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Perforator flaps based on the pectoral branch of the thoracoacromial artery: anatomical basis using 24 dissections

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Abstract

Objectives: A perforator flap based on the pectoral branch of the thoracoacromial artery (TAA) is an attractive option, both in terms of the regional coverage possibilities and the reduced donor site morbidity. And yet this technique has been little documented in the literature. The authors report a series of dissections in order to understand the realization and the indications of this surgical technique.

Methods: We dissected 24 perforator flaps based on the pectoral branch of the TAA in cadaver specimens preserved in a glycerin-rich, formalin-free solution. The TAA was first injected with methylene blue. The vascular territory, location of perforators relative to known landmarks, along with the flap's potential amplitude and arc of rotation were studied.

Results: The main perforator arteries were in the middle of the deltopectoral groove length; they were surrounded by adipose tissue in 80% of specimens. Two perforator arteries were found in two specimens: one was in the middle of the deltopectoral groove length and the other was more proximal. The flap's arc of rotation made it possible to reach the anterior cervical region, the sternal region and the axillary region in every specimen.

Conclusion: Through an anatomical study of perforator flaps based on the TAA, we reviewed the principles and landmarks that can be used by plastic surgeons to easily carry out this surgical technique.

Keywords: dissection; pectoral branch; perforator flap; thoracoacromial artery

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Introduction

For several decades, complex surgical techniques have been used to cover soft tissue defects in the head and neck region. Two advances expanded the options for head and neck reconstruction: the deltopectoral flap technique developed by Bakamjian in 1968[1] for pharynx reconstruction and the pectoralis major flap described by Ariyan in 1979.[2] However, the deltopectoral flap's pedicle is short and a skin graft is often required to close the donor site. The presence of muscle in the pectoralis major flap results in excess flap volume and increases morbidity at the donor site. More recently, the advent of perforator flaps has changed how head and neck reconstruction is done.[3–5] These flaps are based on musculocutaneous perforator arteries that perforate the muscle and terminate on the skin paddle by a vascular territory or perforasome, without vascularizing the muscle itself. They are better suited to these tissue defects, due to their lower morbidity and larger variety of donor sites.

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The TAA arises from the anterior side of the axillary artery, between the middle and lateral thirds of the clavicle. Its origin from the axillary artery is hidden by the pectoralis minor muscle.[6–8] It gives off deltoid and pectoral branches that are always present. It also gives off a clavicular branch that arises directly from the thoracoacromial artery and an acromial branch which arises directly from the deltoid branch. However these branches are not always present.[6–8] The branches of TAA arise immediately below the clavicle; they then penetrate the pectoralis major through its internal surface immediately below the midpoint of the clavicle. The veins are accompanying the arteries. The deltoid and acromial branches supply the clavicular part of the pectoralis major medially and the clavicular branch laterally.[6,8] The latter two branches give off musculocutaneous perforators that vascularize the integuments located in the superior part of the pectoral wall. The deltoid branch often gives off the acromial branch directly. The acromial branch also provides a musculoskeletal perforator towards the integuments covering the deltoid muscle and the acromial end of the clavicle.[6,8] The pectoral branch supplies the sternocostal part of the pectoralis major muscle.[6,8] It then gives off a lateral branch that courses towards the lateral thoracic artery, one medial and one caudal branch directed towards the 4th intercostal space that anastomose with the anterior intercostal arteries and the perforators of the internal thoracic artery (ITA).[6,9,10] The pectoral branch generally courses along a line joining the acromion with the xiphoid process. However, there are several anatomical variations have been described.[11] Several small musculocutaneous perforators arise from this pectoral branch but they can not be used surgically.[6] Injections have shown the cutaneous vascular territory of the pectoral branch extending from the axillary fossa in transverse plane as far as the nipple, laterally beyond the margin of the pectoralis major muscle.[8]

A perforator flap based on the pectoral branch of the thoracoacromial artery (TAA) corresponds to the perforator variant of the pectoralis major musculocutaneous flap. Hence, it has the same advantages but not necessarily the same drawbacks, which makes it a good option for head and neck reconstruction. The authors performed a series of injections and dissections to study the feasibility of developing and using perforator flaps based on the pectoral branch of the TAA to cover tissue defects in the head and neck area.

