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Perforator Mapping and Optimizing Design of the Lateral Arm Flap: Anatomy Revisited and Clinical Experience

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Short Running Title: Lateral Arm Flap Perforator Anatomy

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Abstract

Introduction: The lateral arm flap remains an underutilized flap especially as a free flap. Here, we describe the perforator anatomy to optimize flap design and harvest.

Methods: Perforator locations were mapped in 12 cadavers (24 arms), including a retrospective review of 51 patients undergoing a lateral arm flap.

Results: One to 3 reliable perforators supply the lateral arm flap. Based on cadaveric dissections, from the deltoid insertion, the A, B, and C perforators were located at 7.2±1.0cm, 9.9±1.2cm, and 11.8±0.8cm which was 0.44, 0.61, and 0.72 of the distance from the deltoid insertion respectively. The average pedicle length was 7.0±1.1cm. The cadavers were entirely symmetric in the number and location of the perforators between the right and left arms. All 51 patients (24 male and 27 female) had at least one perforator with an average pedicle length of 7.0±1.3cm, average arterial diameter of 1.7±0.3mm and vein diameter of 2.5±0.5mm. All but one flap was performed as a free flap for head and neck reconstruction with one pedicled flap for shoulder reconstruction. The average flap size was 72.2±37.1cm^2 (range: 21-165cm^2). The non-dominant arm was used for all free flaps. There were no total or partial flap losses. Twenty-eight patients reported donor site numbness, with one infection, one hematoma, and one wound dehiscence.

Conclusions: The lateral arm flap can be harvested reliably based on well-defined perforators and anatomic landmarks with minimal donor site morbidity and should be included in the armamentarium of reconstructive microsurgeons.

Introduction

The lateral arm flap remains a secondary flap for most reconstructive microsurgeons despite a number of reports delineating the anatomy and successful outcomes for reconstruction of a variety of defects. [1-5] Despite the thin pliable tissue that can be harvested, and the added benefits of minimal donor site morbidity with primary closure of the donor site, the lateral arm flap has not gained the popularity seen with other fasciocutaneous flaps. [6-10] Some factors reported that have limited the utility of the lateral arm flap include inconsistent perforator anatomy, short pedicle length, small vessel caliber, and challenging flap dissection. [11] However, others have found the lateral arm flap to be a workhorse flap that can even be harvested as a chimeric flap including bone, and have reported high success rates in head and neck reconstruction as well as extremity reconstruction. [12-14]

Nonetheless, surgeon comfort and preference are factors that often dictate which flaps are selected. Here, we provide an anatomic description of the lateral arm flap based on cadaveric dissections and our clinical experience. The present study aims to provide a simple means of identifying the perforators and flap design based on reliable anatomic landmarks that can facilitate flap harvest similar to other studies describing the anterolateral thigh flap or ulnar artery perforator flap. [15-16]

Methods

Patients

All lateral arm free flaps performed by the authors were included in the study. Measurements of perforator location, number of perforators, path of perforators, and landmarks were recorded. A retrospective chart review was performed of all patients undergoing a lateral arm flap at a tertiary university hospital from 2008-2015 after Institutional Review Board approval. The medical records were reviewed paying particular attention to the operative notes, post-operative follow-up, and complications. Records were also reviewed for clinical indication, pathologic diagnosis, demographics, comorbidities, smoking, adjuvant therapies such as radiation, and complications.

Cadaver Dissection

Twelve fresh cadavers were dissected following injection with latex, and the perforator locations were mapped in relation to the deltoid insertion and lateral epicondyle. The flap elevation was performed as described in the following section, and both arms were dissected in an identical fashion paying careful attention to map the perforators in each arm.

Lateral Arm Flap Anatomy

The lateral arm flap is a fasciocutaneous flap that is supplied by the radial collateral artery that branches from the brachial artery. The perforators travel from the radial collateral artery to the skin through the septum between the biceps brachii muscle and the triceps muscle. The radial nerve emerges from the brachial plexus on the posterior aspect of the humerus and travels anteriorly around the humerus where it is in close proximity to the pedicle. As the pedicle progresses more proximally, the pedicle passes deep the deltoid insertion where it joins with the brachial artery.

