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Original Research Article

Locating the perforators of the trapezius muscle with doppler ultrasound

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ABSTRACT

Introduction: Surgery that incorporates perforator flaps has developed rapidly in recent years. However, this type of surgery is hindered by anatomical variations in the location of the perforating arteries. These anatomical variations require preoperative imaging to plan the surgery properly. Through a Doppler ultrasound study of living subjects, the authors aim to map the perforators of the trapezius muscle.
Materials and Methods: Doppler color ultrasound was carried out in 22 healthy volunteers over the integuments covering the trapezius muscle. Using bone landmarks (spinous process line, inferior angle and spine of the scapula), all the identified perforators were inventoried based on their location, dimensions and direction.
Results: Fourteen women and eight men were included in the study. Their mean age was 25.8 years and their mean height was 1.74 meters. The average number of perforators found on each side of the spinous process line was 10.64. The mean diameter of these perforators was 0.82 millimeters.
Conclusion: Preoperative Doppler ultrasound is useful for surgeons using trapezius perforator flaps, as it can accurately specify the location, diameter, trajectory of a perforator, and in a more general manner, its reliability.

1. Introduction

Use of perforator flaps has increased in recent years. The main advantage of this type of flap is the low donor site morbidity, particularly in terms of muscle and nerve function. However, the numerous anatomical variations around the perforating arteries make perforator flap surgery challenging and risky.[1,2] Dissection of a perforating artery is technically difficult and the irregular anatomy of these vessels amplifies this technical difficulty. For this reason, it is essential to study the exact location of the largest perforating arteries.

Preoperative imaging allows the surgeon to develop an optimal surgery plan, while improving the surgical technique, shortening the surgery time and reducing the risk of complications. During perforator flap surgery, selection of the best perforators based on their location, trajectory and size can be made easier by performing Doppler ultrasonography preoperatively.[3] In reality, even before the introduction of perforator flaps, color Doppler ultrasonography had been used when planning axial flaps. Improvements in the color Doppler ultrasound technology have made it possible to detect small-diameter blood vessels.[4]

The objective of this study was to use color Doppler imaging to analyze the anatomical distribution of trapezius

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perforating arteries in living subjects.

2. Surgical Anatomy

The trapezius muscle originates on the occipital bone, the nuchal ligament, the spinous process of the 7^{th} cervical vertebra (C7) and the thoracic vertebrae. It has three parts. The superior portion (descending fibers) terminates on the posterior margin and superior side of the lateral third of the clavicle. The transverse portion (middle fibers) terminates on the medial margin of the acromion and the superior lip of the posterior border of the scapular spine. The inferior portion (ascending fibers) ends as an aponeurosis on the posterior edge of the scapular spine and the deltoid tuberosity. The trapezius muscle is innervated by the accessory nerve and the cervical plexus. It helps to move the head (extension and rotation) and the shoulders (shrugging, lowering, posterior tipping, bringing the scapulas closer together).

According to the Mathes and Nahai classification,[5] the trapezius muscles receives type II vascularization with a primary pedicle from the transverse cervical artery and secondary pedicles issued from the occipital, posterior intercostal and circumflex scapular perforating arteries.

The transverse cervical artery has a somewhat variable territory. However, its branches anastomose to those of the dorsal scapular artery to contribute to the vascularization of the trapezius, both in the muscle body itself and its integuments. According to an anatomical study of 124 cadavers,[6] the descending fibers receive branches from the occipital artery; the middle fibers and the lateral areas receive branches from the superficial branch of the transverse cervical artery; the ascending fibers receive branches from the dorsal scapular artery and the posterior intercostal arteries. These vessels vastly anastomose with each other.

The occipital artery courses under the superior portion of the trapezius muscle; some of its branches perforate the muscle layer to terminate in the integuments. The occipital artery has two terminal branches: a large medial branch that splits in the body of the trapezius muscle and anastomoses with the deep cervical artery and dorsal scapular artery, and a smaller inconsistent lateral branch.[7,8]

At the nape of the neck, there are typically only two arterial trunks: a branch of the occipital artery and a branch of the deep cervical artery. The dermis and hypodermis networks are very dense in this area. The nape's skin has a reduced number of large arterial trunks but numerous arterioles.[7]

The dorsal region is mainly irrigated by the posterior intercostal arteries and dorsal scapular artery.

