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"Evaluation of perfusion pattern on different kinds flaps using Laser Speckle Contrast Imaging"

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Abstract
Objective: *To post-operatively evaluate the data obtained by Laser speckle contrast imaging to determine the compromised blood circulation in different kind of flaps.*
Method*: From June 2019 to August 2019, 25 patients scheduled to undergo ALT flaps, , median planter artery flaps and local flaps. Mean perfusion were measured every hour throughout the day till 7th post-operative day (POD) and analyzed offline graphically.*
Result*: Flaps without compromised blood supply not only formed wavelike curves but also the perfusion valueremained >40 PU.However, flaps having perfusion value below 40 PU, althoughexperienced a dark skin color, recovered fully without any complication additionally it was a good indicator of performing a revision procedure.*
Conclusion*: In our study, a gradual or rapid drop in the perfusion curve below 40 PU indicated compromised blood circulation which required additional care. This research shows that LSCI is a feasible, noninvasive technique for postoperative tissue perfusion monitoring of different flaps.*
Keywords: Free flap; Laser speckle contrast imaging; Microcirculation; Flap monitoring; Reconstruction surgery; flap necrosis

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I. Introduction

A risk of tissue morbidityremains when different kinds of flaps are constructed for covering a wound.For reconstructed flaps, the feeding vessels play a vital role supplying blood to them. When there is a compromised blood circulation in the flaps, it may cause tissue necrosis, or even lead the surgeons to do a revision procedure which is hazardous and time consuming for both the surgeons and the patients. Boththe functional and aesthetic outcome of the surgery get affected for this incident. There have been several clinical techniques to evaluate flap conditions comprising color change, change in temperature, speed of capillary filling and the flap turgor. These clinical methods are subjective and often not very accurate. Therefore, if we can get the information about the micro-circulation of tissue flaps in real time, or if we can identify the blood flow compromise early, it may help us to facilitate flap salvage. There are severalnoninvasive and minimally invasive technical innovations have been recruited in microsurgeries to facilitate pre-, peri- and post-operative flap monitoring [1,2]. Laser doppler-based systems are often recruited to monitorperfusion data. Up till now, the different laser-based methods reported for intra and post-operative flap monitoring are laser-doppler [3-6], color flow ultrasound [7], minimal invasive methods are tissue pH monitoring [8], micro-dialysis [9,10]. Among them Laser speckle contrast imager permits a swift assessment of a significant area of flap, with a high spatial resolution [11]. In this research, we focus to find out a certain value that may refer to a risk to the valuable flaps.

II. Materials and methods:

Patients: From the year June, 2019 till October, 2019 twenty five male patients of different ages were recruited for reconstruction surgeries. Mean age, 38 years; range, 5-56 years. All the soft defects requiring coverage reconstruction were traumatic injuries. The study was approved by the Institutional Review Board of the Provincial Hospital Affiliated with Shandong University, People's Republic of China, and under all local rules and regulations, informed consent acquired from each patient.

***Equipment*:**For this study, a Laser Speckle Imager (PeriCam PSI System, Perimed) was used in this study.The imager has a simple laser diode which illuminate the tissue with an invisible near infra-red (NIR) laser (785 nm) With the help of the diffuser it creates a speckle pattern on the illuminated area. An advanced CCD camera

records the changes of this speckle pattern[Figure 1]. This results in an instant image of the the circulation in the micro vessels. Blood perfusion is presented both as color-coded images and in graphic form, enhancing the possibilities for understanding and analyzing the microcirculatory data. Blood perfusion is displayed in Perfusion Units (PU).

III. Methods

Surgical techniques: The patients were hospitalized and treated with emergency debridement and fixation of the bones and left for secondary healing process. For the second time surgery, preoperatively, descending branch of lateral femoral circumflex artery (LFCA) for Anterolateral free flaps (ALT) and Medial plantar artery were detected and marked with the help of a hand-held Doppler. The diameter of LFCA and medial planter artery and dorsal metacarpal arterywere 2±0.5mm, 1.5±0.5mm and 0.8±0.2mm respectively. All the flaps were harvested under either brachial plexus nerve block or epidural anesthesia. The surgery was performed using a pneumatic tourniquet. Flaps were tailored slightly larger than the required area.

LSCI data acquisition: All microvascular scans were done with patients in supine position. The distance between the imager and the flap surface was kept between 15 and 20 cm as the distance between infuser and flap does not affect perfusion values recorded by laser speckle imaging [12]Figure 2. The acquisition rate was set to 10 images/s, scanning time was 30 seconds and we scanned 24 times a day till post-operative day seven.