Materials and Methods

Twenty-four sides (12 right and 12 left upper limbs) of 12 BIOMET embalmed cadavers were dissected in this study. The mean age of the cadavers was 69 years (range: 47–88); there were 9 males (range: 47–88) and 3 females (range: 69–87). The cadavers had no history of surgery or deformity around the shoulder region. “BIOMET Solution” is a glycerin-rich, formalin-free solution to preserve tissue suppleness and usually used in the anatomy laboratory of the University of Lille (France) for conservation of the cadavers. The composition for obtaining 13.7 liters of BIOMET Solution is as follows: 4.75 liters of methanol+4.75 liters of distilled water+3 liters of glycerin+1.2 liters of phenol. Prior to our work, all the institutional procedures concerning cadaveric dissection were respected, as well as the ethical framework. From an ethical point of view, our work was based on the legislation at the time of the study.

First, the cadavers were placed in supine position and the clavicles were removed from the lateral triangle of the neck. The subclavian artery and its collateral branches were dissected, identified and marked. The dissection was extended to expose the origin of the TAA on the anterior side of the first part of the axillary artery. The TAA was injected with a mixture of gelatin, methylene blue and iron powder (**Figures 1a** and **b**). The cadaver was then frozen for 24 hours.

In the second phase, the cadaver was thawed out at room temperature and then placed in supine position to dissect the integuments. For this dissection, a superficial incision was made on the lateral, caudal and cranial margins of the cutaneous perforasome, making sure not to breach the muscle layer. Next, the superficial plane was separated from the muscle layer from the periphery to the center of the perforasome (**Figure 2**). This dissection was performed meticulously so as to prevent damaging the satellite veins accompanying each perforator artery. During this procedure, the perforators were dissected and inventoried based on their location, dimensions, orientation, frequency, and size of the cutaneous perforasome (**Figure 3**). Perforasome area was calculated based on a circular shape (radius X radius X π) or elliptical shape (long radius X small radius X π). Dissection of perforators was then continued through the muscle while preserving the integrity of the pectoralis major muscle. The superficial layer (perforator flap) was then harvested completely with its pedicle.

Results

The TAA had an average diameter of 2 mm. An average of 2.4 perforators were found (range: 1–4) on the perforasome corresponding to the territory of the TAA’s pectoral branch. The average diameter of each perfora-

