CHAPTER 14

Tissue Transfers and Pedicled Flaps for Large Abdominal Wall Defects

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INTRODUCTION

The abdominal wall is a complex anatomical construct composed of several important tissue components, which contribute to both function and form. Primarily it is designed to protect the viscera, but the muscular components are essential to maintaining support to the upper torso and limbs. It is also key to spinal support, maintenance of posture and core, and movement of the mid-torso. Inevitably, injury, disease, surgery, or associated complications can have a significant impact upon both form and abdominal wall function.

It is therefore entirely appropriate that a book chapter on flap reconstruction is included in a compendium of minimally invasive abdominal wall surgery. Due to body habitus, complex medical history, and prior abdominal surgeries, there are a subset of patients who present with a loss of abdominal soft-tissue covering. Like bone fractures, the abdominal wall can only heal within a pliable, well-vascularized soft-tissue envelope. Any planned abdominal wall reconstruction requires the solution to two independent but related problems: First, how best to reconstruct the abdominal wall, and second, how best to provide soft tissue cover and closure of the skin. Minimally invasive techniques are often dependent on using sheets of permanent mesh, which are, in turn, dependent on adequate soft-tissue cover. Accordingly, reliable, robust soft-tissue cover is an essential requirement for any successful reconstruction.

Superficial wounds may be resurfaced with a skin graft. This is plentiful but relies on the recipient site to be clean, stable, and above all well vascularized. The aim of using a skin graft is therefore to replace skin and provide cover when surface tissue is lost, such as after a burn injury.

In abdominal wall reconstruction, defects are usually larger, and more complex, involving several soft-tissue layers and types. Indeed, the defect may involve the full thickness of the abdomen. In these situations, one aims to replace "like with like," and the tissue requirements inevitably become more complex and require composites of skin, subcutaneous fat, and possibly muscle and/or fascia. Importantly, these tissues now require their own blood supply. This form of tissue transfer is known as a flap; a flap is a piece of tissue supplied by a known source vessel. The source vessels—more commonly called the pedicle—are something that exist at birth. There are patterns in the human body as to the size and dominance

of particular pedicles and the size of the territory that the pedicle supplies. The larger a pedicle the potentially smaller is the adjacent pedicle. The creation and movement of flaps require surgical experience because of this inherent variability of the pedicle. Over the last several decades and with experience, plastic surgeons have identified common abdominal flaps that are useful and relatively reliable for tissue transfer to aid in patient reconstructions.

BLOOD SUPPLY OF THE ABDOMINAL WALL

Mobilization of the abdominal wall can only be performed with knowledge of the blood supply to the skin of the abdomen. The primary source of blood supply to the abdomen arises from DIEAP, or deep inferior epigastric artery perforators that pierce the rectus muscles to vascularize the central skin. These perforators are called "periumbilical perforators" due to their location.[1] Periumbilical perforators are a constant anatomical feature, but their number, size, and location are all variable. The skin and soft tissues of the upper abdomen are fed by the superior epigastric artery as the source vessel. These vascular territories are connected by a series of "choke" vessels that open due to vascular stress.[2] The choke vessels exist in the subdermal vascular plexus. Using a visual analogy, perforators are tree trunks, and the subdermal plexus are the higher tree branches that potentially connect high above the trunks.

There is great variability in abdominal skin blood flow and great redundancy as well. With pregnancy, there is relative occlusion of the DIEAP blood flow, leading to the opening of choke vessels between vascular territories. Occlusion of the DIEAP flow can lead to increase in size and flow from the superficial inferior epigastric artery (SIEA) and from the intercostal arteries. The SIEA is often noted and coagulated during open inguinal hernia repair. A standard Pfannenstiel incision may divide some of the SIEA vessels, but the DIEAP vessels are typically intact. Blood flow from the intercostals typically runs along an imaginary line from the tip of the scapula to the umbilicus and parallels the somites of embryology. The final named contributor vessel to abdominal skin blood flow is the deep circumflex iliac perforators that emerge lateral to the anterior superior iliac spine.[3]

Surgical experience has taught us that loss of one set of perforators is always well tolerated, and the loss of two sets of perforators is usually well tolerated. The typical abdominoplasty divides the DIEAP perforators and the SIEA blood vessels **(Fig. 1)**, with the remaining skin staying vascularized from the intercostal blood vessels. Healing is the rule rather than the exception **(Fig. 2)**.

