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Comparison between high-frequency ultrasonography and histological assessment reveals weak correlation for measurements of scar tissue thickness

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ABSTRACT

Objective: Current methods for evaluating scar tissue volume following burns have shortcomings. The Vancouver Burn Scar scale is subjective, leading to a high variability in assessment. Although histological assessment *via* punch biopsy can discriminate between the different layers of skin, such an approach is invasive, inefficient, and detrimental to patient experience and wound healing. This study investigates the accuracy of high-frequency ultrasonography, a non-invasive alternative to histology, for measuring dermal and epidermal thickness in scar tissue.

Methods: Scar thicknesses of 10 patients following burns were assessed using a 2-D high-frequency ultrasound probe. The scars were then biopsied using a circular 4mm punch biopsy for histological assessment. Dermal, epidermal, and total thickness of the scar tissue was measured using ultrasound and histology, and correlations between the two measurements were calculated.

Results: There was not a strong correlation between ultrasound measurement and histological analysis for epidermal, dermal, and total thickness (Spearman's rank correlation of −0.1223, −0.6242, and −0.6242) of scar tissue.

Conclusions: Measurements of scar thickness using high-frequency ultrasonography did not recapitulate the *in vivo* dermal, epidermal and total thickness. Based on these findings, strategies for further optimization of 2-D ultrasonography is discussed before clinical and research use.

Abbreviations: STSG, split-thickness skin graft; HSc, hypertrophic scar.

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1. Introduction

Histological quantification of skin and its appendages has been an accepted gold standard to demarcate features such as epidermal and dermal thickness [1], its intrinsic properties such as collagen density [2], and evaluation of several cutaneous carcinomas [3]. Although such an approach is highly accurate in discriminating cell populations within the skin based on morphological features unique to each compartment, its routine usage requires repeated tissue biopsy. This especially presents a challenge for evaluation of burn scars as repeated biopsy-induced perforations can impede wound healing, cause scar tissue to become prone to ulceration, and potentially trigger the onset of malignant transformation as seen in burn scar carcinoma [4].

Dermatological ultrasonography [5] has recently gained attention as a non-invasive alternative for quantitative assessment of cutaneous tissue in a rapid and non-invasive manner [6]. Various studies have demonstrated important progress in the usage of high-frequency ultrasonography for monitoring, diagnosing and determining treatment effects on skin related condition [7,8]. The development of transducers capable of high-frequency imaging in the 1980s permitted microscopic resolution of sub-surface structures within the skin, and subsequently, techniques to measure the cutaneous thickness under normal and pathologic conditions were developed [9]. Ultrasound examination of the skin has previously been proposed for measuring cutaneous repair therapies, especially following skin sclerosis in systemic scleroderma [10] and morphea [11] for example. Ultrasound imaging techniques have also been considered in the determination of therapeutic effectiveness in patients with lipodermatosclerosis [12] and inflammatory dermatoses (such as lichen sclerosus) [13], measurements of skin tumor penetrations (such as malignant melanoma and basal cell carcinoma) [14] and determination of topical and systemic drug effects (such as corticosteroids and oestradiol).

Evaluation of scars should ideally quantify both epidermal and dermal thickness. The tracking of changes in these thicknesses may reveal information about wound healing and allow for the functional quantification of therapeutic and aesthetic outcomes [15]. For all scar types, such as keloid, atrophic, contracted and fine line scars, which may be viewed as aesthetically unpleasing, result in psychological distress and cause functional restrictions, there is a need for objective, accurate and feasible tools which can document and quantify scar evolution following therapeutic modulations such as non-invasive pressure therapies [16]. Current methods for evaluating the thickness of the skin in scarred region include the Vancouver Burn and Scar Scale (VSS), Manchester Scar Scale (MSS), Patient and Observer Scar Assessment Scale (POSAS), Visual Analog Scale (VAS) and Stony Brook Scar Evaluation Scale (SBSES) [17]. VSS was first described by Sullivan et al. in 1990 [18] to subjectively assess four variables: vascularity, thickness, pliability and pigmentation. VAS is a photograph-based scale evaluating variables such as vascularity, pigmentation, acceptability, observer comfort and contour. The primary purpose for POSAS was to capture a broader range of subjective assessments such as pain and pruritus to complement the VSS. In 1998, Beausang et al. [19] proposed MSS to rate seven scar parameters: color (perfect, slight, obvious, or gross mismatch to surrounding skin), texture (matte or shiny), relationship to surrounding skin (range from flush to keloid), texture (normal to hard), margins (distinct or indistinct), size (<1 cm, 1–5 cm, >5 cm), and single or multiple [20]. A standardized VAS is added at each stage of assessment as a reference to evaluate and track changes in the scar tissue. The most recent amongst these is the SBSES which was proposed in 2007 by Singer et al. [21] to measure short-term cosmetic outcomes following wounding by emphasizing the overall appearance of the tissue. Although the VSS scale is the most widely used scale for evaluating hypertrophic scar and has thus become part of standard practice in North America, a common deficiency shared by all scar scales is their inherent subjective and inexact nature, failing to evaluate scar pathology and its evolution objectively through the course of treatment. Furthermore, the precise evaluation of epidermal and dermal thickness with these scales are unreliable. Due to the variable nature of cutaneous scar formation and maturation among patients with different ethnic backgrounds, age, anatomical location, time of closure and presence of other complications, an accurate system for quantifying scars is necessary and could potentially be widely adopted in clinical settings.

Recent studies on high-frequency ultrasonography have investigated the interrater reliability, sensitivity and concurrent validity of a high-frequency ultrasound device developed for skin imaging. The reports suggest the interrater reliability values fall within the acceptable range for measurements of HSc donor and normal skin for scar color and thickness measurements [22,23]. Although comparisons relative to the modified Vancouver Scar Scale were used to evaluate the concurrent validity, measurements were not validated against histological analysis of scar thickness. Since histological assessment serves as the current gold standard for determining epidermal and dermal thickness [1], this study the concurrent validity of echography ultrasound measurements made using the 2D device at 20 MHz frequency against histological quantification of the epidermal, dermal and total thickness of a graft biopsy. By elucidating the accuracy of using the device for quantification of skin thickness measurements in patients with cutaneous scars, this independent analysis seeks to provide evidence to inform both the users and the manufacturers on its clinical usage and limitations and a rationale for customizing the instrument to allow for objective and accurate measurements of scar tissue.

2. Materials and methods

Subjects were recruited through a tertiary outpatient burn clinic. All experimental procedures received prior approval of the Conjoint Health Research Ethics Board at the University of Calgary as well as informed patient consent. Subjects were all adults over 18 years old with scars resulting from burns or other conditions requiring split thickness skin grafting. The area of study was inspected by the investigators not to have open wounds nor over an anatomic region at risk of injury from a punch biopsy.