The Lateral Intercostal Artery Perforators: Anatomical Study and Clinical Application in Breast Surgery

Moustapha Hamdi, M.D., Ph.D.
Andrea Spano, M.D.
Koenraad Van Landuyt, M.D., Ph.D.
Katharina D'Herde, M.D., Ph.D.
Phillip Blondeel, M.D., Ph.D.
Stan Monstrey, M.D., Ph.D.

Gent, Belgium

Background: The lateral intercostal artery perforator flaps are based on intercostal perforators that arise from the costal groove. Cadaver dissections have been performed to improve the understanding of lateral intercostal perforator anatomy. The clinical applications of this study are demonstrated.
Methods: The intercostal perforators were dissected in 24 fresh cadavers and evaluated in a field that extended between the third and the eighth intercostal spaces and between the latissimus dorsi and pectoralis major muscles. Their relationship with the anterior border of the latissimus dorsi muscle and the serratus anterior vessels was investigated.
Results: A mean value of 3.91 perforators per side was found. The majority of the intercostal perforators were found between the fifth and the eighth intercostal space level (88.4 percent). Mean distances of intercostal perforators to the anterior border of the latissimus dorsi muscle varied between 2.67 and 3.49 cm. The largest or "dominant" perforator was most frequently found in the sixth intercostal space (38.6 percent of cases) at an average of 2.5 to 3.5 cm from the anterior border of the latissimus dorsi muscle. In 10 of 47 sides (21 percent), vascular connections were found between the serratus anterior branch and the intercostal perforators. The connection was observed more frequently in the seventh and the sixth intercostal spaces, in 38 percent and 30 percent of cases, respectively. This vascular connection enables harvest of a serratus anterior artery perforator flap.
Conclusion: Lateral intercostal artery perforator flaps can be used to address challenging defects over the breast without sacrificing the pedicle of the latissimus dorsi muscle. (*Plast. Reconstr. Surg.* 121: 389, 2008.)

Many previously described myocutaneous flaps can alternatively be harvested as skin flaps based only on the perforators. The lateral intercostal neurovascular pedicle flap was first described as a musculocutaneous flap[1,2] and later as a perforator flap.[3] Intercostal artery perforator flaps are new in the reconstructive ladder.[4–7] We have recently described the use of intercostal artery perforator flaps for the reconstruction of defects over the thorax, with special focus on the breast region.[6,7] The costal segment of the intercostal vessels gives several perforators to the skin by means of the intercostal, serratus anterior, and latissimus dorsi muscles. The lateral intercostal artery perforator flap can be harvested based on these perforators.

The lateral intercostal artery perforator provides an elegant option with which to fill a defect in the breast because it spares the underlying muscles and their main blood supply. However, because there have been no anatomical studies evaluating the anatomy of these perforators, harvesting the lateral intercostal artery perforator flaps can be hazardous and unpredictable. The purpose of this article is to clarify the location and distribution of the cutaneous perforators of the intercostal vessels in the high lateral thoracic re-

From the Plastic and Reconstructive Department, Gent University Hospital, and the Department of Anatomy, Embryology, Histology, and Medical Physics, Gent University.
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gion. The clinical application of these findings to reconstruction of subtotal defects of the breast is demonstrated.

MATERIALS AND METHODS

We dissected 24 fresh formalin-preserved cadavers, consisting of 10 male and 14 female cadavers. One of the 48 sides was excluded from the study because of previous thoracic surgery. The cadavers were placed in the lateral decubitus position, with the ipsilateral arm positioned in 90 degrees of shoulder abduction and 90 degrees of elbow flexion.

The skin was elevated from the spine to the lateral border of the breast. Cutaneous perforators were evaluated throughout the region extending from the anterior border of the latissimus dorsi muscle to the lateral border of the pectoralis major muscle and between the third and eighth intercostal spaces. Every perforator vascular bundle (artery and vein) greater than 0.5 mm in diameter was mapped, and its relationship to the intercostal spaces and the distance from the anterior border of the latissimus dorsi muscle were noted (Fig. 1, *above*).

We performed the suprafascial dissection using 4.5× loupe magnification. The perforators were dissected toward the skin and toward the chest to evaluate their origin and their connections to the thoracodorsal, intercostal, and serratus anterior vessels. Moreover, the largest or so-called dominant perforator was also identified and mapped. The number of perforators found in each intercostal space was noted. In addition, the average distance of the perforators from the latissimus dorsi muscle was noted.