Scars from prior surgical incisions are important in that they may prevent or disrupt normal skin blood flow; accordingly, any blood that crosses

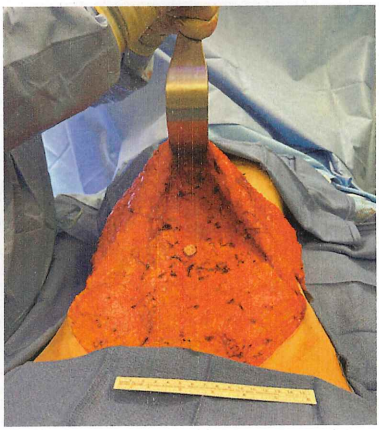

Fig. 1: Standard abdominoplasty skin flap raised from the perineum to the xyphoid, dividing the SIEA and DIEAP vascular contributions. The skin flap is nourished by intercostal blood vessels. (DIEAP: deep inferior epigastric artery perforator; SIEA: superficial inferior epigastric artery)

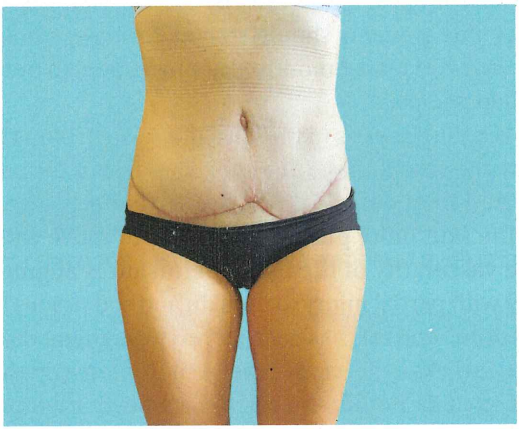

Fig. 2: Standard closure of abdominoplasty incision with good healing.

a scar is laminar, unreliable, and not pulsatile. Pulsatile blood flow has improved healing over laminar flow. Accordingly, planning of any incision, or reconstruction close to an existing scar, needs to take this prior wound into consideration when planning surgery in order to avoid wound healing issues. Inappropriate skin elevation dividing all the perforators on one side of a prior scar typically results in full-thickness skin necrosis **(Fig. 3)**.

There are several means available to improve or maintain the existing skin blood flow. Firstly, after prior surgical insult, with time, the skin and subcutaneous tissues soften and are easier to move and with less tension. Cessation of smoking is a well-understood mechanism to improve skin

Fig. 3: Blood does not flow across a scar for an undermined skin flap. Note the skin necrosis on this patient with parallel incisions for a second liver transplant.

reliability for healing. Smoking prevents the choke vessels from opening (i.e., remain closed) with surgical stress, thereby making skin flap elevation more unreliable. As a guide, patients should stop all forms of smoking (including oral tobacco or vapes) at least 2 months prior to surgery in order to minimize the risk of skin flap necrosis.

Weight loss is a third means to improve the relative blood flow in tissues. With weight loss, the vascular tree does not change, but the amount of tissue supported by the blood vessels decreases. Therefore, significant weight loss can make the skin more pliable and easier to move with less tension, and the relative vascularity of the tissue perfusion is augmented. Surgical preconditioning with partial injury to the skin and soft tissues is referred to as the "delay procedure," and this has been shown to augment tissue vascularity, though it takes 2–3 weeks to develop.[4] Finally, multiple preoperative injections with medicines such as Botulinum toxin have been attempted to create a chemical sympathectomy.[5]

COMMON PATTERNS OF SOFT-TISSUE RECONSTRUCTION

Midline Tissue Loss with Intact Rectus Muscles and a Central Hernia. Move Lateral Tissue to the Midline with Perforator Preservation and Close Vertically

The most common scenario seen in complex abdominal wall reconstruction (AWR) is a deficiency of central soft tissues. Many illnesses can lead to sepsis, loss of abdominal wall closure, a central wound with absent soft tissues, and a midline hernia. These cases do not require significant undermining or a flap reconstruction, as tissue can be brought to the midline to achieve a soft-tissue

closure. After entry into the abdomen, reapproximation of the rectus muscles can be achieved using a combination of anterior component release with perforator preservation. Lateral incisions are made at the inferior aspect of the rib cage, and the external oblique muscle and fascia are divided from above the rib cage down toward the anterior superior iliac spine (https://www.youtube.com/watch?v=VXboIZbxOes&t=134s).

