The Use of Laser Speckle Contrast Imaging in Assessing Burn Wound Healing

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Introduction

Burns remain a prevalent and complex critical care issue, accounting for approximately 40,000 hospitalizations and 3,400 deaths annually.[1] Although many advances have been made in burn care over the past decade, these wounds remain a major source of morbidity and mortality for service members and civilians.[2] In particular, loss of function and unappealing aesthetic appearance can result from scarring and contractures that occur during the healing process of some burn wounds.[3] Early assessment of these wounds is critical to preventing complications and directing further care.

Current methods of assessing burn wounds rely primarily on clinical judgment. These assessments play significant roles in determining the trajectory of treatment plans. Few standardized, quantifiable, reproducible modalities exist in practice to assess burn wounds.[4] Laser speckle contrast imaging (LSCI) has been utilized in the preclinical environment with potential to be of value clinically.

Objectives

- Determine if LSCI is a successful, accurate, and reliable method for assessing burn wound healing
- Understand how LSCI changes over time and how this relates to vascularity of the wound bed

Methods

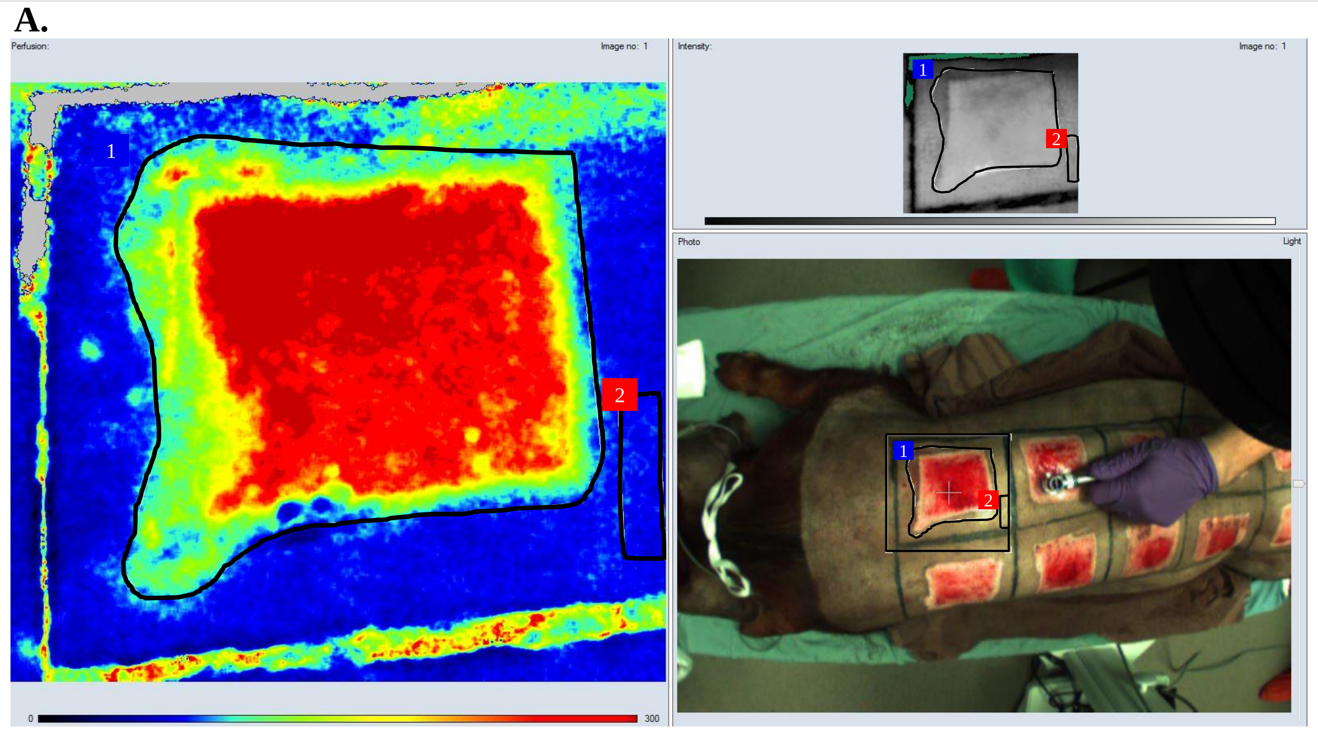
Burns were created on the dorsolateral aspect of 9 anesthetized swine (*Sus scrofa domestica)* using a thermocoupled burn device at 100°C. Data from 2 studies are presented.