RESULTS

A total of 184 perforators in 24 cadavers were identified and mapped, with a mean value of 7.83 perforators per cadaver and 3.91 perforators per side. The distribution and number of intercostal perforators are listed in Table 1. The highest concentration of intercostal perforators was found between the fifth and eighth intercostal spaces (88.4 percent). The mean distance of intercostal perforators from the anterior border of the latissimus dorsi muscle varied between 2.67 and 3.49 cm. The lateral intercostal artery perforator flaps can be raised on one of these perforators (Figs. 2 and 3).

A dominant perforator was identified in 44 of 47 (93.6 percent) dissected sides. No dominant perforator was found in three dissected specimens (6.4 percent). The dominant perforator's distribution and distance from the anterior border of the latissimus dorsi muscle are listed in Table 2. No dominant perforators were identified in the third intercostal space. Retrograde dissection of

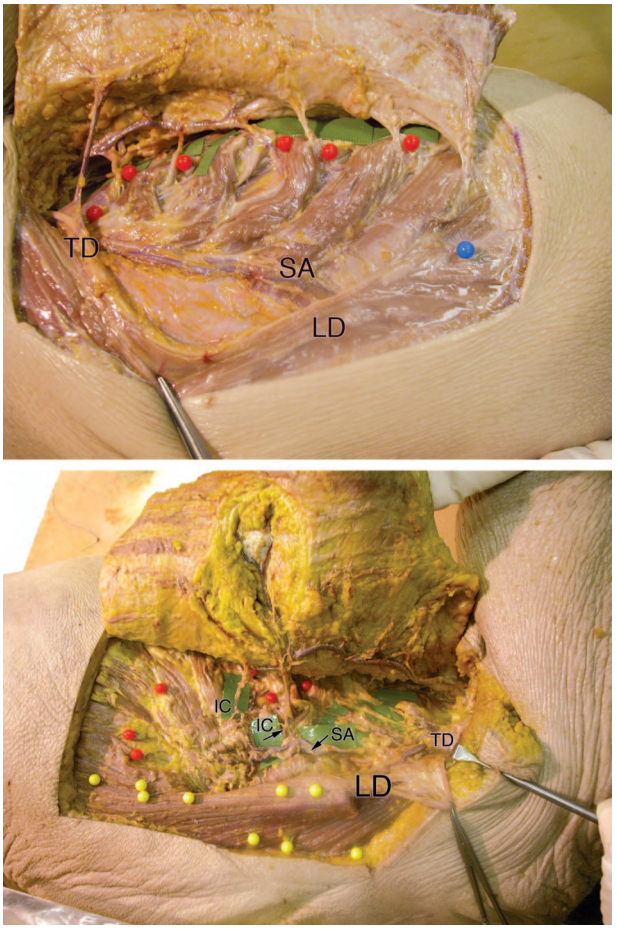

Fig. 1. (*Above*) The intercostal perforators (*red dots*) were mapped within the intercostal spaces and their relationship was identified with thoracodorsal (*TD*) and serratus anterior (*SA*) vessels and their distance from the anterior border of the latissimus dorsi (*LD*) muscle. (*Below*) A vascular connection between the intercostal (*IC*) perforators and the serratus anterior (*SA*) vessels is demonstrated.

Table 1. Number of Perforators Dissected in the Intercostal Spaces and Their Mean Distance from the Anterior Border of the Latissimus Dorsi

	ICS3	ICS4	ICS5	ICS6	ICS7	ICS8
No.	4	17	38	46	47	32
%	2.2	9.2	20.7	25	25.5	17.4
Distance from LD, cm						
Mean	2.75	3.03	3.26	3.49	3.06	2.67
Min	2.00	1.00	0.00	0.00	0.00	0.50
Max	3.00	5.00	7.00	7.00	6.00	6.50
SD	0.50	1.30	1.82	1.87	1.61	1.65

ICS, intercostal space; LD, latissimus dorsi.

