

Early Venous Occlusion Detection in a Free Flap Using Real-time Laser Doppler Imaging

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Summary: Early detection of venous occlusion in free flaps is particularly difficult to identify, and its duration is known to be directly proportional to flap mortality. Here, we report a case of deep inferior epigastric perforator based breast reconstruction in which the intraoperative use of a perfusion camera enabled identifying a venous occlusion based on microcirculatory pulsation dynamics in real time. The sensitivity of our proposed method suggests that in certain cases in which the onset of venous occlusion begins in the operating room we can detect and treat occlusion before sending the patient to recovery. Further development of this technique will allow for earlier and more objective decision making with regard to venous occlusion detection in free tissue transfer. (*PRS GO* 2013;1:e6; doi:10.1097/GOX.0b013e31828d659e; Published online 5 April 2013.)

The quality of cutaneous microvascular perfusion is considered one of the most important parameters when assessing the healing potential of reconstructive surgical procedures involving free tissue transfer.¹ Early identification of risks and objective methods to determine their cause would minimize the severity of postoperative complications while increasing the functional and aesthetic quality of their outcomes.

Clinical assessment remains the most common method of evaluating cutaneous microvascular perfusion.² Recent reviews have suggested that Doppler probes offer the most feasible solution,³ the primary drawbacks being that they require direct contact with the skin, their measurements are not highly reproducible if the probe is removed, and the region sampled is very small (1 mm²). Laser Doppler imaging (LDI) offers an interesting solution to many problems associated with probes, requiring no contact and giving information over a much larger region (up to 2500 cm²). Previous

LDI studies have proven their efficacy in research,⁴ whereas routine clinical applications have been limited primarily to burn-depth assessment.⁵ The drawback with traditional LDI technologies has been the length of time needed to scan and reconstruct an image.

The device used in this study (EasyLDI, Aïmago SA, Lausanne, Switzerland) is operated much like a traditional point-and-shoot digital camera, providing laser Doppler perfusion images in real time. The device illuminates a 7×7 cm² region, providing images with 100 μm pixel resolution at a rate of 12 per second.⁶ There is no health risk associated with exposure to the EasyLDI.

The goal of the present investigation is to report our experience using real-time LDI for early identification of venous compromise following deep inferior epigastric perforator breast reconstruction.

RESEARCH DESIGN AND METHODS

Case Presentation and Imaging Procedure

In October 2011, a 56-year-old woman undergoing a unilateral deep inferior epigastric perforator

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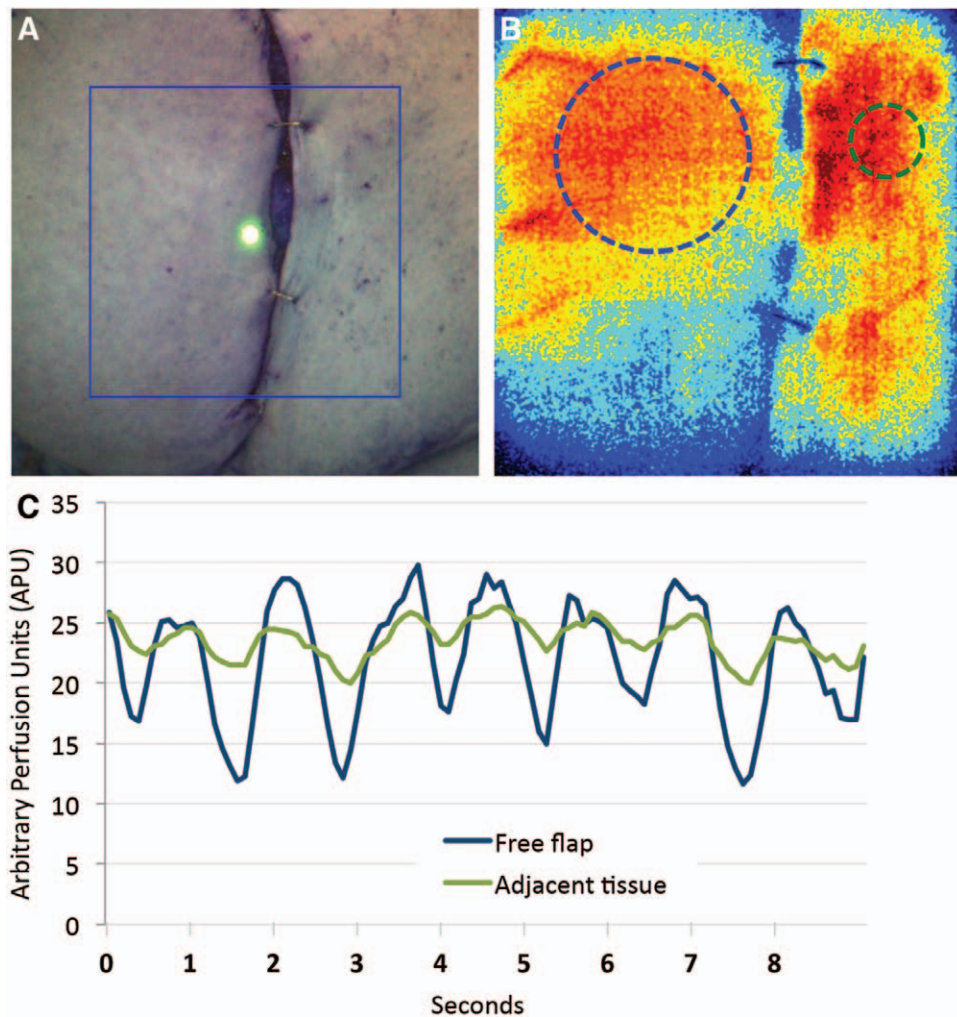