Surgical Technique

The arm is placed across the patient's torso and the deltoid insertion and lateral epicondyle are marked (**Figure 1a**). A line is drawn connecting these two landmarks and the septum is palpated between the triceps and biceps muscles. The posterior incision is made and a subfascial dissection is performed from a posterior to anterior direction. The septum is approached and the perforators are identified (**Figure 1b**). Careful attention must be paid to identifying the radial nerve which clearly must be preserved during the dissection. However, the posterior antebrachial cutaneous nerve of the arm, a sensory branch of the radial nerve, will need to be divided in order to free the perforators and pedicle. The posterior antebrachial cutaneous nerve is ligated distally, and this sensory nerve can be utilized to perform a sensate flap if necessary. While the main nerve travels with the pedicle and progresses distally ending in small cutaneous branches, there are a number of smaller fascicles that travel with the perforators allowing the design of a sensate flap. Once the perforators are identified, the anterior incision is made and the flap is elevated preserving the perforators to the skin paddle. The distal pedicle is ligated and the flap can be elevated from a distal to proximal direction. Occasionally the pedicle can be adherent to the humerus and requires dissection releasing the periosteum to separate the pedicle from the humerus. The pedicle can then be dissected as proximally as possible to obtain longer pedicle length and larger caliber vessels. The deltoid insertion can be divided in order to gain further pedicle length if necessary.

The pedicle was dissected as proximally as possible to the bifurcation and the maximal length was also recorded. The arterial diameter was measured based on the microsurgical background (Synovis Inc., Birmingham AL) with millimeter markings while the venous diameter was based on the coupler size (Synovis Inc.) used for the microvascular anastomosis.

Results

Cadaveric Dissection

Twelve cadavers (males: 5, females: 7) were dissected and demonstrated identical symmetric perforators in the right and left arm in number and location. There were one to three perforators identified in all arms (n=24). The first perforator (A) was found 7.2 ± 1.0 cm from the deltoid insertion while the second perforator (B) was found 9.9 ± 1.2 cm, and perforator C was found 11.8 ± 0.8 cm from the deltoid insertion. Using the deltoid insertion and lateral epicondyle as landmarks, the A, B, and C perforators were located 0.44, 0.61, and 0.72 the distance from the deltoid insertion respectively. Five cadavers were found to have all 3 perforators, 6 cadavers had 2 perforators, and 1 cadaver had one perforator. The location of the perforators was symmetric between the right and left arms. Each cadaver had the same number of perforators in the same location in both arms. The overwhelming majority of perforators were septocutaneous in nature with only 5 of the 56 perforators (8.9%) passing through a short intramuscular course. The average pedicle length was 7.0 ± 1.1cm.

Patients

Overall, 51 patients (males: 24, females: 27) underwent a lateral arm flap with a mean age of 60.7 ± 13.4 years and mean BMI 28 ± 6.1 kg/m^2. The average flap sizes were 72.2 ± 37.1 cm^2 (range 21-165 cm^2), with average dimensions 6.5 x 10.5 cm (range

3x7 cm – 11x15 cm). All flaps were performed for head and neck reconstruction, while one pedicled lateral arm flap was performed for coverage of a shoulder defect following resection of a sarcoma. The non-dominant arm was used as the donor site for all flaps except for the pedicle flap that involved the patient's dominant right arm. The remaining demographics are presented in **Table 1**. All flaps had at least one perforator in the locations identified in the cadaveric dissections (**Table 2 and Figure 2**). The posterior cutaneous nerve of the arm often needs to be divided as it travels directly with the pedicle and perforators; however, the main radial nerve runs in close proximity with the pedicle and was preserved in all dissections (**Figure 3 and 4**). The average pedicle length was 7.0 ± 1.3 cm which was comparable to the pedicle length documented in the cadaveric studies. Measurements of the vessels diameters demonstrated an average arterial diameter of 1.7 ± 0.3 mm and an average venous diameter of 2.5 ± 0.5 mm. There were no flap losses. With an average follow-up of 34.1 months (range: 3-160), 33 patients (64.7%) were alive with no evidence of disease. The remaining patient outcomes are shown in **Table 1**.