The posterior intercostal arteries make their way at the posterior end of the intercostal space, where they leave a dorsal branch. The latter immediately courses posteriorly; once over the intervertebral foramen, it bifurcates into a spinal branch and a musculocutaneous branch. The musculocutaneous branch heads into the intertransverse space and then splits into a lateral muscular branch and a medial musculocutaneous branch. In the skin layer covering the vertebral grooves and the inferior portion of the trapezius muscle, there are two types of cutaneous arteries: posteromedial perforators that stem from the medial musculocutaneous branch and the posterolateral perforators that stem from the lateral musculocutaneous branch.[7,8]

The superior cervical artery courses laterally to the levator scapulae muscle and the rhomboid muscles, before continuing medially to give off a (short) ascending branch and a (long) descending branch that passes next to the scapular spine. Its descending trajectory is superficial to the levator scapulae and rhomboid muscles, and next to a few branches of the external branch of the accessory nerve. At this level, its diameter is generally greater than 0.7 mm.[9]

The dorsal scapular artery courses deep to the levator scapulae and rhomboid muscles. Branches then pierce the fascia separating the two rhomboid muscles (major and minor) and become superficial over the medial margin of the scapula. They form the superficial branch of the dorsal scapular artery. This superficial branch penetrates the deep layer of the trapezius, and then gives off several cutaneous perforators that irrigate the skin covering the ascending portion of the trapezius—here it courses 1 to 2 cm from the muscle's lateral margin. The average diameter of the dorsal scapular artery is 2.7 mm proximally and at its origin, and 1.95 mm over the levator scapulae muscle.[9] A deep branch of the dorsal scapular artery continues its descending trajectory under the rhomboid major muscle. This descending branch gives off several perforators to the rhomboid muscles, trapezius muscle and the overlying skin.

3. Materials and Methods

A color Doppler ultrasound imaging study was carried out in 22 healthy subjects (14 women, 8 men) ranging from 20 to 45 years of age (mean age 25.8). Their average height was 1.74 m (range, 1.62 to 1.97). All the volunteers were informed of the study's procedures and provided informed consent.

The subjects were seated in partial flexion on a cushion with their back facing the operator. This position was maintained for the entire procedure. All ultrasound imaging was performed by the same operator—a radiologist specializing in musculoskeletal imaging with more than 15 years' experience.

The examinations were performed using a Philips EPIQ 7G ultrasound system (Bothell, WA, USA). A linear probe (L12-5 or L18-5) was used. Setting of the optimal color Doppler sensitivity was done systematically before the trapezius region examination was initiated. In every subject, color Doppler ultrasonography was performed from the cranial edge to the caudal tip of the trapezius in order to sweep over the muscle's entire surface. All the perforators identified were inventoried on a data collection sheet based on their location, dimension and direction. A graduated ruler was used to measure the distance between each perforator and the bone landmarks, such as the spinous process line, scapular spine and inferior edge of the scapula (Figure 1). This ensured that each perforator was located exactly. The time needed to perform each examination was also noted.

4. Results

The average number of perforators found on each side of the spinous process line was 10.64 (range, 4 to 18). The mean diameter of these perforators was 0.82 mm (range 0.3 to 1.5) The largest perforators were projected on two lines parallel to the spinous process line (one on each side), and 5–6 cm from it. More detailed findings are given in Table 1 and Figures 2 and 3.

