



## Relationship Between Preoperative Flow Velocity in Recipient Perforator Arteries Determined by Color Doppler Ultrasonography and Intraoperative Pulsation and Blood Spurting During Perforator-to-Perforator Anastomosis

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### Abstract

**Introduction:** Perforator-to-perforator anastomosis in reconstructive surgery is one of the applications of supermicrosurgery. However, we often encounter poor pulsation and spurting of blood from a recipient perforator intraoperatively, which makes it impossible to perform perforator-to-perforator anastomosis. The aim of this study was to identify color Doppler US parameters that can aid reliable preoperative selection of a recipient perforator artery by comparing the preoperative examination data with direct observation of the perforators intraoperatively.

**Patients and Methods:** The study included 38 patients who underwent vascularized lymphatic tissue transfer. In all cases, we searched for perforators in the lower extremities using color Doppler US on the day before surgery. The vessel diameter at maximal pulsation, peak systolic flow velocity, and depth of each perforator were recorded.

As one of the direct observation data, each perforator detected was divided into 4 categories according to the depths of dissection steps required until confirming sufficient pulsation or blood flow.

**Results:** The correlation between the preoperative peak systolic flow velocity in the perforator and completion of the steps for successful perforator dissection was statistically significant ( $p < 0.01$ ). The correlation between preoperative depth where the highest peak systolic flow velocity was detected and completion of the steps for successful perforator dissection was statistically significant ( $p < 0.01$ ).

**Discussion:** Both functional and morphological assessment is necessary preoperatively in order to reduce the intraoperative burden of searching for an adequate recipient perforator. We deduced from our findings that a peak systolic flow velocity of  $\geq 20.0$  cm/s is an important determinant of successful dissection.

**Keywords:** Perforator to perforator anastomosis; Recipient perforator; Dissection; Color Doppler Ultrasonography; Flow velocity

### Introduction

Supermicrosurgery is a minimally invasive technique that allows micro-neurovascular anastomosis between blood vessels with a diameter of 0.3 mm to 0.8 mm and single nerve fascicles [1,2]. Perforator-to-perforator anastomosis in reconstructive surgery is one of the applications of supermicrosurgery [3,4,5]. The advantages of this technique include less morbidity at donor/recipient sites, minimal invasion of major vessels, a smaller skin incision, and multiple/multistage tissue transfers [6]. However, it is difficult to find suitable recipient perforators that require only small skin incisions because of anatomical and functional variability.

Color Doppler Ultrasonography (US) is useful for locating perforators but not for determining their diameter and course. There have been some investigations on US methods that can be used to

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detect and assess perforator flaps [7-13]. Localization and assessment of recipient perforators is an important aspect of the preoperative planning for perforator-to-perforator anastomosis. The usefulness of color Doppler US for localization of recipient perforators has been reported previously [14]. However, we often encounter poor pulsation and spurting of blood from a recipient perforator intraoperatively, which makes it impossible to perform perforator-to-perforator anastomosis even after use of papaverine hydrochloride spray. Strong pulsation of perforators and spurting of blood are indications for use of recipient perforators. The aim of this study was to identify color Doppler US parameters that can aid reliable preoperative selection of a recipient perforator artery by comparing the preoperative examination data with direct observation of the perforators intraoperatively.

## Patients and Methods

The study included 38 patients who underwent vascularized lymphatic tissue transfer [15] between November 2017 and August 2019 at the International Center of Lymphedema, Hiroshima University Hospital. The study protocol was approved by the Hiroshima University Hospital Institutional Review Board. All patients provided written informed consent.

The inclusion criteria were no history of heart failure, renal failure, hypertension or hypotension, arteriosclerosis, chronic arterial obstruction or stenosis and ISL (International Society of Lymphedema) stage late II-III [16]. The Lower Extremity Lymphedema (LEL) index was obtained by dividing the sum of the squares of the circumference in each of 5 areas of the affected lower extremity by the Body Mass Index (BMI) [17]. There were no cases of arterial and/or venous malformation.

In all cases, we searched for perforators in the lower extremities using color Doppler US (Noblus; Hitachi Aloca, Tokyo, Japan) on the day before surgery. The color Doppler US was performed by the first author (SY) with the patient in the supine position, as during surgery. The vessel diameter at maximal pulsation, peak systolic flow velocity, and depth of each perforator vessel identified were recorded. The three-dimensional course of the vessel through the deep fascia and fat tissue was determined to provide information for surgery. We searched in the medial thigh region, which is supplied mainly by the descending branch of the medial circumflex femoral artery or the superior medial genicular artery, and in the medial side of the lower leg, which is supplied mainly by the posterior tibial artery. Our selection criterion for performing dissection at the recipient site was a perforator diameter  $\geq 1.0$  mm on preoperative color Doppler US examination.