Analyzing the data: The backscattered data from the skin wereprovided as mean perfusion unit (PU) by the manufacturer's software (PimSoft 1.5, Perimed) and they were saved in computer. Later the calculation was done offlineon Excel spreadsheet (Excel 2016 V3 ®, Microsoft USA).

IV. Result:

The room temperature was between 22-25°C throughout the protocol.

Clinical evaluation:

We observed the changes in the perfusion value graphically and tried to find out a threshold value under which the reconstructed flaps were considered in danger.

Fluctuation in flap perfusion:

Postoperatively after the patient was returned to ward, the first mean perfusion measured by LSCI was taken as a baseline perfusion. At baseline, the maximum perfusion was recorded 83±12PU and the lowest was 50±19PU. The slighter changes in PU were recorded during sleeping, after meals and at night. For most of the flaps the perfusion gained a stability on 4th or 5^{th} day. And the maximum perfusion was measured on the 3^{rd} day. Most of the flaps in our study had healthy condition. However, two flaps experienced necrosis. For both of the flaps the initial perfusion was above 50 PU. A gradual drop in the perfusion recorded on post-operative day 1. The gradual drop in the perfusion value formed an inclination on the graph. The perfusion value dropped under 40 PU ($P< 0.03$) caused the change in the surface color of the flap.

V. Discussion:

In order to covering a subcutaneous wound, different kind of flap surgeries are performed. For the vitality of the flaps, vascular supply is essential,and flapmicrocirculation is challenging to forecast. Many surgeons report incomplete flap necrosis of the furthestportionfrequently. Xiong and his teammentioned a 6% partial necrosis in flaps performedon lower extremities in their studies [13]. Lie et al., reviewed 98 articles reporting on DIEP flaps that encountered partial necrosis [14]. This partial necrosis absolutely causes significant trouble for the patients, and it even causes them to lengthen the hospital stay and cost. Clinical manifestations are helpful; however, in some cases, it is too late to perform revision surgery to shorten the complication. An ideal flap monitoring ought to be innocuous to both the patient and the flap, precise and dependable, capable of providing a rapid response of circulatory changes, and applicable to all kind of flaps and tissues [3]. Fluorescence angiography has gained popularity in recent years as it can assess superficial blood flow and has an excellent safety profile; however, it should be administrated intravenously and is not cost-effective.

In this study, we recruited LSCI as an instrument to observe the changes in perfusion value graphically in superficial blood flow in the skin; these data may aid us in predicting the flap morbidity.McGuire and Howdieshell predicted the pattern of ischemia using LSCI. They reported it to be faster than the clinical procedures. [15]. In other studies, LSCI technique has been recruited to examine blood flow in retina and optic nerve by Yaoeda et al., [16], on skin by Tomidokoro et. Al [17], on bones to find out femoral head blood supply by Fukuoka et al., [18], fujii et al., [19] measured the dynamic changes of skin blood flow with LSCI.

The perfusion value before and after raising the flap had a significant difference. During the first 30 mins after the flaps were raised, perfusion value decreased dramatically. Intra-operatively we divided a flap into

proximal and distal half, where the perfusion value of proximal ROI did not decrease but increased in several cases. Nevertheless, distal ROI always had a decreased perfusion value.

The changes in the graph of the perfusion pattern were a good indicator to predict compromised circulation. During our studies, we had found that the continuous drop in the perfusion value was a marker of vascular compromise. However, some flap encountered a rapid fall in the perfusion value as well. The perfusion value differed in different kind of flaps. We have found the Medial plantar flap to be stable at average 75±5 PU, ALT flap at average 65±5 PU (P> 0.07). (Table 1)

For patients without any compromised perfusion, the PU always formed a wave-like curve, and the flaps always had a perfusion above 40 PU (P< 0.003) [Figure3].We observed lower perfusion value during night-time measurements, during early morning and after each meal. Comparatively higher perfusion value was recorded in the afternoon. For some patient, perfusion value, even lower than the baseline was recorded in the early morning on the second postoperative day. However, we did not consider it as a precaution as the perfusion in the following hours started to rise higher again. The point should be noted that patients had no chronic illness.

Directly after the surgery were done, initially, ALT flap had ROI with perfusion value 55±5 PU. Figure4shows an example of an ALT flap with initial perfusion value of 50 PU that experienced changes in color on second day with the drop of perfusion value below 40PU. On Figure 5 another median plantar artery flap experienced changes in color of the surface with the drop-in perfusion value below 40 PU. However, both of these two flaps experienced gradual drop in the perfusion value and encountered tissue morbidity.Flaps with perfusion value above 40 PU did not experience any changes in surface color. Additionally, an artificial heating source, heparin and loosing the stitches helped resolving the blood compromise in several cases.

