Reconstruction of Complex Abdominal Wall Defects with Free Flaps: Indications and Clinical Outcome

Chin-Ho Wong, M.R.C.S.
Chih-Hung Lin, M.D.
Brian Fu, M.R.C.S.
Jen-Feng Fang, M.D.

Taipei, Taiwan; and Singapore

Background: Free flaps have a distinct role in a select group of patients with large abdominal wall defects. They offer a completely autologous reconstructive solution in a single stage for difficult abdominal wounds for which pedicled flaps would be inadequate.

Methods: From 1996 to 2005, five patients with complex abdominal wall defects underwent reconstruction using free flaps. All patients had multiple comorbidities, making the use of alloplastic materials relatively contraindicated. Flaps used included a free radial forearm flap in one patient, a tensor fasciae latae myocutaneous flap in two patients, a free anterolateral thigh myocutaneous flap in one patient, and free conjoined tensor fasciae latae and anterolateral thigh myocutaneous flaps in the last patient.

Results: The mean defect size was 470 cm^2 (range, 136 to 875 cm^2). The femoral artery and long saphenous vein reliably provided recipient vessels in cases for which suitable vessels could not be located within the abdomen. A temporary arteriovenous shunt of the long saphenous vein to the femoral artery could be created. This was later divided to provide a recipient artery and vein. Flap complications were wound edge necrosis, hematoma, infection, and venous thrombosis. All were successfully managed and there were no flap failures. The average length of hospitalization was 64 days (range, 41 to 128 days). Lateral thigh flaps based on the lateral circumflex femoral system are our preferred donor site. A large amount of soft tissue, strong fascia, and innervated muscle are available, enabling single-stage autologous reconstruction of the entire anterior abdominal wall.

Conclusions: Free flaps offer a reliable single-stage solution to complex abdominal wall defects. With these techniques, even the most challenging defects can be reconstructed with completely autologous tissue. (*Plast. Reconstr. Surg.* 124: 500, 2009.)

Reconstruction of complex abdominal wall defects is clinically challenging and technically demanding. Requirements for satisfactory reconstruction are soft-tissue coverage and restoration of the musculofascial support for abdominal contents.[1] In patients with significant tissue loss, primary closure is not feasible. Techniques such as component separation and local flaps are generally the preferred reconstructive options.[1–3] Alloplastic materials such as Gore-Tex (W. L. Gore and Associates, Flagstaff, Ariz.) or Marlex mesh (Davol, Inc., Cranston, R.I.) have been widely used for restoration of the musculofascial integrity of the abdominal wall, with variable success.[4–9] Such foreign materials are relatively contraindicated in immunocompromised patients, as they are associated with unacceptably high complication rates.[10] Free tissue transfer is often regarded as the option of last resort in abdominal wall reconstruction. However, free-tissue transfer offers some distinct advantages over local flaps and has a definite role in a selected group of

From the Division of Trauma, Department of Plastic and Reconstructive Surgery, Chang Gung Memorial Hospital, Chang Gung University; the Department of General Surgery, Chang Gung Memorial Hospital; and the Department of Plastic, Reconstructive, and Aesthetic Surgery, Singapore General Hospital.
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patients. This article described our experience with the use of free flaps in the reconstruction of complex abdominal wall defects and details our indications for the use of free flaps in abdominal wall reconstruction.

PATIENTS AND METHODS

From 1996 to 2005, five patients with complex abdominal wall defects underwent reconstruction with free flaps. All patients were treated initially by general surgeons at our institution and were subsequently referred to the senior author (C.-H.L.) for reconstruction. Four patients were men and one was a woman. Contaminated or infected abdominal wounds were débrided serially and covered temporarily with occlusive dressings until the wounds were clean and the nutritional status of the patients was optimized.[11] Reconstruction was performed with a free tensor fasciae latae myocutaneous flap in two patients, a free radial forearm flap in one patient, a free anterolateral thigh myocutaneous flap in one patient, and a free conjoined tensor fasciae latae and anterolateral thigh myocutaneous flap in one patient. The selection of flap was guided by defect requirement in terms of size and components needed. The lateral thigh based on the lateral circumflex femoral system is our preferred donor site. The entire anterior abdominal wall can be reconstructed by harvesting conjoined vascular territories such as that of the tensor fasciae latae and anterolateral thigh, safely incorporating up to half the skin of the lateral thigh. In one of our patients, the radial forearm was used, as the patient has severe peripheral vascular disease with bilateral above-knee amputations.