Donor Site

The donor site was closed primarily in all but one patient who required a skin graft. One patient developed a hematoma of the donor site requiring surgical evacuation. One patient developed a superficial infection that resolved with oral antibiotics, and another patient suffered superficial dehiscence of the donor site that was managed conservatively and healed secondarily with local wound care. The remaining donor sites healed without complication (**Figure 5**). In certain circumstances, a branch of the posterior antebrachial cutaneous nerve had to be divided in order to separate the perforators from the main radial nerve; however, only 28 patients (59.6%) reported an area of numbness in the distribution of the nerve. No patients underwent repair of the nerve. No patients reported any limited range of motion or changes in strength following flap harvest.

Anatomic Variations

In two patients undergoing a free lateral arm flap, an anatomic variation was noted where a separate pedicle was present supplying one of the perforators. Both patients had a B and C perforator; however, each perforator arose from a separate pedicle. Proximal dissection of the pedicle demonstrated that the two pedicles did not converge into a single pedicle, and the decision for which perforator to preserve was based on pedicle length and caliber. In one circumstance the B perforator was used which provided a larger perforator with an adequate caliber pedicle, but a shorter pedicle. The other patient's flap was harvested on the C perforator which was smaller, but had a longer pedicle length necessary to reach the recipient vessels (**Figure 6**).

Discussion

The lateral arm flap was first described in the 1980's;[1] however, it continues to be considered a secondary flap typically when other flaps such as a forearm or an anterolateral thigh flap are not available. The hesitation to utilize the lateral arm may stem from unfamiliarity with the anatomy or perceived limitations of the flap itself such as small caliber vessels, shorter pedicle length, and potential risk of injury to the radial nerve. Another consideration is the difficulty in utilizing a two-team approach if the resection occurs in close proximity to the lateral arm donor site; however, a forearm flap would have similar limitations in allowing a two-team approach. However, with the identification of reliable perforators based on anatomic landmarks, the flap can be harvested reliably centering the skin paddle on anticipated location of perforators similar to other studies describing other free flap donor sites. [15-16] Knowing the location of the perforators allows reliable planning of the incision without the need of imaging or Doppler to identify the perforators, and the reconstructive microsurgeon can be confident a perforator exists that can support a flap. Adequate sized perforators were identified in all cadavers and patients, and the perforators provided sufficient perfusion of the flap with no patients developing compromised flap perfusion, partial flap loss, or total flap loss.

Despite the limitations described, the lateral arm flap can provide thin pliable tissue with minimal donor site morbidity. The donor site can be closed primarily for flaps less than 7 cm in width without difficulty which is preferable to a skin graft as is often necessary for a forearm based flap, especially the radial forearm. In certain patients the flap can be too thick to replace a forearm flap; however, in other patients, the lateral arm may be only slightly more bulky which may shrink following radiation therapy. However, primary closure of the donor site can avoid the social stigmata associated with the forearm donor site, especially in Asian cultures. Only one patient in our series needed a skin graft for the donor site. The donor site morbidity of patients undergoing the lateral arm flap was marginal with 28 patients noting numbness overlying the distribution posterior antebrachial cutaneous nerve. The nerve often travels in close proximity to the pedicle and the perforators and often is divided to minimize risk of injury to the vessels. However, if the main nerve segment is divided in order to release the perforators, immediate primary repair can restore sensory function. [17-19] Alternatively, because the nerve sends fascicles to the overlying skin paddle typically along the vessels and perforators, a sensate flap can be harvested which have been shown to improve functional outcomes in glossectomy reconstruction. [20] No patients experienced permanent pain, weakness, or significant debilitation from flap harvest which is comparable to previous studies examining the donor site morbidity of other popular flaps such as forearm flaps or the anterolateral thigh (ALT) flap. [16, 21-22]