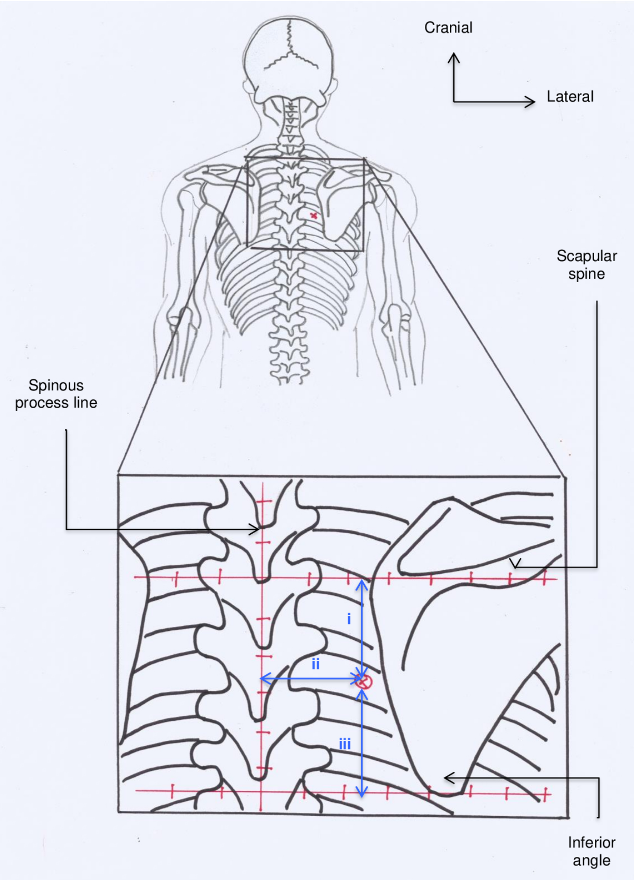

Fig. 1: Locating a perforating artery relative to known bone landmarks – i: distance between perforator and medial tip of scapular spine, ii: distance between perforator and spinous process line, iii: distance between perforator and inferior angle of scapula

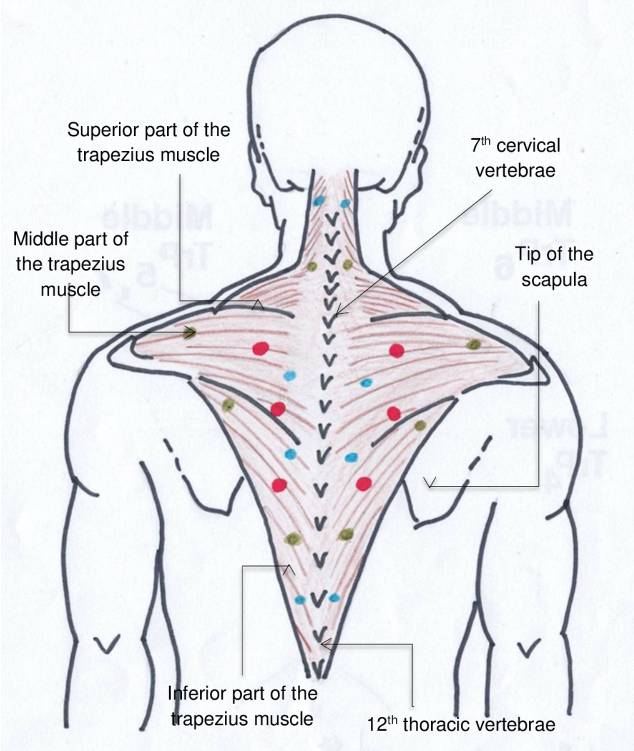

Fig. 2: Distribution of the trapezius perforators found with Doppler ultrasonography based on how often they were present: blue < 40%, green 40% to 70%, red > 70%.

5. Discussion

Given the variations in vascular anatomy, preoperative imaging of perforators is now routine. Several methods can be used, with Doppler ultrasonography and CT angiogram being the most popular.[10,11] Doppler ultrasonography is based on the Doppler effect. With perforator flaps, it analyzes and displays information on the location, dimension and blood flow in perforating arteries. When performing free perforator flap reconstruction, Doppler ultrasonography also analyzes the perivascular anatomy of the flap.

In order to successfully raise the flap and close the donor site, it is critical to master the preoperative anatomy of the perforators. The key point in the design of the perforator flap is acquiring information about the perforators: trajectory, diameter and location. While there is little information on the use of ultrasonography to study the perforators in the trapezius muscle area, other areas have been evaluated during the planning stage of perforator flap surgery.[12,13]

Four studies comprising 54 anterolateral thigh flaps showed that Doppler ultrasonography had a sensitivity of 97.5% for identifying perforators.[2,14–16] In the Tsukino et al. study,[4] all points detected by the Doppler ultrasound preoperatively coincided with the perforators found intraoperatively. Thus the agreement rate was 100%.