## Dissection Procedure

The dissection procedures were performed by three microsurgeons who have experienced supermicrosurgery for more than five years as follows. A straight 5-cm skin incision was made at the site of the recipient perforator, which had been marked preoperatively. The recipient perforator was then bluntly dissected using the tip of an electric knife from the superficial layer downwards under an operating microscope. Small groups of vessels were dissected using a bipolar coagulator. The vessels were exposed by removing perivascular tissues with micro forceps and scissors.

The recipient perforators were dissected in three steps. In step 1, the superficial fascial layer (directly beneath the dermis to the

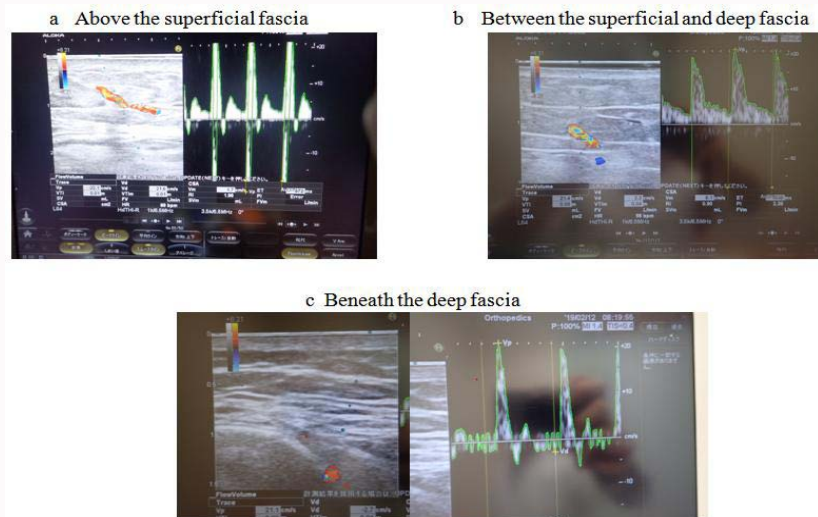
subdermal fat layer) was dissected to a depth of 1 cm. Two types of vessels were identified in this layer: (1) relatively large vessels with a diameter of 1 cm to 2 cm that ran horizontally beneath the skin, usually corresponding to cutaneous veins; and (2) bundles consisting of 2 to 3 relatively small vessels with a diameter of 0.1 mm to 0.5 mm that ran vertically from the deep layer to the superficial layer, usually corresponding to perforators. Pulsation could sometimes be seen in these perforators in step 1 of the dissection but sometimes could not be seen even after application of papaverine hydrochloride spray. If adequate pulsation and blood flow was detected in step 1, we performed a vascularized tissue transfer by perforator-to-perforator anastomosis (Video 1).

If no pulsation or blood flow was seen, we proceeded to step 2, in which the dissection was continued down to the deep fascial layer. At this level, we were able to see the saphenous vein, which could be adapted to serve as a recipient vein. During this step, we often had to dissect a recipient vessel from adherent fascial tissue or adipose tissue because of the fibrous tissue formed in response to the chronic inflammation associated with lymphedema [18]. In step 2, recipient perforators were often seen to change their course and run horizontally in the deep fascia. Sometimes we were able to see pulsation in the perforators in this dissection step but sometimes not, even after application of papaverine hydrochloride spray. If sufficient pulsation and blood flow were detected in step 2, we then performed a vascularized tissue transfer by perforator-to-perforator anastomosis (Video 2).

If inadequate or no pulsation or blood flow was seen in step 2, we proceeded to step 3, in which we dissected and removed the deep fascial tissue and all other fibrous tissue around the recipient perforators at the level of the deep fascia. After dissection, we identified muscle tissue through the window of the deep fascia around the recipient perforators. Pulsation could sometimes be seen in perforators in step 3 but sometimes not, even after application of papaverine spray. If adequate pulsation and blood flow were seen, we performed a vascularized tissue transfer by perforator-to-perforator anastomosis (Video 3). In steps 2 and 3, we removed as much adipose and scar tissue as possible to secure a wide operative view. If no pulsation or blood flow was seen in step 3, we moved to another candidate perforator.