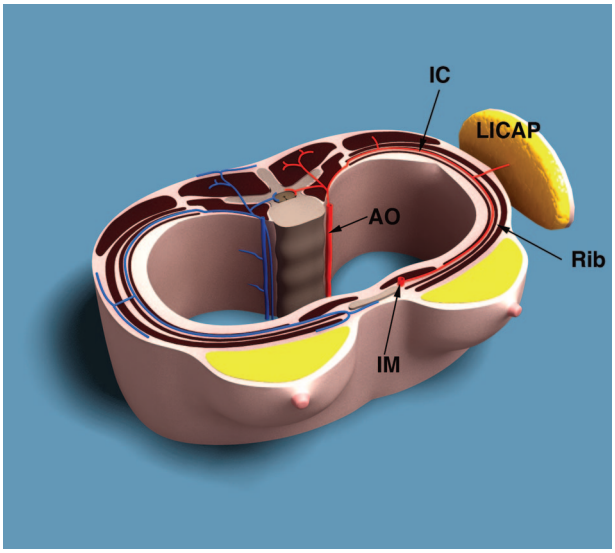

Fig. 2. Schematic diagram depicting the origin of the intercostal (*IC*) vessels, which form an arcade between the aorta (*AO*) and the internal mammary (*IM*) vessels. The lateral intercostal artery perforator (*LICAP*) is based on one of the perforators that originates from the costal segment of the intercostal vessels.

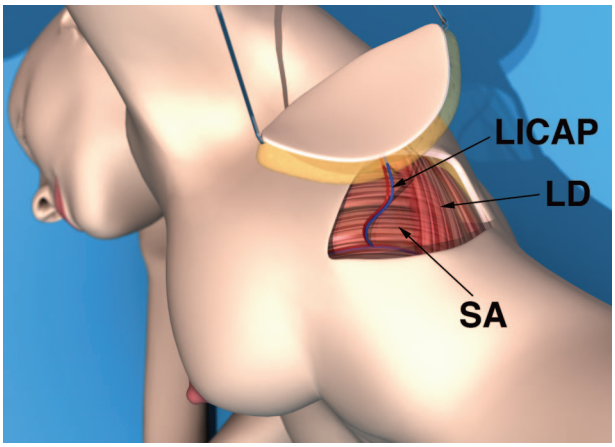

Fig. 3. The lateral intercostal artery perforator (*LICAP*) is based on the intercostal perforators that pierce the serratus anterior (*SA*) muscle in front of the anterior border of the latissimus dorsi (*LD*) muscle.

the dominant perforator revealed that it travels obliquely under a slip of the origin of the serratus anterior muscle into the intercostal space deep to the internal and external intercostal muscles. Once deep to the intercostal muscles, it emerges from the subcostal groove. The dominant perforator typically had a smaller posterior branch, which bifurcated above the serratus anterior muscle. This branch was found to communicate with the thoracodorsal perforators or serratus anterior vessels. When it bifurcated under the serratus anterior muscle (in 10 percent of cases), it had a diameter similar to that of the anterior branch.

Table 2. Distances of the Dominant Perforators from the Anterior Border of the Latissimus Dorsi Muscle

		Distance from the LD			
	No. (%)	Mean	Minimum	Maximum	SD
ICS4	3 (6.8)	2.67	1	4	1.53
ICS5	7 (15.9)	3.86	0.5	6	1.93
ICS6	17 (38.6)	3.79	0	6	1.57
ICS7	13 (29.6)	2.77	0	5.5	1.45
ICS8	4 (9.1)	4.00	3	5	0.82

LD, latissimus dorsi; ICS, intercostal space.

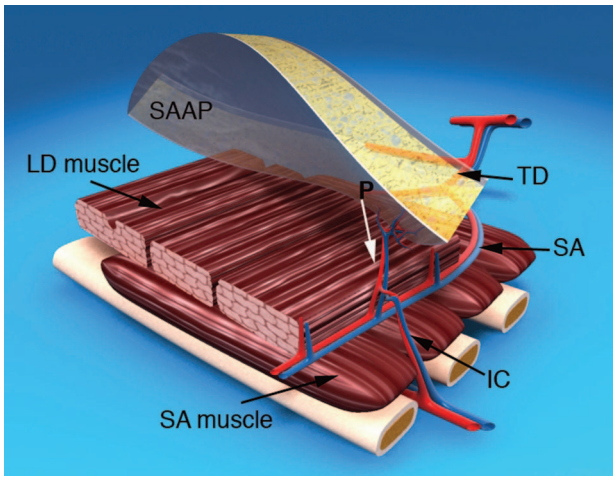

Fig. 4. The serratus anterior artery perforator (*SAAP*) flap is based on the connection between the serratus anterior and the intercostal vessels. *TD*, thoracodorsal; *SA*, serratus anterior; *LD*, latissimus dorsi; *P*, perforator.

