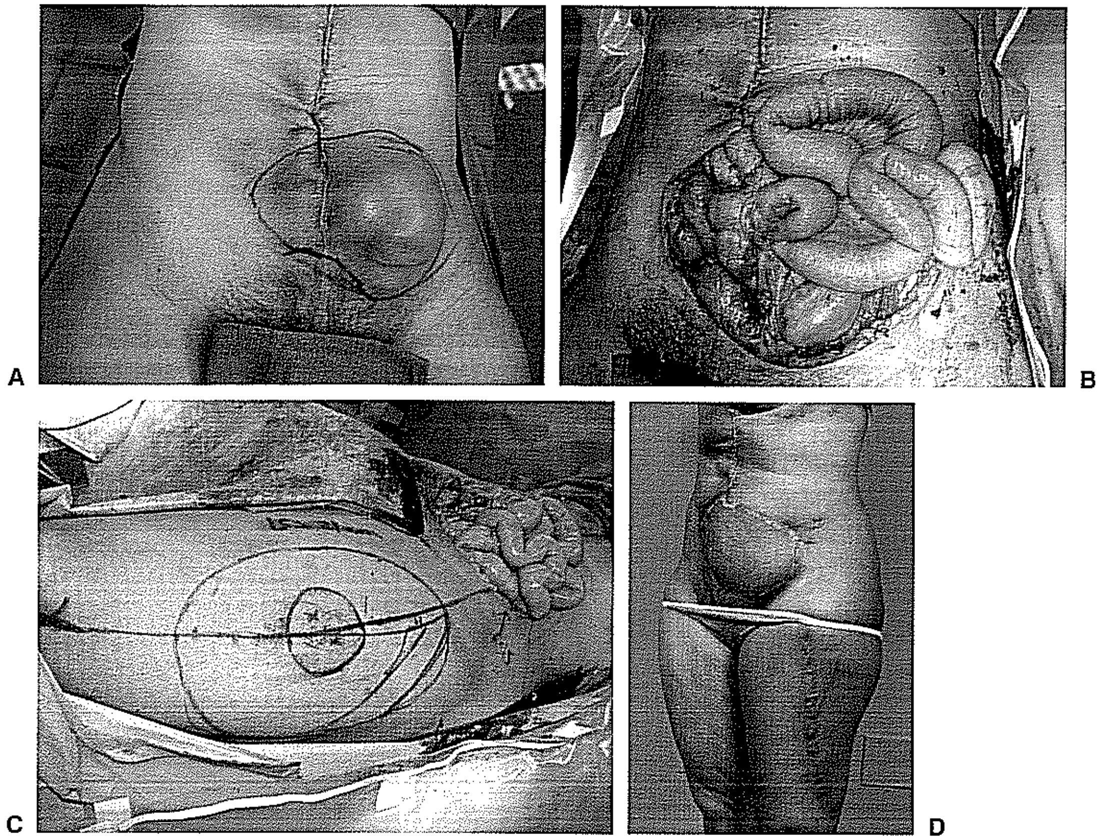

Figure 12.2. A 28-year-old woman with a multiply recurrent abdominal wall desmoid tumor with previous radiation therapy. (Case courtesy of Dr. Kevin Bethke). **(A)** Pre-operative view of tumor outlined in pen. There was poor-quality soft-tissue cover and inadequate greater omentum for interposition between mesh and the bowel. **(B)** Appearance of defect after tumor excision. **(C)** Design of an anterolateral thigh free flap for reconstruction of soft tissues. The lateral thigh fascia included in the flap was used to replace the muscle/fascia defect and the skin of the flap replaced the overlying skin defect. The left femoral vessels with vein graft interposition were used as recipient vessels for vascular anastomoses. **(D)** Oblique view of flap donor site on leg after abdominal wall reconstruction.

do not suffice for closure. If the abdominal wall is intact and only a skin defect exists, then a simple skin graft can be used for closure. However, if the abdominal cavity has been entered and mesh is used for reconstruction and would be exposed, then a soft-tissue flap with vascularized tissue must be transferred to cover the defect. Several groups have devised algorithms for flap reconstruction of soft-tissue defects of the abdomen, based on the location of the defect *(14,15)*. The most useful soft-tissue flaps come from the abdominal wall itself or the thigh. The tensor fascia lata flap can be used to provide soft-tissue cover to the lower abdomen; however, the distal tip of the flap may be unreliable owing to inconsistent vascular perfusion to the distal skin. A "delay" of the skin flap—outlining and elevating the flap without actually transferring it—is helpful to improve the flap's reliability several days to weeks prior to

transfer to the abdomen. For the upper abdomen, the latissimus myocutaneous flap can be transferred from the back to the upper, lateral abdominal wall to provide soft-tissue coverage. Larger defects may require a free tissue transfer, in which the soft tissue is transferred and revascularized by reattaching the flap blood vessels recipient vessels near the defect. These free tissue transfers to the abdominal wall often require vein grafts from the leg to extend the reach of the transferred tissue because adequate recipient vessels may not be available close to the defect (Figure 12.2).

