Review Article
The critical evaluation of laser Doppler imaging in determining burn depth

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Abstract: This review article discusses the use of laser Doppler imaging as a clinimetric tool to determine burn depth in patients presenting to hospital. Laser Doppler imaging is a very sensitive and specific tool to measure burn depth, easy to use, reliable and acceptable to the patient due to its quick and non-invasive nature. Improvements in validity, cost and reproducibility would improve its use in clinical practice however it is difficult to satisfy the entire evaluation criterion all the time. It remains a widely accepted tool to assess burn depth, with an ever-increasing body of evidence to support its use, as discussed in this review. Close collaboration between clinicians, statisticians, epidemiologists and psychologists is necessary in order to develop the evidence base for the use of laser Doppler imaging as standard in burn depth assessment and therefore act as an influencing factor in management decisions.

Keywords: Burns, burns assessment, clinimetrics, laser Doppler imaging

Introduction

The accurate measurement of burn depth has challenged clinicians, as the importance of correct diagnosis leads to the prompt management to optimise scarring and functional outcome.

Jackson’s burn wound model initially described the three zones of a burn [1] – the zone of coagulation (permanent cell necrosis), stasis (potentially reversible damage) and hyperaemia (reversible damage). These zones can progress in either direction depending on the promptness of management.

Clinically burns are often classified as superficial epidermal, superficial dermal, deep dermal and full thickness [2]. Superficial epidermal burns heal within seven days leaving no scars, superficial dermal burns are painful, deep dermal burns are insensate and full thickness burns are leathery white and insensate [3].

Traditional assessment of burn depth

Traditionally, clinicians used clinical judgement by taking a complete history looking at mode of injury, length of contact of heat with skin, age of patient and initial first aid administered [4]. Examination includes calculation of total surface body area affected and inspection of the burn looking at colour, pain sensation and capillary refill [2, 3]. Histological diagnosis by biopsy is the gold standard used to determine burn depth [5, 6], however it does not assess the whole burn, is invasive therefore causes pain and scarring and is affected by sampling variation as biopsy can miss deepest part of the burn [7].

The ideal tool to measure burn depth should be sensitive (positive for proportion of population with burn), specific (negative for proportion of population with no burn), reliable (produce the same results repeatedly), valid (measure what it is claims to measure), reproducible (can be replicated by different observers), cost-effective, non-invasive and acceptable to the patient and clinician (practically and ethically) [2, 8]. These terms are discussed later in this assignment. It is difficult to find tools that fulfil all these requirements but this assignment aims to look at the clinimetrics of laser Doppler imaging (LDI) in assessing burn depth.
Laser Doppler imaging for determining burn depth

The term Clinimetrics was introduced by Feinstein [9, 10] focusing on the measurement issues present in clinical medicine and research. It looks at the quality of measurement instruments and the performance of the actual measurement itself when carrying out research or in clinical practice [10]. An evaluation looking at the clinimetrics of an instrument is important before establishing it as a diagnostic tool [11].

Use of laser doppler imaging (LDI) to measure depth of burns

LDI measures the extent of superficial dermal microvascular blood flow [8, 12, 13]. Disruption of this blood flow can correlate with extent of injury, with deep dermal/full thickness burns showing significant reduction in dermal blood flow [8, 14], therefore it can assess burn depth in patients.

The importance of correct assessment is paramount as superficial epidermal and dermal burns can be managed conservatively with dressings [3], whereas deep dermal and full thickness burn require surgical intervention in order to heal quicker and with less complications [15, 16]. Due to the face validity of the LDI as an assessment tool, correct diagnosis reduces mortality, cost and unnecessary surgical interventions [17-19].

LDI uses a red diode laser, which is reflected by circulating erythrocytes and immobile tissue, therefore displaying the ‘Doppler Shift Effect’ which states that light reflected from an object that is moving is relative to the light source undergoing a frequency shift [20]. The reflected light is detected by a transducer, which derives values for dermal perfusion and these are used to produce a colour map of the wound [14, 21]. Micheels et al. [14] reported that superficial burns show high rates of perfusion, whereas deeper burns show low rates of perfusion due to damaged blood vessels. The colour maps are red/yellow in areas of high perfusion (e.g. superficial epidermal and superficial dermal) and green/blue in areas of moderate-low perfusion (deep dermal) and blue in areas of low perfusion (full thickness) [14, 21]. These maps can be compared to clinical photographs and examination of the patient in order to allow accurate measurement of burn depth as alone they are not sufficient for assessment [2, 3, 22].

