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Laser Doppler Imaging of paediatric burns: Burn wound outcome can be predicted independent of clinical examination☆

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Abstract

This study sought to assess the validity of independent, blinded reporting of Laser Doppler Imaging (LDI) prediction of burn wound outcome in children. Two experienced paediatric burn consultants were invited to report on LDI scans performed routinely within 3 days of burn. They were provided with the LDI flux image, a low-resolution colour digital photograph of the burnt area and a basic history. Report predictions were correlated with outcome. Reports were compiled on 50 scans performed on 31 patients at a mean of 54 h post burn. Of the 100 reports generated, mean correlation with outcome was 97%. If the LDI predicted a deep burn, it was always correct. Non-correlations were due to a number of factors including inadequate scanning of the affected area, excessive movement and residual wound debris. Accurate prediction of burn wound outcome could be made via the standard information generated by LDI and appeared more reliable than clinical prediction. The correlation improved with increasing experience with LDI.

Keywords: Laser Doppler Imaging (LDI); Paediatric; Burn wound outcome

1. Introduction

Prediction of burn wound outcome, or the accurate diagnosis of the depth of a burn, has always challenged those involved in their treatment [1,2]. Clinicians have long realised that the appearance of the burn correlated with outcome: Wiseman, a Sergeant-Surgeon to King Charles II, accurately described and correlated the visage of burn wounds with subsequent wound healing in 1676 [1,2]. Jackson clearly described the relationship between the external features of burn wounds, burn depth progression and cutaneous microvascular blood flow [2]. This established the theoretical basis for measurement of blood flow as a means of assessing burn depth and likely burn wound outcome [2,3].

Early excision and closure of deep burn wounds has been shown to be associated with reduced mortality and morbidity [4–6]. Early prognostication of likely burn wound outcome would facilitate optimal treatment [1,4–6]. Prediction of burn wound outcome remains especially difficult in children, however, due in part to the predominance of mixed depth scald burns, children's thin skin and their unpredictable response to injury [4,7,8]. Laser Doppler Imaging, a technique which assesses skin blood flow based on the frequency shift of reflected laser light on a 'flux' scale, has been shown to accurately indicate burn wound outcome in both adults and children [3,8–10].

In performance of an LDI scan, the operator unavoidably visualises the burn wound [8]. This raises the possibility that any clinician involved in the performance of the scan, by bringing their clinical expertise to the assessment, would inevitably bias interpretation, artificially enhancing the

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sensitivity and specificity of LDI. This study sought to test the hypothesis, therefore, that LDI would remain accurate in predicting burn wound outcome in children in the absence of any direct clinical assessment of the burn wound.

2. Materials and methods

The ethics committee of the Children's Hospital at Westmead approved the study. The LDI scanner was operated under guidelines stipulated by the Laser Safety Committee of our institution. A Moor LDI version 2 near infrared system was used, based on a helium–neon 2.5 mW Class IIIR laser operating at a wavelength of 780 nm. It was controlled by an IBM compatible PC using moorLDI V4.1 software (Moor Instruments Ltd., Axminster, England, UK). The colour digital image of the area scanned was obtained using the systems integrated CCD camera.

2.1. Patients

All inpatients and outpatients who presented within 3 days of injury between March 2002 and August 2002 had a Laser Doppler scan performed. All scans were performed by either the first author or a dedicated burns resident and were most commonly performed on the third day after burn. Patients with facial burns in which the eyes could not be satisfactorily screened were excluded, together with those patients with multi-system trauma.

2.2. Methodology

The technique used for performance of the scan has been described [8]. All scans were performed by the first author in a dedicated, light shielded, air-conditioned room at 22 °C between 24 and 72 h post injury. Burn wounds were debrided in fasted patients under nitrous oxide sedation using our standard burns unit technique: all blisters were unroofed and the wound manually cleansed to separate as much eschar as possible. The wound was temporarily covered with a sterile drape and the patient immediately transferred to the LDI room for scanning. All scans were performed during office hours and from a distance of between 0.4 and 0.7 m. No additional analgesia or sedation was required beyond that used for the wound debridement, although compliance was improved with the use of music, play therapy and milk feeds.

Following scanning, a report form was printed on a single plain A4 paper sheet using a Hewlett Packard 1200 series colour bubble-jet printer (Hewlett Packard, Blackburn, Victoria). In addition to the LDI flux scan, this sheet contained basic patient details including age and gender; time and date of burn and scan; a brief history of the injury; whether first aid was instituted; and a low-resolution digital colour image of the region scanned produced using the systems integrated CCD camera (Fig. 1). All scans thus produced were provided independently to both the second and third authors for reporting. No scans were excluded from the reporting process although several scans were sub-optimal. Both reporters were 'blinded', never visualising the burn wound nor having any direct patient contact. Reporters were not involved with each patient's treatment and were unaware of the final burn wound outcome.