In 10 of 47 sides (21 percent), vascular connections were found between the serratus anterior branch and the intercostal perforators (Fig. 1, *below*). This connection was noted more frequently in the seventh intercostal space and the sixth intercostal space, in 38 percent and 30 percent of cases, respectively. Multiple connections between the intercostal perforators and the serratus anterior branch were found in two cases (fifth to sixth to seventh intercostal space and sixth to seventh intercostal space). This vascular connection presents a valuable clinical application. It would enable safe harvest of a skin flap based on the connection between the intercostal perforators and the serratus anterior branch, creating the potential for harvest of a flap with a long pedicle and preserving the thoracodorsal vessels. After the terminology established in the Gent consensus,[8] the flap is called the serratus anterior artery perforator flap (Fig. 4).

CASE REPORTS

Clinical Applications

The thoracodorsal artery perforator flap is our first choice in partial breast reconstruction.[5] However, the lateral intercostal artery perforator flap is a good alternative for defects in the lateral quadrants of the breast.[7] Using the lateral intercostal artery perforator flap preserves the latissimus dorsi muscle and its blood supply, unlike the thoracodorsal artery perforator flap. The dissection of the perforators is not technically difficult and provides adequate perforator length to rotate the flap 180 degrees without torsion of the perforator. If the vascular connection between the serratus anterior vessels and intercostal perforators is found, a serratus anterior artery perforator flap can be raised. The advantage of a serratus anterior artery perforator flap is a significantly longer pedicle than the lateral intercostal artery perforator flap, with the potential to reach defects that are located more medially in the breast.

Case 1: Lateral Intercostal Artery Perforator Flap

A 59-year-old patient was admitted for quadrantectomy and partial breast reconstruction for right breast cancer located in the lateral quadrant of the breast (Fig. 5). She had already been treated for a left breast cancer by mastectomy and immediate deep inferior epigastric artery perforator flap breast reconstruction 2 years previously. A 22 × 9-cm flap was designed in the bra region (Fig. 6). Two perforators were marked using a unidirectional Doppler probe. The resected specimen weighed 155 g. The resulting defect in the lateral quadrant of the breast was appropriate for reconstruction by either a thoracodorsal artery perforator or lateral intercostal artery perforator flap (Fig. 7, *above*). During flap dissection, a thoracodorsal artery perforator was found, but an intercostal perforator was also encountered anterior to the anterior border of the latissimus dorsi muscle (Fig. 7, *center*). Therefore, the intercostal perforator was chosen to perfuse the flap and the thoracodorsal artery perforator was ligated (Fig. 7, *below*). The lateral intercostal artery perforator flap was then isolated on this intercostal perforator and completely deepithelialized and folded to fill the defect. The donor site was closed primarily. Radiotherapy was initiated 4 weeks after surgery. The 6-month postoperative results are demonstrated (Fig. 8).

Case 2: Serratus Anterior Artery Perforator Flap

A 65-year-old patient was admitted for a quadrantectomy to treat a breast tumor located at the junction of the superior quadrants of the right breast (Fig. 9). Immediate partial breast reconstruction with a pedicled perforator flap was planned. The perforators were marked and the flap was designed in the bra region parallel to the relaxed skin tension lines (Fig. 10). A connection between the serratus anterior and intercostal vessels was present (Fig. 11, *above*); therefore, a serratus anterior artery perforator flap was raised with preservation of the latissimus dorsi and serratus anterior muscles and their associated nerves

