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Versatility of the pedicled anterolateral thigh flap for surgical reconstruction, a case series

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A B S T R A C T

Background: The pedicled anterolateral thigh flap is a versatile flap that offers many advantages. These include a long and reliable pedicle that enables a wide arch of rotation, the possibility to harvest a large skin area, raising the flap with underlying fascia and muscle and minimal donor site morbidity.

Methods: From 2009 to 2018 nine patients were reconstructed with a pedicled anterolateral thigh flap. The flap was applied for coverage of knee infections, trochanteric defects, an abdominal defect, a gluteal defect, and a defect of the inguinal region. The patient group consisted of five males and four females. The age range was 30–90 years with a mean age of 61 years.

Results: Flap size ranged from 10 × 5 cm (50 cm²) to 15 × 30 cm (450 cm²) with a mean size of 222 cm². We experienced no flap loss. The donor site was closed directly in seven out of nine patients, and the remaining two patients were closed by split-thickness skin grafting. Satisfactory aesthetic and functional outcome was achieved in all patients.

Conclusion: Our experience illustrates the versatility in the clinical application of the pedicled anterolateral thigh flap. The many ad-
Background/ introduction

The free anterolateral thigh (ALT) flap was introduced by Song et al. in 1984. Since then the ALT flap has gained international popularity, especially after the publication from Wei et al. The flap has become a workhorse for the reconstruction of soft tissue defects in the head and neck, extremities, and the trunk.

Kimata et al. were the first to use the flap as a pedicled flap for an abdominal reconstruction. Their work has led to an increased application of the pedicled ALT flap. There are many advantages to the pedicled ALT flap, the primary one being the wide arc of reach that is created by the long and reliable pedicle. The flap is supplied by the descending branch of the lateral circumflex femoral artery, a branch from the profunda femoris artery. The length of the pedicle is mostly reported to be between 4 and 20 cm. One case article reported a pedicle length of 37 cm. Due to the notable length of the pedicle, the ALT flap can reach several regional locations such as the lower abdomen, perineum, groin, gluteal region and thigh making it very versatile. In addition to the possibilities mentioned above, the pedicled ALT flap offers minimal donor site morbidity and can be closed primarily if the flap does not exceed 21 × 9 cm in size.

In this series, we present our experiences with the flap in nine diverse patients. We describe the recipient site and the complexity of the reconstruction.

Patients and methods

In this case series, we have analyzed data from nine patients who underwent surgical reconstruction using the pedicled ALT flap at the Department of Plastic and Reconstructive Surgery, Odense University Hospital, Denmark, from 2009 to 2018. The patients had a broad variety of defects including, necrotizing fasciitis, gunshot wound, prosthetic infections, pyoderma gangrenosum, and pressure sores. The patient group consisted of five men and four women. The age range was 30–90 years with a mean age of 61 years. For further patient details regarding age, sex, underlying disease, flap size, donor site closure, and complications see Table 1.

The same surgeon (senior author) performed all procedures.

Operative technique

The patient is placed in a supine position, which in most situations, allows a simultaneous two-team approach. A straight line is made from the anterior superior iliac spine to the lateral edge of the patella. The majority of perforators are located in a circle of 3–5 cm inferolateral around the midpoint of this line. The perforators are mapped by a handheld Doppler ultrasonography probe.

A medial incision is made 1–3 cm medial to the straight line, depending on what flap size is required. Skin and subcutaneous tissue are dissected off the fascia laterally until the perforators are located. The perforators can either be septocutaneous (12–15%) or musculocutaneous (85–88%). The perforators are dissected until the main pedicle is reached. When the perforator is septocutaneous, the dissection is straight forward and fast. The musculocutaneous perforators always give off many advantages of the flap, such as the long and reliable pedicle, a large area of skin that can be harvested, the potential to supercharge the flap and the minimal donor site morbidity highlights the diversity of defects that can be reconstructed using this flap.