Fig. 1. A, Intraoperative color image of the reconstructed breast. B, Intraoperative LDI of the reconstructed breast—region delineated in blue on the color image. C, Intraoperative pulsation profile of flap (blue) versus adjacent tissue (green).

breast reconstruction following mastectomy was treated by our service. We followed our standard operating procedure and incorporated real-time LDI at the following surgical stages:

- Pre-op: before cutting
- Intra-op: (I) flap at donor site with perforator still attached, (II) at recipient site postanastomosis, and (III) following suturing in place
- Post-op: at 6, 24, and 96 hours

The images and video addressed in this case report were taken during the intra-op (II) and (III) phases in which use of the device suggested a potential venous blockage. At this stage, the flap was promptly lifted, the vein was found to be positioned awkwardly, and blood flow was compromised. The vein was then repositioned and the flap was sutured in place. We estimate that the venous blood flow was compromised for roughly 30 minutes before detection.

Statistical Analysis

Pairs were analyzed using Student’s *t* test. *P* values less than 0.05 were considered significant.

RESULTS

Raw Data Acquisition

The patient was imaged twice: (1) following trimming/positioning the flap at the recipient site and (2) after restoring blood flow from the venous anastomosis and suturing the flap in place. At each of these locations, a 10-second perfusion video (Figs. 1B and 2B) was recorded along with the corresponding color photograph (Figs. 1A and 2A). For each video sequence, a region of interest was manually defined and applied to the same location of all images in the video sequence. Next, the average perfusion per unit area of the region of interest was plotted versus time (Figs. 1C and 2C). Here, microcircula-

