The role of the anterolateral thigh flap (ALTF) in reconstructive microsurgery grows systematically from mid-eighties of the twentieth century until now. Significant anatomic variability of the perforators supplying the ALTF was described in literature.

**The aim of the study** was ultrasonographic assessment of the ALTF perforators in terms of localization, symmetry, diameter and flow velocity.

**Material and methods.** The study was performed using ultrasound machine with 12 MHz linear transducer. Both thighs of 30 healthy volunteers (15 men and 15 women) aged from 18 to 60 (mean 37.9) were examined. The line from anterior superior iliac spine (ASIS) to lateral border of the patella was traced, and divided into 10 equal segments. Point where perforator pierces the deep fascia was marked and its diameter was measured and recorded. Maximal flow velocity was measured and recorded. Symmetry of perforator location was confirmed as positive if difference in position of two perforators on both thighs was less than 1.5 cm in diameter.

**Results.** Total number of 119 perforators supplying skin of 60 thighs was found (mean 1.98 perforator per thigh). No perforators were found in 4 thighs (6.6%). Perforators were most abundant in segments from 5 to 7 (74.6%). Perforators with largest diameters and maximal flow velocity reaching 30-47 cm/s were localized in segments 5 and 6. Perforators in segments 4 and 5 were more abundant in men (50.9%) than in women (36.7%). Septal perforators make up to 26.9% of the total. Eighty percent of the septal perforators were localized in segments 5 and 6. Perforator distribution was elicited in the middle of the ASIS – patella line. In the range of ±1.5 cm from the midpoint of the line 33.6% of the perforators were found.

**Conclusions.** 1. Most of perforators with large diameter and big flow velocity are located in segments 5 and 6. 2. Perforators are more common in men in segments 4 and 5 than in women. 3. No perforators found in 4 thighs suggests that preoperative perforator mapping should become a preoperative routine, which can spare intraoperative dilemmas.

**Key words:** anterolateral thigh flap, color Doppler assessment, preoperative planning

The anterolateral thigh flap (ALTF) was described for the first time by Song in 1984 (1). Its applications have been progressively increasing, in line with the worldwide trend of more and more common use of perforator flaps in reconstructive surgery. Currently, it is one of the most commonly used free flaps (2). This flap can be planned as a skin or skin-fascial one, may include a muscle fragment or bone elements, may have sensory innervation or may be used as a flow through flap. If separate vascular pedicles are used, the flap may have independent skin islets that can be used for the reconstruction of multi-layer structures (3). This flap has found universal applications in head and neck reconstructive surgery (reconstructing intraoral defects, reconstructions of the cheek, jaw or tongue). A skin-fascial ALTF may be also used with success for the reconstruction of laryngeal and oesophageal segments (4).
The pedicled ALTF variant is used for the reconstruction of lower abdomen tissues and soft tissues of the pelvic girdle. An ALTF with sensory innervation and a muscle fragment is suitable for reconstructions within the lower extremity, including the load-bearing parts of the foot (fig. 1). During flap harvest, the patient is in the supine position. This makes it possible to operate in two teams, which often shortens the duration of surgery. Morbidity after flap harvest is acceptable, and the harvest site can be easily hidden under clothes. Due to all these considerations, plastic surgeons performing reconstructive operations often use the anterolateral thigh flap in the first instance.

The use of an ALTF for the reconstruction of complex tri-dimensional structures requires careful planning. Clinical situations requiring the use of several skin islets result in the need of providing to them an independent blood supply (3).

Anatomically, the flap skin islet is supplied with blood by perforators from the descending branch of the lateral femoral circumflex artery (fig. 2). Perforators may be present in different numbers and locations. Muscular and septal perforators may be present. For a microsurgeon performing a reconstruction, the knowledge of the exact location and type of the perforator is of extreme importance. The length of the vascular pedicle that can be isolated is also an important factor. Exact localisation allows precise planning of the flap architecture and is an important guideline during its preparation. Determining the types of perforators allows to approximately plan the duration of the reconstructive surgery (muscular perforators require longer intramuscular isolation, which prolongs the procedure). It becomes also important to select the “better” thigh, with a better distribution of perforators on its surface.