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Table 1

| Patient | Age (years) | Gender | Underlying disease | Flap size (cm) | Donor site | Follow up | Complications |
|---------|-------------|--------|--------------------|----------------|------------|-----------|---------------|
| 1       | 81          | Female | Necrotizing fasciitis | 26 × 13 (338 cm²) | Primary closure | 6 months | Prolonged healing |
| 2       | 67          | Female | Gun wound          | 10 × 30 (300 cm²) | Primary closure | 9 months | None |
| 3       | 46          | Male   | Paraplegic pressure sore | 7 × 20 (140 cm²) | Primary closure | 11 days | None |
| 4       | 61          | Female | Pyoderma gangrenosum | 22 × 9 cm (198 cm²) | Primary closure | 9 months | None |
| 5       | 90          | Female | Multiple sarcoma recurrence from clear cell carcinoma. | 25 × 10 (250 cm²) | Primary closure | 30 days | None |
| 6       | 46          | Male   | Recurrent infections in multiple hip replacements. | 10 × 5 (50 cm²) | Split skin Graft | 8 months | None |
| 7       | 58          | Male   | Post OP knee replacement infection | 21 × 7 (147 cm²) | Primary closure | 13 days | Re-operation day two post-operative due to venous thrombosis. |
| 8       | 69          | Male   | Staph. Aureus Infection | 18 × 7 (126 cm²) | Primary closure | 10 days | None |
| 9       | 30          | Male   | Recurrent metastasis in left inguinal region | 15 × 30 (450 cm²) | Split skin graft | 0 days | None |

* Follow up only refers to patients seen post OP at the department of plastic and reconstructive surgery. Patients with short follow up times were seen by other doctors or health care professionals that had the possibility to contact a plastic surgeon if necessary.

branches to the vastus lateralis muscle. These branches should be carefully cauterized. The main pedicle is the descending branch of the lateral circumflex femoral artery and is located in the intramuscular space between the rectus femoris and vastus lateralis muscles as seen in Fig. 1. Usually, a pedicle length of more than 8 cm can be achieved. If distally based it can be dissected up to 7 cm proximal to the patella. The flap size is determined by the defect that is to be covered. The lateral incision of the flap is made superficial to the fascia lata and dissected medially until the elevation of the flap completed. If desired, a substantial piece of vastus lateralis muscle can be included in the flap. The donor site can usually be closed directly (flap width less than 8 cm) or with a split-thickness skin graft (STSG). Proximally based flaps have a wide reach and can be rotated either medially or laterally depending on the defect that needs to be covered as seen in Fig. 2. Distally based flaps should be venous supercharged in order to prevent venous congestion and thereby necrosis.

Results

We reconstructed nine patients with a pediced ALT flap. Two flaps were applied for coverage of knee defects (infections). Four flaps for trochanteric defects (gunshot wound, hip replacement surgery, pyoderma gangrenosum, and pressure sores). One flap was used for abdominal defect (necrotizing fasciitis). One flap was applied for a gluteal defect. Finally, one flap was used to cover a defect of the inguinal region (recurrent metastasis on the left inguinal region from clear cell carcinoma on the left foot).

Two patients (patient 7 and 8) were treated with supercharged distally based ALT flaps.

The flap size ranged from 10 × 5 cm (50 cm²) to 15 × 30 cm (450 cm²) with a mean size of 222 cm².
Nine out of nine flaps survived. Minor complications occurred in two patients: prolonged healing time and an abscess under the flap, which was treated with antibiotics. One major complication occurred in one of the supercharged flaps. Temporary clotting of the greater saphenous vein used to supercharge the flap required re-operation day two post-operative, as seen in Table 1. None of the complications resulted in flap necrosis, loss of function or poor aesthetic outcome.

Seven out of nine patients had their donor site closed primarily. The remaining two patients were treated with a split-thickness skin graft. Primary closure was not possible in one of the two patients because of the considerable flap size $15 \times 30$ (450 cm$^2$). The other patient could not be closed primarily because of the location of the defect in the trochanteric region where a primary closure would result in tension on the flap.

In all cases, satisfactory functional and aesthetic outcome was achieved.