Midline Defects

A special situation exists for midline tumors. For these tumors, especially in the supra-umbilical location, skin mobilization for a superior-inferior closure is difficult. For these patients, a closure of BOTH the abdominal wall and the skin can be aided by the creation of bilateral rectus abdominis myocutaneous flaps (Figure 12.3) This technique referred to as "component

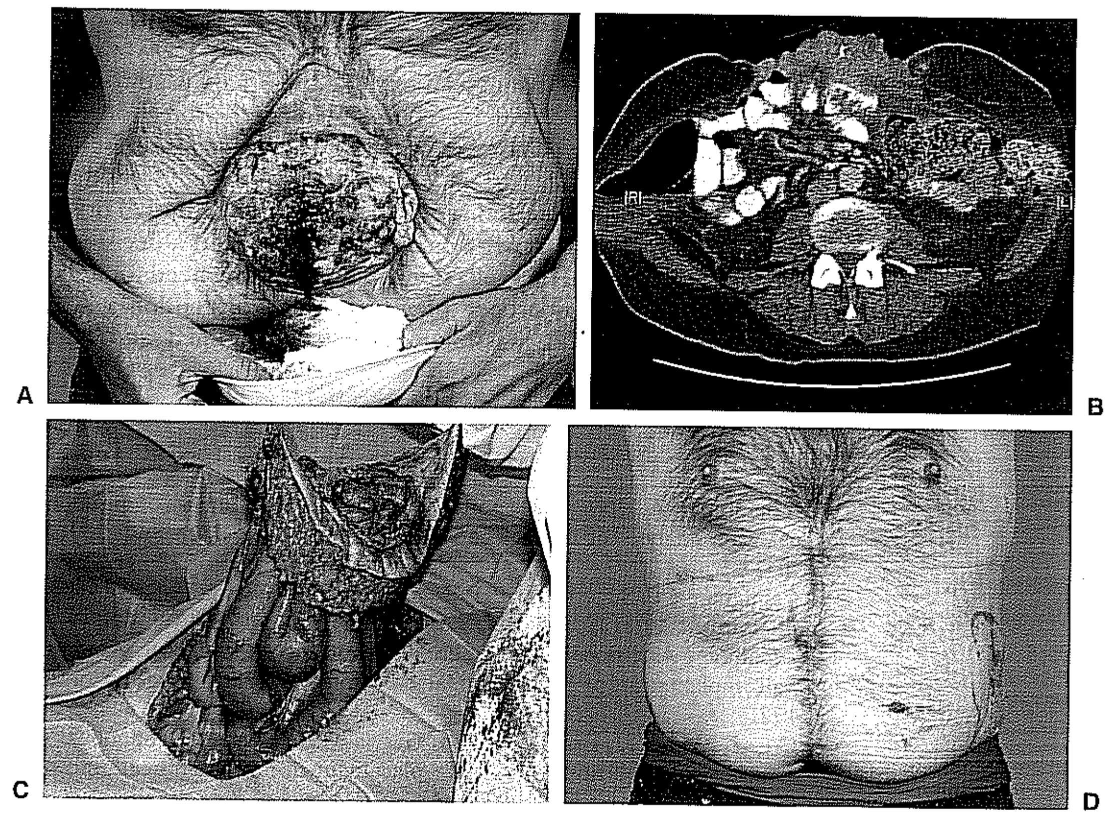

Figure 12.3. A 47-year-old male with a 14 × 16 cm^2 Marjolin's ulcer (squamous cell carcinoma) of the abdominal wall, invading into the bowel. An open abdominal wall wound with exposed polypropylene mesh for 11 years was believed to contribute to the development of this carcinoma. **(A)** Pre-operative appearance of abdomen prior to resection. **(B)** CT scan demonstrating involvement of the small bowel. **(C)** The entire cancer and contaminated abdominal wall wound was resected, en bloc, including loops of small and large bowel, which required small and large bowel resections. **(D)** Post-operative appearance of the abdominal wall after reconstruction with component separation and fascia lata graft.

separation" or the "separation of parts" involves releases of the external oblique muscle tendon as it inserts onto the anterior rectus fascia, which allows for a tremendous mobilization and medial transportation of lateral skin and abdominal wall muscle fascia towards the midline. The external oblique is the least elastic of the three lateral abdominal wall muscles. A disinsertion of the external oblique as it joins with the rectus abdominis sheath allows for 6–10 cm of movement of the medial-most tissue towards the midline. Previously, this procedure had been associated with a high post-operative wound complication rate owing to the wide elevation of skin flaps in order to perform the release of the external oblique. The post-operative wound complication rate has been shown to be markedly reduced when the skin is left attached to the abdominal wall. This maintains skin vascularity and reduces dead space. The releases of the external oblique muscle at the semilunar line can be performed through tunnels created through separate transverse incisions placed at the inferior aspect of the rib cage *(16)*.

Conclusion

The abdominal wall is essentially an expendable organ, used for movement of the upper torso and for containment and protection of the abdominal wall viscera. Tumor excision of the abdominal wall is limited only by what can be reconstructed. A straightforward analysis of the two related but independent questions of how to repair the internal or structural abdominal wall and how to close the skin leads to a decision tree involving mesh or fascial flap selection and the possible need for a simultaneous skin flap. With proper planning and coordination with the oncologic surgeon the reconstruction can be simplified and patient outcomes improved.

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