We classified each perforator detected as “easy”, “difficult”, “very difficult”, or “unsuitable” according to the number of dissection steps required. For example, the recipient perforator was classified as “easy” if we confirmed pulsation and circulation of blood during step 1, “difficult” if we found pulsation and circulation only during step 2, “very difficult” if we found pulsation and circulation only during step 3, or “unsuitable” if no pulsation or circulation was found after step 3. The diameter of the dissected perforator vessel was measured under direct observation and categorized as  $\leq 0.3$ , 0.4 to 0.6, or  $\geq 0.7$ . These were then used as recipient vessels for perforator-to-perforator anastomosis.

The intraoperative findings in the 38 patients were compared with the results of the preoperative US assessment and categorized as follows: Vessel diameter at maximal pulsation, 1.0 mm to 1.5 mm or 1.6 mm to 2.0 mm; peak systolic flow velocity,  $\leq 14.9$ , 15.0 to 19.9, or  $\geq 20.0$  (cm/s); depth, above the superficial fascia, between the superficial fascia and deep fascia, or under the deep fascia according to the layer where the highest peak systolic flow velocity was detected (Figure 1).



**Figure 1:** Ultrasonographic parameters assessed preoperatively included vessel diameter at maximal pulsation, peak systolic flow velocity, and the layer where the highest peak systolic flow velocity was measured. (a) A case in which the highest peak systolic flow velocity was detected above the superficial fascia. (b) A case in which the highest peak systolic flow velocity was detected between the superficial and deep fascia. (c) A case in which the highest peak systolic flow velocity was detected beneath the deep fascia.

The mean perforator diameter measured by direct observation intraoperatively and the preoperative examination data were compared using the Student’s t-test. The Spearman’s rank correlation coefficient was calculated to assess the relationship between the preoperative US assessment and the findings at the 4 dissection steps where a perforator was found to be suitable. The Spearman’s rank correlation coefficient was also used to assess the relationship between the findings during the 4 dissection steps and the intraoperative diameter of the perforator arteries, BMI, and LEL index. All statistical analyses were performed using Statcel4 software (OMS Ltd., Tokyo, Japan). A p-value <0.05 was considered statistically significant.

**Results**

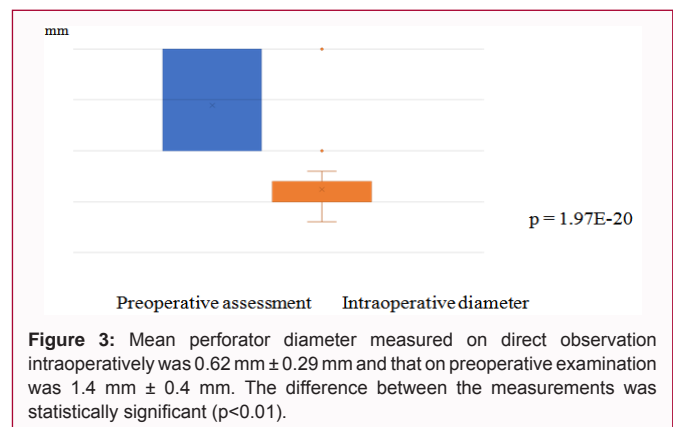
All perforator-to-perforator anastomoses were performed under general anesthesia. When a perforator vessel was found to be unsuitable at the time of the first dissection, we moved on to a second dissection. In all cases, an “easy”, “difficult”, or “very difficult” perforator was successfully found within the first 2 dissections. Various types of perforator flaps were harvested, including superficial circumflex iliac artery and first metatarsal artery flaps; the diameters of the flap artery and vein ranged from 0.5 mm to 1.0 mm and from 0.5 mm to 2.0 mm, respectively. In most cases, there was no discrepancy in vessel size for arterial anastomoses, which allowed us to perform an end-to-end anastomosis using the super microsurgical technique. For the venous anastomoses, we used a subcutaneous vein or comitant vein in an end-to-end fashion or a saphenous vein in an end-to-side fashion to resolve any discrepancy in vessel size. All flaps survived (Figure 2) and we confirmed the patency of the anastomosed vessels by color Doppler US.

No false-positive results were registered for localization of the perforators when comparing the preoperative examination data with the direct observation data. However, the mean perforator diameter measured on direct observation intraoperatively was 0.62 ± 0.29 mm and the value measured on preoperative examination was 1.4 ± 0.4 mm; the difference was statistically significant (p<0.01; Figure 3).