The skin remains perfused with its dominant DIEAP vessels. The rectus muscles can be approximated with a mesh suture (Duramesh Mesh Suture, MSI, Chicago, IL) with modest skin elevation to identify unscarred abdominal wall and avoid division of perforators **(Figs. 4 and 5)**. Mesh suture improves the hold on the rectus muscle closure and does so without

Fig. 4: Apparent central soft-tissue deficit with associated midline incisional hernia.

Fig. 5: The soft tissues become approximated in the midline with the perforator preserving anterior component release (divisions of the external oblique muscle and fascia) and midline hernia repair.

Fig. 6: Patient with central and lower soft-tissue loss after bowel perforation that occurred during liposuction. On physical examination, the soft tissues cannot be brought to the midline, even if an anterior component release is performed. Her muscles were also damaged by the liposuction trauma, making repair of the abdominal wall even more difficult.

significant skin elevation that is required for planar mesh. In combination with perforator preservation, the closure of a large incisional hernia can be achieved with the complication profile of a laparotomy.[6] However, there can be some situations where the loss of soft tissue is too great and would not be able to be approximated in the midline even with anterior component release **(Fig. 6)**. These more complex defects require the provision of additional soft tissue that is routinely obtained from the upper thigh, or via soft-tissue expansion using first-stage tissue expansion, or progressive pneumoperitoneum.

Hypogastric Tissue Loss with Available Upper Abdominal Skin: Transverse Panniculectomy and Primary Closure

Tissue defects in the hypogastrium can be addressed with panniculectomy concepts.[7] As long as the upper abdominal skin can be elevated and mobilized downward, the majority of soft-tissue defects, either preexisting or that arise after skin excision, are treatable with a panniculectomy incision, flexion of the patient at the waste, and primary closure. **Figures 7 to 9** is a morbidly obese female with an incarcerated large umbilical hernia. The soft tissues over the hernia were excised, along with removal of additional soft tissues above and below the defect, prior to primary closure. **Figures 10 to 12** demonstrate a similar case of a soft-tissue defect created with excision of inflamed and infected mesh. Closure was performed with a soft-tissue mobilization of epigastric tissue and downward movement.

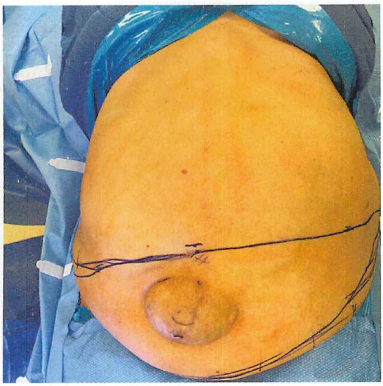

Fig. 7: Central soft-tissue defect located over a hernia in a morbidly obese female who currently smokes.

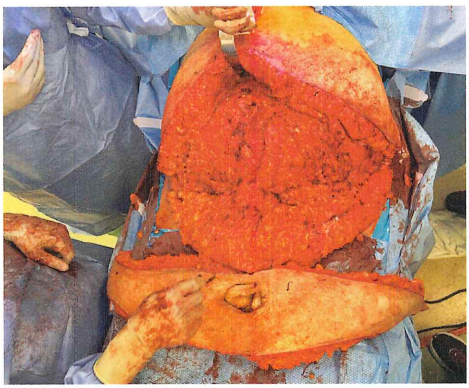

Fig. 8: Excess skin excised and the hernia reduced. Hernia repair with mesh suture.

Fig. 9: Healed postoperative photo.

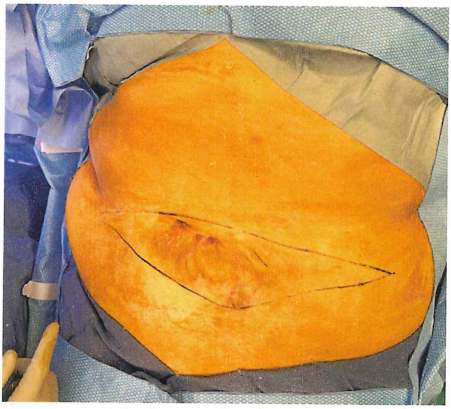

Fig. 10: Draining right lower quadrant areas due to retained infected mesh. Patient to undergo panniculectomy soft-tissue excision and closure.