There are some studies have been done for the assessment of the microcirculation in pigs [19-24]. It is assumed that porcine skin is fairly similar to human skin; additionally, LSCI can record similar perfusion value in both species [25,26]. Moreover, we plan to evaluate the perfusion pattern of replanted fingers and other flaps using LSCI technique to predict necrosis in our future studies.

Study Limitations

The main weakness of this study is that as we took an hourly reading of the flap, the regions of interest (ROIs) were chosen along the central axis of the distal segment of the flap only as most of the flap was covered up with a bandage.

Moreover, we tested the microvascular perfusion on flaps of different sizes (artery diameter was different as well). Additionally, we measured the perfusion value on different kinds of skin i.e., medial planter free flap, ALT flap etc.

Last, the extreme sensitivity of LSCI to movements might show a limitation of the technique in method. [28].

VI. Conclusion:

In conclusion, we have found that considering a revision surgery was helpful when the perfusion value was between 35 and 40 PU. So, we can conclude that, laser speckle contrast imaging is a reliable technique to evaluate the flap condition as it helps to know the real time perfusion data on the flaps which helps clinicians to take immediate decision to salvage the valuable flaps.

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Table no 1: Shows the detailed parameters of perfusion unit of different kind of free flaps.

Order	Flap	Patient number (n)	Mean vascular diameter	Safe perfusion range (PU)	Gained stability (PU)	Partial necrosis	Changes in color
1	ALT (LFCA)	13	2±0.5mm	40~ (P< 0.003)	65±5	One	35±4 (P< 0.03)
2	Medial Planter artery	7	1.5±0.5mm		75±5	One (entire necrosis)	
3	Rotation flap	5	0.8±0.2		--	None	

ALT: Anterolateral Thigh Flap; LFCA: Lateral femoral circumflex artery; SCIA: Superficial circumflex femoral artery; PU: perfusion unit.

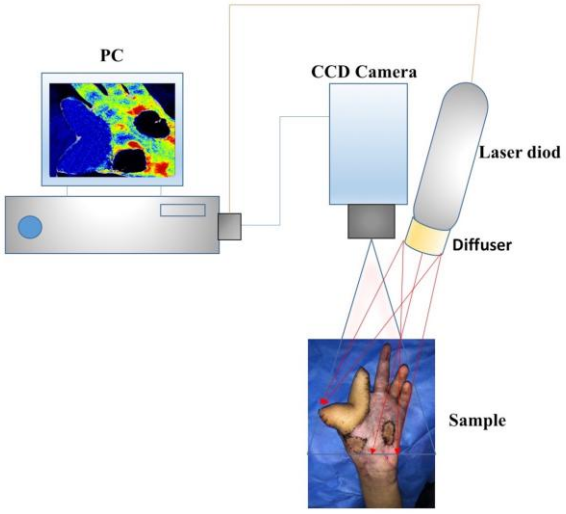

Figure1:Shows the basic configuration and simplicity of laser speckle contrast imager.