Validity

Validity is the degree to which an instrument measures what it claims to measure [23]. Criterion validity is the most powerful subtype as it compares the instrument’s ability to provide results to the gold standard in burn assessment, which is histological diagnosis [24]. In the absence of a gold standard concurrent validity is used, however a hypothesis needs to be defined about how the scores from the instrument under study will correlate with scores from other instruments [11, 24]. Content validity assesses whether all the components under the construct are covered by the instrument and face validity looks at whether on face value the components are adequate without looking in detail at each component [11, 24]. LDI can potentially be compared to the gold standard of histological diagnosis therefore using criterion validity, however not all the studies do this, instead they compare LDI to clinical diagnosis due to the invasive nature of biopsies.

LDI was compared to clinical examination in a prospective blinded trial of 23 patients with a total of 41 burns, of which 16 were treated conservatively and 25 underwent surgical intervention [19]. Twenty-one wounds were biopsied, of which the surgeon correctly determined burn depth in 15 burns and the LDI correctly determined 7 burns that need excision and graft but incorrectly identified 8 out of the 21 biopsied burns as superficial burns when they were deep histologically. This was due to the surrounding hyperaemia skewing the results. Nil correlation found between clinical examination and LDI in 18 out of the 41 burns, with clinical examination overestimating burn depth in 10 out of 18 cases. Clinical assessment is 60-80% accurate [25]. As only 21 burns were biopsied, this study offers concurrent validity as LDI was not compared to gold standard but primarily to clinical assessment.

Positive predictive value (PPV) is number of true positive results out of the total positive result and negative predictive value (NPV) is number of true negative results out of the total negative results [26]. For this study not all burns were biopsied and therefore a true PPV and NPV value cannot be stated.

Pape et al. [3] looked at 48 patients with a total of 76 burns of intermediate depth (between
superficial and deep dermal) and performed clinical and LDI assessment at 42-72 hours post-injury. Burns were managed according to LDI assessment – with high perfusion suggestive of superficial burn depth therefore treated conservatively and low perfusion suggestive of deep dermal/full thickness burn depth and therefore managed surgically with biopsies sent for histology. LDI correctly identified 41 out of 43 burns as superficial requiring conservative management, with 2 clinically found to be infected, requiring antibiotics. Clinical judgement accurately identified 30 out of 43 to be superficial using visual parameters of colour, pain, capillary refill and presence of blisters [1], overestimating 13 as requiring surgical intervention. LDI identified 25 of the 76 burns as low perfusion requiring surgery, in 100% agreement with the histological diagnosis, clinical assessment only had 84% agreement. Again, this only offers concurrent validity as LDI and clinical assessment were being compared.

Reliability

Reliability is the degree to which the tested variable can be distinguished from others with the presence of sampling errors, with repeated measurements of the same variable, under similar conditions to produce similar results [24]. Inter-rater reliability refers to the test to produce similar results for the variable when tested on 2 separate occasions [8].

The reliability with regards to time to scan the burn post-injury has been debated as the burn evolves over 48-72 hours [1], therefore 48 hours has been suggested to be the optimal time for scanning [3, 20]. Jeng et al. [19] showed that repeated daily scans of 23 patients did not change significantly from day 1 post-injury, therefore scanning at 36-72 hours is adequate.

The angle that the LDI probe is held over the skin affected results in a study by La Hei et al. [22] with 31 paediatric burns patients. Angles <90 degrees or >135 degrees, had reduced reliability in this study, other studies found beams close to 90 degrees to be most accurate [27] or between 15-30 degrees [28].

Within the paediatric population, movement adversely affects the reliability of LDI, whereas adults are usually compliant and remain still during scanning [22, 29], explaining the lack of paediatric LDI studies. Sedation or general anaesthesia can be considered when scanning children however this may be deemed unacceptable due to risks of anaesthetic. Clinicians should weigh the pros and cons of sedation/anaesthetic per individual case and may use the opportunity to perform LDI if the patient is being sedated/anaesthetised for wound debridement/dressing changes but should it for the pure purpose of performing LDI.

Failure to debride the burn adequately results in residual debris and intact blisters, which reduce the reliability of the LDI as false colour indicates deeper burns [27]. This is important to avoid as the result affects management of the wound. The false positive findings result in inappropriate surgical intervention, which could potentially have been treated with dressings alone.

Dressings such as Acticoat® can produce silver particle residues and affect LDI readings [19]. Haslik et al. [30] have supported this study by assessing the accuracy of burn depth using indocyanine green videoangiography, showing that signal was reduced in the presence of Inadine®, Bactigras® and Flammazine®. The authors recommended cleaning of the wound using topical antiseptics such as Octenisept® and waiting 10 minutes before scanning to prevent the effect of reactive hyperaemia due to cleaning. Although videoangiography was used to look at burn depth and not LDI, this study is important to show the effect of residue on the reliability of signal transduction and therefore LDI reliability. Standard practice is to remove any debris from the wound by cleaning before application of dressings.