The femoral artery (just below the inguinal ligament) and the long saphenous vein offer a reliable and robust source of "extraabdominal" recipient vessels in cases where intraabdominal vessels are unavailable or inadequate. It is particularly useful in cases where severe trauma or multiple previous incisions have compromised the commonly used intraabdominal recipient vessels. In two patients, a temporary arteriovenous shunt was created. The long saphenous vein was mobilized from the groin down to the thigh and leg for the required length. An end-to-side anastomosis of the distal end of the greater saphenous vein to the femoral artery was then performed in the groin just below the inguinal ligament. This arteriovenous loop was then swung 180 degrees into the abdominal and subsequently divided at its midpoint to create an inflow and outflow for arterial and venous anastomosis to the donor vessels. In one patient, when long segments vein grafts were needed, both the long and short saphenous veins were harvested. In another patient, the long saphenous vein was used to provide a second venous anastomosis to improve venous outflow.

RESULTS

Table 1 gives a summary of the patients and reconstructive outcomes. The mean defect size was 470 cm^2 (range, 136 to 875 cm^2). The mean follow-up was 23 months (range, 12 to 102 months). Flap complications occurred in three of our five patients, partly because of the multiple comorbidities and poor nutritional status of our patients. These were successfully managed with débridements and reanastomosis if necessary. There were no flap failures. The average time of hospitalization was 64 days (range, 41 to 128 days). At follow-up, none of the patients developed any abdominal wall herniation and the donor-site morbidity was well tolerated.

CASE REPORTS

Case 1

A 38-year-old woman fell from a height of three floors. This resulted in blunt abdominal trauma and a right femoral shaft fracture. An emergent laparotomy found hemoperitoneum with hepatic laceration, pancreatic contusion, and small bowel perforations. Postoperatively, she developed enterocutaneous fistula and wound edge necrosis of the midline laparotomy wound. She was given total parenteral nutrition and the wounds were débrided serially. She presented to us 33 days after her initial operation with a 25 × 35-cm^2 defect (Fig. 1, *left*). The wound was clean but the rectus abdominis was partially resected and there was significant loss of domain of the abdominal wall. A conjoined anterolateral thigh and tensor fasciae latae myocutaneous flap was designed incorporating the deep fascia of the lateral thigh based on the lateral circumflex femoral artery system (Fig. 1, *above* and *below, right*). Inset was performed in layers, with the deep fascia sutured to the musculofascial layer of the abdomen to restore abdominal wall support (Fig. 2, *left*). The long saphenous vein was harvested down to the knee and a temporary arteriovenous loop created as described. This was then turned cephalically into the abdominal wall and divided, creating a recipient artery and vein measuring 20 cm each. The donor site was closed with split-thickness skin grafts.

Forty-four days after the initial procedure, the edge of the flap was also noted to be dusky (Fig. 2, *right*). The patient went into hypovolemic shock and was resuscitated aggressively with fluid and blood transfusions. Emergent exploration noted an abscess around the pedicle, with an arterial blow-out at the site of the end-to-side anastomosis (Fig. 3, *left*). Débridement was performed and the artery anastomosis was redone. The necrotic wound edge was excised and the wound resutured (Fig. 3, *right*). Healing was subsequently achieved. At 2-year follow-up, good abdominal support with no herniation was noted (Fig. 4).

Case 2

A 41-year-old man with a history of diabetes mellitus sustained blunt abdominal trauma in a road traffic accident. He sustained thoracolumbar spine fracture (T12 to L1), lower limb

Table 1. Summary of Cases*

Case	Age/Sex	Comorbidities	Cause of Defect	Site of Defect	Size of Defect (cm^2)	Type of Flap	Anastomosis	Reinnervation	Flap Complications	Preoperative/Postoperative Pain Scores
1	38/F	CRF, HTN	Blunt abdominal trauma, burst abdomen following laparotomy and intraabdominal sepsis	Midline anterior abdomen	25 × 35	Free ALT and TFL conjoined myocutaneous flap	LCFA to the femoral artery with the GSV as interpositional vein graft	No	Flap edge necrosis, femoral artery blow-out following wound infection, successfully salvaged	9/0
2	41/M	DM	Left flank incisional hernia from a nephrectomy, with chronic, intractable neuralgia	Left flank	15 × 25	Free TFL myocutaneous flap	LCFA and LCFV to femoral artery with interposition vein grafts from GSV	Yes	Nil	8/4
3	41/M	DM	Penetrating abdominal wall injury complicated by abdominal wall necrotizing fasciitis	Midline anterior abdomen	15 × 30	Free TFL myocutaneous flap	LCFA to the GEA; two venous anastomoses, VCs of the LCF to the GEV and GSV	No	Venous thrombosis, successfully salvaged	8/1
4	54/M	DM	Blunt abdominal trauma; laparotomy wound edge necrosis with intraabdominal sepsis	Midline anterior abdomen	15 × 35	ALT myocutaneous flap	LCFA and LCFV to femoral artery with interposition vein grafts from GSV and LSV	Yes	Nil	8/1
5	56/M	DM, ESRF, HTN, PVD	Blunt abdominal trauma, burst abdomen following laparotomy complicated by enterocutaneous fistula and partial necrosis of the rectus abdominis; patient previously had bilateral above-knee amputations	Midline anterior abdomen	8 × 17	Free radial forearm	RA and VC to the DIEA and its VC with the cephalic vein as interpositional vein grafts	No	Wound dehiscence treated by débridement and secondary suture	9/0