Table 1: Summary of the Doppler ultrasonography findings in 22 healthy subjects (M: male; F: female)

Subject number	Age	Sex	Subject height (meters)	Number of perforators found	Minimum diameter (mm)	Maximum diameter (mm)	Average diameter (mm)	Total duration of examination (in minutes)
1	24	H	1.8	13	0.4	0.8	0.7	30
2	21	F	1.7	11	0.4	1	0;8	33
3	22	F	1.76	12	0.6	1.14	0.8	37
4	35	H	1.82	6	0.8	1.3	1	28
5	21	H	1.72	15	0.5	1.3	0.9	33
6	43	H	1.97	13	0.5	1.1	0.9	40
7	45	H	1.76	13	0.7	1.3	1	38
8	26	F	1.67	11	0.5	1.5	0.9	27
9	22	F	1.73	8	0.4	0.7	0.6	26
10	23	H	1.76	18	0.4	1	0.7	27
11	23	H	1.77	6	0.4	0.9	0.7	32
12	24	F	1.75	10	0.3	1.2	0.8	23
13	24	F	1.63	7	0.7	1	0.9	29
14	34	F	1.64	9	0.4	1	0.8	29
15	21	F	1.73	4	0.5	0.8	0.7	34
16	25	F	1.73	8	0.6	0.9	0.7	24
17	23	F	1.62	14	0.5	1.23	0.9	30
18	22	F	1.73	10	0.4	1	0.8	27
19	20	F	1.76	9	0.5	0.9	0.7	25
20	24	H	1.78	12	0.4	1	0.8	31
21	22	F	1.69	12	0.5	1.2	1	35
22	24	F	1.72	13	0.5	1.2	0.9	27

Furthermore, color Doppler ultrasonography provides additional information about the blood vessels and surrounding tissues, such as the three-dimensional anatomy of the stem vessels and the blood flow inside the perforators. Tsukino et al.[4] estimated the size of perforators up to approximately 1 mm in diameter, including in obese patients. In our study, we identified perforators less than 0.5 mm in diameter. In the Tsukino study, approximately 20 minutes was required to evaluate the femoral vascular system on both sides.[4] This is less than the 30 minutes needed in our study on average to study the perforators in the trapezius muscle.

The Giunta et al. study[13] found that preoperative Doppler ultrasonography had a 47.6% false positive rate, a trend confirmed by Blondeel et al.[17] This high false positive rate is likely due to this imaging modality's high sensitivity, which identifies very small blood vessels that cannot be used for a perforator flaps because of their diameter. Giunta et al.[13] also reported an 11% false negative rate. These false negatives are likely technical: if the operator puts excessive pressure on the integuments with the probe, this can cause temporary interruption of the blood flow (hence the signal) in the small vessels.[13] When making perforator flaps, Giunta et al.[13] were able to use at least one of the perforators they had identified during the preoperative Doppler scan in 80% of patients (37 of 46). In their study, the perforators were located an average of 0.8 cm from their true emergency point through the fascia. This gap is acceptable for the purposes of surgical planning and raising of a perforator flap. According to Giunta et al.,[13] these findings show that preoperative Doppler ultrasonography provides an overview of the distribution of individual perforators, including their anatomical variations. In our study, color Doppler ultrasonography was used to inventory and classify the main perforators of the trapezius. The resulting preoperative markings (see Fig. 2) facilitate the intraoperative dissection of the perforating arteries and shorten the duration of the surgery.

Various authors recommend performing Doppler ultrasonography when planning perforator flap surgery.[11,13,18,19] Other authors suggest using laser Doppler velocimetry (LDV) to measure the blood flow inside vessels.[20] The latter examination requires a considerable amount of time, especially for small-diameter vessels such as perforators. This limits its use.[13] The results of the Ogawa study show that color Doppler ultrasonography is superior to LDV for evaluating perforator vascularization.[3] However, they also used Doppler flowmetry in the same indications. Doppler flowmetry is also a useful, low-cost tool for evaluating the position and flow in superficial vessels. However, its effectiveness is limited by the fact that it does not always differentiate between perforating vessels and larger-diameter axial vessels.[3] Thus it can be a source of false