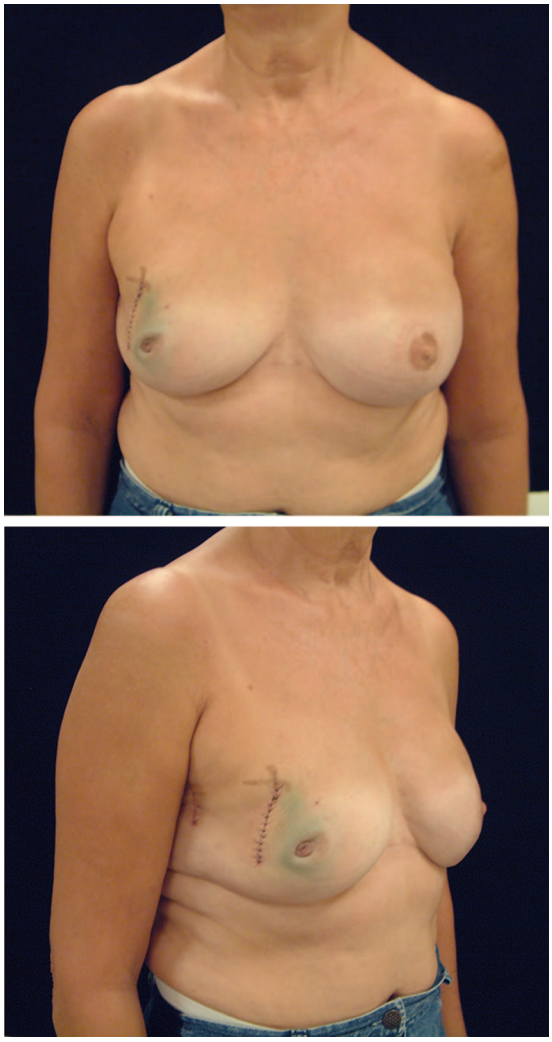

Fig. 5. Preoperative views of a 59-year-old patient admitted for quadrantectomy, with partial breast reconstruction for right breast cancer located at the superolateral quadrant.

Fig. 6. Flap design with the mapped perforators.

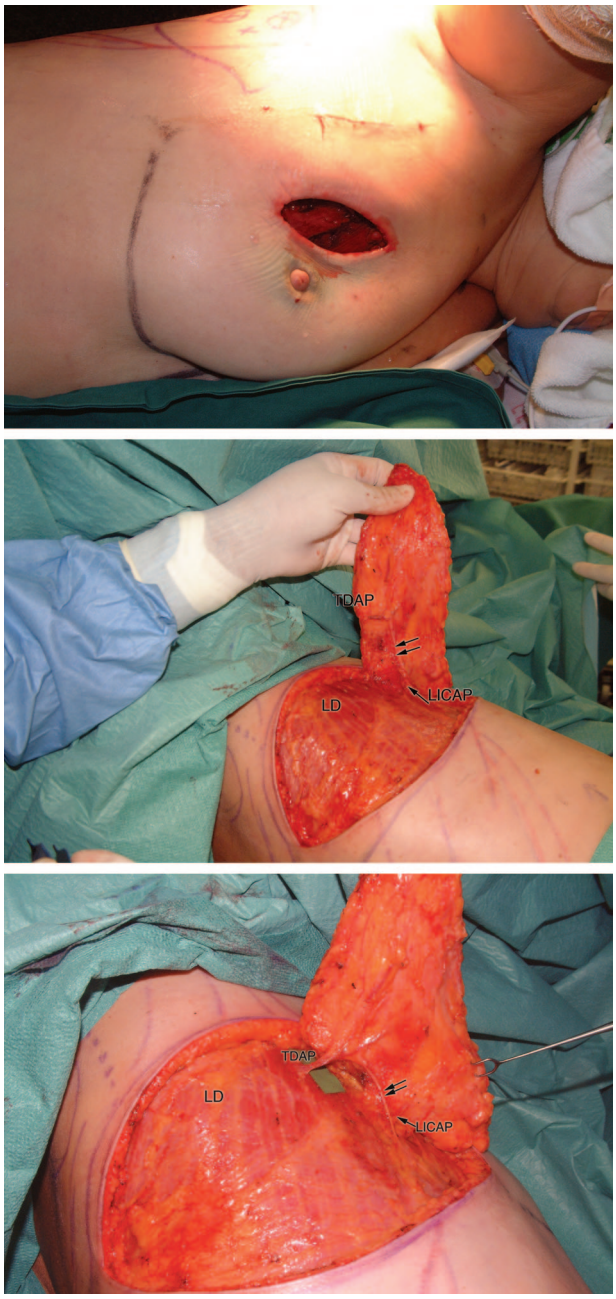

Fig. 7. (*Above*) The defect after the quadrantectomy. (*Center*) Two perforators were found: one thoracodorsal artery perforator (*TDAP*) and one lateral intercostal artery perforator (*LICAP*) (*single arrow*). The intercostal nerve (*double arrows*) was included in the flap. (*Below*) The thoracodorsal artery perforator was clipped and the flap was based on the intercostal artery perforator (*single arrow*) and the intercostal nerve (*double arrows*).

(Fig. 11, *below*). The flap was deepithelialized and transferred to the defect. Wound healing was uneventful and the patient was referred for chemotherapy followed by radiotherapy. Stable results were observed at 2-year follow-up (Figs. 12 and 13).