Case reports

Abdominal defect

Case no. 1:

An 81-year-old female presented with a large defect on the right side of her abdomen due to necrotizing fasciitis. The patient was admitted to the intensive care unit (ICU) but was initially a general surgery patient. The defect included an area from the inguinal region to the costal curvature and from the anterior axillary fold to the midline of the abdomen (Fig. 3a).

This considerable defect included an area measuring $10 \times 15$ cm (150 cm$^2$) where the entire abdominal wall was excised and the intestines exposed. A pedicled ALT flap with a cutaneous area measuring $26 \times 13$ cm (338 cm$^2$) and underlying fascia measuring $26 \times 20$ cm (520 cm$^2$) was raised on the descending and the transverse branch of the lateral circumflex femoral artery (Fig. 3b). Tensor
Fig. 2. The many possible recipient sites that the pedicled anterolateral thigh flap offers.

Fig. 3. A) The abdominal defect showing the area of exposed intestines measuring 10 × 15 cm. B) The pedicled ALT flap measuring 26 × 13 cm with additional underlying fascia. C) The flap is transposed to reach the exposed gut and cover the defect. The rest of the defect is covered by a split-thickness skin graft. D) The outcome at 23 days post operation follow-up.
facia lata was used to cover the exposed intestines (Fig. 3c). The rest of the defect was closed using split-thickness skin grafting from the other femur (Fig. 3d).

Trochanteric defects

Case no. 2:
A 67-year-old woman presented with a gunshot wound in her left trochanteric region. After debridement of the wound, it measured $15 \times 12$ cm ($180$ cm$^2$). (Fig. 4a)
The flap measured $10 \times 30$ cm ($300$ cm$^2$) and was based on the more distal of the two septocutaneous perforators. The donor site was closed directly. (Fig. 4b) The patient was discharged from the hospital seven days post-surgery (Fig. 4c). After 15 days, the flap was healed very well (Fig. 4d). The patient was satisfied with the aesthetic and functional outcome at follow up eight months after the operation, and no further consultations were scheduled.

Case no. 3:
A 46-year-old paraplegic male presented with a pressure sore in the right trochanteric region with an underlying peritrochanteric femur fracture. The pressure sore had a diameter of 7 cm. A $7 \times 20$ cm flap with a 12 cm long intramuscular pedicle was raised. The donor site was closed directly. The patient was discharged 11 days post-operative.

Case no. 4:
A 61-year-old female presented with an infection in her right prosthetic hip along with pyoderma gangraenosum. A pedicled musculocutaneous ALT flap was raised. A large portion of the vastus lateralis muscle was used for bulk. In order to cover the entire defect, a split skin graft was harvested.
from the left femur in combination with the ALT flap. The donor site was closed directly. She was discharged 51 days post-operative and last seen at follow-up after seven months.

Case no. 5:
A 90-year-old female known with multiple sarcoma recurrences. Histology of the primary tumor showed malignant fibrous histiocytoma. She presented with a new sarcoma recurrence in her right gluteal region. A 10 × 25 cm ALT flap was raised. A 15 cm pedicled was dissected. In order to create such a long pedicle, the ascending branch of the lateral circumflex femoral artery was ligated. The donor site was closed directly. The patient was transferred from our department 14 days post-operative and last seen in our department 15 days later.

Case no. 6:
A 46-year old male with a long history of hip surgeries and re-operations presented with septic arthritis in the left hip. The patient had previously had a hip replacement surgery. The prosthetic material was removed because of infection, and the defect covered by a pedicled fasciocutaneous ALT flap measuring 10 × 5 cm. The patient was transferred to the orthopedic department after 18 days with no flap related complications. Four months later, the patient was operated at our department with V-Y flaps to increase range of motion. The patient was last seen at follow-up seven months post-surgery.