With the increasing experience and comfort with perforator flaps, the lateral arm flap can easily be incorporated into the reconstructive microsurgeon's armamentarium of flaps with the benefit of providing a thin flap with minimal donor site morbidity. [23-24] With the reliable perforator anatomy documented in the study, consistent symmetry between the right and left arm allowing selection of the non-dominant arm, and average pedicle length of 7 cm, the lateral arm flap provides some attractive options when the thigh is too thick as may occur in Western cultures and avoids the donor site morbidity of a skin graft to a forearm flap. However, in general, the lateral arm is still thicker than the forearm, so in circumstances when slightly more bulk is necessary, the lateral arm represents an attractive option to consider.

Another potential reason for the limited use of the lateral arm flap is the pedicle. In the current study, we demonstrate that the average pedicle length was approximately 7 cm which may require a vein graft in certain circumstances although none of the patients in the current study needed a vein graft to reach the recipient vessels. However, this is comparable to the average pedicle length of the ulnar artery perforator flap which is gaining in popularity. The vessel diameters are also adequately sized with nearly a 2 mm artery and a 2.5 mm vein, and should not pose any difficulty for the microvascular anastomoses or result in significant size mismatches given the variety of recipient vessels particularly in the head and neck region. Knowing the average length and size of the pedicle is also critical in flap design allowing the reconstructive microsurgeon to optimize flap design and plan the use of recipient vessels. For example, in the setting when a longer pedicle is needed, the operating surgeon can preferentially plan on using a more distal perforator to obtain greater pedicle length. Fortunately, the most common perforator was the C perforator which can provide a slightly longer pedicle length if necessary.

Unfortunately, the present study is limited to patients treated at our institution, and body habitus is an important factor to be considered. While we are not recommending the lateral arm flap as a primary flap, the lateral arm flap may serve as a useful alternative when the forearm or thigh is not usable. In general if a thin pliable flap is needed, we prefer using a forearm flap or the ALT if the tissue is thin enough. However, for obese patients, the ALT flap may be too thick, or in thin, emaciated patients, the forearm may be prohibitively thin. In these circumstances, the lateral arm is a useful intermediate thickness alternative that can be incorporated into the reconstructive microsurgeon's armamentarium.

Similar to the ALT flap where a perforator may arise from a transverse or oblique branch off the main lateral descending circumflex femoral vessels, [25] we did encounter two patients who appeared to have a separate pedicle supplying the perforators. In such scenarios, the operative microsurgeon will need to assess which perforator and pedicle to use. Conversely for patients with limited tissue in the forearm, the lateral arm flap can be a reliable alternative providing adequate tissue without the need for a skin graft to resurface the donor site. Nonetheless, the present study provides consistent guidelines for flap design and harvest as all flaps had at least one perforator in reliable locations, and all patients who underwent a lateral arm flap were successfully reconstructed with no flap losses, and no significant donor site complications.

Conclusions

The lateral arm flap can be reliably harvested based on septocutaneous perforators consistently located 7.2 cm, 9.9 cm, and 11.8 cm from the deltoid insertion with an average pedicle length of 7 cm. Given the symmetric location and reliable nature of the perforators, the non-dominant arm can always be utilized further limiting the donor site morbidity of the flap.

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Figure Legends

Figure 1a: Positioning of the arm for the harvest of the lateral arm flap with the elbow flexed and the forearm lying across the patient's torso. **1b**: Graphical representation of anatomic landmarks for optimal harvest of lateral arm flap. A white * marks the deltoid insertion, and the black * marks the lateral epicondyle.

Figure 2: Graphical distribution of perforator locations identified based on ratio of distance from deltoid insertion to lateral epicondyle. The contour of the deltoid is marked and the lateral epicondyle is noted with an *.

Figure 3: Dissection of lateral arm flap from the posterior approach identifying the perforators (black asterisks) and the posterior brachial cutaneous nerve (white asterisk) that is divided in order to harvest the flap but also allows for a sensate flap if needed.