Laser speckle contrast imaging (LSCI, laser 785nm) images were captured with a 1388x1038-pixel CCD camera. LSCI produces a visual depiction of the scattering of light as the result of interference between coherent light and moving particles, such as red blood cells moving within a blood vessel. Changes in the interference pattern are recorded by a camera as fluctuations in intensity: the more movement, the more blurred the speckle pattern becomes. [5] Regions of interest (ROI) are highlighted and laser speckle contrast values are calculated (Figure 1). As LSCI can only measure up to 700µm in depth, the superficial vasculature of the skin is the main target of this measurement strategy. [6]

In the first study, LSCI images were captured prior to and immediately following the creation of superficial partial-thickness (SPTB), deep partial-thickness (DPTB), and full-thickness burns (FTB), and on post-burn day (PBD) 1, 2, and 3 (Figure 2 and 4). Burn times were 10, 15, and 20 seconds respectively. In the second study, LSCI images were obtained before and after DPTB creation and on post-debridement day (PDD) 0, 7, 14, 21, 28, 60, 90, and 120 (Figure 2, 3, and 5).

Results

A.



B.

Calculations							
		Mean	Area mm²	StdDev	Points	Int.mean	AUC PU*s
1. ROI							
	Image 1	165.83	5,599.27	139.19	51,311	0.14	- - -
	Image 2	160.08	5,599.27	134.45	51,311	0.14	- - -
	Image 3	159.28	5,599.27	141.94	51,311	0.14	- - -
	Image 4	162.93	5,599.27	137.26	51,311	0.14	- - -
	Image 5	169.70	5,599.27	140.33	51,311	0.14	- - -
	Image 6	171.40	5,599.27	143.46	51,311	0.14	- - -
	Image 7	163.21	5,599.27	132.05	51,311	0.14	- - -
	Image 8	169.84	5,599.27	135.45	51,311	0.14	- - -
	Image 9	170.61	5,599.27	142.43	51,311	0.14	- - -
	Image 10	163.81	5,599.27	136.49	51,311	0.14	- - -
	Entire rec	165.54	5,599.27	138.31	51,311	0.14	7,515.56
2. ROI							
	Image 1	70.04	256.22	8.43	2,348	0.13	- - -
	Image 2	60.63	256.22	7.99	2,348	0.13	- - -
	Image 3	59.21	256.22	8.58	2,348	0.13	- - -
	Image 4	65.51	256.22	8.33	2,348	0.13	- - -
	Image 5	78.54	256.22	9.05	2,348	0.13	- - -
	Image 6	80.67	256.22	10.20	2,348	0.13	- - -
	Image 7	58.60	256.22	9.60	2,348	0.13	- - -
	Image 8	71.97	256.22	10.12	2,348	0.13	- - -
	Image 9	79.21	256.22	9.06	2,348	0.13	- - -
	Image 10	68.38	256.22	8.79	2,348	0.13	- - -
	Entire rec	68.65	256.22	9.01	2,348	0.13	3,116.99

Figure 1. Raw LSCI data results. **A.** Data obtained from one wound as represented by the software accompanying the LSCI device. **B.** Calculated LSCI values for the outlined regions of interest (ROI).

