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Prospective comparative evaluation study of Laser Doppler Imaging and thermal imaging in the assessment of burn depth

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ABSTRACT

Introduction: The accurate assessment of burn depth is challenging but crucial for surgical excision and tissue preservation. Laser Doppler Imaging (LDI) has gained increasing acceptance as a tool to aid depth assessment but its adoption is hampered by high costs, long scan times and limited portability. Thermal imaging is touted as a suitable alternative however few comparison studies have been done.

Methods: Sixteen burn patients with 52 regions of interests were analysed. Burn depth was determined using four methods LDI, thermal imaging, photographic and real-time clinical evaluation at day 1 and day 3. LDI flux and Delta T values were used for the prediction of outcomes (wound closure in <21 days). Photographic clinical evaluation of burn depth was performed by 4 blinded burn surgeons.

Results: Accuracy of assessment methods were greater on post burn day 3 compared to day 0. Accuracies of LDI on post burn day 0 and 3 were 80.8% and 92.3% compared to 55.8% and 71.2% for thermal imaging and 62.5% and 71.6% for photographic clinical assessment. Real-time clinical examination had an accuracy of 88.5%. Thermal imaging scan times were significantly faster compared to LDI.

Discussion: LDI outperforms thermal imaging in terms of diagnostic accuracy of burn depth likely due to the susceptibility of thermal imaging to environmental factors.

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1. Introduction

The accurate assessment of burn depth is a critical step in the management of the burn injured patient, with a key decision being whether a wound will benefit from surgical management. The depth of the burn injury is a key determinant of wound healing time and a relationship between the time to wound closure and the incidence of hypertrophic scarring (HTS) has been clinically demonstrated [1]. Establishing the difference between superficial dermal burns that will heal spontaneously within 21 days and deep dermal burns which can result in longer healing time and associated pathological scarring is challenging, even for experienced burn surgeons [2–4]. Burn depth classification via visual interpretation has remained relatively unchanged since the 16th century [5], however in the last few decades the increasing use of technology to aid the assessment of burn depth and the progression of the burn wound has allowed earlier diagnosis of burns that may benefit from excision, and tissue preservation of those that will heal spontaneously.

Douglas Jackson, at the Birmingham Accident Hospital, was the first to identify a link between progression of the clinical depth of the burn wound and the dermal microvascular blood flow [6]. The link between burn depth and blood flow in the superficial vascular plexus inspired the development of a number of technologies to measure this, either directly or indirectly. Laser Doppler Imaging (LDI) utilizes a 623 nm red diode laser, which superficially penetrates the skin and is reflected by circulating erythrocytes in the dermal vasculature. A transducer measures the Doppler shift in light frequency from the erythrocytes moving relative to the laser source and provides a semi-quantitative measure of perfusion. LDI has now been validated in a large multi-centre study over of over 400 burn wounds and shown to have a technical accuracy of 96% in predicting whether wounds will be healed by 21 days [7,8]. The National Institute for Clinical Excellence (NICE) in the UK recommends the use of LDI in addition to clinical assessment for clinically indeterminate burn wounds [9].

Thermal imaging provides an indirect measure of cutaneous blood flow and was originally described by Lawson in 1961, to accurately predict the depth of burns in dogs [10]. Mladick et al. in 1966 found that thermograms correlated very closely with the pattern of depth of the burn injuries in patients [11] and later, Hackett concluded that clinical examination of the burn failed to predict depth in one third of cases compared to 10% failure with thermal imaging [12]. Hardwicke et al. conducted a pilot evaluation study at our centre utilizing a current generation high resolution real time thermal imaging camera and found that it could differentiate between clinically full thickness, deep partial thickness and superficial partial thickness burns based on temperature comparisons with non-burnt skin [13]. The images were high resolution and could be acquired rapidly suggesting potential advantages over other imaging modalities such as LDI. We therefore conducted a comparative evaluation study to compare the accuracy of high-resolution digital thermal imaging with the current gold standard, LDI, in assessing wound healing potential in adult burn injured patients.

2. Materials and methods

2.1. Patient selection

Adult patients admitted to the Birmingham Burns Centre, University Hospitals NHS Foundation Trust between were screened for eligibility for prospective recruitment into the study over a 12 month period from May 2012. The study included adults aged 18 years and above presenting within 24 h of an acute burn injury <15% of Total body surface area. Detailed inclusion and exclusion criteria can be seen in Table 1 and Fig. 1. Burn wounds overlying skin tattoos were not included due to reflectance artifact. The study protocol received approval by an NHS Research Ethics Committee (REC reference: 12/SW/0028).

2.2. Study protocol

Patients enrolled into the study underwent study visits for burn depth assessment on day 1 (within 24 h after-injury); again on day 3 (at 48–96 h after-injury) and wound healing evaluation on Day 14; and Day 21 if not fully healed at Day 14. Burn depth estimation was performed by four methods: (1) Laser Doppler Imaging (LDI) with a Moor LDI2-B1 (Moor Instruments, Axmoor, UK); (2) Thermographic imaging with the FLIR SC660 thermal imaging camera (FLIR Systems, Inc., Wilsonville, USA); (3) Clinical assessment with 2D photography; and (4) Real-time clinical assessment. Two dimensional (2D) clinical photography was undertaken at all visits using a Nikon D300S DSLR camera (Nikon Corporation, Tokyo, Japan) by the clinical photography team and these photographs were then assessed by four consultant burn surgeons blinded to the outcomes. Real-time clinical assessment at the time of presentation (day 0) by the on-call consultant was collected retrospectively. Decisions on need for surgical excision and skin grafting were made on clinical grounds in obviously full thickness or deep dermal burns; LDI was used to assist decision-making in the case of clinically indeterminate burn wounds. Cases which were found to have a significant area with a healing potential of >21 days underwent excision and skin grafting, in line with the standard of care prior to commencement of the study. If the patient had multiple separate burn wounds, all were included as study wounds and

Table 1 – Inclusion and exclusion criteria for study.

Inclusion criteria	Exclusion criteria
Adults (18–99 years)	Children (<18 years)
Within 24 h of burn injury	Unable or refusal to give informed consent
<15% TBSA	Suspected burn wound infection/cellulitis
All burn depths	Chemical burns
	Incomplete images at day 0 and 3
	Excised and grafted before day 21
	Skin tattoos
	Participation in other interventional trials