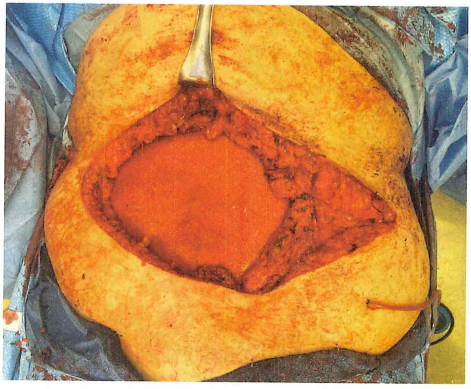

Fig. 11: Radical soft-tissue excision and reconstruction with bioprosthetic mesh as too much abdominal wall had been removed for primary closure.

Fig. 12: Closure with upper abdominal skin mobilization and downward placement.

Periumbilical Perforator-based Flaps into the Pelvis or for Other Reconstructive Purposes

Central skin can be mobilized as a flap based on the DIEAP vessels for reconstructive purposes. The most common is perineal reconstruction after an abdominoperineal resection for colon cancer, other pelvic exenterations, loss of the vaginal wall, or even reconstruction of the thighs when there are no other good options. Various orientations of the skin paddles have different names, including the vertical rectus abdominis myocutaneous (VRAM) flap and the transverse rectus abdominis myocutaneous (TRAM) flap. **Figures 13 to 15** illustrate a VRAM flap placed into the pelvis. **Figure 16** demonstrates the concept of a *flap delay* in a TRAM flap. In order for a skin paddle to become more reliable for transfer, preliminary skin incision can be made approximately 1 week early before final transfer. Flap delays open choke vessels and ensure that the entire skin paddle receives its blood flow from the pedicle.

Fig. 13: Vertical rectus abdominis flap (VRAM—vertical skin paddle based on periumbilical rectus perforators) for vaginal reconstruction after cystectomy.

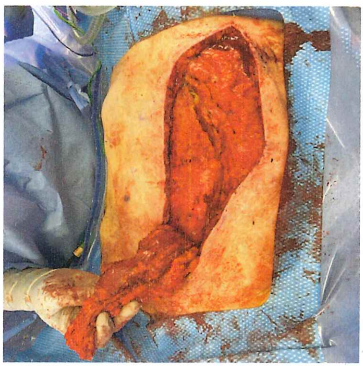

Fig. 14: Flap brought inferiorly to demonstrate partial rectus harvest.

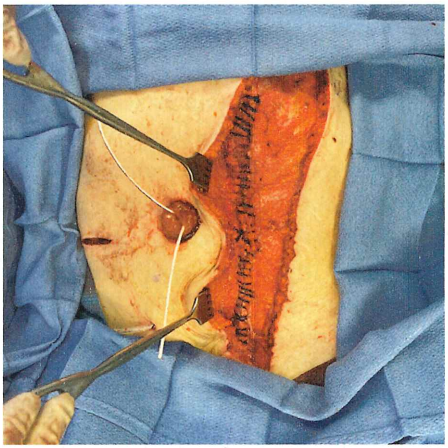

Fig. 15: Closure with mesh suture and right perforator sparing component release.

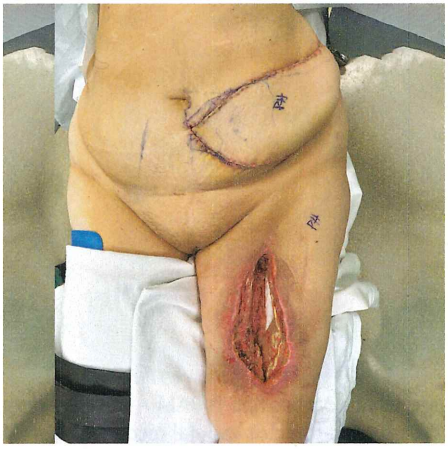

Fig. 16: Transverse rectus abdominis (TRAM) flap outlined with previous surgical delay. The tissue would be used to cover an exposed radiated femur after tumor excision.