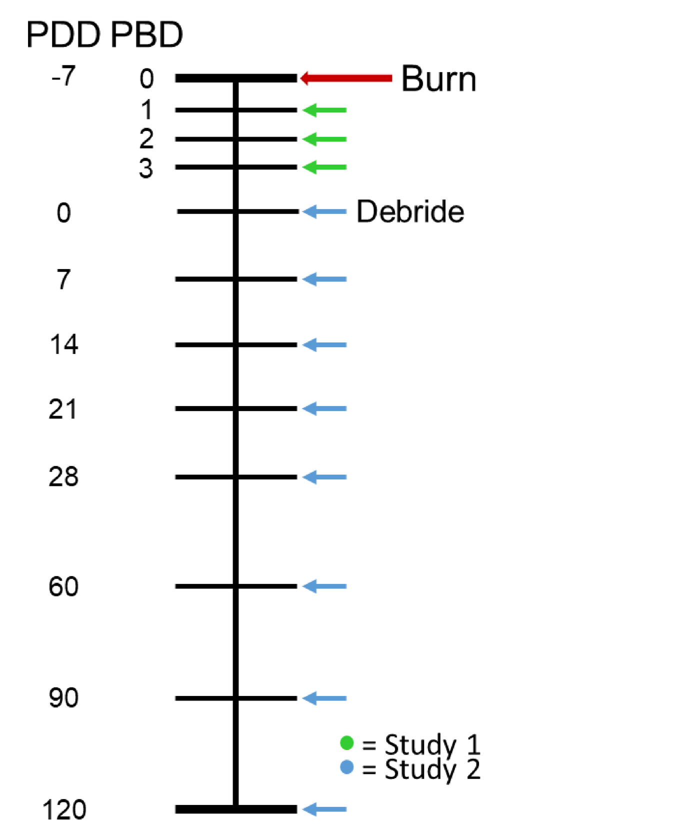


Figure 2. Timeline

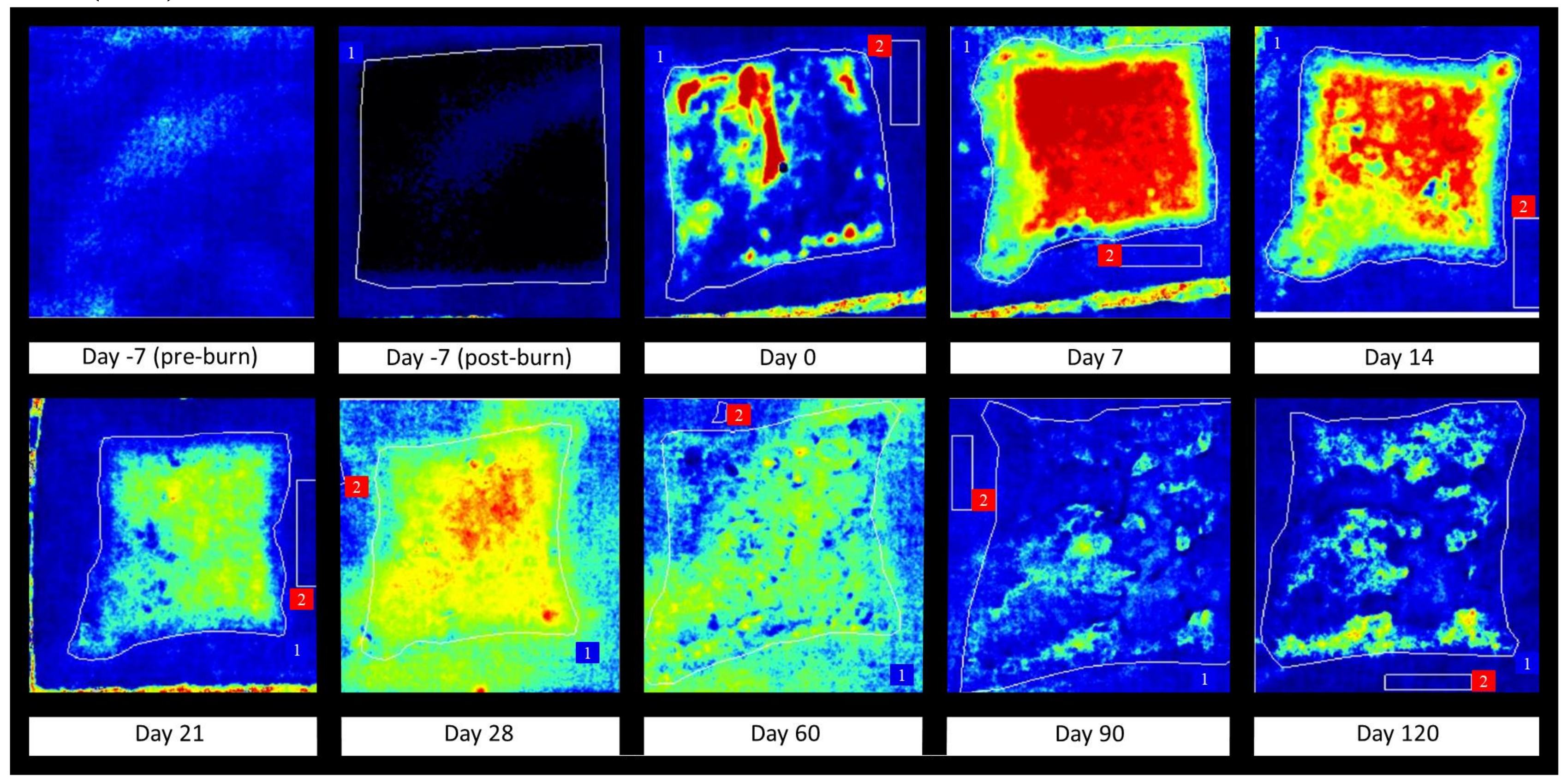


Figure 3. LSCI images over time. Images were captured immediately pre-burn until PDD 120.