One of the methods used for exact determination of the perforator course, diameter and flow rate is an ultrasound examination with the use of the Colour Doppler function. This method, described for the first time by Hallock, allows also to precisely measure the length of the vascular pedicle of the planned flap, to map the sites where the perforators pierce the fascia, and to determine the number and spatial orientation of the perforators (5, 6, 7). It is a relatively accurate, cost-effective and non-invasive method. There is a more modern method of computed tomography but it is more expensive and requires contrast agent administration and patient’s exposure to a dose of ionising radiation. Magnetic resonance is currently in the phase of clinical trials.

The objective of this study is to evaluate and compare the locations, symmetry, diameter and flow rate of the ALTF perforators in healthy volunteers of both sexes in the Polish population.

**MATERIAL AND METHODS**

Perforator mapping was performed with the use of an Esaote My Lab 25 ultrasonograph with a high-frequency 12 MHz linear head.
The presence and types of the perforators supplying the anterolateral surface of both thighs were examined in 30 healthy volunteers (15 women and 15 men) aged 18-60 years (mean 37.9). Before the examination, interviews for diabetes and severe atherosclerosis were conducted and the persons with these disorders were not included in the study. During the study, the volunteers were in the supine position. Before examination, the line between the anterior superior iliac spine (ASIS) and the lateral upper border of the patella was traced. The length of this line in the study subjects ranged from 40 to 51 cm. The line was divided into 10 equal segments, starting from ASIS. Perforators were searched by slowly moving the device head along the traced line. The device was set to the Colour Doppler mode with maximum signal enhancement. The same parameters were used in each examination. The sites where the perforator pierced the deep fascia were marked with a colourful dot (fig. 3). The perforator diameters and the flow rate of its blood flow were measured and recorded. In view of the possible measurement error, the flow rate was measured three times and an arithmetic mean was calculated. The symmetry of perforator distribution on both thighs of the patient was determined. The symmetric distribution of the perforators was found when their locations differed by not more than ±1.5 cm.

RESULTS

The examinations performed revealed the presence of 119 perforators in total on the surface of 60 thighs (mean 1.98 perforators per thigh). The maximum number of perforators per thigh was 5 in two study subjects. No perforators were found on 4 thighs (6.6%).

The perforator diameter ranged from 0.6 to 3.5 mm. The perforator blood flow rate ranged from 10 to 47 cm/s (tab. 1).

The perforators were most abundant in segments 5 to 7 (74.6%). Perforators with the largest diameters and flow rate of 30-47 cm/s were located in segments 5 and 6 (tab. 2). More

Table 1. Distribution of perforators in the individual segments, broken down by the diameters

<table>
<thead>
<tr>
<th>Segments</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perforators with a diameter of 0.5-1 mm</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Perforators with a diameter of &gt;1-2 mm</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>8</td>
<td>28</td>
<td>21</td>
<td>10</td>
<td>7</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Perforators with a diameter of &gt;2 mm</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>9</td>
<td>9</td>
<td>3</td>
<td>2</td>
<td>0</td>
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</tr>
</tbody>
</table>

Table 2. Distribution of perforators in the individual segments, broken down by the blood flow rates

<table>
<thead>
<tr>
<th>Segments</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perforators with a flow rate of 10-22 cm/s</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>4</td>
<td>21</td>
<td>21</td>
<td>9</td>
<td>7</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Perforators with a flow rate of &gt;22-35 cm/s</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>5</td>
<td>10</td>
<td>7</td>
<td>7</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Perforators with a flow rate of &gt;35-47 cm/s</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>8</td>
<td>6</td>
<td>0</td>
<td>1</td>
<td>0</td>
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</tbody>
</table>
frequent perforator presence in segments 4 and 5 was found in men (50.9%) than in women (36.7%). These data are illustrated on charts (fig. 4, 5, 6).