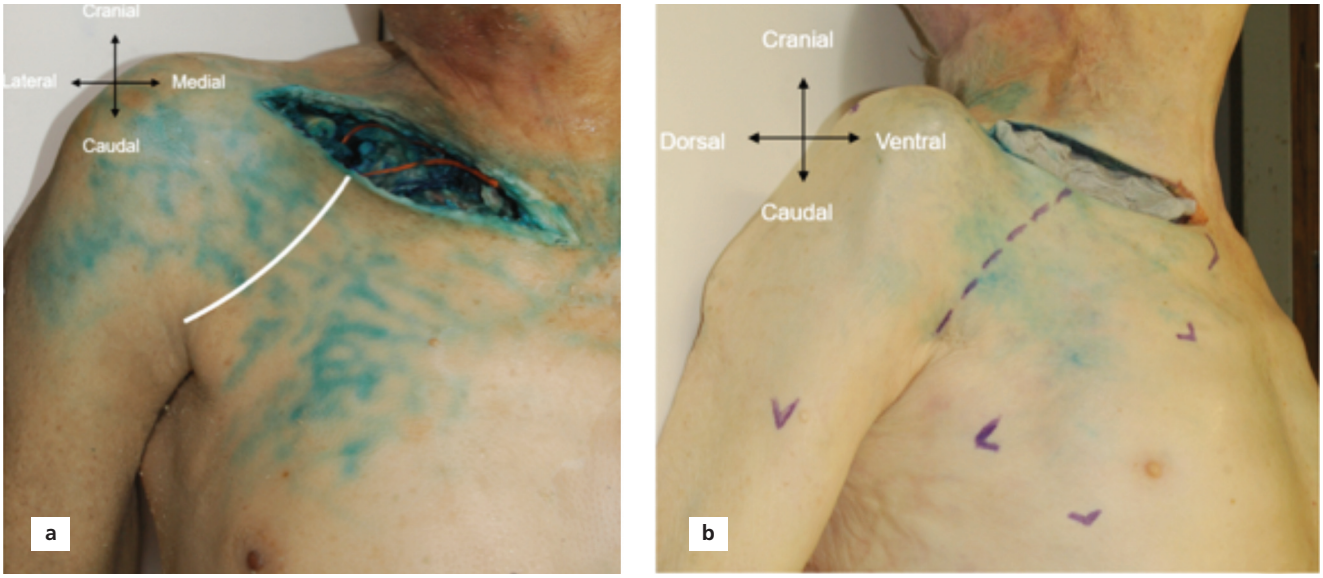

Figure 1. Injecting and coloring of the branches of the thoraco-acromial artery in two subjects (**right side**). The deltopectoral groove is represented as a white line (**a**) and in blue dotted lines (**b**), as the limit of the cutaneous perforasome. Specimens numbers 7 and 14 (*see* **Table 1**).

tors was 0.9 mm (range: 0.3–1.8). The average dimensions of the perforasome was 5×9 cm, corresponding to a mean area of 35.3 cm^2 (range: 22–80). Its general orientation was caudal and medial. The extramuscular pedicle had an average length of 1.5 cm (range: 0.5–4) and the transmuscular pedicle had an average length of 8 cm (range: 5–12). A 180° arc of rotation of the perforator artery was possible from the pivot point. In 21 of the 24 specimens, the pectoral branch of the TAA and its perforators converged over the middle third of the deltopectoral groove (pivot point) (**Figures 4** and **5**).

The following topographic boundaries can be used when dissecting this flap, although the perforasome area often extends beyond these boundaries: the nipple and 4th intercostal space caudally; lateral margin of the pectoralis major muscle and anterior axillary line laterally; vertical line through the medial third of the clavicle medially; the tip of the perforator flap is located at its pedicle over the deltopectoral groove (**Figure 4**). More detailed findings are given in **Table 1** and **Figure 4**.

Discussion

The pectoralis major musculocutaneous flap has long been the workhorse flap in head and neck reconstruction.[12] Little research has been carried out up to now on the perforator variant of this flap–a perforator flap based on the TAA's pectoral branch. Anatomical studies performed on the TAA show that its perforators are small in diameter and that several variations exist in their origin.[6,8] While there is little known about perforator flaps based on the TAA's pectoral branch, its perforators have already been used for axillary wound contractures[13] and in facial and cervical reconstruction.[7,14–16] Most of the injection studies done on the pectoralis major muscle showed these muscle perforators originate either medially from the anterior intercostal and internal mammary arteries, or laterally from the lateral thoracic artery.[6,8,17] However, particularly in the cranial part of the muscle, distinct perforators have been found that originate in the TAA, although this has been obscured by numerous authors.[9,17] In the 1960s, Bakamjian[1] used axial flaps for

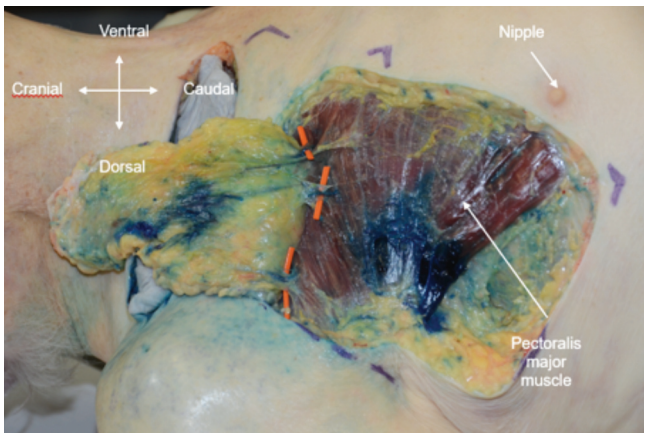

Figure 2. Dissecting the perforasome of the pectoral branch of the thoraco-acromial artery on the right side. Specimen number 13 (*see* **Table 1**).

