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Three-dimensional imaging is a novel and reliable technique to measure total body surface area

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ABSTRACT

Objective: The aim of this study was to explore the diverse clinimetric aspects of three-dimensional imaging measurements of TBSA in clinical practice compared with the methods currently used in clinical practice (i.e., the rule of nines and palm method) to measure TBSA in clinical practice.

Method: To assess reliability, two independent researchers measured the TBSAs of 48 burn patients using Artec MHT™ Scanner and software. Subsequently, a resident and burn specialist estimated the TBSA of the same wounds using the rule of nines and palm method.

Results: Three-dimensional imaging showed excellent inter-observer reliability, with an intra-class correlation coefficient (ICC) of 0.99, standard error of measurement (SEM) of 0.054, and limits of agreement (LoA) of $\pm 0.15 \times$ the mean TBSA (between the measurements of two researchers). The inter-observer reliability of the methods used in current clinical practice was less reliable, with an ICC of 0.91, SEM of 0.300 and LoA of $\pm 0.78 \times$ the mean TBSA. The inter-observer reliability was least reliable between three-dimensional imaging and the residents compared with the burn specialists for the estimated TBSA, with an ICC of 0.68, SEM of 0.69 and LoA of $\pm 1.49 \times$ the mean TBSA.

Conclusion: The inter-observer reliability of three-dimensional imaging was superior compared with the rule of nines and palm method.

Abbreviations: BSA, body surface area; ICC, intra-class correlation coefficient; LoA, limits of agreement; SEM, standard error of measurement.

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1. Introduction

A correct estimation of burn wound size, which is defined as total body surface area (TBSA), is essential for adequate burn wound management in acute care setting. TBSA determines the need for intravenous fluid resuscitation and whether the patient must be transferred to a specialized burn unit [1]. Moreover, an accurate TBSA estimation is important to manage nutritional support and evaluate treatment efficacy, as well as for research purposes.

In current clinical practice, the rule of nines [2], palm method [3] and Lund and Browder chart [4] are used to estimate TBSA. However, these methods have some limitations. The rule of nines tends to overestimate TBSA [5]. The definition of the palm method is not always clear to the clinicians, and the area of the palm, including the fingers, does not resemble 1% of the body surface area (BSA) in adults, which could lead to overestimation of the burn area [3,6–10]. The Lund and Browder chart is based on a two-dimensional model, and it does not consider the three-dimensional aspect of the body. However, the inter-rater reliability of this method is better compared to the rule of nines [5]. Moreover, digital Lund & Browder charts showed high reproducibility and fewer estimation errors compared to the paper Lund & Browder chart [11–13]. In general, the reliability of each described method is highly dependent on the size and irregularity of the wound, the body mass index (BMI) of the patient, and the experience of the physician [14,6,15,16].

Recent research indicates that computerized techniques are a promising and likely more accurate method of estimating TBSA. Three-dimensional imaging of the wound surface area is a novel technique that has the potential to overcome the limitations of the described methods to estimate TBSA. With this technique, a full-coloured three-dimensional reconstruction of the burn wound can be performed. TBSA is then obtained from the measured wound surface area and body surface area (BSA).

To assess the applicability of three dimensional imaging in clinical practice, the clinimetric properties, such as reliability, of this method must be investigated first.

In a previous study, we found that three-dimensional imaging using the Artec MHT^{TM} Scanner and software to be a non-invasive and reliable technique for measuring burn wound surface area. The objective of this explorative study was to investigate the inter-observer reliability of three-dimensional imaging for measuring the TBSA in clinical practice compared with methods currently used (rule of nines and palm method).

2. Patients and methods

2.1. Study population

Data were obtained from our validation study [17]. In short, burn patients were included consecutively from the Burn Center of the Red Cross Hospital, Beverwijk, from August 2012 to January 2013. The Red Cross Hospital is one of the three tertiary burn centres in the Netherlands. All burn patients were eligible for study inclusion, except those who had undergone surgical intervention. Informed consent was obtained from all patients before they were included in the study. The local ethics committee approved this study.

2.2. Three-dimensional imaging

To measure the burn wound surface area, the Artec MHT^{TM} 3D Scanner, a non-invasive, handheld device (the Artec Group, San Diego, CA, USA), was used. This device projected structured light flashes on a burn wound and then reconstructed the three-dimensional view of the scanned area. This device also provided a coloured image of the scanned area every 15 frames. As a result, a full-coloured three-dimensional reconstruction of the burn wound was obtained. Scans were performed perpendicular to the burn wound at a distance of 40-60 cm. Then the software program (Artec 3D Studio 9.0) generated a three-dimensional image of the wound. Thereafter, the clinician had to mark the boundaries of the burn wound on a full-coloured, three-dimensional reconstruction of the wound. Finally, the software program calculated the surface area of the burn wound in mm^2, as marked by the boundaries determined by the clinician. We comprehensively described the technique and procedure of this novel technique in our validation study [17].

2.3. TBSA

To determine the TBSA, the burn surface area measured with three-dimensional-imaging was divided by the body surface area (BSA). The BSA was calculated using the DuBois and DuBois formula (BSA (m^2) = 0.20247 × Height(m)$^{0.725}$ × Weight (kg)$^{0.425}$) [18] for adults and the Haycock formula (BSA (m^2) = 0.024265 × height (cm)$^{0.3964}$ × weight (kg)$^{0.5378}$) [19] for children. To determine the TBSA in clinical practice, a resident and a burn specialist used the rule of nines and palm method to estimate the TBSA. The TBSA estimate performed by a resident and a burn specialist was thought to be most relevant, as for most burn patients, the TBSA is first determined by a resident from a general hospital. When referred to a specialized burn centre, the TBSA is estimated again by a burn specialist.

2.4. Study design

2.4.1. Inter-observer reliability of three-dimensional imaging

To assess the inter-observer reliability of determining the TBSA using Artec MHT^{TM} 3D scanner, the TBSAs of all burn wounds were independently calculated by two researchers (A and B). Researcher A and B were researchers at the Burn Centre of Red Cross Hospital and had the clinical experience of a resident. Both used the Artec MHT^{TM} 3D Scanner to scan the burn surface area. Next, researcher A measured the burn surface area of the scan of researcher B with the Artec 3D software program, and vice versa. This design most accurately reflects clinical practice with divided task and shifts. Finally, TBSAs were calculated by dividing the measured burn surface area by the BSA times a hundred.

2.4.2. Inter-observer reliability of current clinical methods

To put the results of the reliability of three-dimensional imaging in perspective with the reliability of methods used

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