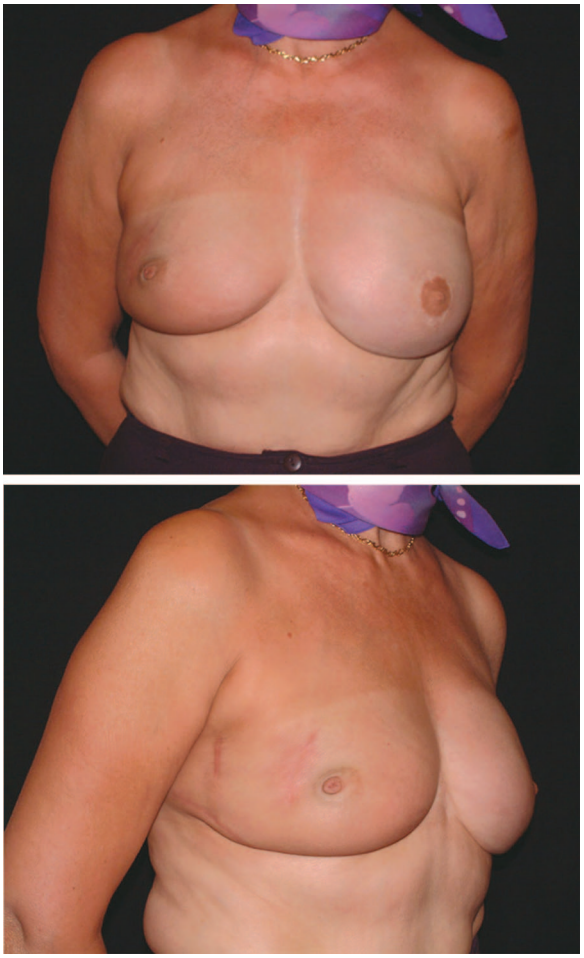

Fig. 8. Postoperative views.

DISCUSSION

The anatomy and course of the intercostal vessels has been studied thoroughly in the anatomical work of Kerrigan and Daniel.[2] The intercostal vessels form an arcade, which can be divided into four segments: vertebral, intercostal, intermuscular, and rectus segments. The intercostal neurovascular segment, which is the longest (12 cm), is very important because it gives rise to between five and seven musculocutaneous perforators. The major musculocutaneous perforators are approximately 0.8 mm in diameter.

Until recently, there have been no additional anatomical studies of the intercostal perforators in the upper trunk. Badran et al.[3] described the anatomy of a large perforator or so-called lateral cutaneous branch of the intercostal vessels. It was found at the level of the midaxillary line. However, only the anatomy of the last three intercostal arteries was investigated, and the authors made the assumption that the remaining lateral cutaneous branches of the trunk have a similar course.[3] More

Fig. 9. Preoperative views of a 65-year-old patient who underwent a partial right breast reconstruction with a pedicled serratus anterior artery perforator flap.