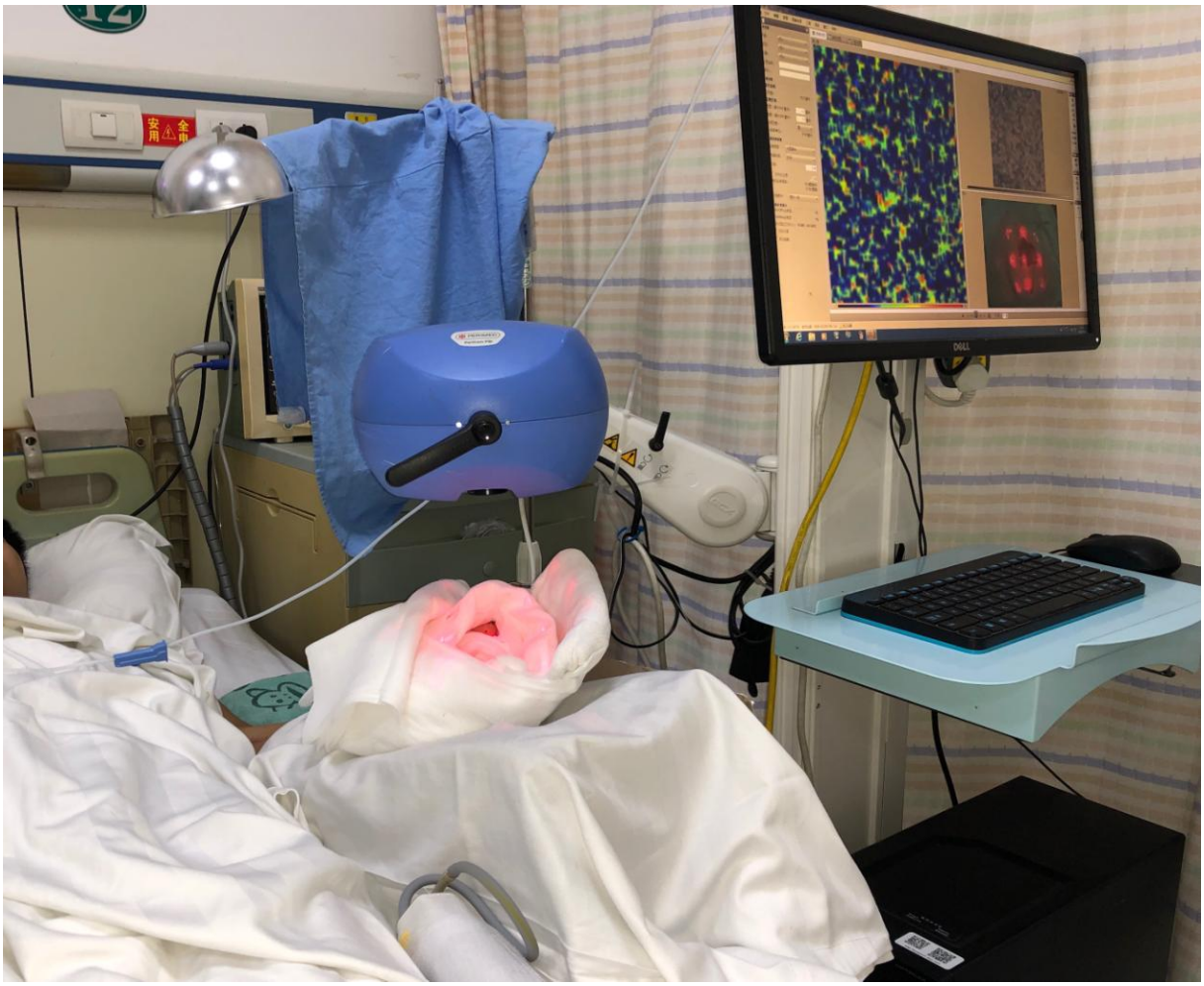

Figure 2: Post-operative data acquisition in ward.

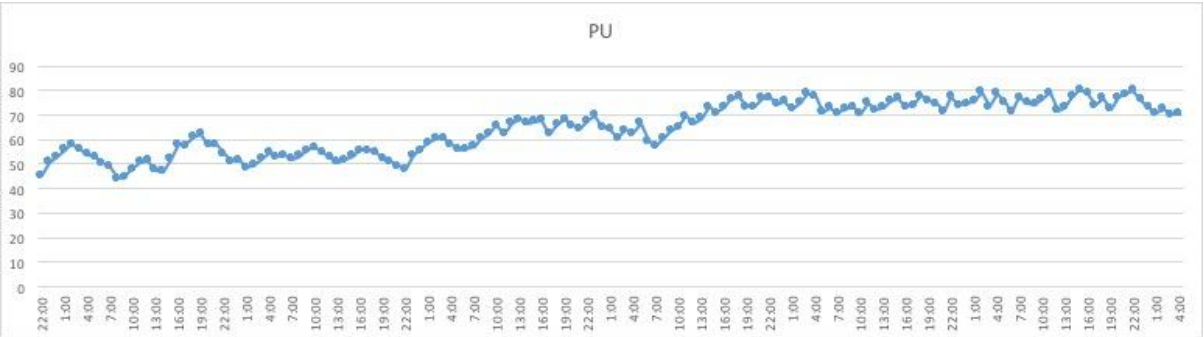

Figure 3: shows the mean perfusion graph of an ALT flap of post-operative seven days. A raise in blood perfusion was observed on post-operative day two. ALT flaps gained stability of perfusion at around 65±5 PU ($P<0.003$).