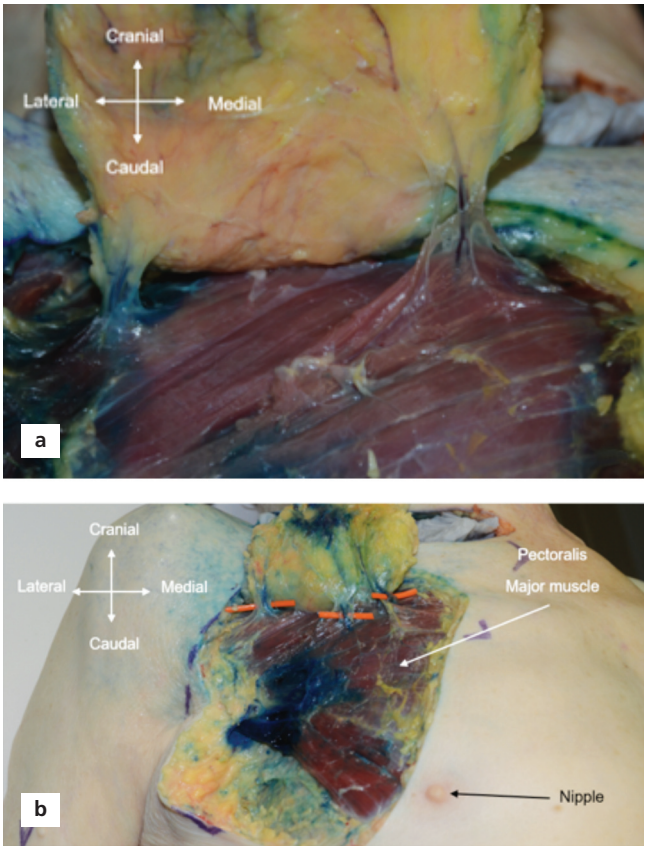

Figure 3. Identification and dissection of perforators of the pectoral branch of the thoracoacromial artery, in close-up (**a**) and in panoramic view (**b**). Specimen number 13, right side (*see* **Table 1**).

cervicofacial reconstruction. He went on to describe the deltopectoral flap, which has a wide medial base at the cranial part of the thorax and shoulder. Then, several pioneers understood that including an axial pedicle within a flap improves its vascular pedicle.[3] Since perforators have anatomical variations, their location may need to be defined preoperatively. This is most often done through a computed tomography scan with contrast and/or Doppler ultrasonography.

The anterior thoracic wall has long been used as a donor site for head and neck reconstruction because of its proximity to the cervicofacial area and its similar color, texture and thickness. Traditionally, the primary choices for head and neck reconstruction are the pectoralis major musculocutaneous flap and the deltopectoral flap.[2] Despite the benefits of these two types of flaps, functional and esthetic requirements limit their use. Research has shifted towards flaps with characteristics that correspond exactly to the recipient site, with less donor site morbidity. The main drawbacks of deltopectoral flaps are the high necrosis rate, the need for a skin graft to cover the donor site, and the small arc of rotation due to the short pedicle.[6] Our study shows that a perforator flap based on the TAA's pectoral branch does not have such drawbacks. As for pectoralis major musculocutaneous flaps, its perforator variant corresponds to TAA perforator flaps. Hence, the latter shares its advantages but not its disadvantages. Like the ITA perforator flap, the perforator flap based on the TAA's pectoral branch is a good option for exploiting the pectoral integuments for head and neck tissue defects. The benefits include acceptable color, texture and suppleness.[7,16] Moreover, a perforator flap based on the TAA's pectoral branch has the same topographic advantages as the pectoralis major flap, along with being thinner (avoiding excess volume at the defect site), having a longer vascular pedicle and preserving the function of a major trunk muscle.[7,16] This result is close to what we found in our work. We defined the limits of the area in which the perforator branches of the pectoral branch of the TAA usually project. In addition, inside the described area, the orientation of the perforator branches was mediocaudal.