DM, diabetes mellitus; CRF, chronic renal failure; ESRF, end-stage renal failure; HTN, hypertension; PVD, peripheral vascular disease; TFL, tensor fasciae latae; ALT, anterolateral thigh; LCFA, lateral circumflex femoral artery; LCFV, lateral circumflex femoral vein; GSV, greater saphenous vein; GEA, gastroepiploic artery; GEV, gastroepiploic vein; RA, radial artery; VC(s), vena comitans/venae comitantes; DIEA, deep inferior epigastric artery.

*All outcomes were successful.

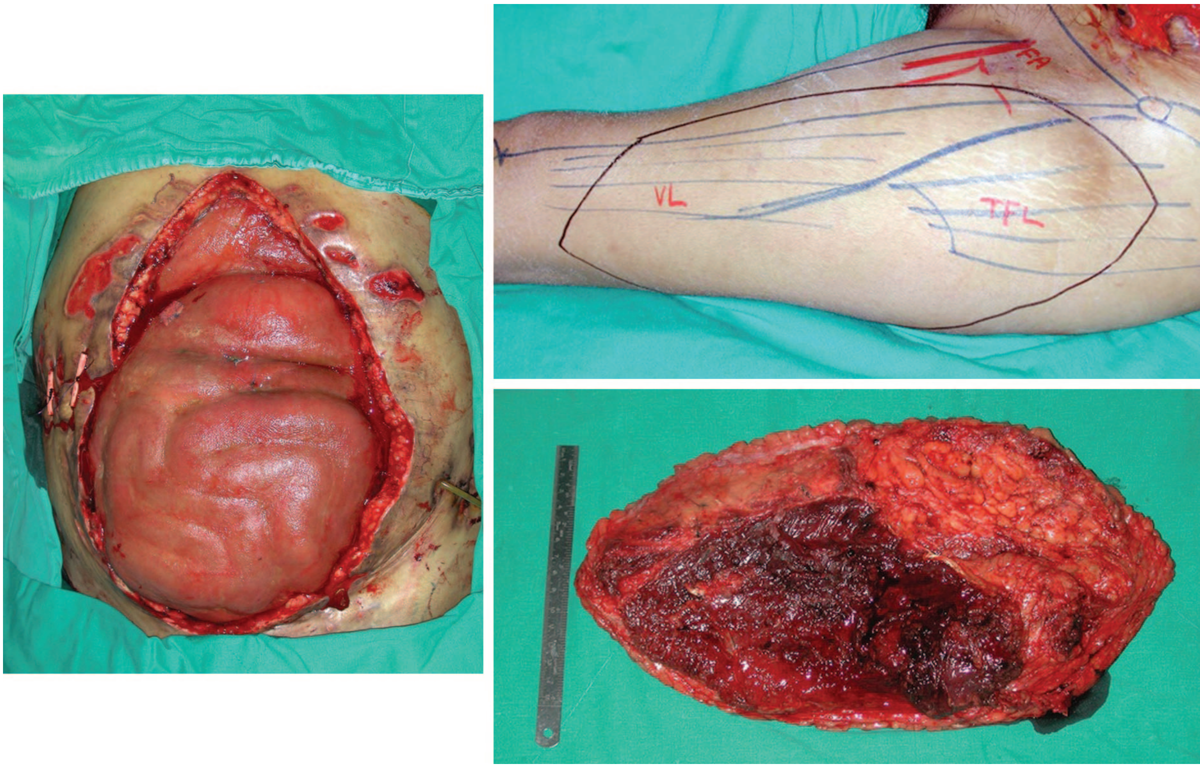

Fig. 1. Case 1. (*Left*) A large abdominal wall defect measuring 25 × 35 cm^2. The rectus abdominis was very scarred and there was significant loss of domain of the abdominal wall. (*Above, right*) A large conjoined tensor fasciae latae and vastus lateralis myocutaneous flap based on the lateral circumflex femoral arterial system was planned. (*Below, right*) The conjoined flap harvested.

Fig. 2. (*Left*) Inset completed. (*Right*) One week after the initial surgery, discharge and swelling were noted from the groin wound. Small areas at the edge of the flap were also noted to be dusky.

