Abdominal Wall Skin Loss Defects Reconstruction Using Pedicled Anterolateral Thigh Flap

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Received: 14 December 2021 / Accepted: 28 May 2022 / Published online: 7 June 2022
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Abstract
It was extremely difficult to deal with the complex full-thickness abdominal wall defect post serious trauma. The pedicled anterolateral thigh flap had been reported to be applied in reconstructing full-thickness abdominal wall defect in lower abdomen and groin. However, less cases in upper abdominal wall defect reconstructed by anterolateral thigh flap were reported due to some limitations. The aim of this study was to introduce our experiences in applying anterolateral thigh flap in upper abdominal wall defect reconstructing. In this study, seven patients with a large area of upper full-thickness defect in abdominal wall complicated with multiple organ damage were retrospectively identified due to acute trauma. Immediate organ-repair surgeries were performed. Meanwhile, the patients underwent complete debridement in the zone of abdominal wall defect, together with anti-infective treatment. Then, the appropriate timing was chosen to perform pedicled anterolateral thigh flap for reconstructing large area of full-thickness defect involving the upper abdomen. Postoperative follow-up data demonstrated that all the flaps survived, with no hernia complications or other discomforts. The outcome of the patients was also good. Thus, we conclude that pedicled anterolateral thigh flap was feasible to repair full-thickness defect in upper abdominal wall as long as well designed.

Keywords Abdominal wall defect · Pedicled anterolateral thigh flap · Reconstruction · Trauma

Introduction
Secondary abdominal wall defect (AWD) could be caused by removal of cancer tissues, serious infection, and electric injury [1]. The defected abdominal wall was supposed to be repaired and reconstructed in order to cover local skin and maintain the integrity of abdominal wall. For patients who underwent AWD reconstruction, attention should be paid to prevent the ventral hernia. In clinical practice, it was difficult to deal with the full-thickness defect in the abdominal wall induced by trauma [2]. AWD usually coexists with multiple abdominal injuries, and the vital signs were unstable in such an acute situation. Furthermore, local AWD after trauma was more complicated as it usually presented with extensive necrosis in local wound surface after severe infection. This may lead to treatment delay in patients with AWD after trauma [3]. According to previous reports, meshes or flaps were used for repairing and reconstruction of large AWD. However, the mesh repair was not suitable for full-thickness AWD with a size of > 40 cm² as it induced a high incidence of tissue necrosis or abdominal compartment syndrome (ACS) [4]. For large-sized full-thickness AWD, autologous tissue transplantation was considered to be an effective method which could promote local vascularization [5–7]. Autogenous anterolateral thigh (ALT) flap, a workhorse flap for various wounds [8], has been used for treating abdominal wall with large skin paddle defects. There exist two types of ALT flaps: pedicled [9] and free [10]. Pedicled ALT flaps are featured by better blood flow, easy to perform, low incidence of complications, large area of reconstruction, and strong anti-infective ability. So far, the applying range of pedicled ALT flap reached to the groin area and even the lower abdomen area. However, for AWD located in the upper abdomen, the selection of pedicled anterolateral thigh flap is still controversial. It had been reported by Kimata et al. that one disadvantage of pedicled ALT flap...
in abdominal wall defect reconstructing is its limited range of orientation [11]. In other words, it is difficult applying pedicled ALT flap for upper AWD or large AWD beyond the midline. In this study, we aim to investigate the efficacy of pedicled ALT flaps for the reconstruction of upper or large AWD and introduce experiences of our team.

**Patients and Methods**

A total of 7 patients with complex post-trauma AWD admitted to our hospital for treatment from 2012 to 2017 were retrospectively reviewed in this study. All patients had large full-thickness AWD, which covered the upper quadrant area of the abdomen (U area). Some of the patients presented AWDs in the lower quadrant area (L area) and the midline area (M area). AWDs in all seven patients belonged to type 2 which had unstable or absent skin cover based on Mathes’ category [4]. All patients showed intra-abdominal organ damage and other organ injuries. Physical examination and several auxiliary tests including computer tomography (CT) scan and ultrasound were performed before making a treatment regimen.