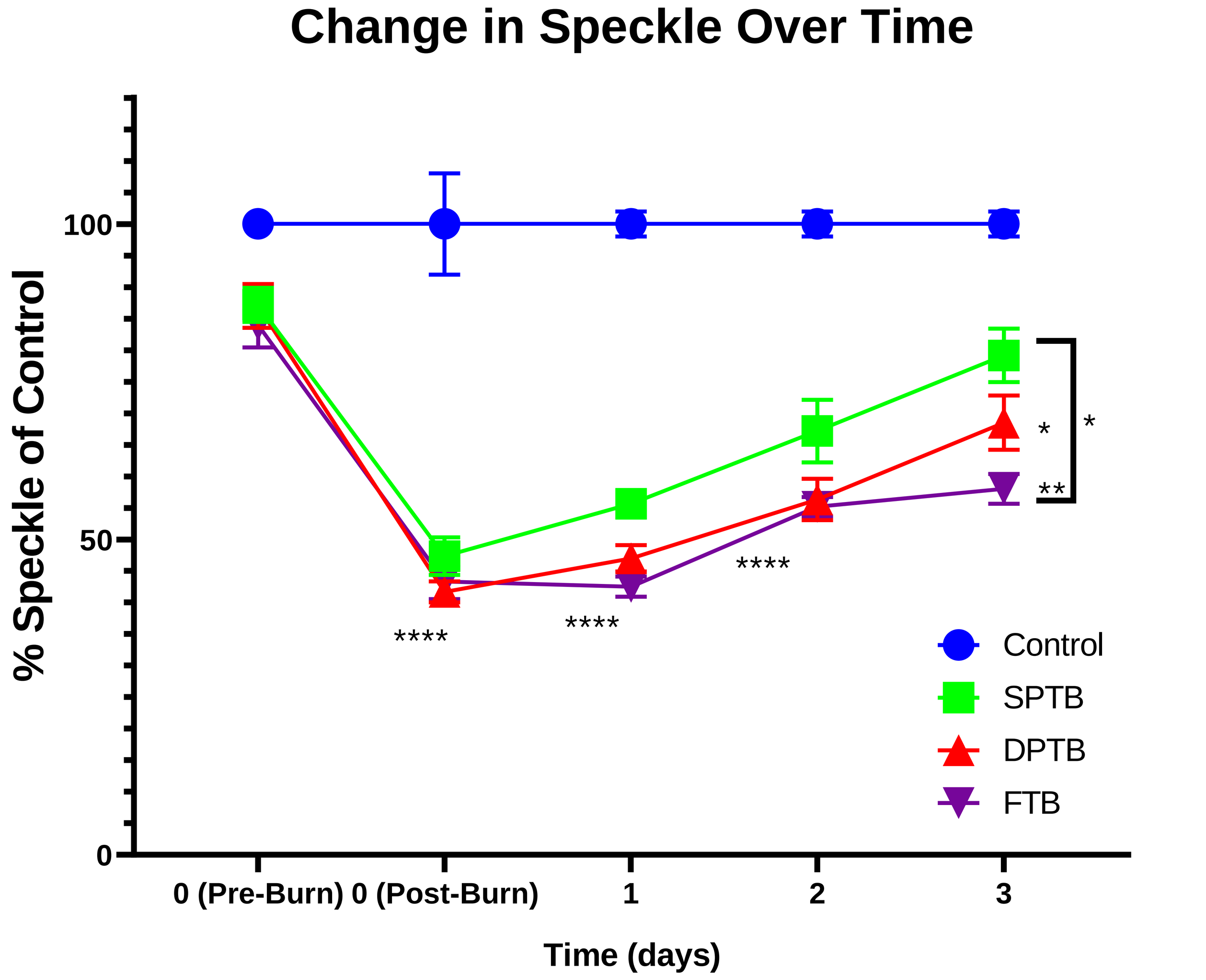


Figure 4. Results of first study. Speckle data was normalized to control sites and converted to percentages ((Speckle wound/speckle control) x 100), producing speckle percentage of control (SPOC) which quantifies relative decrease or increase in speckle output and thereby vascularity. SPOC was significantly decreased for all burn times immediately after burn. PBD 1, SPOC trended upwards. By PBD 3, only DPTB and FTB remained diminished (p=0.028 and p=0.005, respectively). FTB SPOC was significantly less than the SPTB (p=0.015) on PBD 3.