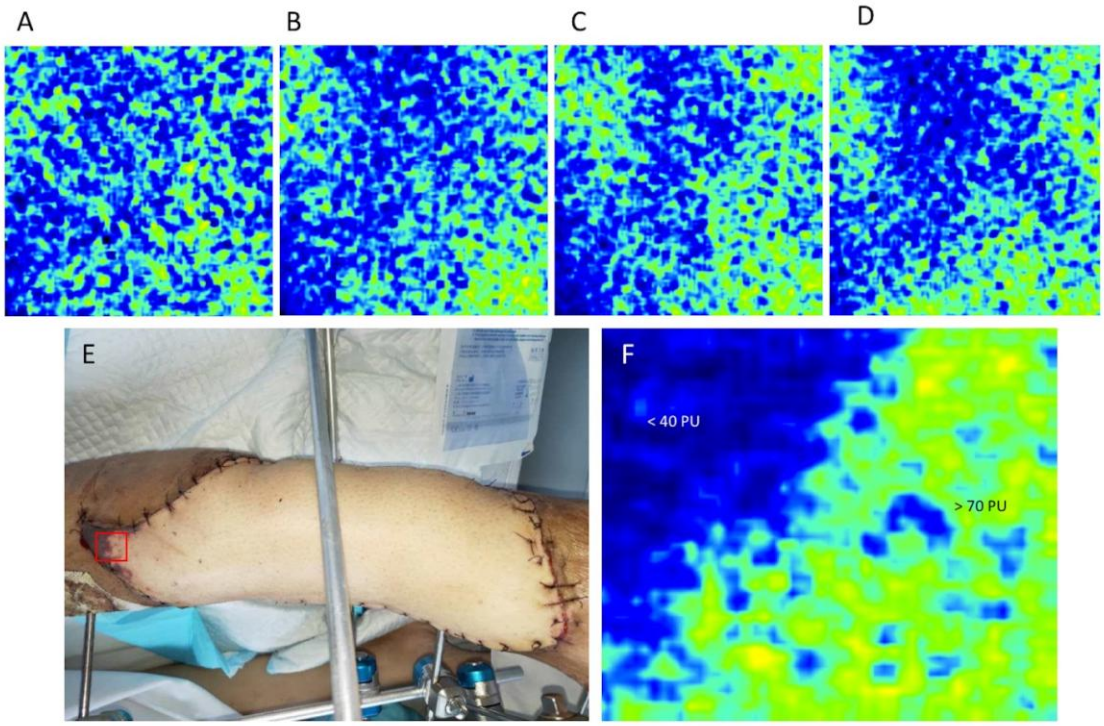

Figure 4 *shows a partial necrosis of ALT flap (E). (F) shows the difference of microcirculation between the normal and necrosed tissue.Whereas from (A) to (D) shows the gradual changes in perfusion. The surface color started to change from below 40 PU and kept dropping and resulted in necrosis.*

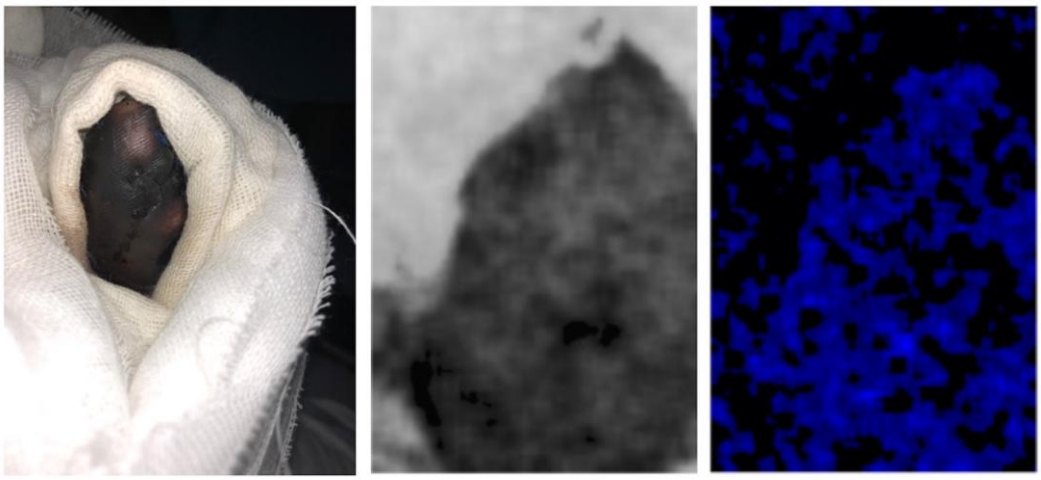

Figure 5 *shows a low perfusion value on a median plantar artery flap.The surface color started to change from below 40 PU and kept dropping and resulted in necrosis.*

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Conflict of interest: None

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