Superficial Inferior Epigastric Artery-based Flaps

Flaps based upon the SIEA are relatively uncommon, as the SIEA are usually smaller caliber vessels than the DIEAP system. Because of the small vessel size, these flaps are considered less reliable than those dissections based on the DIEAP system.[8] **Figures 17 to 19** illustrate a patient with prior division of the periumbilical perforators who has significant scar adjacent to his ostomy appliance that makes fitting difficult. The scar was excised, and a lower abdominal skin flap was created based on the SIEA to be moved several inches toward the ostomy site.

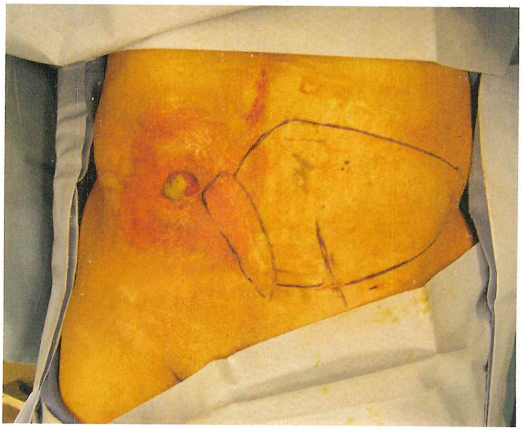

Fig. 17: A patient has an indented midline scar adjacent to his permanent ileostomy making appliance fitting difficult.

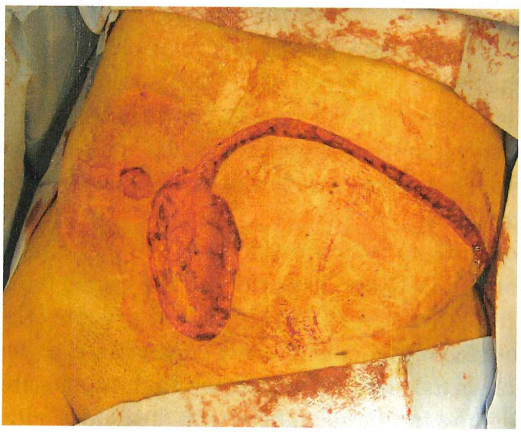

Fig. 18: An SIEA-based pedicled flap is drawn out and incised. (SIEA: superficial inferior epigastric artery)

Thigh-based Flaps for Abdominal Reconstruction

Large or complex defects that involve full-thickness tissue loss require replacement and reconstruction using well-vascularized tissue to provide both lining and cover. In this instance, the main source of flaps is derived from the anterior lateral thigh. These are vascularized by the descending branch of the lateral circumflex femoral artery that supplies the vastus lateralis and the fascia lata for abdominal reconstruction.[9] This vessel also supplies skin and fascia of the anterolateral thigh; hence, these flaps are referred to as the anterolateral thigh flap, or ALT flap. The pedicle that supplies the fasciocutaneous aspect of the flap can be identified using a hand-held

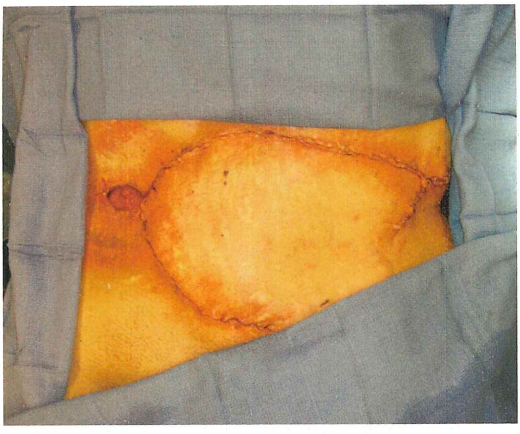

Fig. 19: The SIEA-based flap is moved toward the ostomy to help with later bag fitting. (SIEA: superficial inferior epigastric artery)

Doppler, and a significant skin island elevated from almost above the knee up to the trochanter if so required. The vascular pedicle can be isolated to allow "islanding" of the flap and rotation of the flap up onto the abdominal wall. Due to the available length of the vessels, the pedicled ALT is ideally suited for resurfacing central lower abdominal wall defects. The vascularity of this flap makes it a very reliable source of soft-tissue cover, particularly if a mesh is placed deep to the flap.