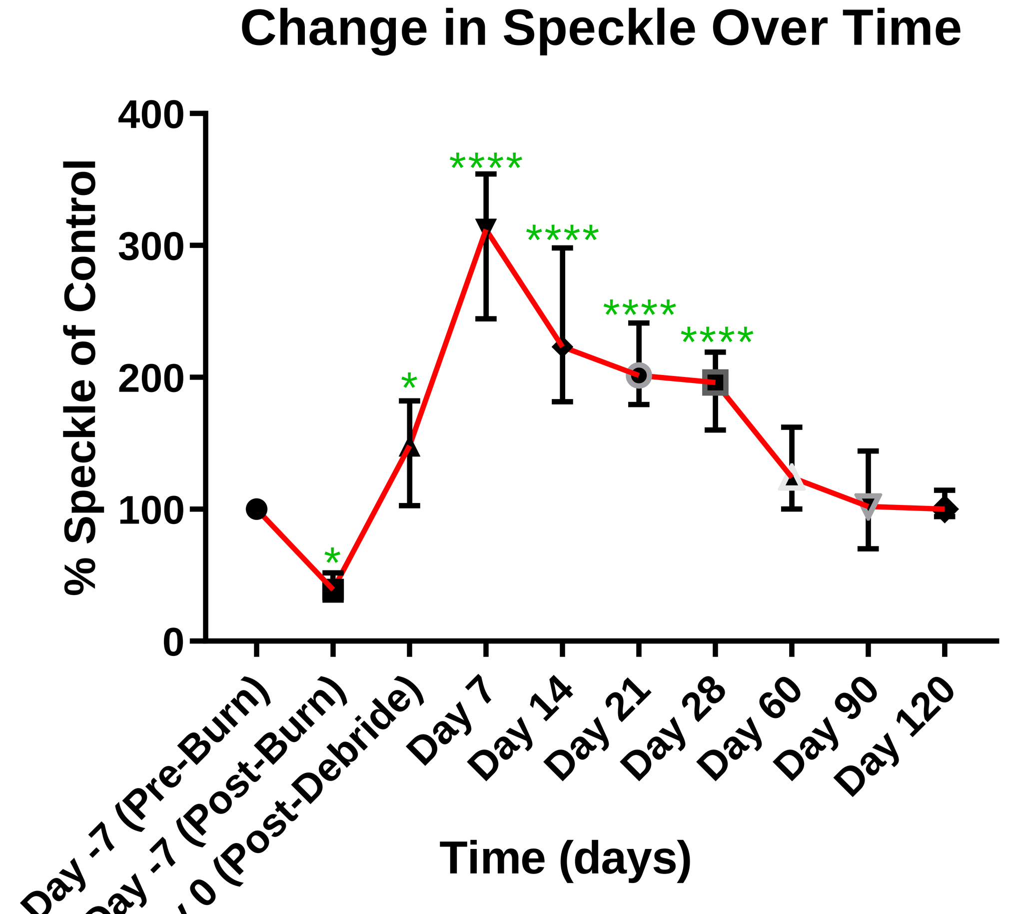


Figure 5. Results of second study. SPOC again decreased immediately following burn. SPOC showed an increase post-debridement on PBD 7, noted as post-debridement day (PDD) 0. SPOC continued to increase significantly to a peak at PDD 7 (p = <0.0001), remaining increased up to PDD 28. By PDD 60, SPOC was no longer significantly increased.

Conclusions

- LSCI is a reliable method for analyzing burn depth and wound healing in the preclinical setting.
- LSCI data indicates an immediate decrease in vascularity at all burn depths immediately following burn creation.
- Vascularity begins to increase PBD 1 with a peak in vascularity seen on PDD 7
- LSCI shows vascularity returning to normal by PDD 60.
- The promising application of LSCI in the preclinical setting portends its utility in the clinical setting.

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Statements

Research was conducted in compliance with the Animal Welfare Act, the implementing Animal Welfare Regulations, and the principles of the Guide for the Care and Use of Laboratory Animals, National Research Council. The facility's Institutional Animal Care and Use Committee approved all research conducted in this study. The facility where this research was conducted is fully accredited by AAALAC.