Besides upper AWD, all the patients suffered from both bladder rupture and intestinal rupture. Two cases had pelvis fracture. Bladder repair or intestinal repair was performed immediately after admission. External fixation was performed to stable the pelvic fracture. All the patients were given artificial peritoneum or using omentum to cover the defect after repairing bladder and intestinal rupture. For large abdominal wall defects, abdominal wall traction should be carried out at the same time during debridement to reduce the defect area. The wound of AWD in all patients were thoroughly debrided and treated with vacuum-assisted closure (VAC) every 5 days, together with postoperative anti-infection therapy. The new granulation tissue would completely cover the wound after 1 month. Then, the pedicled flap was transplanted.

AWD reconstruction was carried out in all the patients using pedicled ALT flaps. A detailed surgical planning was made for each patient before AWD reconstruction upon evaluating the size and location of defect. Before surgery, a hand-held Doppler probe was routinely used to locate perforator vessel of ALT flaps in order to make flap designing. The lateral circumflex femoral artery was determined as the starting point of ALT flaps. According to “flap surgery,” the midpoint between the superior iliac spine and the lateral edge of the patella was usually considered as the pulsatile point of perforator of the femoral artery on the surface of the thigh. Kimato suggested that the perforator close to the distal thigh should be selected for large ALT flap. However, the specific distance and scope were not mentioned. According to our clinical experiences in ALT flaps, we recommend a modification via moving the center point of the flap distally by 3–5 cm, in order to ensure that the distal side of the flap could reach the upper edge of the knee joint. The vastus lateralis was preserved when the island flap was cut. In the presence of musculocutaneous branch during isolation of vessels, the part of the cutaneous branch was removed apart from the muscles as much as possible. To ensure the blood supply of the flaps and the length of vascular pedicle, the cutaneous branches were preserved as many as possible. Usually, the 2–4 branches were preserved. The higher cutaneous branches were preserved to form a double-vessel pedicle accompanied with the lateral circumflex femoral artery. Nerves were deliberately protected when detaching the vessel back to its origin of the descending branch during isolation. Thus, one vascular pedicle (about 10–13 cm) was formed ideally. The island of flap was transferred through the groin subcutaneous tunnel to the defective area of the abdominal wall. Alternatively, the skin layer of the tunnel was interrupted, and the flap was stitched with the edge of defect with drainage. Finally, the donor sites were covered with split-thickness skin graft and closed.

Blood supply was monitored postoperatively combined with daily treatment of heparin. Broad-spectrum antibiotics were treated for 5 days to prevent infection. Before the application of antibiotics, local secretion was checked for cultivation, and the management of antibiotics was used based on the results of drug sensitivity tests. Patients were not allowed to move and they should stay in bed for 7–20 days at the bending position in order to reduce the tension of the vascular pedicle from the tunnel and influence blood supply. The drainage was discontinued 3 days after surgery. The patient was not allowed to lift heavy objects and climb stairs for 3 months.

**Results**

The mean age of all patients was 38.7 ± 9.2 years old. The mean size of defects was 686.9 ± 432.4 cm². The size of ALT flaps in all patients was 463.2 ± 191.1 cm². The mean length of the vascular pedicle was 11.1 ± 0.97 cm. The mean follow-up period was 47.42 ± 16.12 months. The hospital stay was 46.71 ± 4.23 days. The mean duration before AWD repair was 29.28 ± 3.35 days. Causes of abdominal wall loss in this case series are shown in Table 1. Among the seven patients, three of them had abdominal wall defect due to explosive injuries accompanied by damage to the abdominal organs. The remaining four patients suffered defects of the abdominal wall skin due to a car accident with multi-organ damage.