The reach of the flap is improved when the pedicle is passed under the rectus femoris muscle and the artery to the rectus femoris is divided. Despite all of these maneuvers, it is difficult to provide a large amount of skin either above the umbilicus or to the contralateral aspect of the body. When the pedicle is too short or the tissue requirements are too great, the flap is converted into a free tissue transfer with the help of additional vascular anastomoses.

For the larger, upper abdominal defect, the ALT can be transferred via microsurgical transfer. Specifically, the vascular pedicle can be divided and anastomosed to recipient vessels such as the internal mammary artery and vein, or the gastroepiploic arcade. In this way, extensive defects can be reconstructed and viscera covered with robust skin and fascia, and where necessary, a mesh placed deep to the flap **(Figs. 20 to 24)**.

Tissue Expansion

In certain situations, tissue expansion of lateral skin is necessary for later mobilization to the midline.[10] Tissue expanders are flat balloons that are inserted underneath good abdominal skin. An internal port is placed over solid bone or ribs, and it is accessed through the skin to slowly inject saline

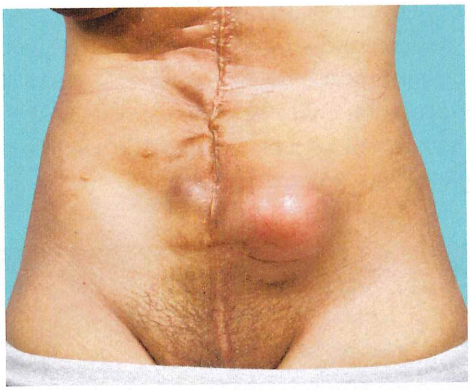

Fig. 20: Patient with a giant recurrent radiated dermatofibrosarcoma protuberans of the abdominal wall. The patient already had an anterior component release and reconstruction.

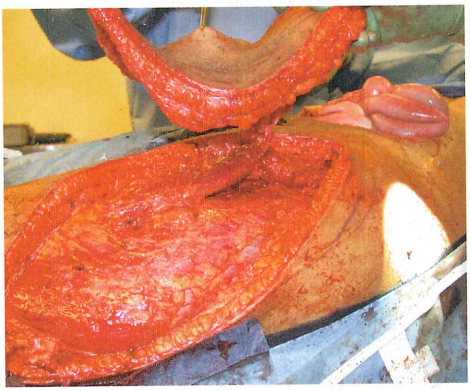

Fig. 21: Giant ALT flap dissected on single perforating blood vessel off of the descending branch of the lateral femoral circumflex artery. (ALT: anterolateral thigh)

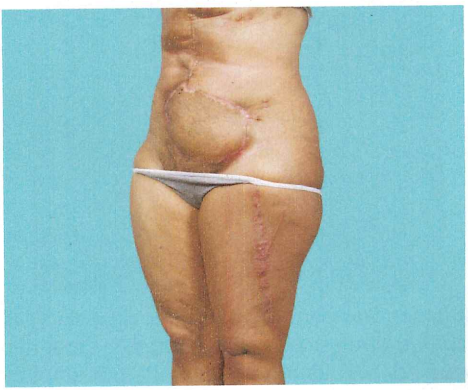

Fig. 22: Final reconstruction with thigh-based ALT flap. (ALT: anterolateral thigh)

into the flat balloon. Over time, the balloon stretches the overlying skin to make it available at a second surgery for abdominal wall closure. As the stretched skin and planning are not always reliable, there should not be any prosthetic mesh placed that could become exposed in the AWR. Therefore, biologic mesh or even tensor fascia lata should be used for the AWR for these large complex defects **(Figs. 25 to 29)**.