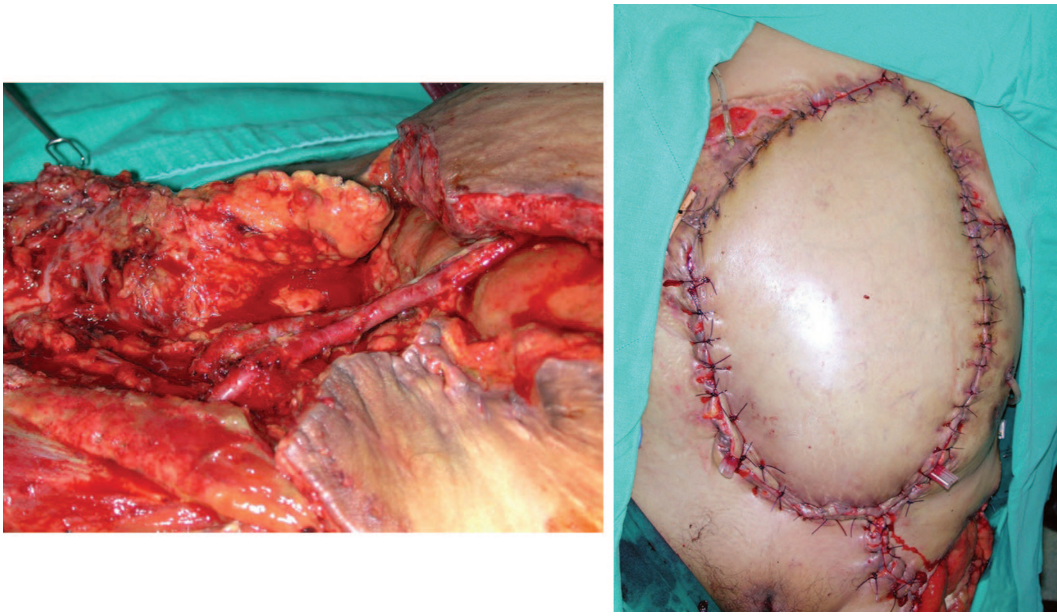

Fig. 3. Case 1. (*Left*) An abscess and hematoma were noted during exploration at 44 days postoperatively. Active bleeding was noted from a segment of the arterial vein graft that was necrotic. This was excised and the anastomosis revised. (*Right*) The necrotic edges were débrided and wounds resutured.

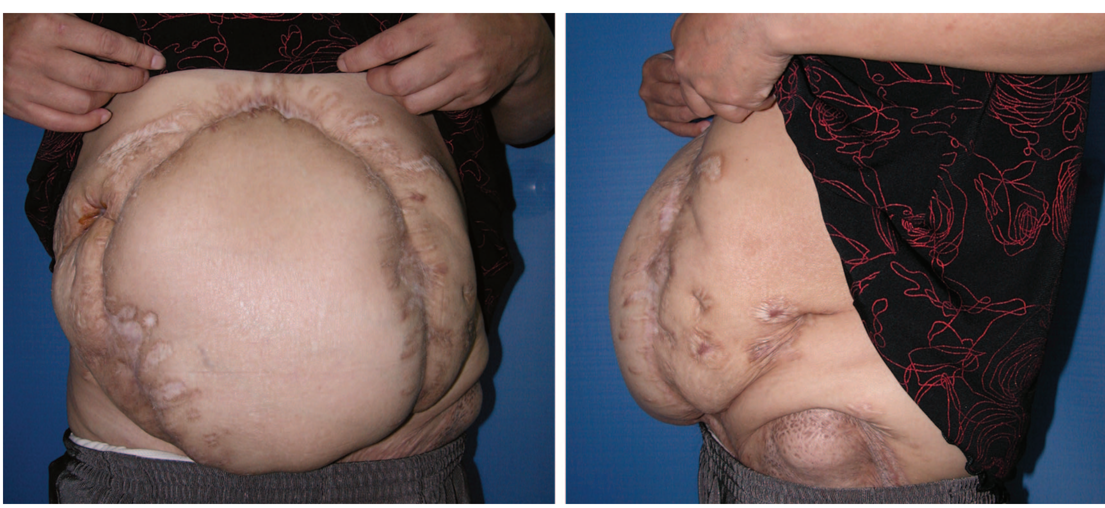

Fig. 4. The patient at 2-year follow-up.