All patients experienced extensive resection and flap transfer some days after acute multiple organ repair. All flaps survived without re-exploration postoperatively. There were no complications of thrombosis and infection post operation in all patients. During regular 3-month follow-up, the results
showed that satisfactory coverage was achieved with soft texture and moderate thickness. By the 6 months of follow-up evaluation of the straight-leg-raising test, there were no complications of ventral hernia, or other discomforts. All the patients returned to normal life 1 year later.

In case 1, a 27-year-old gentleman (65 kg) presented intestinal rupture and hand defect after a high explosion. The defect was located in both the upper abdomen and lower abdomen. In addition, he had a large AWD (22 × 28 cm) that covered the upper, lower, and middle areas in the abdomen. The length of the vessel pedicle was 11 cm while the skin paddle size was 20*27 cm. After admission, he underwent an immediate surgery of intestinal repair and extensive debridement in the abdominal wound. After regular dressing per week, the reconstructive surgery for AWD and hand defect was achieved using ALT flap. The flap survived well postoperatively with blood supply. Also, his condition maintained favorable without any complication during postoperative follow-up. The recovery of abdominal wound was good with no pain, and abdominal bulging was slight (Fig. 1).

A 52-year-old lady patient (75 kg) suffered from severe trauma after a serious traffic accident. The defect was located in both the upper abdomen and lower abdomen. In addition, she had a large AWD (22 × 28 cm) that covered the upper, lower, and middle areas in the abdomen. The length of vessel pedicle was 11 cm while the skin paddle size was 20*27 cm. After admission, she underwent an immediate surgery of intestinal repair and extensive debridement in the abdominal wound. After regular dressing per week, the reconstructive surgery for AWD and hand defect was achieved using ALT flap. The flap survived well postoperatively with blood supply. Also, her condition maintained favorable without any complication during postoperative follow-up. The recovery of abdominal wound was good with no pain, and abdominal bulging was slight (Fig. 1).

### Table 1 Patient data and characteristics

| Age/gender | Cause                 | Location       | Defect size | Acute complication | Skin expansion | Vessel pedicle | Skin paddle size |
|------------|-----------------------|----------------|-------------|--------------------|----------------|----------------|------------------|
| 27y/m      | High explosion        | U and L M2 and M3 | 28*22       | Intestinal rupture | No             | 11             | 27*20            |
| 41y/m      | Traffic accident      | L              | 24*18       | Bladder rupture    | No             | 9              | 22*18            |
| 35y/m      | Traffic accident      | U and L        | 32*24       | Intestinal rupture | No             | 11             | 28*21            |
| 52y/f      | Traffic accident      | U and L        | 40*24       | Bladder rupture    | Yes            | 12             | 35*24            |
| 29y/m      | High explosion        | U and L        | 29*21       | Intestinal rupture | No             | 10.6           | 25*20            |
| 48y/f      | Traffic accident      | U              | 23*20       | Ribs fracture      | No             | 11             | 20*19            |
| 39y/f      | Traffic accident      | L              | 25*22       | Intestinal rupture | No             | 8.5            | 23*20            |

U, upper; L, lower; M, midline

Discussion

The reconstruction of full-thickness AWDs involved two main aspects, including repair of the stability of the abdominal wall and the skin or soft tissue defects. Defect with a small size can be directly closed. However, full-thickness AWDs with larger area usually require the reconstruction of the abdominal wall. It was reported that for the repair of large areas of soft tissue defects in the abdominal wall, pedicled or free autologous tissue flaps were usually performed for the management of AWD reconstruction. Different kinds of soft tissue flaps were utilized for the repair of defect at different locations.