Optimal environment conditions such as ambient temperature, lighting and removal of blisters and debris from the skin should be maintained to increase reliability of the LDI scanning results [8].

Sensitivity and specificity

Sensitivity is the ability of the LDI to correctly identify deep burns, whereas specificity is the LDI’s ability to identify superficial burns [31]. LDI rates of sensitivity range from 90-100% and specificity from 92-97% [3, 21, 27, 32].
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LDI is reported to be sensitive to a depth of 1-2mm [33] but skin thickness at the sole of the feet and back is thicker than this. Location of the burn has not been discussed in the studies above, but this may play a role in affecting sensitivity and specificity.

Holland et al. [27] commented that operator bias might increase the sensitivity as the burn is clearly visible to the LDI operator and therefore clinical judgement may be used to scan over an area that looks worse. However, a study to assess the ability to use LDI results and photographs of the burn without carrying out a clinical assessment in order to make a management decision was completed by La Hei et al. [22], showing an observer sensitivity of 97% and a specificity of 100%. All 76 reports predicted on LDI to be deep in depth correlated with clinical outcome resulting in a sensitivity of 100%. 4 out of 82 LDI reports were found to be superficial but were found to be deep clinically therefore giving a specificity of 95%. No histological diagnosis was performed and healing time cut off used was 14 days, whereas other studies use 21 days therefore results should be taken with caution as the results are not comparable. I would suggest a cut-off of 21 days so that comparisons to other studies can be made.

Reproducibility

Reproducibility is the ability of the scientific experiment to be replicated by a separate observer on a separate day [8]. It is derived from agreement and reliability [11], where agreement is lack of measurement error and reliability is the degree to which individuals can be distinguished from each other, despite measurement error.

Gschwandtner et al. [34] used LDI to examine perfusion through 10 arterial ulcers and 10 venous ulcers on five consecutive days at 5 specific time points when PGE1 was used for treatment. The same measurements were made on 3 consecutive days without PGE1 treatment. Following statistical analysis using coefficient variables, the study showed that LDI reproducibility was good when carried out on the same day, however, when carried out on separate days the reproducibility was significantly reduced. The authors explained this as the presence of non-viable material on the ulcer affecting results in following days. Therefore this study shows that reproducibility will on be seen on single days when using LDI. This can be related to burns injuries as presence of debris and formation of Marjolin’s ulcers can affect the reproducibility of the LDI in the same way [35].

Responsiveness

Responsiveness is an important clinimetric parameter as it measures change over time of the measured quantity [36]. Many methods exist to calculate responsiveness; however calculating changes in clinical scores for a cohort of patients with expectant health changes over a scale of time is a good way to look at responsiveness [37]. Responsiveness can be used to measure the evolution of a burn by observing the healing of the wound.

Jeng et al. [19] used daily LDI assessments in 23 patients with 41 burns until they were deemed to be healed or need surgical intervention. The mean length of stay was 14 days, with LDI accuracy found to be 100% when compared to clinical observation of 71.4%. It estimated that when LDI and surgeon were in agreement, the length of stay in hospital could have been decreased by 2 days.

Acceptability

LDI is well tolerated by adults and some paediatric cases due to its non-invasive nature, the fact that no contact with the burn area is required and large burn areas can be assessed at once. As a result, there is no scarring or cross-infection risk [2]. Helpful parents and play therapists can be an invaluable support during LDI scanning of paediatric cases [22, 27].

There is minimal clinical burden on staff as usually scanning time is <2 minutes with a co-operative patient and an experienced scanner [11]. The main problem is cost, with initial capital cost of an LDI unit to be above £35,000 [21]. However, this initial cost may be justified as studies have shown a reduction in inpatient stay by 2 days, decreased risk of infections and increased bed availability [19]. LDI scanning can facilitate the clinical decision-making and allow treatment on an outpatient basis, reducing overall costs to the NHS [8].
Conclusion

LDI is a very sensitive and specific tool to measure burn depth, easy to use, reliable and acceptable to the patient due to its quick and non-invasive nature. It remains a widely accepted tool to assess burn depth, with an ever-increasing body of evidence as discussed to support its use. It is the only diagnostic modality that has regulatory approval from the United States Food and Drug Administration [11].

With respect to LDI, improvements in validity, cost and reproducibility would improve this clinimetric tool, as it is difficult to satisfy the entire evaluation criterion all the time. Close collaboration between clinicians, statisticians, epidemiologists and psychologists is necessary in order to develop clinimetrics to develop both clinical practice and clinical research.

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Conflict of interest statement

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this review.

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References

[22] La Hei ER, Holland A, Martin H. Laser Doppler Imaging of paediatric burns: Burn wound out-
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1 come can be predicted independent of clinical examination. Burns 2006; 32: 550-553.