Geddes et al.[6] reported that the TAA arises in an isolated manner from the axillary artery in all specimens he dissected. The average diameter of the TAA was 2.5±0.5 mm in his study. The average external diameter was 2 mm in our study, although it varied greatly. We also found that the TAA is the primary vascular source for the pectoralis major muscle and that is courses deeply in the adipose tissue dividing the pectoralis major muscle from other muscles. He showed the TAA gives off three main branches: pectoral, clavicular and deltoid. The acromial branch could also be considered a main branch; however, he found it to be supplied by the deltoid branch of TAA in 18 of 20 specimens and by the TAA in the other 2. The pectoral branch of the TAA supplies the largest vascular territory. Geddes et al.[6] revealed its average diameter as 1.7±0.6 mm. In most cases, it gives off three secondary branches that course obliquely, medially and caudally against the internal surface of the pectoralis major muscle. The medial and caudal branches anastomose with perforators from the ITA. These arteries are issued from small diameter (less than 0.5 mm) musculoskeletal perforators. The lateral ramus of the pectoral branch anastomoses with the terminal branches of the lateral thoracic artery inside the pectoralis major muscle. We found the pectoral branch can give off three or four viable perforators in 50% of specimens that are 1 mm in diameter.

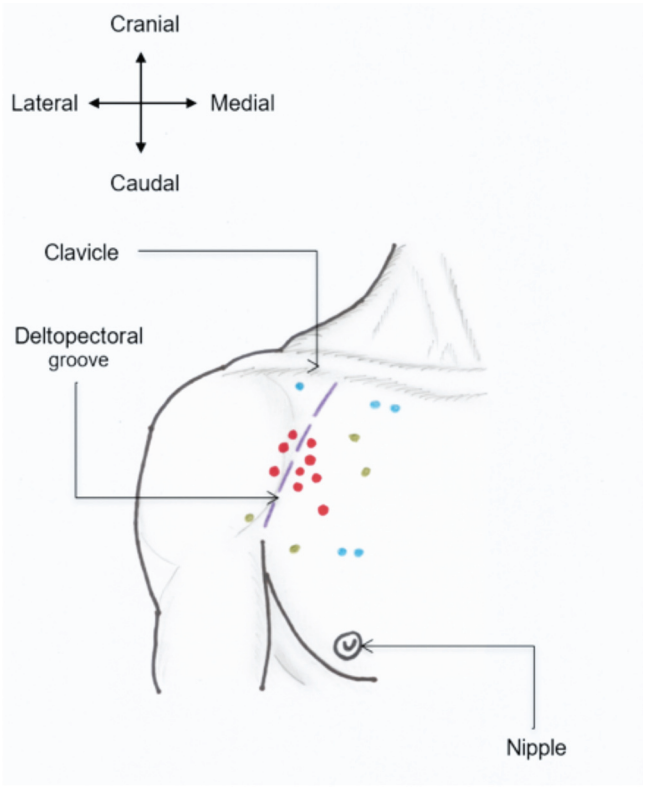

Figure 4. Distribution of perforator arteries of the pectoral branch of TAA based on incidence. **Blue:** <40%; **green:** between 40 and 70%; **red:** >70%.