Figure 4: Elevated lateral arm flap demonstrating pedicle length and preservation of the radial nerve (white asterisk).

Figure 5: Postoperative photo of lateral arm donor sites when used as a pedicle flap for reconstruction of a shoulder/deltoid defect (**a**) and as a free flap (**b**).

Figure 6: Anatomic variation demonstrating a B and C perforator that did not arise from the main pedicle and failed to join together more proximally. In such situations, the decision for which perforator to keep should be made based on pedicle length and caliber.

Tables

Table 1: Demographics and outcomes of patients undergoing lateral arm flap.

Age	60.7 ± 13.4 years
Gender	27 females (52.9%)
BMI	28 ± 6.1 kg/m^2
CAD	7 (13.7%)
DM	3 (5.9%)
HTN	20 (39.2%)
Smoker	29 (56.9%)
Preoperative Radiation	17 (33.3%)
Preoperative Chemotherapy	12 (23.5%)
Outcomes	
No Evidence of Disease	33 (64.7%)
Alive with Disease	4 (7.8%)
Death Secondary to Disease	9 (17.6%)
Death of Other Cause	5 (9.8%)

Table 2: Number of A, B, and C perforators in the lateral arm flap.

Perforator	Number
Perforator A	21
Perforator B	28
Perforator C	30
Pedicle Length	7.0 ± 1.1cm

Figure 1.

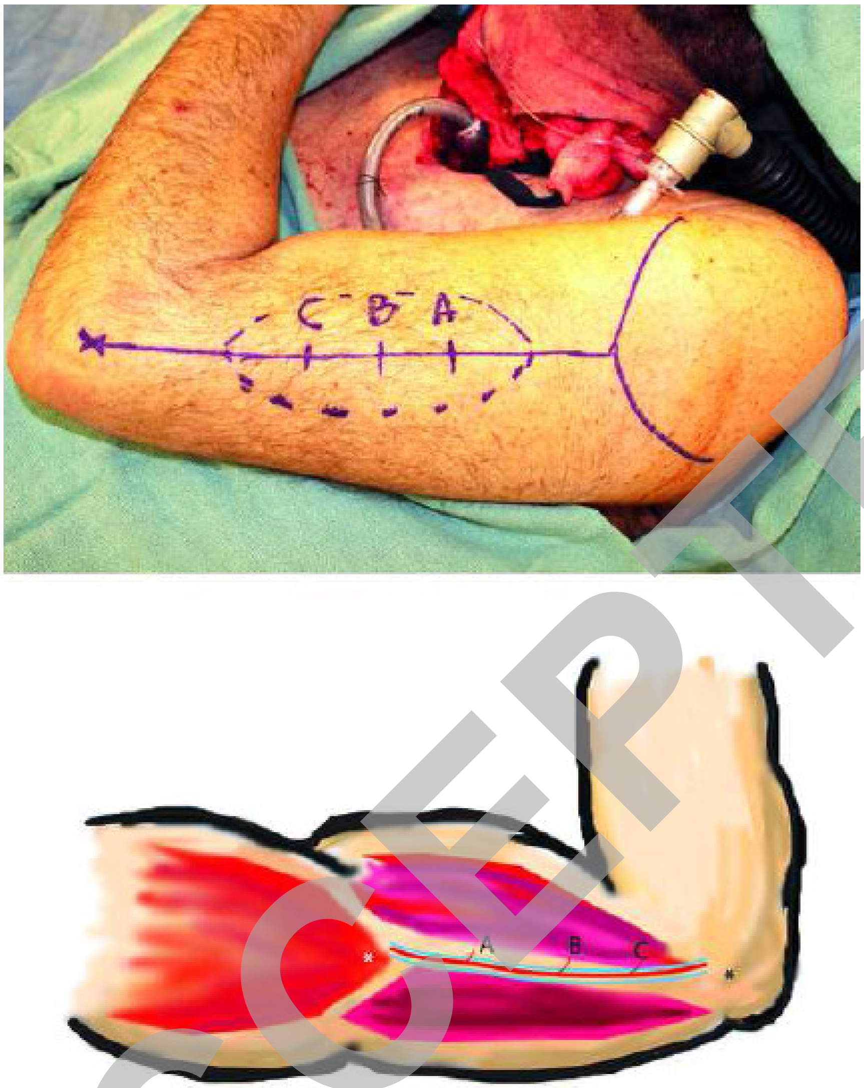

Figure 2.