**Patellar defects / distally based venous supercharged flaps**

Case no. 7:
A 58-year-old man known with diabetes mellitus type II, hypertension and recurring rupture of the quadriceps tendon presented with a serious infection in his right knee along with necrosis of the quadriceps tendon (Fig. 5a). The patient was initially treated by the orthopedic surgeons who performed a knee arthrodesis. The defect was covered with a distally based pedicled ALT flap. The flap measured 21 × 7 cm and included a cuff of the vastus lateralis muscle measuring 5 × 4 cm

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**Fig. 5.** A) A large defect of the right knee due to infection. B) The pedicled ALT flap raised from the right femur. C) The flap is tunneled to reach the defect and cover it. D) The flap at six days post-operative.
(Fig. 5b). The great saphenous vein was used to supercharge the flap. The donor site was closed directly (Fig. 5c). Six days post-operative the flap was healed sufficiently (Fig. 5d).

The patient was followed for five months after the operation with a satisfactory result.

Case no. 8:
69-year-old male known with chronic kidney disease initially presented with a patella fracture and infection, which resulted in necrosis of the quadriceps tendon and a skin defect. A distally based ALT flap of 7 x 18 cm was raised on two septomuscular perforators. The flap was supercharged using the great saphenous vein. The donor site was closed directly. The patient was discharged from the department of orthopedic surgery ten days post-operative.

*Inguinal defect*

Case no. 9:
A 30-year old male known with clear cell sarcoma on his right foot presented with sarcoma metastasis in the right inguinal region. After radical excision, a 15 x 30 cm pedicled ALT flap was raised to cover the defect. Two intramuscular perforators supplied the flap. The donor site received split skin grafting. The patient was discharged seven days post-operative with no complications.

**Discussion**

Since the introduction of the ALT free flap in 1984 by Song et al., the flap has gained popularity and is often described as the workhorse for the reconstruction of skin and soft tissue defects. The pedicled flap has since gained an increase in the application. The ALT flap offers a long and reliable pedicle. The flap is very versatile and can be designed to match the defect that requires reconstruction. There have been case reports of flap sizes up to 38 x 20 cm (760 cm²). The flap can be raised as an adipocutaneous, fasciocutaneous or a myocutaneous flap, depending on the requirements of the defect being reconstructed. When harvested as a myocutaneous flap it is possible to use part of the rectus femoris muscle, the vastus lateralis muscle or the tensor facia lata muscle. The muscle harvested with the myocutaneous flap depends on the individual anatomy of the patient and the requirements of the recipient site.

The pedicled flap is not as complex and significantly less time-consuming compared to a free flap that requires microsurgical anastomosis.

Large soft tissue defects at or above the patella often represent a reconstructive problem due to paucity of soft tissue options in the region. Free flaps are a good option that provides sufficient coverage. However, they require surgical expertise, prolonged operating time compared to pedicled flaps, and deep location of recipient vessels in this region. The gastrocnemius flap has become a common choice when reconstructing large defects at in patellar region. The primary disadvantage is the volume of the distal part of the muscle is small and sometimes unable to provide enough coverage for large defects around the knee joint, which can result in a knee joint with decreased mobility. Furthermore, sensory deficits, the possible need for split-thickness skin grafting at the donor site, and suboptimal overall functional outcomes have been described.

We believe that the distally based anterolateral thigh flap is a valuable alternative. The ALT flap is technically more demanding, but offers a larger variety in size and shape, with better skin match and less bulkiness, in comparison to the gastrocnemius muscle flap. It has a longer arc of rotation which allows the flap to reach suprapatellar defects and is sufficient to cover significant defects affecting the entire knee.

Usually, the pedicled ALT flap is known for reliable blood supply. However, in the distally based flaps there is a risk of venous congestion. In general, the reverse-flow flaps are criticized for their predisposition to venous congestion. This problem occurs because veins rely on small interconnections (anatomical shunts) to bypass functional valves, whereas arteries function bidirectionally. Fortunately, antegrade drainage is possible with venous supercharging to the great saphenous vein (GSV).