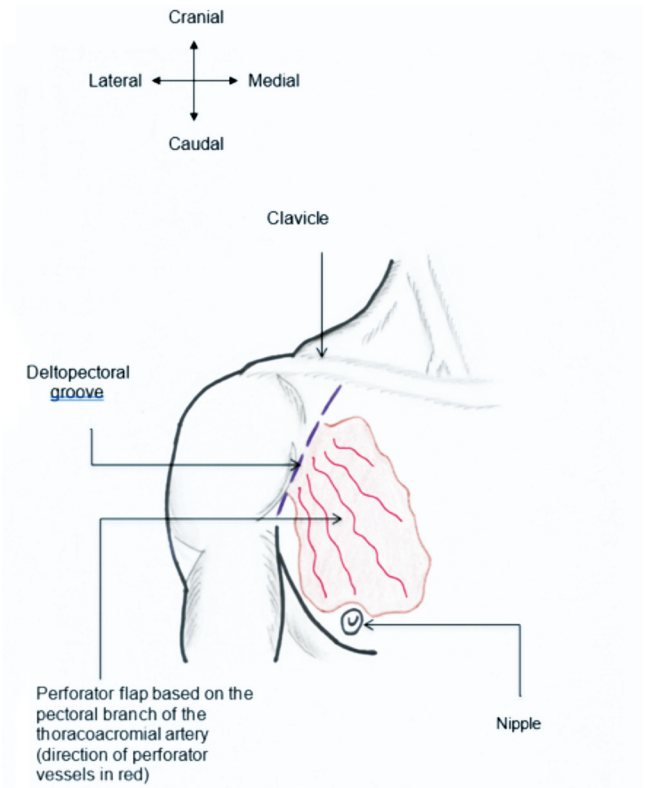

Figure 5. Drawing of the perforator flap based on the pectoral branch of TAA.

It appears from Salmon's works that the TAA represents the main integumentary artery of the anterior deltoid region, and that it quickly branches into an acromial branch and a thoracic branch.[18,19] He found that the thoracic branch largely irrigates the pectoralis major muscle. Our work also shows that the pectoral branch of TAA supplies a large area of the pectoralis major muscle. However, we find that TAA is constantly divided into a deltoid branch and a thoracic branch. The clavicular and sternocostal parts of the pectoralis major muscle receive independent vascularization.[6] The sternocostal part receives the pectoral branch of the TAA, while the clavicular part is supplied medially by the clavicular branch and laterally by the deltoid and acromial arteries. The integuments located cranially are supplied by musculocutaneous perforators of the deltoid and clavicular branches, a few branches from the transverse cervical artery, and by the suprascapular arteries. According to Geddes et al.,[6] the musculocutaneous perforators of the TAA's pectoral branch are limited to small perforators in the laterocaudal and intermediate areas of the pectoralis major muscle.

Contrary to what we found in our study, Geddes et al.[6] has not consistently identified large musculocutaneous perforators from the pectoral branch of TAA. However, when the dissection is completed by an angiography, there appears a significant variability in the vascular network of the pectoralis major muscle. Our work shows that it is possible to dissect the perforators of the pectoral branch of the TAA, including through the muscle. The arc of rotation and the dimensions of the pedicles would facilitate the mobility of a perforator flap. However, the inconsistent nature of this artery between individuals and from one side to the other limits its use according to Geddes et al.[6] On the contrary, we found that two potential pedicled perforator flaps can be developed from large, consistent musculocutaneous perforators from the clavicular and deltoid branches. The proximity of these flaps to the head and neck region provides them with an additional advantage in terms of color and texture for tissue defects in this region. The absence of hair is also a strong point. Our study found that–despite the considerable variations in arterial territories–the trajectory of the various perforators is more consistent, at both the integument and the muscle level.

Table 1
Summary of the findings in the 24 dissected specimens.

Specimen number and side	Age	Sex	Diameter of thoracoacromial artery (mm)	Number of pectoral perforators	Average (min–max) diameter of pectoral perforators (mm)	Dimensions of pectoral branch's perforasome (cm)	Length of extrafascial pedicle (cm)	Length of pedicle after transmuscular dissection (cm)	Arc of rotation from pivot point (°)
1 L	72	H	2	3	0.8 (0.5–1.2)	8×5	0.5	7	180
2 R	72	H	2	3	1.2 (0.3–1.5)	8×4	0.5	10	180
3 L	58	H	2	1	0.8 (0.8–0.8)	7×6	1.5	12	180
4 R	58	H	1 .5	3	0.8 (0.5–1.2)	8×8	2	10	180
5 L	63	H	2	2	1.2 (0.8–1.5)	7×7	1	6	180
6 R	63	H	2.5	2	0.8 (0.6–1.0)	5×7	1.5	8	180
7 L	88	H	1	1	0.8 (0.8–0.8)	5×8	2	11	180
8 R	88	H	1	2	1.2 (0.8–1.6)	5×8	0.5	9	180
9 L	67	H	2	3	0.7 (0.5–0.8)	5×8	0.5	7	180
10 R	67	H	2	2	1.3 (0.9–1.8)	7×10	2.5	10	180
11 L	64	H	2	4	0.9 (0.8–1.8)	4×7	1	11	180
12 R	64	H	1.5	3	1 (0.7–1.5)	5×7	0.5	8	180
13 L	75	F	1.5	1	0.9 (0.9–0.9)	6×10	1.5	6	180
14 R	75	F	1.5	2	0.8 (0.5–1.0)	5×8	1	5	180
15 L	87	F	2	3	1 (0.8–1.2)	6×10	2	7	180
16 R	87	F	2	2	0.7 (0.5–1.0)	8×8	3.5	5	180
17 L	82	H	2.5	1	0.8 (0.8–0.8)	6×10	1.5	6	180
18 R	82	H	2.5	3	1 (0.8–1.5)	6×10	2	8	180
19 L	69	F	2.5	4	1.2 (0.8–1.8)	5×8	1.5	9	180
20 R	69	F	2	2	0.9 (0.6–1.2)	5×8	1	10	180
21 L	57	H	3	3	0.9 (0.8–1.2)	8×12	4	6	180
22 R	57	H	3	3	0.9 (0.6–1.0)	8×10	3	6	180
23 L	47	H	1.5	2	0.8 (0.8–0.8)	5×8	0.5	5	180
24 R	47	H	2	3	0.9 (0.7–1.2)	6×7	0.5	6	180