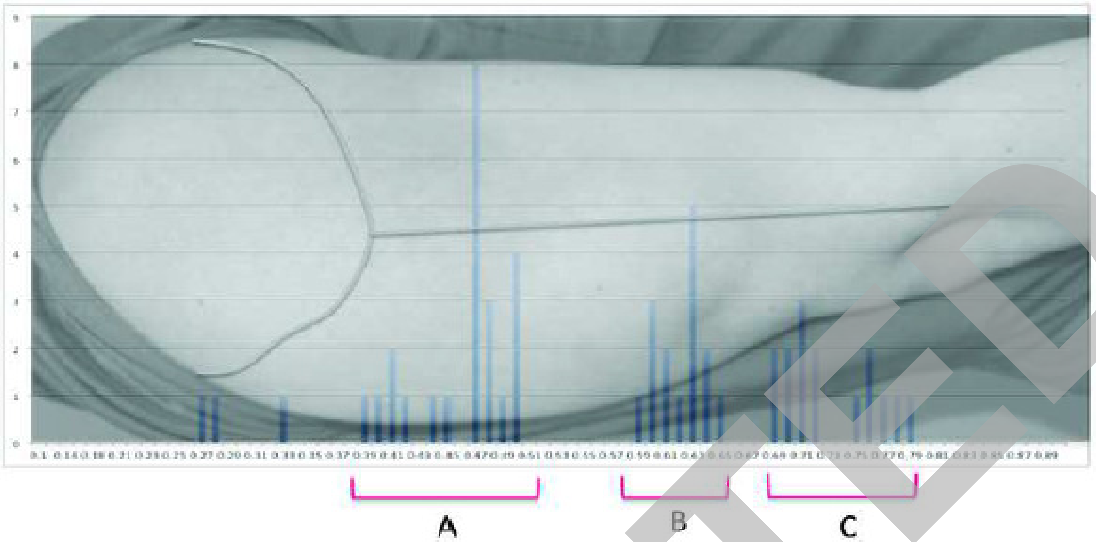

Figure 3.