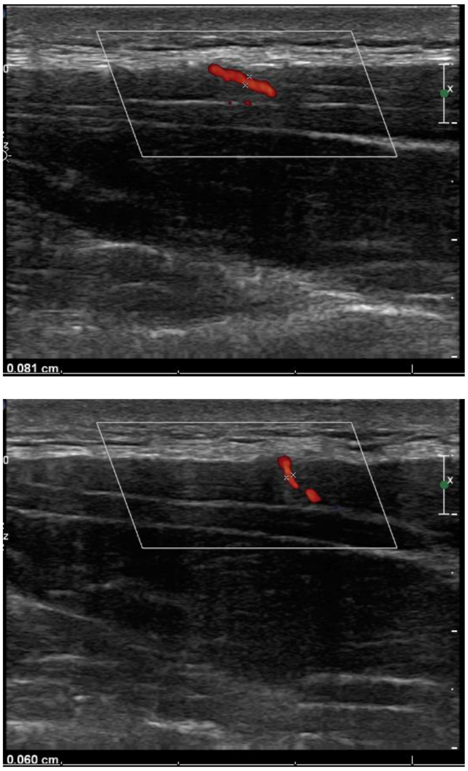

Fig. 3: a, b. Example of the perforators found in the trapezius muscle of a healthy volunteer

positives when the axial vessels have a superficial course.

Other diagnostic imaging methods such as angiography and MR angiograms can be used to study the distribution of perforators in the integuments.[4] Angiography is the most reliable method to identify medium-size arteries. However, it is an invasive method that exposes the patient to harmful radiation and is expensive. MR angiogram is a highly specific, non-invasive method to show blood vessels. However, its sensitivity is low, especially for vessels less than 2-mm in diameter. Consequently, this examination only has limited applications for identifying perforators that are often less than 2 mm in diameter. When compared to these two examinations, color Doppler ultrasonography is a simple, non-invasive, low-cost method.[4]

In previous studies, it has been show that color Doppler ultrasonography has high sensitivity and good specificity for the presurgical mapping of perforators.[15,21,22] In the Feng et al. study,[18] color Doppler ultrasonography identified the dominant perforators in 95% of cases, while CT angiography identified them in 90%. The accuracy of the dominant perforator's position during the preoperative period (compared to intraoperative data) was 95% for Doppler ultrasonography and 82.5% for CT angiography.

When ultrasonography is used with the Doppler mode, it can detect perforators as small as 0.5 mm in diameter. Currently, ultrasonography is the imaging modality with the highest spatial resolution able to identify anatomical structures less than 1 mm in size. It has various other advantages: a perforator located superficial to the muscle fascia can be identified selectively. Furthermore, other than the perforators, it provides good definition of the neighboring anatomical structures. It provides a color-coded map of the directional blood flow inside a vessel and the orientation of this vessel relative to neighboring structures[12] (Fig. 3). Using this method, the minimum diameter found in the Ogawa study[3] was 0.5 mm for perforators from the posterior intercostal arteries. The minimum diameter in our study was 0.3 mm for perforators from the dorsal scapular artery.

However, color Doppler ultrasonography has certain drawbacks: it is operator dependent and requires some knowledge of the anatomy of the vascularization of the flap of interest, along with lengthy interpretation time. Like in the Ogawa study,[3] it required an average of 30 minutes to identify the perforators in the trapezius muscle. This can be limited by the patient's compliance, who must maintain the same (somewhat uncomfortable) position during the entire examination.[23,24] Also, it is less reproducible than CT angiogram. While CT angiography provides structural information on the perforators and adjacent tissues on a single image, color Doppler ultrasonography provides information on a single perforator at a time, over a limited area and depth.[24] Doppler ultrasonography is limited to detecting perforators 0.5 mm or larger in diameter, while CT angiography can show perforators as small as 0.3 mm in diameter.

While Doppler ultrasonography does not provide detailed information on the trajectory of the perforators inside the deep tissue layers, this information is not relevant to the surgical technique. The most important information is the exact location of the perforator. When raising a perforator flap, dissection below the deep fascia is rarely necessary. Thus preoperative imaging contributes the most information above the fascial plane, as the main vascular trunks do not need to be dissected or viewed, except in specific cases. Our study shows that Doppler ultrasonography can be a useful tool for planning surgery involving pedicled trapezius perforator flaps.

6. Conclusion

Despite the limitations of preoperative Doppler ultrasonography and its moderate supplemental cost, it is relevant for surgeons using trapezius perforator flaps. It is able to specify the location, diameter, trajectory and general quality of arteries perforating the trapezius. Because of this fact, many authors have recommended using it when planning perforator flap surgery. It appears to be a useful tool when planning trapezius perforator flap surgery. The next step is to evaluate its use in clinical practice.

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8. Source of Funding

Conflicts of Interest

None.

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