Contrary to Geddes et al.,[6] our study's findings were similar to those of the study by Zhang et al.[16] The latter group found at least one perforator from the TAA's pectoral branch in a 4 cm2 area around the intersection of two lines: one is the xipho-acromial line and the other perpendicular to the first line and passing through the mid-point of the ipsilateral clavicle. We also found a consistent perforator ramus from the TAA's pectoral branch. However, in our study, this perforator was generally projected on the middle third of the deltopectoral groove. Although we used different anatomical landmarks than Zhang et al.,[16] the areas on which the TAA's pectoral branch is projected, as defined in the respective studies, are similar.

In the study by Zhang et al.[16] at least one perforator was always present at the septum between the clavicular and sternocostal insertions of the pectoralis major muscle in 87% of flaps (21 of 24). Two musculocutaneous

perforators were found in 13 of their 21 specimens and only one in the other 8 flaps. Each perforator had two satellite veins. Our study found an average of 2.4 perforators arising from the TAA's pectoral branch (range: 1–4); one perforator in 4 specimens, two perforators in 8 specimens, three perforators in 10 specimens and four perforators in 2 specimens. Zhang et al.[16] reported the perforator diameter ranged from 0.4 to 1.1 mm (average: 0.7 mm). We found slightly larger diameters ranging from 0.3 to 1.8 mm with an average of 0.9 mm. The vascular pedicle after dissection to the TAA's origin at the axillary artery was 7.1 cm long (range: 6.1 to 8.3 cm) in the study by Zhang et al.[16] versus 8 cm in our study (range: 5 to 12 cm). In the study by Zhang et al.,[16] the perforasome supplied by the TAA's pectoral branch had a different medial boundary comparing to our study. Despite the TAA's pectoral branch giving off a consistent number of perforators that supply the integuments of the lateral region of the nipple up to the lateral margin of the pectoralis major muscle, none of these perforators were found below the 4th intercostal space, and they were rarely found medial to a vertical line passing through the medial one-third the clavicle.

A perforator flap based on the TAA's pectoral branch is thinner and has a longer vascular pedicle than the pectoralis major musculocutaneous flap. While the donor site can reclose itself, or can be closed with prior expansion, it can induce breast deformity or areolar attraction, particularly in women. The 12-cadaver study performed by Zhang et al.[16] showed the potential clinical application of perforators flaps based on the TAA's pectoral branch. The authors found perforators in almost all of their dissections. In this way, the findings of the Zhang et al. study[16] contradict those of the Geddes et al.[6] who demonstrated that TAA's pectoral branch was inconsistent and had only tiny musculocutaneous perforators. This reduced the feasibility of a pedicled perforator flap with the pectoral branch, contrary to flaps using the deltoid and clavicular branches of the TAA. Our findings are most like those of Zhang et al.[16] When we performed a retrograde dissection of the perforasome and then the perforator artery while using the middle third of the deltopectoral groove as a landmark, the pedicle from the TAA's pectoral branch to its axillary origin was up to 12 cm long, versus 8 cm in the study by Zhang et al.[16]