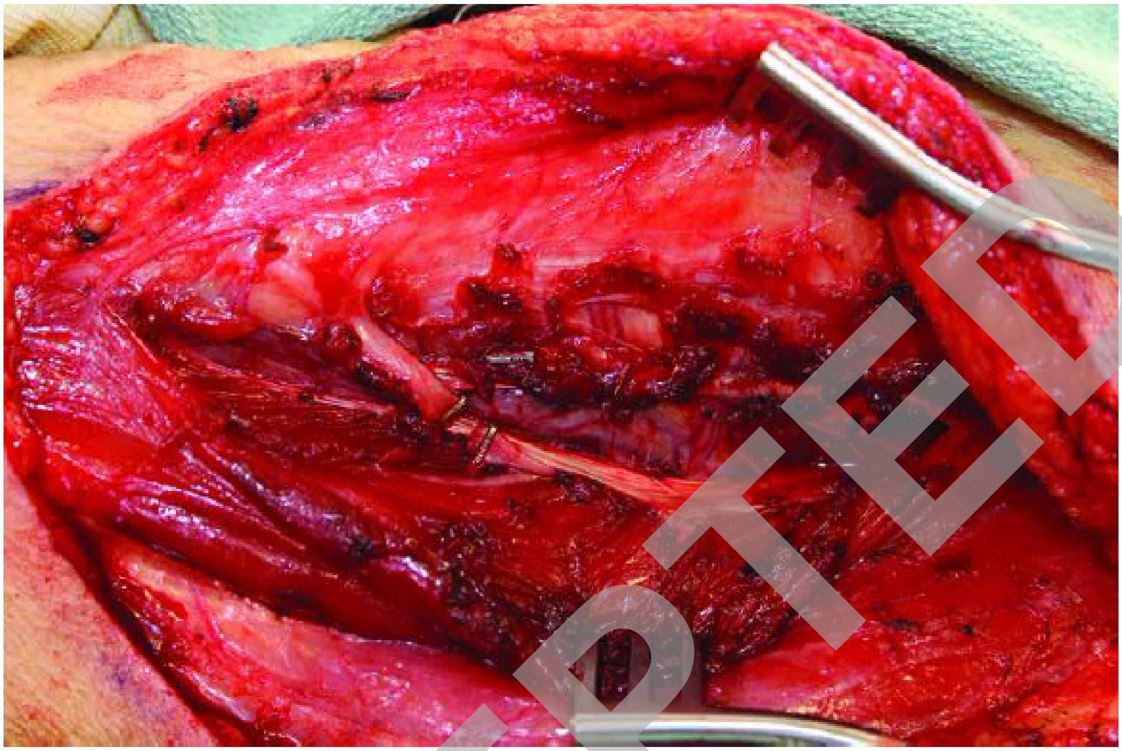

Figure 4.

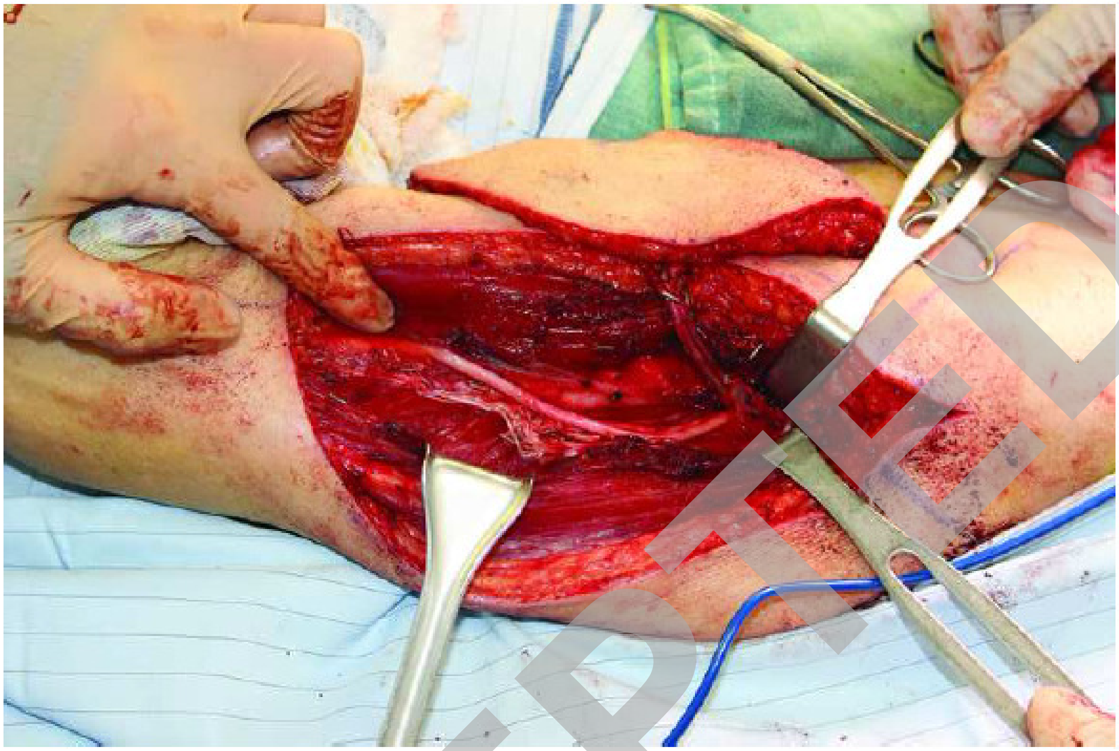

Figure 5.

Figure 6.