The correlation between the preoperative diameter of the

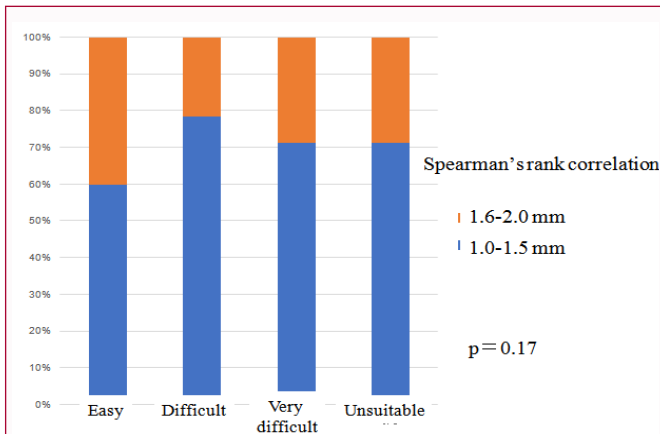


**Figure 2:** The status lymphadiposal flap was survived by successful perforator to perforator anastomosis.

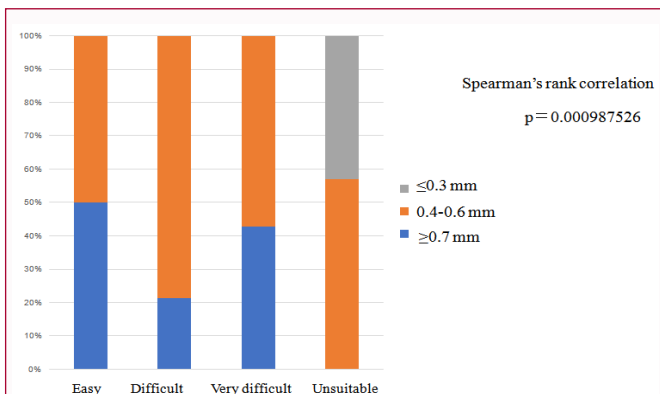


**Figure 3:** Mean perforator diameter measured on direct observation intraoperatively was 0.62 mm ± 0.29 mm and that on preoperative examination was 1.4 mm ± 0.4 mm. The difference between the measurements was statistically significant (p<0.01).

perforator and the completion of the steps for successful perforator dissection was as follows: 1.0 mm to 1.5 mm; 60% (6 cases), 1.6 mm to 2.0 mm; 40% (4 cases) were in the “easy” category; 1.0 mm to 1.5 mm; 78.6% (6 cases), 1.6 mm to 2.0 mm; 21.4% (3 cases) were in the “difficult” category; 1.0 mm to 1.5 mm; 71.4% (10 cases), 1.6 mm to 2.0 mm; 28.6% (4 cases) were in the “very difficult” category; and 1.0 mm to 1.5 mm; 71.4% (10 cases), 1.6 mm to 2.0 mm; 28.6% (4 cases). There was no significant correlation between the preoperative diameter of the perforator and its ease of dissection (p>0.05; Figure



**Figure 4:** Correlation between the preoperative diameter of the perforator and completion of the steps for successful perforator dissection was as follows: 1.0 mm to 1.5 mm; 60% (6 cases), 1.6 mm to 2.0 mm; 40% (4 cases) were in the “easy” category; 1.0 mm to 1.5 mm; 78.6% (6 cases), 1.6mm to 2.0 mm; 21.4% (3 cases) were in the “difficult” category; 1.0 mm to 1.5 mm; 71.4% (10 cases), 1.6 mm to 2.0 mm; 28.6% (4 cases) were in the “very difficult” category; and 1.0 mm to 1.5 mm; 71.4% (10 cases), 1.6 mm to 2.0 (mm); 28.6% (4 cases) were in the “unsuitable” category. The relationship was not statistically significant ( $p>0.05$ ).