ALT flap had been commonly used for various soft tissue defects [12]. There are some evidences that indicated that ALT flap was a good choice for full-thickness and complex AWD involving a large size [8]. To date, there are still controversies in the utilization of pedicled ALT flaps in the upper abdomen. In a previous study, the pedicled ALT flap alone can be used for reconstruction of lower AWDs [13]. Tamai et al. in 2015 reported that only less than a third of the pedicled ALT flaps could approach the umbilicus due to limited arc and pedicle [14]. Apparently, the pedicled ALT flap was not preferred for treating AWD above the umbilicus. On this basis, free ALT flaps were recommended for the management of full-thickness defect in the upper abdomen [15]. Nevertheless, free ALT flap requires microsurgical vascular anastomosis, which was more difficult and technically demanding. Meanwhile,
the vascular condition in donor and recipient area was supposed to be important for the vascular anastomosis. In this study, the AWD of our patients was caused by trauma. However, there were no candidate vessels to be selected for anastomosis that were associated with local infection. Thus, we suggested to use pedicled ALT flap instead of free ALT for a large or complex defect, particularly in a traumatic condition that required late construction.

Tissue expansion has been adopted to minimize the defect [16]. In our study, based on skin expansion, the defect area was reduced obviously in patients who had large defect before reconstructive surgery. During the surgery, the original large area defect in the abdomen was reduced via stretching the skin with silk threads. Therefore, after pulling skin co-combined with ALT, the large-sized AWD in the upper abdomen was successfully repaired. Moreover, there were compound injuries in our patients. The original surgery was usually performed by general and urology surgeons to repair the bowel and bladder.

Both mesh and surgical techniques contribute to the AWD reconstruction [3, 17]. Nevertheless, it is impossible to use mesh alone to close the large-sized defect. Surgical autograft is the only approach for the repair of defect, and mesh is used to reinforce the abdominal wall. In a previous study [18], three cases that underwent mesh for treating large AWD showed a low recurrence. Meanwhile, Deerenberg et al. in 2015 reported that mesh reinforcement repairing incisional hernia showed a low recurrence rate and hazards [19]. According to our experiences, long-term follow-up showed good outcomes without recurrence and hernia. Meanwhile, abdominal bulging was slight after repair. It has been believed that mesh is not necessary to treat collaborated with surgical technique regarding good prognosis. The broad fascia was achieved as far as possible with deep fascia edges to strengthen the intensity of the abdominal wall. It was considered that the disadvantages of the pedicle flap were its limited range of orientation [11]. As the vascular pedicle of

![Fig. 1 The general views of AWD in case 1. A, before reconstruction; B, holistic view of the flap; C, the thigh flap area was covered by skin grafting; D, enlarged view of the pedicle; E, immediate view of post reconstruction; F, 3 weeks after reconstruction; G, 3 months after reconstruction.](image-url)
pedicled flap was not long enough for the rotation. Kuo et al. in 2004 reported that in the surgical process, the primary muscle branch to the rectus femoris from the descending branch of the lateral circumflex femoral artery was supposed to be isolated for further lengthening vascular pedicle [20]. Then, the flap was completely separated to allow rotation of 180° in their study [15]. Based on our experience, the blood supply of ALT was provided by the direct perforators from muscular clearance and the indirect perforators through the vastus lateralis muscle. It is not necessary to keep the primary muscle branch to the rectus femoris. However, during the surgery, it was suggested to keep the higher cutaneous branches to form double strengthened blood vessel pedicle. The starting point for higher cutaneous branches is generally near the starting point of the lateral femoral circumflex artery. Therefore, retaining the dual vascular pedicle will not affect the length of the vascular pedicle. Hence, a modified eccentric design is able to assist to extend the distance of vascular pedicle of the flap.

Taken together, it is feasible that pedicled ALT flaps can be used for the reconstruction of large and complex AWDs involving the upper abdomen since they have enough long pedicles and wide arcs with better blood supply. The procedures are easy to perform with no demanding of vascular anastomosis. It is technically simple to apply as a myocutaneous/fasciocutaneous flap with minimal donor site morbidity.

**Declarations**

**Ethical Approval** This research study was conducted retrospectively from data obtained for clinical purposes. We consulted extensively with the IRB of Qilu Hospital of Shandong University who determined that our study did not need ethical approval. An IRB official waiver of ethical approval was granted from the IRB of Qilu Hospital of Shandong University.

**Competing Interests** The authors declare no competing interests.

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