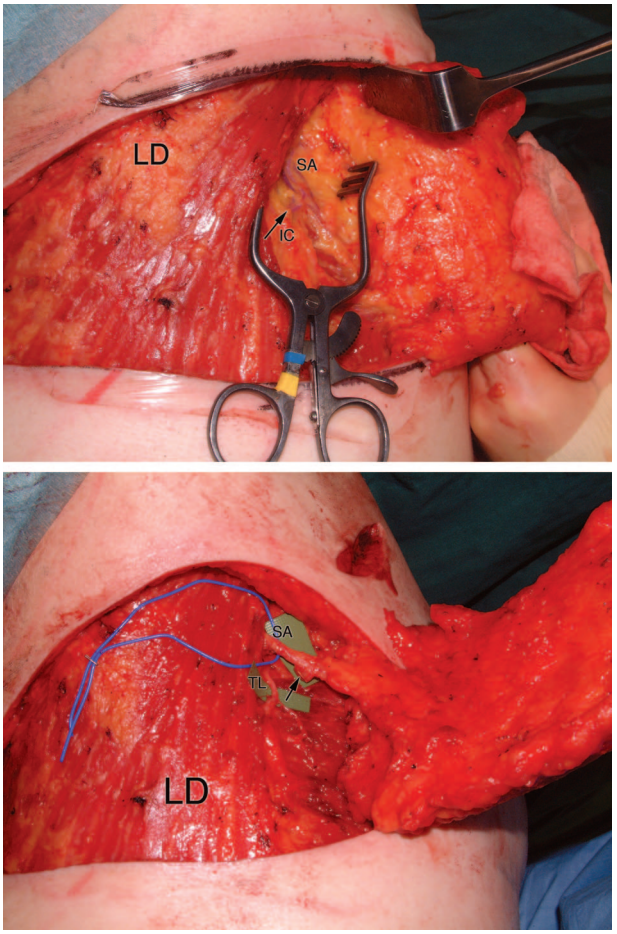

Fig. 11. (*Above*) The flap was based on the communication between the serratus anterior (*SA*) and the intercostal perforator (*IC*) (*arrow*). (*Below*) The connection between the intercostal perforator is clipped and the flap harvested, based on the serratus anterior vessels, without sacrificing the motor nerve.

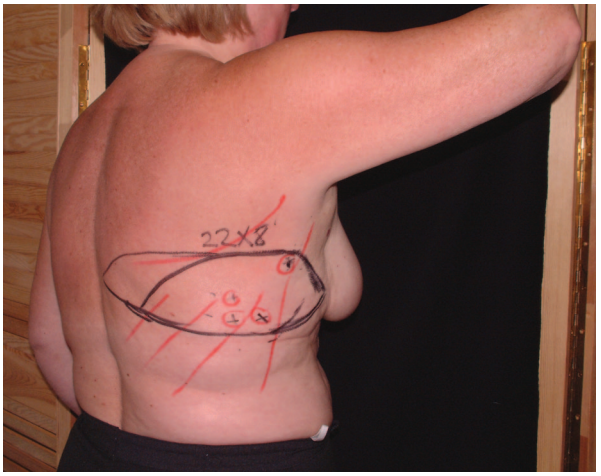

Fig. 10. A 22 × 8-cm flap was designed with marked perforators.

clinical studies are required to better understand the anatomy of the intercostal perforators at the upper trunk, which will improve the clinical use of skin flaps in breast surgery.

Despite the potential clinical importance of intercostal flaps in breast surgery, their use has not been widely reported in the literature, possibly because dissection of the main pedicle is difficult, with the potential for pneumothorax. In addition, when harvested as myocutaneous flaps, the dissection necessitates the transection of several different muscles, such as the latissimus dorsi, external oblique, and intercostal muscles.[1–3] Literature describing intercostal flaps based solely on the perforators in the lower trunk has been limited to case reports.[3,4]

Our cadaver dissection showed a variable number of intercostal perforators that can be clinically used in the area between the latissimus dorsi and pectoralis major muscles. A "dominant perforator" was identified in most cadavers (92 percent), as was the case in the investigations of Badran et al.[3] These dominant perforators were located in

Fig. 12. The donor site.

the fourth to eighth intercostal spaces, with a higher concentration in the sixth and seventh intercostal spaces. The dominant perforators are located an average of 3.5 cm from the anterior border of the latissimus dorsi muscle.

Recently, we have reported the definition, classification, and surgical technique of intercostal artery perforator flaps.[6,7] Intercostal artery perforator flaps are classified depending on perforator locations as follows:

Dorsal intercostal artery perforator (dorsal): Based on the perforators that are raised from the vertebral segment. These flap are designed near the midline of the back.

Lateral intercostal artery perforator (lateral): Based on the perforators that are raised from the costal segment.

Anterior intercostal artery perforator (anterior): Based on the perforators that are raised from the muscular or rectal segments.

The lateral intercostal artery perforator flap, which is based on perforators arising from the costal segment, has significant clinical potential in breast surgery.[5–7] The lateral intercostal artery perforator is an alternative to pedicled flaps (latissimus dorsi musculocutaneous or thoracodorsal artery perforator flaps) based on the thoracodorsal vessels for partial breast reconstruction. However, the usefulness of the lateral intercostal artery perforator flap is limited to defects in the lateral quadrants of the breast because of its short vascular pedicle.