In view of the heterogeneous nature of many of the burns, reporters were asked to clearly demarcate on the clinical and Laser Doppler scan images of the reporting form areas of deep, superficial or equivocal burn (Fig. 2). There was no restriction placed on the number of areas within the burn wound that the reporter wished to describe, although usually between two and three were described.

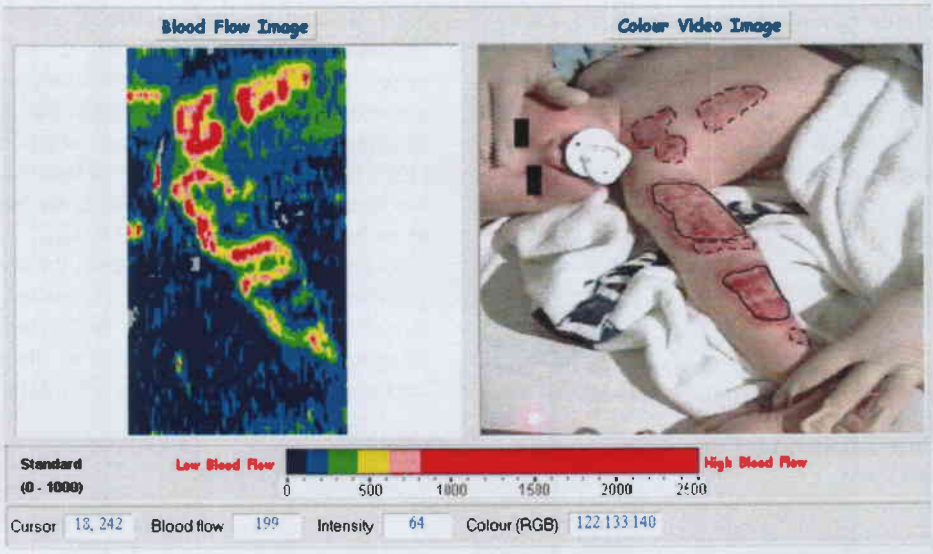

Fig. 1. Example of moorLDI Laser Doppler report images. Patient identifying details have been deleted. Note quality of low-resolution colour digital image of burn. Deep burns outlined with solid black line, superficial burns with dashed line.

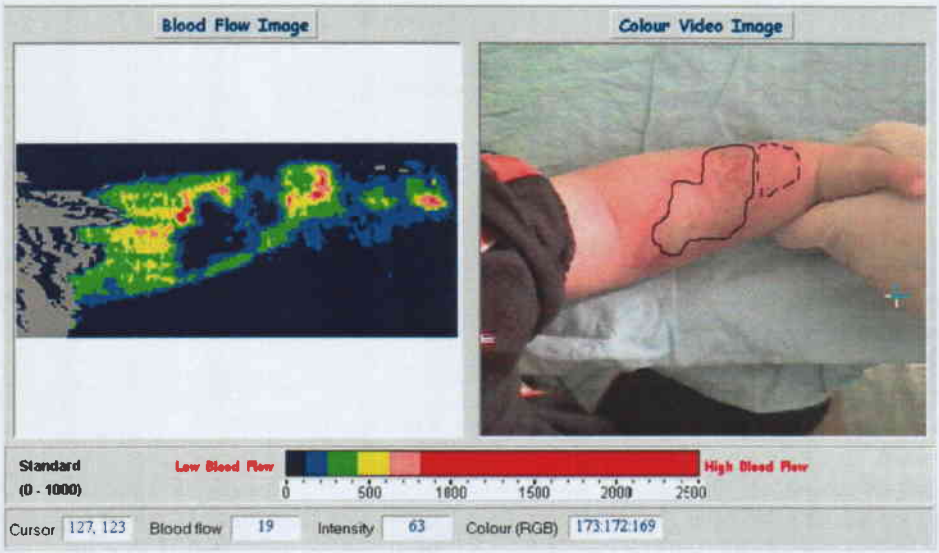

Fig. 2. Example of report in a patient with a mixed depth scald injury of the right upper limb, with areas of deep burns requiring grafting (outlined with solid black line) correctly predicted based on the LDI scan. Superficial burns outlined with dashed black line healed within 12 days.

Failure of the burn wound to heal was determined by the treating burns surgeon, an experienced paediatric or plastic surgeon, independent of the LDI flux scan report. Healing was regarded as complete epithelialisation of the burn wound as assessed by the treating surgeon's clinical examination. The treating clinician was blinded to the LDI flux scan report and their treatment decisions therefore were independent of this assessment modality.