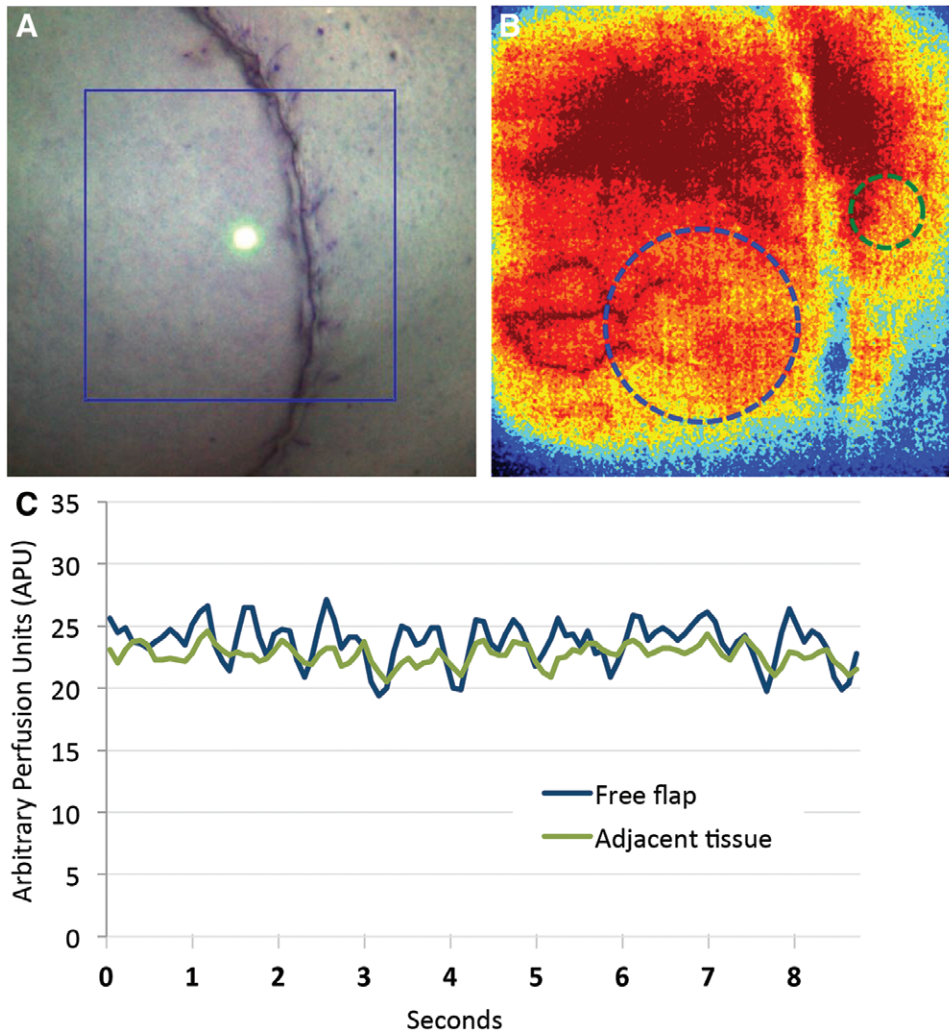


Fig. 2. A, Intraoperative color image of the reconstructed breast following venous exploration. B, Intraoperative LDI of the reconstructed breast following venous exploration. C, Intraoperative pulsation profile of flap (blue) versus adjacent tissue (green) following venous exploration.

tory pulsations can be clearly visualized for the defined sequence.

Calculation of Average Perfusion/Pulsation and Statistics

Average perfusion for each plot (Figs. 1C and 2C) was calculated by averaging the region of interest values used to create the plots over the entire video sequence. Average perfusion with venous congestion was calculated to be 21.9 and 23.5 APU for the free flap and adjacent skin, respectively. Following corrective procedure, the average perfusion without venous congestion was calculated to be 23.7 and 22.7 APU, respectively. Percent average perfusion values were calculated by normalizing the free flap to adjacent value for both “with” and “without” venous occlusion cases (Tables 1–3).

Table 1. Perfusion and Pulsation Characteristics for the “with” Venous Congestion Tissue

	With Venous Congestion	
	Free Flap	Adjacent Tissue
Average perfusion	21.9	23.5
Average pulsation	±6.5*	±1.7*

Data represented as APU and %, *P < 0.0001.

Table 2. Perfusion and Pulsation Characteristics for the “without” Venous Congestion Tissue

	Without Venous Congestion	
	Free Flap	Adjacent Tissue
Average perfusion	23.7	22.7
Average pulsation	±2.5*	±1.2*

Data represented as APU and %, *P < 0.001.

Table 3. Perfusion and Pulsation Characteristics for the “with” and “without” Venous Congestion Tissue

	With Venous Congestion		Without Venous Congestion	
	Free Flap	Adjacent Tissue	Free Flap	Adjacent Tissue
Average perfusion (APU/%)	21.9/93.2	23.5/100	23.7/104	22.7/100
Average pulsation (APU/%)	±(6.5/29.7) ⁺	±(1.7/7.2) ⁺	±(2.5/10.5) [*]	±(1.2/5.3) [*]

Data represented as APU and %, ⁺*P* < 0.0001 and ^{*}*P* < 0.001.

From each plot (Figs. 1C and 2C), average pulsation was calculated by manually locating 7 consecutive maximum and minimum pairs, calculating their differences, and averaging over all 7. Finally, these numbers were divided by 2 to provide a ± average pulsation term. Average pulsation with venous congestion was calculated to be 6.5 and 1.7 APU for the free flap and adjacent skin, respectively. Following corrective action, the average pulsation without venous congestion was calculated to be 2.5 and 1.2 APU, respectively. Percent average pulsation was calculated by normalizing each average pulsation to its respective average perfusion value. A Student’s *t* test comparing the 7 pulsation measurements of free flap to that of adjacent tissue was used to determine significance for the “with” and “without” venous congestion cases as ⁺*P* < 0.0001 and ^{*}*P* < 0.001, respectively (Tables 1–3).

DISCUSSION

Microvascular free tissue transfer is a trustworthy method for reconstructing complicated surgical defects, with the best centers reporting rates of complications of less than 10%. Although the origins of many postoperative complications remain difficult to identify, venous and arterial occlusions are two whose cause and effects are devastatingly obvious. Venous occlusions remain more difficult to identify than their arterial counterparts, based on the fact that blood remains trapped in the flap—early onset will seem to be normal clinically.

In the present study, we have shown that although the early onset of free flap venous occlusion is not marked by an immediate difference in average perfusion, it is marked by a significantly increased pulsation parameter, as assessed with real-time LDI. Of the measures recorded for this work, average perfusion of the flap and adjacent tissue with or without venous occlusion never varied by more than 9%, whereas the pulsation parameter recorded on the flap during the venous occlusion was nearly 4 times higher than that which was measured on adjacent tissue.

What makes these results particularly interesting are two-fold: (1) the increased sampling frequency of real-time LDI has allowed us to use pulsation as a new diagnostic parameter, and (2) due to the sensi-

tivity of the proposed method, we were able to detect the early onset of venous occlusion in the operating room saving the need for reoperation. Whereas recent works have suggested that the median time to detect venous thrombosis is 1.5 days postsurgery,⁷ employing our method would most certainly reduce the time to reexploration, ischemic damage to the flap, and associated complications, without increasing workload or time in the operating room.

CONCLUSION

We believe that further development of this technique will allow for earlier and more objective decision making with regard to venous occlusion detection in free tissue transfer procedures.

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