fractures, and abdominal aorta dissection. Among other surgical procedures, a left nephrectomy was performed for kidney rupture and uncontrolled bleeding. He then developed a large incisional hernia over the left flank. Two attempts at repair with Marlex meshes were complicated by infections that necessitated removal of the meshes. He also developed intractable chronic neuralgia in the flank area that was severely limiting his activities and work. On examination, a large flank incisional hernia measuring 15×25 cm^2 and a tender neuroma were noted over the intercostal nerve area (Fig. 5, *above, left* and *right*). After extensive discussion with the neurologists and pain management team, a functional muscle transfer was planned to simultaneously address the pain resulting from the hernia and the neuralgia resulting from the neuroma. A functional tensor fasciae latae myocutaneous flap was planned (Fig. 5, *below*). The wound was explored and the transacted tenth intercostal nerve was found (Fig. 6). The margins of the hernia were repaired by plication (Fig. 7). The free tensor fasciae latae myocutaneous flap with its motor nerve was harvested (Fig. 8). The wound was repaired in layers, with the fascia lata onlayed onto the plicated hernia sac to reinforce the repair. The neuroma was excised and the intercostal nerve coapted to the motor nerve. Interpositional vein grafts measuring 35 cm each from the greater and lesser saphenous veins to the femoral artery and vein were used to revascularize the flap (Fig. 9). At 1-year follow-up, muscle contraction was noted (Fig. 10). On a subjective pain scale from 0 to 10 (with 0 being no discomfort and 10 being intolerable pain), his preoperative pain score was reported to be 8; at 1 year after surgery, this improved to 4. He noted significant improvement of the pain and was able to resume work despite slight discomfort.

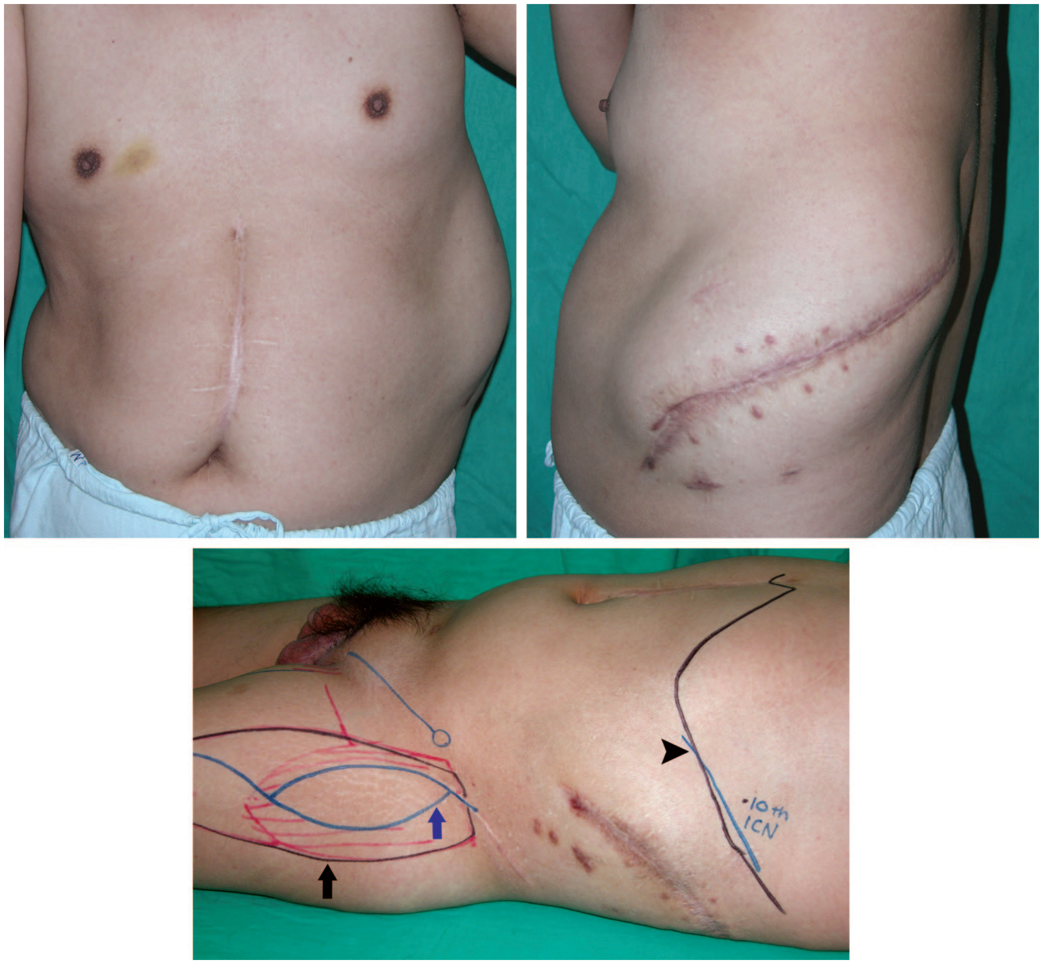

Fig. 5. Case 2. (*Above, left* and *right*) Preoperative views showing a large flank incisional hernia measuring 15×25 cm^2. Marked tenderness and hyperesthesia over the left subcostal area was also elicited. (*Below*) Preoperative markings. The tenth intercostal nerve was planned to be used as the recipient motor nerve (*arrowhead*). The planned tensor fasciae latae functioning muscle was marked with the blue line (*blue arrow*) indicating the incision site and the black markings (*black arrow*) delineating the planned fascia lata to be harvested.