Another application of the lateral intercostal artery perforator flap should be in patients after massive weight loss. A combination of bilateral

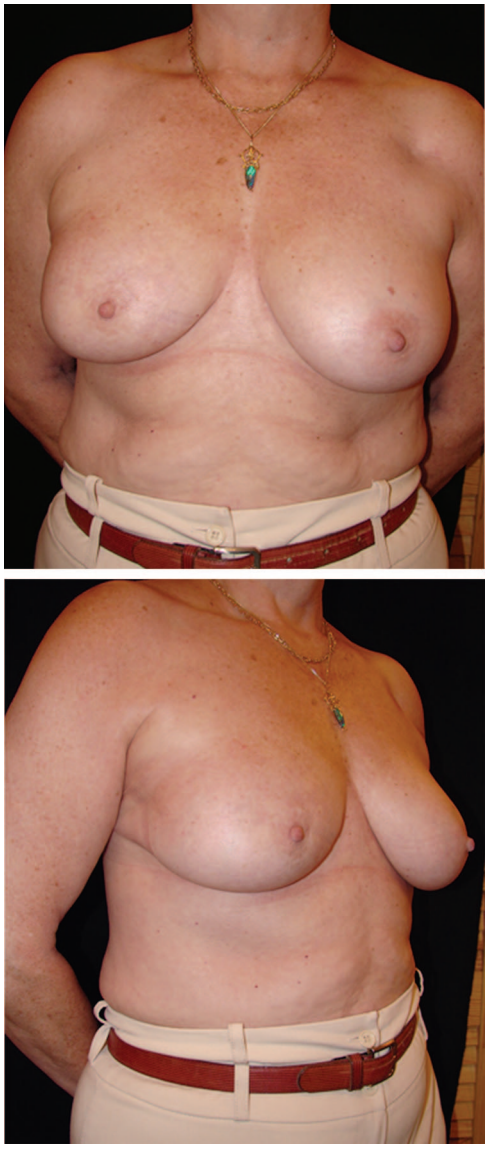

Fig. 13. Postoperative views.

mastopexy with autogenous breast augmentation based on the side-roll can be done by harvesting bilateral lateral intercostal artery perforator flaps.

Kwei et al. recently reported their experience in five patients after massive weight loss.[9] The authors used a combination of a Wise-pattern mastopexy with a pedicled "intercostal artery perforator" flap for breast augmentation. We would suggest the use of the term "lateral intercostal artery perforator" flap to more accurately describe the specific intercostal artery perforator being included within the flap and to maintain consistent terminology with other perforator flap literature.[3,8]

Dissection of the intercostal perforator through the serratus anterior and intercostal muscles up to

the exit from the costal groove provides an additional 3 to 4 cm of pedicle length to the lateral intercostal artery perforator flap. The flap can be rotated up to 180 degrees. Care must be taken to free the perforator from the surrounding tissue to avoid perforator torsion. If a longer pedicle is required for a more distant defect, dissection of the main pedicle should proceed within the costal groove. The latissimus dorsi and serratus anterior muscles should be retracted to expose the interspace. Splitting these muscles in the direction of their muscular fibers prevents the need to transect them, thereby reducing blood loss and donor-site morbidity. Dissection of the intercostal vessels within the costal groove is tedious and time consuming and may result in a pneumothorax. As an alternative, a longer pedicle can be obtained if the flap is based on the connection between the intercostal and the serratus anterior vessels. A serratus anterior artery perforator flap has 6 to 9 cm of pedicle length, giving it a useful arc of rotation well into the region of the areola. Unfortunately, in this study, this vascular connection was found between the intercostal and the serratus anterior vessels in only 21 percent of cases. When such a connection is found, the serratus anterior artery perforator flap can cover breast defects up to the retroareolar region. The flap can then be based on the serratus anterior vessels, with sparing of the associated nerve. The serratus anterior pedicle can be dissected up to the thoracodorsal vessels. The thoracodorsal vessels can be freed from the muscle with ligation of the major branches to add length to the serratus anterior vessels. By preserving the latissimus dorsi muscle and its blood supply, one can still harvest a latissimus dorsi muscle flap, if needed, in the future.

CONCLUSIONS

The introduction of the perforator concept in flap surgery has resulted in significant progress in the field of reconstructive surgery during the past decade. The lateral intercostal artery perforator flap presents valuable options in breast surgery and in the reconstruction of challenging defects on the trunk. A serratus anterior artery perforator flap can also be harvested when the connection between the intercostal and serratus anterior vessels is found (21 percent of the cases). Harvesting such perforator flaps without sacrifice of the underlying muscle not only reduces donor-site morbidity but also preserves these muscles for use in cases of initial flap failure or in situations of recurrent disease.

Moustapha Hamdi, M.D., Ph.D.
Plastic Surgery Department
Gent University Hospital
De Pintelaan 185
Gent B-9000, Belgium
moustapha.hamdi@ugent.be

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