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# Zonal perfusion patterns in pedicled free-style perforator flaps



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## KEYWORDS

Perforator flap;  
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**Summary** *Introduction:* Local perforator flaps have become a standard procedure in reconstructive surgery. They allow the transfer of large tissue units with minimal donor-site morbidity. However, clinical studies on flap perfusion changes over time are lacking. The aim of this study was to investigate the perfusion of free-style single perforator flaps with an eccentrically located main perforator by combined laser Doppler spectrophotometry.

*Patients and methods:* Ten patients (six male, four female, 29–71 years) were included in this prospective clinical study. All flaps were based on one perforator. Flaps were harvested from the trunk ( $n = 6$ ) or the proximal upper or lower extremity ( $n = 4$ ). Flap perfusion was assessed using a combined laser Doppler spectrophotometry (CLDS) device (O2C, Oxygen to See, LEA Medizintechnik, Giessen, Germany) at days 0, 1, 7 and 14 in different zones.

*Results:* Flap dimensions were  $18.6 \pm 4.7 \times 7.2 \pm 1.6$  cm. Two flaps developed minor tip necroses (<10%), eight flaps survived completely. CLDS proved to be very sensitive for the detection of regional perfusion problems. A considerable perfusion gradient was observed at days 0 and 1. Here, reduced blood flow and post-capillary oxygen saturations were found at the tip when compared to the region above main perforator (RAMP). Blood flow remained stable proximally while it improved significantly from day 1 to 14 at the tip region.

*Conclusion:* CLDS is an effective method for objective evaluation of flap perfusion. Although distal flap perfusion is diminished initially, the majority of perforator flaps with eccentrically located perforators survive completely. Obviously, flap perfusion improved between days 1 and 14. This clinical finding might be explained by reorganisation of the vascular system with

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opening of so-called connecting or choke vessels. This knowledge might influence decision making in perforator flap surgery.

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Local perforator flaps have become a powerful tool in reconstructive surgery. They allow the transfer of large tissue units with minimal donor-site morbidity.<sup>1–11</sup> However, while free perforator flaps such as the anterolateral thigh (ALT) flap<sup>12</sup> or the deep inferior epigastric artery (DIEP) flap<sup>13–15</sup> are standardised procedures that are frequently performed, local free-style propeller flaps are perceived as more challenging due to the sometimes unpredictable course of the perforators and the necessity of a flexible surgical strategy. The free-style concept has been introduced by Wei and co-workers for the dissection of free flaps.<sup>16,17</sup> This flexible strategy allows an individualised reconstruction with optimal functional results. Later, this approach was adopted successfully for local perforator flaps.<sup>8,18,19</sup> Free-style flaps can be raised at virtually any region of the human body, if adequate microsurgical techniques are applied. However, while the location of perforators can be predicted reliably using Doppler ultrasound and imaging modalities such as duplex ultrasound, computed tomography angiography (CTA) and magnetic resonance imaging (MRI),<sup>20–24</sup> the size of the individual skin territory that is sufficiently perfused by a given perforator is difficult to define. Today, reconstructive decision making regarding free-style perforator flap dimension and flap volume is based mainly on personal experience, cadaver studies and some general rules regarding orientation of the angiosomes or perforasomes.<sup>25–28</sup>

Recently, ICG angiography<sup>14,29,30</sup> and laser Doppler imaging<sup>31,32</sup> have been used for intra-operative assessment of flap perfusion. In addition, a combined laser Doppler spectrophotometry (CLDS) device has been applied for evaluation of zonal perfusion patterns in DIEP flaps.<sup>15,33,34</sup> CLDS is a technique that quantifies perfusion in tissue. The Doppler shift caused by the movement of erythrocytes is used for analysis of blood flow velocity and blood flow in a given tissue volume while assessment of oxygen saturation (SO<sub>2</sub>) and relative haemoglobin content (rHb) is based on evaluation of white light absorption/reflection. The aim of this study was to investigate the development of regional perfusion patterns in free-style single perforator flaps over time using CLDS, with a special focus on oxygenation and blood flow at the most distal region of the flap.

## Patients and methods

Between August 2010 and July 2011, 10 consecutive patients with skin and soft-tissue defects at the trunk and proximal extremities were included in this prospective study. The patient's details are summarised in Table 1. The study protocol was approved by the medical ethics committee of Friedrich-Alexander-University of Erlangen-Nuremberg, Germany, and the local governmental

authorities. Written informed consent was obtained from all patients prior to enrolment. The mean age was  $53.4 \pm 17.7$  years. Five patients had at least one cardiovascular risk factor such as nicotine abuse, diabetes or peripheral arterial occlusive disease. Indications for flap surgery were oncological resection ( $n = 5$ ), decubital ulcers ( $n = 3$ ) and posttraumatic defects ( $n = 2$ ). Single stage reconstruction was performed in three patients. Topical negative pressure dressings (VAC, Kinetic Concepts Inc., San Antonio, TX, USA) were applied in seven patients prior to reconstruction for 4–5 days.

Free-style perforator flaps were raised using standard techniques (Figure 1).<sup>8,9,11,18</sup> The main perforator was exposed and dissected microsurgically over at least a 3-cm distance. The propeller design was chosen in eight patients, local v–y advancement was performed in two patients. All flaps were based on a single, eccentrically located perforator. Flaps were harvested from the trunk ( $n = 6$ ) or the proximal upper ( $n = 2$ ) and lower extremity ( $n = 2$ ). Flap inset was performed without any major tension of the flap and only moderate tension of the donor sites.

CLDS (O2C, Oxygen to See, LEA Medizintechnik, Giessen, Germany) was applied to evaluate intra- and postoperative flap perfusion. All parameters are measured at the same time and via one probe. CLDS has been used in DIEP flap surgery by our group and by Rahmanian-Schwarz et al. for characterisation of intra- and postoperative flap perfusion.<sup>15,33,34</sup>

The measurements were performed in two standardised zones, at the region above main perforator (RAMP) and at the tip of the flap in all patients. In addition, perfusion gradients were assessed in 4-cm intervals at several points between these two zones. Statistical analysis was performed only for the RAMP and most distal points as described below. The other points were used only for evaluation of individual perfusion gradients. The post-capillary SO<sub>2</sub>, rHb and relative blood flow (FLOW) were recorded at different time points: at the end of surgery and after 1, 7 and 14 days. Core temperature was assessed prior to measurements at the end of surgery and was never less than 35.5 °C. For postoperative measurements, 10 min prior to each CLDS measurement the patients were positioned horizontally and warmed with a blanket. Data were recorded over a 10-s period and mean values were used for further analysis. Capillary refill and flap colour were assessed at the same time (data not shown).

Flap dimensions were assessed at the time of surgery, prior to intra-operative CLDS measurements using a ruler. Postoperative flap necrosis was assessed quantitatively on digital photographs that included a standard ruler. The proximal point above the perforator (RAMP) was defined as reference point and SO<sub>2</sub>, rHb and FLOW at the tip of the flap were expressed relative to the proximal reference

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