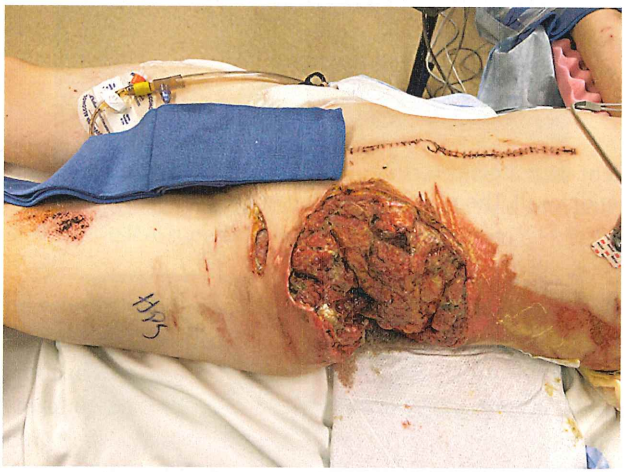

Fig. 23: Massive traumatic defect with loss of left abdominal wall. He needs good soft-tissue to repair his pelvis.

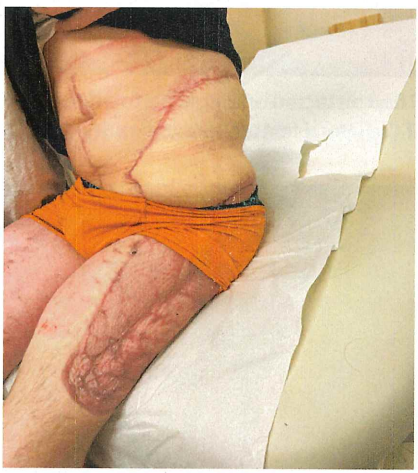

Fig. 24: The reconstruction was performed using a giant skin/vastus lateralis/tensor fascia muscle and flap. The donor site was skin grafted. In order to place the flap in the proper position, the pedicle was elongated with interposition saphenous vein grafts between the femoral artery/vein and the pedicle.

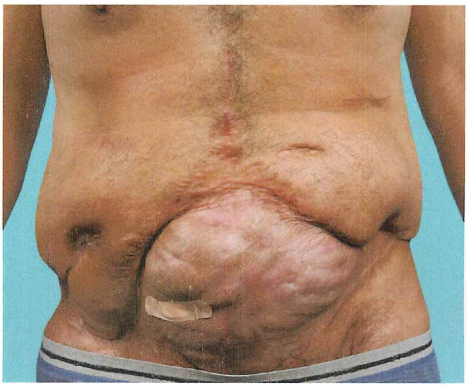

Fig. 25: Massive lower abdominal defect from trauma. The trauma injured both common femoral arteries, and he had necrosis of bilateral thigh-based flaps at a prior operation. The only means left for his reconstruction is tissue expansion.

Fig. 26: Patient with fully filled bilateral expanders in place.

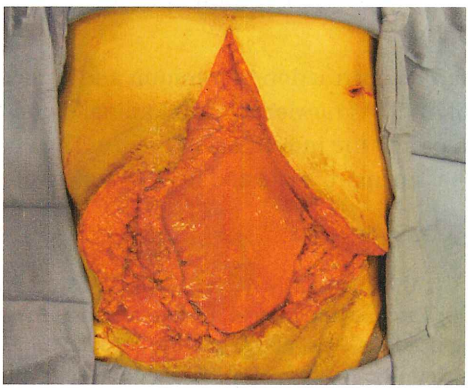

Fig. 27: Biologic mesh reconstruction due to unreliability of expanded tissue flaps.

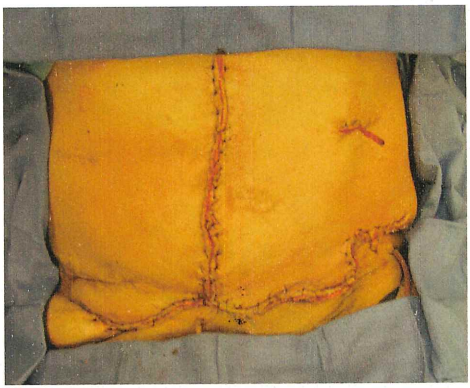

Fig. 28: Image after closure, on the table.

Fig. 29: Partial flap loss due to tension. The wound would go on to close with local wound care. His soft tissues and abdominal wall reconstruction have been slowly stretching for the last decade, but he has not undergone additional surgery.

CONCLUSION

Abdominal wall flap reconstruction is common and a necessary part of the armamentarium of AWR. A knowledge of abdominal blood flow is combined with experience to permit the movement of tissues. The abdominal wall can only heal when it has an appropriate and healthy soft-tissue environment.

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