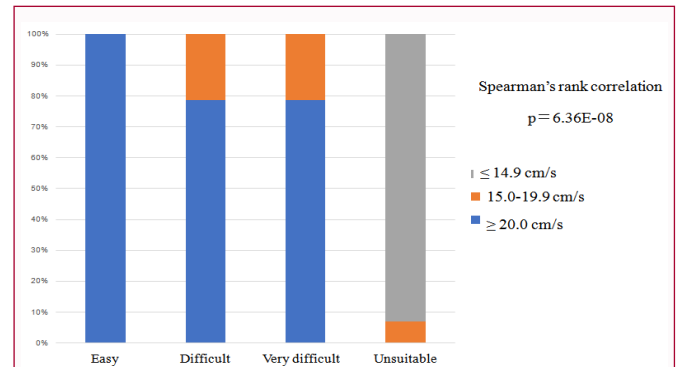


**Figure 5:** Correlation between the intraoperative diameter of the perforator and completion of the steps for successful perforator dissection was as follows: ≥ 0.7 mm; 50% (5 cases), 0.4 mm to 0.6 mm; 50% (5 cases) were in the “easy” category; ≥ 0.7 mm; 21.4% (3 cases), 0.4 mm to 0.6 mm; 78.6% (11 cases) were in the “difficult” category; ≥ 0.7 mm; 42.9% (6 cases), 0.4 mm - 0.6 mm; 57.1% (8 cases) were in the “very difficult” category; 0.4 mm to 0.6 mm; 57.1% (8 cases), ≤ 0.3 mm; 42.9% (6 cases) were in the “unsuitable” category. The relationship was statistically significant ( $p<0.01$ ).

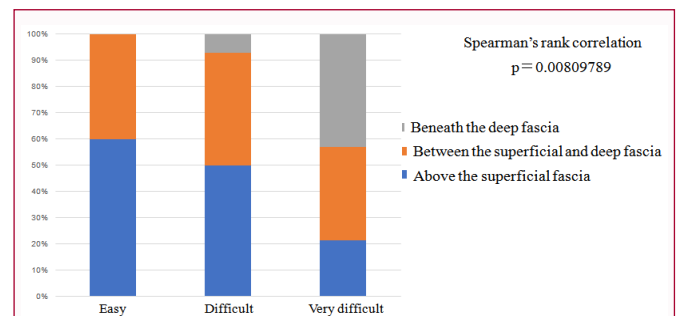
4).

The correlation between the intraoperative diameter of the perforator and the ease of completion of steps for perforator dissection was as follows: ≥ 0.7 mm; 50% (5 cases), 0.4 mm to 0.6 mm; 50% (5 cases) were in the “easy” category; ≥ 0.7 mm; 21.4% (3 cases), 0.4 mm to 0.6 mm); 78.6% (11 cases) were in the “difficult” category; ≥ 0.7 mm; 42.9% (6 cases), 0.4 mm to 0.6 mm; 57.1% (8 cases) were in the “very difficult” category, 0.4 mm to 0.6 mm); and 57.1% (8 cases), ≤ 0.3 mm; 42.9% (6 cases) were in the “unsuitable” category. The relationship was statistically significant ( $p<0.01$ ; Figure 5).

The correlation between the preoperative peak systolic flow velocity in the perforator and completion of the steps for successful perforator dissection were as follows: ≥ 20.0 cm/s; 100% (10 cases) were in the “easy” category, ≥ 20.0 cm/s; 78.6% (11 cases), 15.0 cm/s to 19.9 cm/s; 21.4% (3 cases) were in the “difficult” category; ≥ 20.0



**Figure 6:** Correlation between the preoperative peak systolic flow velocity in the perforator and completion of the steps for successful perforator dissection was as follows: ≥ 20.0 cm/s; 100% (10 cases) were in the “easy” category; ≥ 20.0 cm/s; 78.6% (11 cases), 15.0 to 19.9 cm/s; 21.4% (3 cases) were in the “difficult” category; ≥ 20.0 cm/s; 78.6% (11 cases), 15.0 to 19.9 cm/s; 21.4% (3 cases) were in the “very difficult” category; 15.0 to 19.9 cm/s; 7.1% (1 case), ≤ 14.9 cm/s; 92.9% (13 cases) were in the “unsuitable” category. The relationship was statistically significant ( $p<0.01$ ).



**Figure 7:** Correlation between preoperative depth where the highest peak systolic flow velocity was detected and completion of the steps for successful perforator dissection was as follows: above the superficial fascia 60% (6 cases), between the superficial and deep fascia; 40% (4 cases) were in the “easy” category; above the superficial fascia; 50% (7 cases), between the superficial and deep fascia; 42.9% (6 cases), under the deep fascia; 7.1% (1 case) were in the “difficult” category, above the superficial fascia; 21.4% (3 cases), between the superficial and deep fascia; 35.7% (5 cases), under the deep fascia; 42.9% (6 cases) were in the “very difficult” category. The relationship was statistically significant ( $p<0.01$ ).

cm/s; 78.6% (11 cases), 15.0 cm/s to 19.9 cm/s; 21.4% (3 cases) were in the “very difficult” category; and 15.0 cm/s to 19.9 cm/s; 7.1% (1 case), ≤ 14.9 cm/s; 92.9% (13 cases) were in the “unsuitable” category. The correlation was statistically significant ( $p<0.01$ ; Figure 6).