Fig. 6. The offending neuroma was located (*arrow*).

DISCUSSION

In the management of abdominal wall defects, three main factors should be taken into consideration: (1) medical status of the patient (in particular, the presence of any comorbidities); (2) wound depth (full-thickness versus partial-thickness defects); and (3) size and position of the defect.[1] In general, patients with significant comorbidities such as diabetes mellitus have much higher infective complications associated with the use of foreign materials, and autologous tissue is preferred.[10] In particular, a history of previous failed attempts at reconstruction with alloplastic materials should be regarded as a relative contraindication for the further use of such foreign materials. Disa et al. have clearly demonstrated the superiority of autologous free fascia lata grafts in

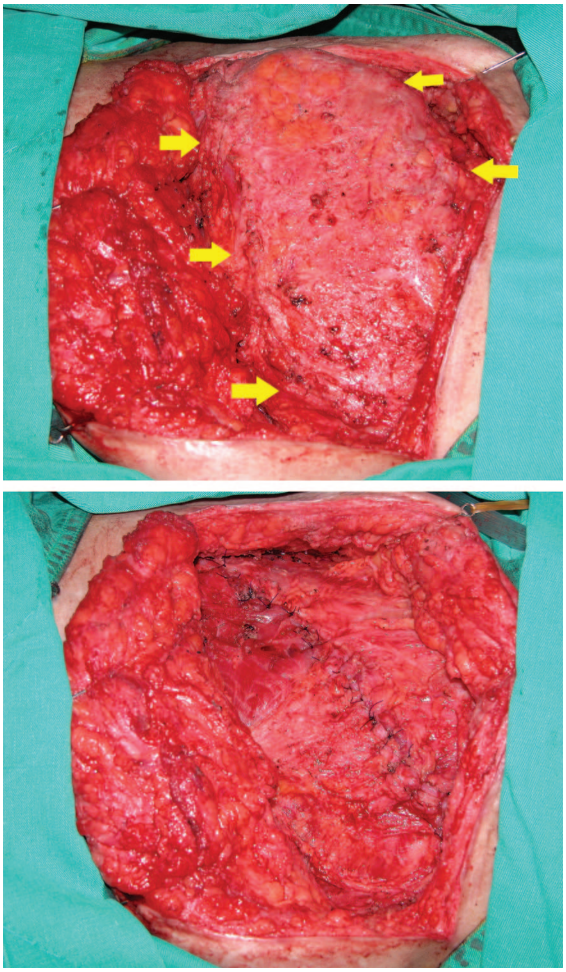

Fig. 7. Case 2. The margins of the hernia were delineated (*arrows*) and plicated.

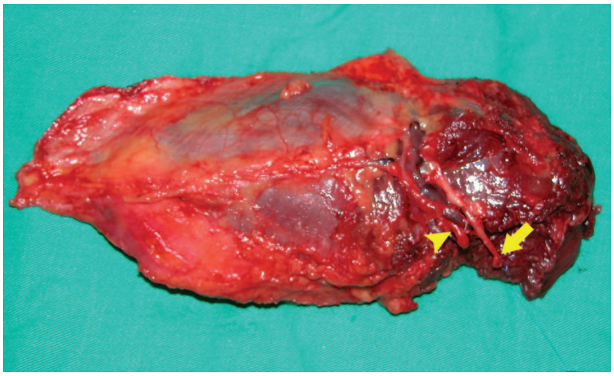

Fig. 8. The functioning tensor fasciae latae myocutaneous flap harvested with its pedicle (*arrow*) and its nerve supply (*arrowhead*).

the setting of contaminated wounds.[10] However, free fascia lata grafts are only applicable for partial-thickness defects of the abdominal wall in which adequate soft-tissue coverage is available. Component separation can be used for small to medium-sized midline defects when bilateral functional rectus abdominis muscles are available. It has been

