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ISBN
9781424471119

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Publication Date
2010-12-01

DOI
10.1109/acp.2010.5682705

NONINVASIVE BLOOD FLOW MAPPING FOR SURGICAL GUIDANCE OF VASCULAR BIRTHMARKS

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Port-wine stain (PWS) birthmarks are progressive capillary malformations which occur typically on the face or neck. To treat these birthmarks, the standard protocol involves use of pulsed laser light. The intent of this protocol is to heat selectively and coagulate the PWS vasculature.

Patient response to laser therapy, remains highly variable and somewhat unpredictable. Our central hypothesis is that regions of the PWS vasculature are not photocoagulated, and that this incomplete stoppage of blood flow facilitates ensuing angiogenesis and hence revascularization of the skin with the abnormal PWS blood vessels.

The long-term objective of our research is to determine the efficacy of image-guided retreatment of PWS skin. We have used the method of laser speckle imaging (LSI) to generate maps of skin blood flow before and after laser therapy (Huang *et al.*, 2008; Huang *et al.*, 2009). Based on prior experience with our first-generation LSI instrument, we have concluded that the clinical impact of LSI would be maximized only if a true intraoperative LSI instrument could be engineered. This instrument would need to satisfy the following design criteria: 1) real time and 2) nonintrusive.

To achieve a real-time LSI instrument, we exploited the processing power of graphics processing units (GPUs). Application of GPU technology to LSI, first was reported by Liu et al. (Liu *et al.*, 2008). We first developed a LabVIEW-based graphical user interface to communicate with a NVIDIA GPU card (GeForce 8800GTS) via NVIDIA's Compute Unified Device Architecture (CUDA). We then integrated this hardware architecture into our first-generation LSI instrument (Huang *et al.*, 2008) to achieve a real-time LSI instrument (Figure 1).

To date, we have collected real-time, intraoperative LSI images during laser therapy of PWS skin, from three subjects (Figure 2). The preliminary findings are extremely encouraging. With laser treatment using a deeply-penetrating alexandrite laser (λ = 755 nm), minimal perfusion reduction of superficial vasculature, has been observed. With treatment using pulsed-dye lasers, a more pronounced reduction in blood flow has been observed, with regions of persistent perfusion clearly evident. In one treatment session, the treating clinician (co-author JSN) used the real-time LSI imagery to re-treat specific regions with apparent resistance to laser irradiation. The real-time nature of the instrument allows the clinician to identify easily the regions of persistent perfusion, because the aperture of the laser handpiece is clearly visible in the LSI images (Figure 2, center image).

In summary, we now possess a clinic-ready imaging instrument which provides the treating clinicians with instantaneous feedback during the laser surgery session (Figure 2). We now are well poised to determine the degree to which immediate re-treatment affects the clinical outcome of laser treatment of PWS birthmarks.

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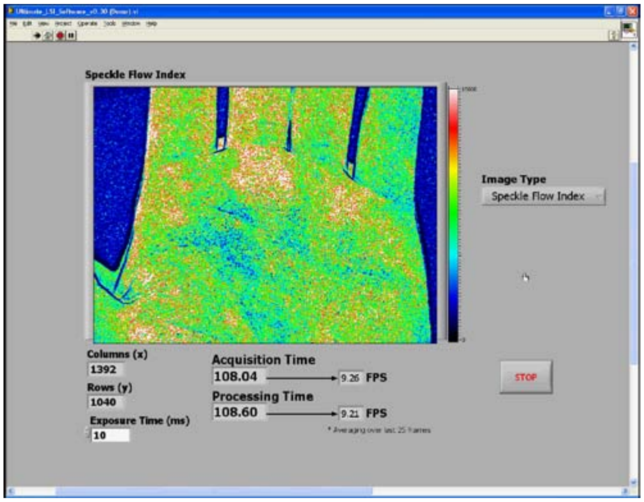

Figure 1. Software control panel of real-time clinical LSI instrument. This specific image depicts a hyperperfused hand of a subject immediately after occlusion of the brachial artery with a pressure cuff held at 200 mmHg. From the video feed, the hemodynamics associated with pressure elevation (blood-flow shutdown) and release (hyperemia) are readily visible.

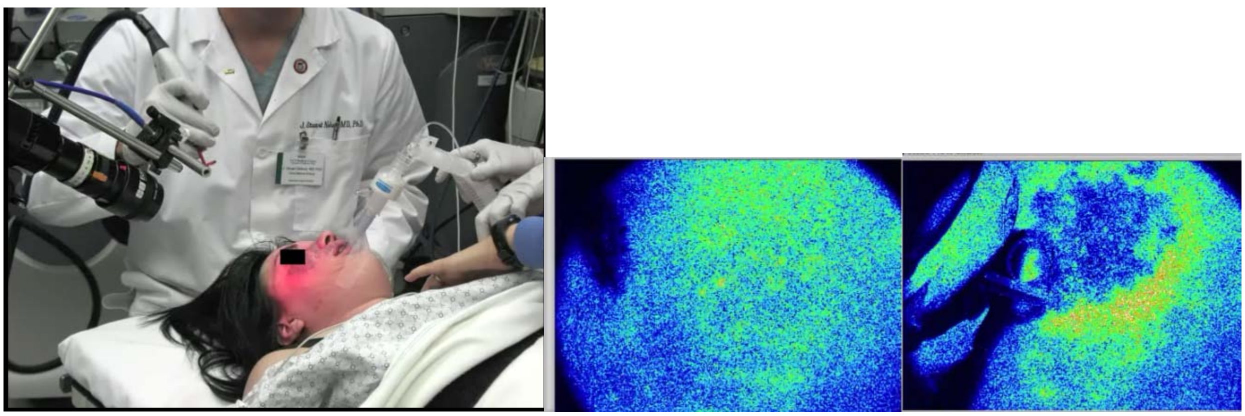

Figure 2. Intraoperative clinical LSI now can be performed in a routine fashion. (Left) Photograph of clinical LSI instrument set up to perform noninvasive, real-time blood flow imaging of the right-hand side of an anesthetized subject's face. The clinician (co-author JSN) is positioned behind the subject's head, to perform laser surgery. (Center) Real-time blood-flow map of subject collected prior to laser surgery. The subject's eye is clearly visible in the upper left of the map. (Right) Blood-flow map collected during laser surgery. The positioning guide of the laser handpiece can be seen, and a considerable reduction in blood flow can be observed. Furthermore, apparent regions of persistent perfusion can be seen in the already-treated area. The real-time imaging of our clinical LSI instrument, allows the treating clinician to identify these regions and re-position the laser handpiece to re-irradiate these sites, if desired.

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