We believe that venous augmentation improves the reliability of the distally based ALT flap. The ALT flap is larger than many other reverse-flow flaps; therefore, sufficient venous drainage is even
more crucial. Both our patients (no. 7 and no. 8) were reconstructed with a GSV supercharged distally based ALT flap. One of our patients (no. 7) experienced a venous thrombosis. We removed the thrombosis and redid the anastomosis. After the operation, there were no further complications. None of our patients suffered from any long-term venous congestion-related problems. Therefore, prophylactic venous supercharge is recommended for the distally based anterolateral thigh flap.

Despite the growing application of the pedicled anterolateral thigh flap, the literature on the use of the venous supercharged version is still minimal. Lin et al. have described their experience with the distally based, venous supercharged ALT flap. They also found that the reliability of the flap increased when supercharged.

Since Kimata presented his experience with the pedicled ALT flap for full-thickness abdominal wall reconstruction, it has become a flap of choice for many surgeons in the reconstruction of this type of defect. We treated a patient (no. 1) for an abdominal defect in her right side that covered an area from the inguinal region to the costal curvature and from the anterior axillary fold to the midline of the abdomen. Inside this defect, there was a full-thickness abdominal wall defect measuring 10 × 15 cm (150 cm²). Fernandez-Alveraz et al. describe that one of the advantages when using the pedicled ALT flap for complex abdominal defects is the possibility to harvest a great amount of fascia which in combination with prosthetic mesh can be used to cover the exposed intestines. This was one of the primary reasons we choose the pedicled ALT flap in this patient. Furthermore, the great size of the defect in this case limited our options in alternative flaps, since the ALT flap offers one of the largest designs. The flap components consisted of a cutaneous part measuring 26 × 13 cm (338 cm²) and underlying fascia measuring 26 × 20 cm (520 cm²). The possibility to harvest such an extensive amount of skin and fascia is favorable in abdominal reconstructions because it allows the surgeon to avoid using artificial mesh and thereby minimizing potential side effects of increased intraabdominal pressure.

Long-term bedridden patients often develop pressure sores as a complication to their immobility. A common location is the trochanteric region. Instead of using the tensor fascia lata (TFL) flap which has become the primary choice for trochanteric pressure sore reconstruction since it was introduced by Nahai et al., we have reconstructed a pressure sore with the pedicled ALT flap (Patient no. 3). We have chosen this approach due to multiple factors. Chin et al. describe that the potential pitfalls of the TFL flap such as dog-ear deformity and the problem with the most distal part of the flap which is frequently poorly vascularized can be avoided by using the pedicled anterolateral thigh flap. Secondly, we saved the TFL flap for potential later use because recurrence of pressure sores is frequent in paraplegic patients, such as patient no. 3. The TFL flap is supplied by the ascending branch of the lateral circumflex femoral artery which is preserved when you raise the ALT flap.

The TFL flap is not just a popular choice when reconstructing trochanteric pressure sores but also trochanteric defects in general. We have applied the pedicled ALT flap in this region to reconstruct defects caused by a gunshot wound (patient no. 2) and patients with infections after hip replacement surgery (patient no. 4 and no. 6). All patients had a satisfactory functional and aesthetic outcome.

In modern-day plastic surgery, we seek not only to create the best possible outcome for the patient in terms of function and aesthetics at the recipient site but also at the donor site. For these reasons, the pedicled ALT flap is a valuable flap with minimal donor site morbidity and a good functional outcome. When closing the donor site, it is possible to close primarily if the width of the flap is approximately nine cm or less. If the defect is wider than nine cm a split-thickness skin graft will be needed.

To our knowledge, no randomized trials have been conducted yet. Many case series describing the different applications of the pedicled ALT flap have been published. However, due to the low level of evidence associated with a case series, the need for randomized studies is a crucial next step towards providing inferences on benefit. This would be a good objective for future studies.

**Conclusion**

Our experience with the pedicled ALT flap illustrates the versatility in the clinical application of the flap. The many advantages of the flap, including a long and reliable pedicle, the large area of skin
that can be harvested, the potential to supercharge the distally based flap and the minimal donor site morbidity highlights the diversity of defects that can be reconstructed using the pedicled ALT flap.

Declaration of Competing Interest

None.

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None.

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