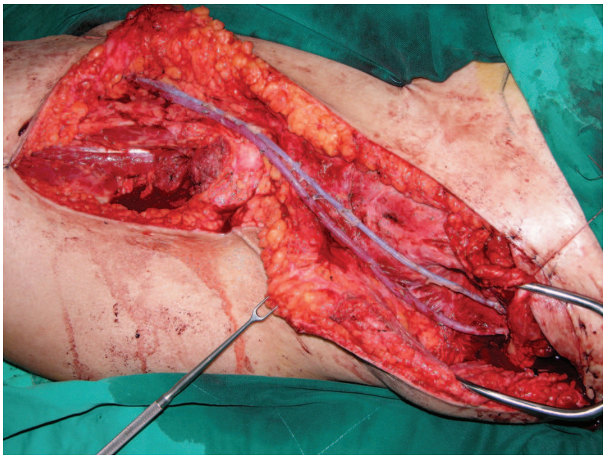

Fig. 9. Two interpositional vein grafts measuring 35 cm each were used from the femoral artery and vein to revascularize the flap.

reported that advancements of up to 10, 16, and 10 cm in the upper, middle, and lower abdomen, respectively, can be achieved with bilateral mobilizations.[2] Large lateral defects generally need some form of flap coverage.

Local flaps such as the pedicled tensor fasciae latae, anterolateral thigh, rectus femoris, rectus abdominis, and latissimus dorsi are useful and adequately address the reconstructive needs of most abdominal wall defects.[12,13] Pedicled flaps have certain inherent limitations, such as restricted reach; tip necrosis (especially when extended flaps are used); limited size of defects that can be covered (mainly small to medium-sized defects); and, except for the pedicled tensor fasciae latae flap, a strong fascial layer cannot be incorporated with the flaps, thereby necessitating the need for the use of alloplastic materials or a second donor site for the harvest of the free fascia lata graft. In this respect, free flaps have certain distinct advantages over local flaps. Free flaps, by their nature, are not restricted by pedicle reach. When larger flaps are needed, adjacent flaps can be harvested together in a conjoined manner.[14–16] Sufficient tissue can be recruited to reconstruct the entire abdominal wall. The tensor fasciae latae and the anterolateral thigh with or without the vastus lateralis muscle based in the lateral circumflex femoral artery system are prime examples of this. Furthermore, free flaps import a large volume of well-vascularized tissue into the abdomen, promote rapid healing, and are more resistant to infections. A large amount of strong fascia can be harvested with the flap in the lateral thigh region. This fascia can be used for the reconstruction of the musculofascial layer of the abdomen, thereby

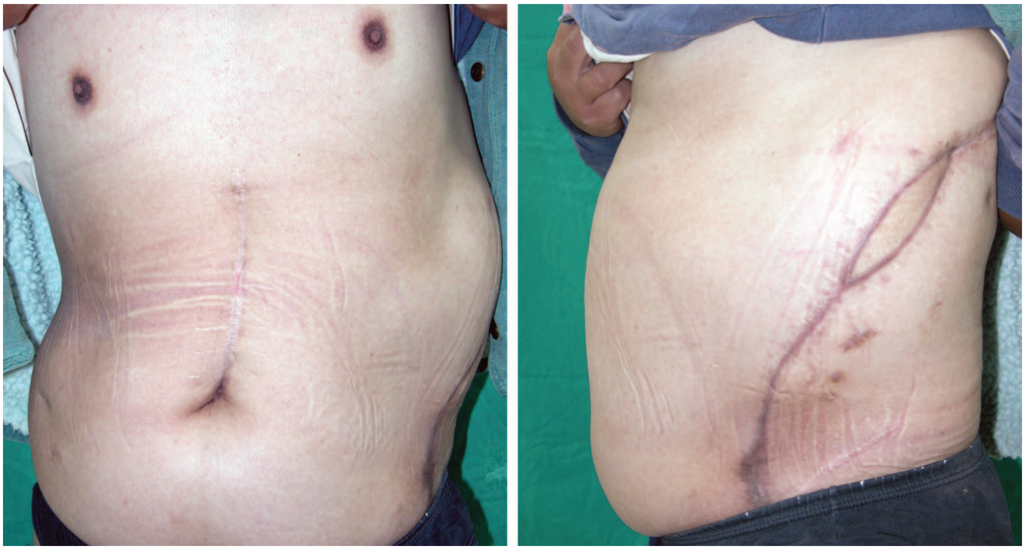

Fig. 10. Case 2. The patient at 1-year follow-up. No recurrence of the hernia was noted during abdominal straining and his neuralgia was much improved, although some residual discomfort remained. The slight bulge was from the bulk of tensor fasciae latae muscle.

precluding the need to use alloplastic materials. Functional muscle transfer is also possible with the inclusion of the nerve supply to the muscle.[17]

Our indications for the use of free flaps in abdominal wall reconstruction include the following: (1) immunocompromised patients and patients with previous failed reconstruction with alloplastic materials resulting from infection or extrusion; (2) contaminated or infected wounds in which the use of totally autologous tissue is preferred and the defects are more laterally located such that local flaps would be inadequate; and (3) patients with large midline defects precluding the use of component separation or in cases where the rectus abdominis and its fascia sheath are unavailable.