The correlation between preoperative depth where the highest peak systolic flow velocity was detected and completion of the steps for successful perforator dissection were as follows: above the superficial fascia, 60% (6 cases) and between the superficial and deep fascia, 40% (4 cases) were in the “easy” category; above the superficial fascia, 50% (7 cases), between the superficial and deep fascia; 42.9% (6 cases), beneath the deep fascia; 7.1% (1 case) were in the “difficult” category, above the superficial fascia; 21.4% (3 cases), between the superficial and deep fascia; 35.7% (5 cases), beneath the deep fascia; 42.9% (6 cases) were in the “very difficult” category. The relationship was statistically significant ( $p<0.01$ ; Figure 7).

There was no significant relationship between BMI and completion of the steps for successful perforator dissection ( $p=0.98$ ). There was also no significant relationship between the LEL index and the completion of these steps ( $p=0.96$ ).

## Discussion

Selection of the recipient perforator is as important as the choice of perforator flap when performing vascularized tissue transfers using perforator-to-perforator anastomosis. The problem of location of the recipient perforator has been largely solved by imaging with acoustic Doppler, multi-detector row computed tomography angiography, or color Doppler US. Color Doppler US is particularly useful for detecting the size and course of the vessels [14]. However, we often encounter the problem that severe spasm in the recipient perforator makes it impossible to perform a vascularized tissue transfer using perforator-to-perforator anastomosis. Strong pulsation in the perforators and spurting of blood are the indications for use of recipient arteries. Both functional and morphological assessment is necessary preoperatively in order to reduce the intraoperative burden of searching for an adequate recipient perforator.

In our study, the diameter of the perforator determined by direct observation was significantly smaller than that measured preoperatively. Furthermore, no significant relationship was found between successful perforator dissection and preoperative assessment of vessel diameter, BMI, or the LEL index. However, there was a significant relationship between the diameter measured intraoperatively and successful perforator dissection. We deduced from these findings that spasm occurs during dissection and affects the diameter of the perforator and the likelihood of successful dissection. It is also possible that the diameter measured includes the fibrous tissues around the perforators, given the difficulty of identifying the outer or inner diameter of vessels with a measured diameter of 1 mm to 2 mm.

Furthermore, there was a significant relationship between the preoperative peak systolic flow velocity in the perforator and successful perforator dissection. The rate of successful dissection was highest for perforators with a peak systolic flow velocity of  $\geq 20.0$  cm/s. Perforators with a velocity of  $\geq 20.0$  cm/s were more likely to be dissected successfully than those with a velocity of 15.0 to 19.9 cm/s. We deduced from these findings that a peak systolic flow velocity of  $\geq 20.0$  cm/s is an important determinant of successful dissection.

To our knowledge, there are some reports on preoperative flow velocity in perforators used for flap harvesting [19-22]. These reports indicate that a flow velocity of  $>20$  cm/s is needed for successful harvesting of a flap. A previous article on the preoperative flow velocity in recipient perforators reports  $>15$  cm/s to 20 cm/s is adequate to allow successful perforator-to-perforator anastomosis in vascularized tissue transfers [23]. In our study, however, some of those with a velocity of 15.0 cm/s to 19.9 cm/s were not reliable for recipient perforators. We recommend perforators with a velocity of  $\geq 20.0$  cm/s as recipient perforators.

There was a significant relationship between the preoperative depth where peak systolic flow velocity was measured and completion of the steps needed for perforator dissection.

To identify the recipient perforator using the smallest possible skin incision, it is advantageous to detect vessels that have strong pulsation and are spurting blood in the most superficial layer as this also contributes to make anastomosis easier. It is also important to select the most superficial perforator with the highest flow velocity.

## Conclusion

A significant relationship was seen between the findings on

preoperative examination of flow velocity using color Doppler US and strong pulsation and spurting blood detected intraoperatively in the lower extremity before performing perforator-to-perforator anastomosis. Selecting perforators with a high systolic blood flow velocity in the superficial layer is key to successful vascularized tissue transfer using perforator-to-perforator anastomosis.

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