Our findings are also consistent with the two clinical cases described by Hallock[7] and the four cases described by Nishi et al.,[14] although the latter included fibers from the pectoralis major muscle in the perforator pedicles. Hallock[7] raised and applied two perforator flaps based on the TAA's pectoral branch for two reconstruction cases (cervical and facial). As in our study, they separated the pectoralis major muscle fibers to increase the length of the pedicle and the arc of rotation. Muscle function was preserved in both patients. According to Hallock[7] there is no guarantee that adequate perforators are present. Consequently, standard drawing of a perforator flap based on the pectoral branch is impossible, the pedicle length is indeterminate, and perforators located too caudally require muscle dissection that can cause partial denervation of the pectoralis major muscle. Although these fears are justified, we believe that drawing of the flap is possible when certain precautions are taken such as identification and use of fixed anatomical landmarks, careful dissection of the perforator branches.

Perforator flaps based on the TAA's pectoral branch and perforator flaps based on the ITA have common advantages. However, in contrast with the increasing popularity of ITA flaps, the feasibility and reliability of perforator flaps based on the TAA's pectoral branch has been questioned.[4–6,16] The size of the perforator artery arising from the TAA and the small diameter of its perforators are not often compatible with flap surgery. However, our work showed that perforators issued from the TAA's pectoral branch are certainly viable. The ITA perforator flap can be used in the same indications as perforator flaps based on the TAA's pectoral branch. And unlike the latter, ITA flap has been the subject of several studies.[17,20,21] For this flap, obtaining a long enough pedicle can require removal of one or more rib cartilages, which causes thorax deformity. Another contraindication to use of ITA perforator flaps are iatrogenic factors such as prior incisions from cardiovascular surgery. However, it has several other advantages such as primary closure of the donor site, possibility of cutaneous pre-expansion, along with absence of nipple asymmetry after the flap is applied.[16] As for the perforator flap based on the TAA's pectoral branch, its location limits the area than can be expanded, and while it is larger in size, it can lead to nipple asymmetry due to ipsilateral nipple elevation after application.[16] Despite these drawbacks, the donor site can be sutured in a single step, and pedicle dissection is easier and less invasive than for the ITA perforator flap. Due to the length of the pedicle and the anatomical boundaries of the flap, it is technically possible to reach large tissue defects in the head area.

Based on our experience, a perforator flap based on the TAA's pectoral branch can be raised in a laterocaudal location on the cranial part of the thorax and applied to a mediocranial recipient site in the head or neck area.

Small clinical studies have shown this perforator flap can be used to cover frontal, nuchal and even dorsal defects.[7,14,16] However, certain guidelines must be followed when raising and applying this flap: its orientation before development (caudal or slightly mediocaudal according to Salmon et al.[18]), its anatomical boundaries and average dimensions, the converg ence point (pivot point) of perforators over the middle of the deltopectoral groove, and the potential length of the pedicle. It is also important to preserve the perforator and muscular vascularization in this area. If necrosis was to occur with a TAA perforator flap, an ITA perforator flap or a flap pedicled to the pectoralis major muscle could be used as "rescue flap".

Conclusion

Our study showed that viable muscle and integument vascularization is provided by the TAA and its perforator arteries in the laterocranial regions of the anterior thoracic wall. In most cases, the pectoral branch of the TAA gives off several perforator branches, which are consistent and have dimensions compatible with perforator flap surgery. A perforator flap based on the TAA's pectoral branch is feasible when the anatomical boundaries described in this study are followed. This flap is one more weapon in the therapeutic arsenal of surgeons tasked with covering cervical, cephalic and dorsal defects while preserving the color, texture, thickness and pilosity of the site.

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Conflict of Interest

All authors declare no conflict of interest.

Author Contributions

PMMN: protocol, project development, data collection, data analysis, and manuscript writing. CF: protocol development, data analysis, and manuscript editing. VDM: protocol development, data analysis, and manuscript editing. XD: protocol development, data analysis, and manuscript editing. AB: protocol development.

Ethics Approval

All the institutional procedures concerning cadaveric dissection were respected, as well as the ethical framework.

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