The lateral thigh is our "warehouse" donor site for a variety of reconstructive needs in abdominal wall reconstruction.[18–20] The lateral circumflex femoral system is versatile and allows the harvest of the tensor fasciae latae myocutaneous flap, anterolateral thigh flap, or anteromedial thigh flap either alone or in combination as conjoined flaps. An important advantage of the thigh is the presence of the strong deep fascia in the lateral thigh, including the iliotibial tract and fascia lata that can be used to reconstruct the musculofascial layer of the abdominal wall, thereby preventing postoperative hernia. This strong and tough deep fascial layer is considered the ideal material for abdominal fascial restoration. In this respect, the tensor fasciae latae myocutaneous flap is preferred for smaller defects, as this flap harnesses the strongest part of the deep fascia, the iliotibial band. More distally and medially (i.e., in the territory of the anterolateral thigh flap), the deep fascia tends to become thinner and more attenuated.

Intraperitoneal or extraperitoneal recipient vessels can be used in abdominal free flaps. The former include the gastroepiploic vessels and the latter include the superior epigastric vessels, inferior epigastric vessels, intercostal vessels, and superficial circumflex iliac vessels. When available, these vessels are reliable and can be safely used. In our experience, the use of "extraabdominal" recipient vessels with the creation of a temporary arteriovenous loop is often necessary for two reasons. First, the abdomen may be severely scarred and vessels damaged from placement of drains and stomas so that they are unavailable for reconstruction. Second, the pedicle may be short. This is particularly so when conjoined flaps are raised. The inclusion of both the transverse and descending branches of the lateral circumflex femoral vessels in the flap tethers the pedicle to the flap, resulting in a short "usable" pedicle. We therefore prefer the use of a temporary arteriovenous loop technique to reliably import extraabdominal recipient vessel into the abdominal wall. The greater saphenous vein is conveniently located and highly versatile for this purpose. It is easily accessible and can be mobilized down to the level of the ankle and turned cephalad to achieve a venous pedicle length of up to 80 cm. We have found this to be a reliable and safe method of revascularizing the flaps. In addition, in cases where venous outflow is insufficient with a single venous anastomosis or there is significant mismatch in vein sizes, the greater saphenous vein can reliably be used to provide additional venous outflow.

To prevent herniation, the fascia should be sutured to healthy, innervated abdominal wall tissue. The fascia is inset using in an underlay technique as described by McCarthy and Tweist, placing the fascia in an intraperitoneal position.[6] Care should be taken to ensure even distribution of tension. The repair should be taut but not excessively tight. One rare but devastating and potentially fatal complication with closure of massive abdominal defects with techniques that exert significant tension to recruit surrounding tissue such as the component separation technique is abdominal compartment syndrome. An added advantage of flap repair in this regard is that, as additional tissue is delivered to the abdominal wall, raised intraabdominal pressures following repair is therefore much less likely. This is an important consideration for frail patients with poor respiratory reserves.

Abdominal wall transplantation is a subject that has been hotly debated recently. Currently, the only place for this is probably in patients undergoing intestinal autotransplantation with concomitant abdominal wall defects that cannot be closed primarily.[20–22] There is currently no role for isolated abdominal wall transplantation, because of the side effects and risks of immunosuppression. Furthermore, as demonstrated by the cases presented here, advancements in reconstructive techniques (in particular, the use of conjoined flaps) have enabled us to safely and reliably replace almost the entire anterior abdominal wall when necessary.

CONCLUSIONS

The use of free flaps in abdominal wall reconstruction provides an added dimension for reconstruction of complex abdominal wall defects. Their versatility offers satisfactory solutions to problems where pedicle flaps are inadequate to completely address the problem. With techniques available today, the entire abdominal wall can be reliably and safely reconstructed. The use of completely autologous tissue in a single stage offers a definite advantage in immunocompromised patients, in whom the incorporation of alloplastic materials into the reconstruction is associated with unacceptably high complication rates. The lateral thigh region based on the "dispensable" lateral circumflex femoral system, has the potential to provide a large amount of soft tissue and a large amount of strong fascia. It is our first choice free flap donor site for complex abdominal wall defects.

Chih-Hung Lin, M.D.
Trauma Center
Department of Plastic Reconstructive Surgery
Chang Gung Memorial Hospital
5, Fu-Hsing Street
Kweishan, Taoyuan 33333, Taiwan
chihhung@cgmh.org.tw

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