Septal perforators represented 26.9% of all perforators found in the study. Eighty percent of septal perforators were located in segments 5 and 6.

Moreover, symmetry of perforator distribution on both thighs was investigated. Close symmetry of perforator distribution with a tolerance ±1.5 cm was found for 27 perforator pairs (45.3%).

In accordance with the Wei's studies (9), where the author recommends searching for ALTF perforators within a 3 cm-diameter circle drawn from the midpoint of the line connecting the anterior superior iliac spine and the lateral border of the patella, the perforators distribution within an area of 3 cm and 5 cm from the midpoint of this line was mapped (fig. 3). The percentage of perforators within the midpoint ±1.5 cm area was 33.6% and of those within the midpoint ±2.5 cm area was 47%.

DISCUSSION

There are many reports on anatomical variability of the lateral femoral circumflex artery and its descending branch whose perforators supply blood to the skin islet of the flap (9-12). Within the literature on ALTF, there are studies conducted on an extensive material, describing the variability of the structure of the perforator itself in its suprafascial and intramuscular course. Typically, an arterial perforator is present along with two accompanying veins. However, there were cases observe where the perforators were present along with four accompanying veins, and sometimes with one vein or even without any vein at all. The authors claim that this can explain some of the failures in transferring ALTFs (13). Precise preoperative mapping of the vascular system makes it possible to minimise the complications related to an untypical vessel distribution. The 1993 study by Koshima who recommended the performance of arteriography to avoid intraoperative difficulties resulting from anatomical variants (12) supports the usefulness of thorough vascular mapping before ALTF transfer.

In articles on ALTF, there are many various opinions on preoperative perforator mapping. There are studies whose conclusion is the absence of indications for preoperative evaluation (18). The authors of these studies indicate an area with a 3 cm diameter around the line connecting the anterior superior iliac spine and the lateral border of the patella, where there is the highest (empirically confirmed) probability of perforator presence (9). In the study presented in this article, only 33.6% of the perforators were contained within this area. The studies of Taylor from 1990s underline the need to perform preoperative examina-
Colour Doppler assessment of perforators and its usefulness in preoperative planning

According to Taylor, blind pencil Doppler is sufficient for vessel evaluation (14). It is a rapid and cheap test method which allows to obtain the information if a vessel with blood flowing through it is present in the area examined. However, it is not possible to accurately evaluate the vessel course or to measure the vessel diameter and flow rate. Therefore, it is difficult to conclusively select the vessel through which the major amount of blood is flowing only on the basis of an acoustic signal. This is of particularly high importance at the elevation of flaps of large dimensions. During this examination, it is possible to commit an error of finding a vessel which is indeed located nearby and has a good flow but does not supply the skin in the given area. Another drawback of this method is low accuracy of the measurement. Some authors evaluate the accuracy ALTF perforator mapping with the use of blind Doppler as 40% in relation to the intraoperative image (10, 15).

More advanced imaging techniques which include Colour Doppler must be used for more precise evaluation of perforators (5, 6, 7). This is a non-invasive examination using the ultrasound principle combined with flow evaluation based on the phenomenon described by Doppler. It is possible to accurately determine the site where the perforator pierces the deep fascia. The number of perforators present can be determined and their diameters and blood flow can be evaluated. The accuracy of this method in relation to the intraoperative image is rated highly – around 95% (8). This is of particular importance when planning large flaps and flaps with independent skin islets used for the reconstruction of multilayer structures. It is also possible to trace the whole vascular pedicle of the planned flap. Its length and diameter can be measured. If it is necessary to use a long pedicle, the most distal perforator should be used. In older patients, if it is necessary to use a free flap for the reconstruction, the examination in B presentation makes it possible to evaluate the condition of the vessel itself, the potential presence of wall thickening or atherosclerotic plaques – and thus enables the prediction of potential technical difficulties during the performance of the microvascular anastomosis. In these cases, evaluation of blood flow rate seems to be invaluable, and it is impossible with any other of the methods discussed. The flap skin islet may be supplied by septal and muscular perforators. Isolation of septal perforators is incomparably more quicker, easier and less time-consuming. In its pioneering study on ALTF, Song described the presence of septal perforators (1). The subsequent studies reported predominance of muscular perforators – septal perforators represented 18% (9) or 23% (16) of all perforators. There are also anatomical studies on cadavers reporting on the frequency of septal perforator presence in the order of 30% (17). In the present study, septal perforators represented 26.9% of all perforators found (fig. 7).