2.3. Data analysis

Predictions as to the depth of the burn and time to healing were made based on previously established guidelines [8]. The revised Standard scale of 0–1000 perfusion units (PU) was used. If an area appeared blue (0–250 PU) it was designated as "deep or will require grafting". If an area appeared yellow or green (250–625 PU) it was designated as "heal <21 days or may require grafting". If an area appeared orange or red (>625 PU) it was designated "likely to heal within 14 days". These predictions were then correlated with actual outcome.

3. Results

A total of 50 scans were performed on 31 patients over 6 months, generating 100 reports. The scans were performed at a mean of 54 h post burn injury. The epidemiology was typical of our regional paediatric burn population. The median age was 1 year and 9 months, with a range from 5 months to 15 years. There were 18 boys and 13 girls. The commonest burn was a scald ($n = 21$), accounting for over two-thirds of all burns, with five each of contact and flame burns. The median body surface area burnt was 8% with a range from less than 1–34%. Overall 22 burns wounds required grafting in 22 patients at a mean of 11 days (range 4–21 days). One patient was not grafted and the burn wound healed within 23 days.

Reporter one identified 82 areas of differing burn wound depth within the 50 scans, and Reporter two 76 areas (Table 1). Overall, 97% of predictions were correct, with just four areas of deep burn incorrectly predicted to heal within 14 days. No superficial burns were reported as deep (that is, predicted to not heal within 14 days). The sensitivity and specificity of LDI was 0.97 and 1.0, respectively. There were no complications associated with the use of LDI during this study.

4. Discussion

Detailed reviews have confirmed that the typical reported accuracy of clinical examination in the prediction of burn wound outcome varies between 50 and 65% [1,6]. Despite these low values, experienced burn surgeons continue to advocate clinical examination by an experienced clinician as the best available predictor of burn wound outcome [11].

Table 1
Summary of comparison between the individual report predictions and actual outcome with respect to each individual zone identified

	Superficial heal <14 days	Deep heal > 14 days or graft	Overall
Reporter 1			
LDI prediction	43	39	82
Actual outcome	42	39	81
Accuracy (%)	98	100	99
Reporter 2			
LDI prediction	39	37	76
Actual outcome	36	37	73
Accuracy (%)	92	100	96

This study again demonstrates, however, at least in children, the ability of LDI to greatly assist in predicting burn wound outcome [3,7,8,10,12,13]. At the very least, LDI appears extremely accurate when performed within 3 days of the injury in predicting deep burns that will not heal within 14 days. In this situation, the patient and parents may be advised and the appropriate treatment expedited, facilitating optimal use of both in and outpatient resources [14].

There appeared to be a significant but short 'learning curve' associated with reporting LDI scans. Reporter one was very experienced in the use of the LDI and had previously published on the subject [8]. Reporter two was less experienced in the use of LDI. After the first 18 of 50 scans Reporter two had an overall accuracy of 83%, but this had risen to 96% by the end of the study conducted over a 6-month period.

No diagnostic tool will ever be completely reliable [13]. In the scans in which the LDI did not exactly predict outcome a number of causative factors were identified. The most important factor, particularly in limb burns, was the angle of incidence of the laser beam to the burn wound surface. In our experience the LDI works optimally when the angle of incidence of the laser beam was at or close to 90° [8,12]. Reduced reliability occurred once the angle of incidence increased beyond 135° [12]. Multiple scans may therefore be required to adequately image burns extending over curved areas in order to ensure predictive accuracy [8,12].

Excessive movement remains detrimental to accurate imaging [8]. This may explain why many studies have been confined to adult burn patients, more likely to comply with need to remain still during the scanning process [3,7,9,10]. With the median age of our patients 21 months, several techniques were employed to reduce movement. All scans were performed with a parent present and often cuddling the child. We have found a Play Therapist invaluable in providing non-pharmacological analgesia and anxiolytic therapy. Rarely a scan was unable to be performed satisfactorily, but even in these situations returning for a second attempt within 24 h was always successful.

Finally, the burn wound needed to be adequately debrided to avoid debris mimicking a deeper burn. Thus intact blisters or necrotic epidermis will reduce reflected laser light, potentially falsely indicating a deep burn [8,12]. Dressings may also impact on the LDI scan, with the use of Acticoat dressings associated with false readings due to the interaction between the laser light and silver particles contained within the dressing [10].

5. Conclusion

LDI in children appears to be extremely accurate in predicting burn wound outcome in children, with a sensitivity and specificity of 0.97 and 1.0, respectively, when performed within 3 days of the burn injury. This accuracy appeared independent of examination of the burn wound. Although optimal patient management would seem most likely to occur by combining clinical and LDI assessments of burn wounds, burns surgeons should be guided by LDI data.

Conflict of interest

None. This investigation was entirely supported by The Children's Hospital at Westmead and included the leasing of the moor LDI from Moor Instruments Ltd. for the duration of this study. No payments were made by the company in connection with any work associated with this investigation.

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