The remaining results presented in this study are consistent with the results obtained in other studies investigating perforator distribution (8, 16). Perforators are present in the highest number in segments 5 and 6. Variability of perforator distribution depending on the sex is worth noting. This has not been described so far in the available literature. In the present study, more frequent presence of perforators in segments 4 and 5 was found in men (50.9%) than in women (36.7%), which may be of importance for flap planning, when vessel imaging techniques are unavailable. It should also be borne in mind that 80% of septal perforators, and thus those easier to isolate, are found in segments 5 and 6.

In the present study, no symmetry of the perforator system on both thighs of the same person was found (symmetric presence of single perforator pairs in 45.3% of the cases),

Fig. 7. Colour-Doppler examination. Visible septal perforator. Rectus femoris muscle (RF), vastus lateralis muscle (VL)
Ł. Ulatowski

has technical equipment and experience allowing to evaluate small blood vessels. In view of the high cost of the examination in combination with a low valuation by the National Health Fund of reconstructive microsurgical procedures, the operator not always is able to use this examination.

Magnetic resonance angiography is one of the most advanced methods of obtaining tri-dimensional reconstruction of flap vessel images. Until recently, it has been an unreliable method in the evaluation of vessels with a diameter below 2 mm. Currently, the most advanced devices and state-of-the-art software allow to perform a technically perfect examination with tri-dimensional reconstruction. It is a non-invasive and accurate examination, for the time being used mainly for the evaluation of DIEP flap perforators (22). In the future, it will probably constitute the basis for preoperative evaluation of blood vessels in reconstructive surgery. Currently, the low availability and the very high cost eliminate this method from everyday clinical practice.

CONCLUSIONS

1. Most of the perforators (including the septal ones) are located in segments 5 and 6.
2. The presence of perforators in segments 4 and 5 is more frequent in men than in women.
3. The absence of perforators in 6.6% of the thighs examined suggests that perforator mapping should be performed routinely, which will prevent intraoperative complications.

It is worth noting that the anterolateral thigh flap is the flap which is most often used in head and neck tissue reconstructions in the Asiatic population. The studies on the most extensive material reporting on the transfer of more than 1000 ALTFs originate from the study sites on Taiwan, in China and in Japan (8-11, 13, 15). In the Western world, this flap is used slightly less commonly (20). According to the literature data, this is caused by substantial anatomical differences in flap vasculature (9, 20). The present study provides an opportunity for comparing the perforator distribution in the Polish population with that found in the studies conducted in other countries. Moreover, the better developed adipose tissue in the Western population may be another obstacle to more frequent ALT finger utilization (20).

Multi-row-detector computed tomography (16, 21) constitutes a useful tool in preoperative evaluation of an ALT. It allows to obtain tri-dimensional reconstructions of vessel course, which may help plan and significantly shorten the duration of surgery. The most important drawback of this method is exposing the patient to ionising radiation. The limited availability of this technique is also a significant factor. Not every radiological laboratory

has technical equipment and experience allowing to evaluate small blood vessels. In view of the high cost of the examination in combination with a low valuation by the National Health Fund of reconstructive microsurgical procedures, the operator not always is able to use this examination.

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