Intensive and Critical Care Nursing xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Intensive and Critical Care Nursing

journal homepage: www.elsevier.com/iccn

High frequency ultrasound sacral images in the critically ill: Tissue characteristics versus visual evaluation☆

Mary Jo Grap[a,*], Christine M. Schubert[e], Ruth S. Burk[a], Valentina Lucas[b], Paul A. Wetzel[d], Anathea Pepperl[d], Cindy L. Munro[c]

[a] Adult Health and Nursing Systems, Department of the School of Nursing, Virginia Commonwealth University, Richmond, VA, United States
[b] Department of Surgery, Virginia Commonwealth University Heath System, Richmond, VA, United States
[c] University of South Florida, Tampa, FL, United States
[d] Biomedical Engineering Department, School of Engineering, Virginia Commonwealth University, Richmond, VA, United States
[e] Department of Mathematics and Statistics, Air Force Institute of Technology, Wright-Patterson Air Force Base, Dayton, OH, United States

ARTICLE INFO

Article history:
Received 11 November 2016
Received in revised form 29 January 2017
Accepted 2 February 2017

Keywords:
High frequency ultrasound
Pressure ulcers
Evaluation
Critical care

ABSTRACT

Purpose: High frequency ultrasound (HFUS) systems may identify tissue injury. We compared HFUS tissue characteristics (dermal thickness and dermal density) with visual image examination.
Methods: Longitudinal study in critically ill mechanically ventilated adults, from three ICUs (Surgical Trauma, Medical Respiratory, Neuroscience) enrolled within 24 hours of airway intubation. Sacral HFUS images were obtained daily for up to seven days. Expert evaluation of the best image per day was completed and compared to HFUS generated tissue characteristics (dermal thickness and dermal density).
Results: Of the113 subjects with 1614 comparisons analysed, 73.2% to 84% were normal, and 6.3% to 11.8% of the comparisons had injury present but no change was noted in the injury observed. There were no significant differences in one-day comparisons among type of injury and mean dermal thickness ($p = 0.6645$) or dermal median intensity (adjusted $p = 0.06$-0.17). All other day-to-day comparisons were similarly non-significant.
Conclusions: We found no association among dermal density, dermal thickness and visual examination of changes in sacral HFUS images for any day-to-day comparison. The use of sacral HFUS as a screening tool for the development of tissue injury is in its infancy. Additional comparative studies should be conducted to identify its future clinical usefulness.

Implications for clinical practice

- Identification of early tissue injury prior to the development of pressure ulcers is ideal.
- Common and standard HFUS measures of tissue injury are not available.
- There was no association between sacral HFUS tissue characteristics and visual examination of changes in sacral HFUS images.
- Additional comparative studies should be conducted to identify HFUS clinical usefulness.

Introduction

Ultrasonography has been widely used in clinical practice as an inexpensive, non-invasive and portable diagnostic tool. High frequency ultrasound (HFUS) using a −20 MHz probe has been used to provide images for both dermatologic practice and research (Gniadecka, 1997; Jasaitiene et al., 2011; Jemec et al., 2000) with more limited data available about the use of HFUS to evaluate tissue characteristics in the development of pressure ulcers (PUs) (Gefen et al., 2013; Gniadecka, 1996; Gniadecka and Quistorff, 1996; Helvig and Nichols, 2012; Quintavalle et al., 2006; Moghimi et al., 2010a).

In mechanically ventilated, critically ill patients, pressure ulcer risk is high and may result in negative patient outcomes and increased health care costs (Alderden et al., 2011; Shahin et al.,

☆ Supported by funding from NIH, R01 NR010381 (Grap PI).
* Corresponding author at: 1000 Lady Jean Ct, Midlothian, VA 23114, United States.
E-mail address: mjgrap@vcu.edu (M.J. Grap).

http://dx.doi.org/10.1016/j.iccn.2017.02.001

2009a; Anon, 2001; Whittington and Briones, 2000; Beckrich and Aronovitch, 1999). Methods to quantitatively evaluate patients at risk or identify early stages of pressure ulcer development, especially the more elusive, deep tissue injuries are limited (Gefen et al., 2013; VanGilder et al., 2010). Certain deep tissue injuries may develop through a "deep-to-superficial" pattern resulting in delayed clinical recognition of significant and often extensive tissue injury and changes (Gefen et al., 2013; Black et al., 2007). Deep tissue injury and the resulting inflammation may cause tissue edema and tissue changes that may be identified using HFUS (Gefen et al., 2013; Quintavalle et al., 2006). Recently, Aliano et al. (Aliano et al., 2014) found in 20 patients with pressure ulcers that all had some evidence of deep tissue injury upon ultrasound examination. Since deep tissue ulcers are difficult to recognise, identification of quantitative measures to determine risk and early stage tissue injury, which may be invisible to visual skin examination, would be clinically useful.

In addition to producing HFUS images for visual evaluation, HFUS systems provide quantitative data and objective measurements to show contrast between healthy tissue and tissue with change, which may assist in the detection of subtle changes over time that may not be identified by visual assessment of images alone (Moghimi et al., 2010b). The most common tissue characteristics are dermal thickness and dermal density (also referred to as echogenicity) (Nedelec et al., 2016; Yalcin et al., 2013; Olsen et al., 1995). However, there are no data that compare changes in these tissue characteristics (dermal thickness and dermal density) to changes found using visual evaluation of the HFUS scan to determine the usefulness of these HFUS objective tissue measures for early identification of tissue injury. Therefore this secondary analysis of data from a larger study (Grap et al., 2016), will compare sacral HFUS tissue characteristics (dermal thickness and dermal density) with visual examination of the HFUS image.

Methods

Sample and setting

The parent study, from which this analysis was derived, was a descriptive, longitudinal study of skin integrity of 150 intubated and mechanically ventilated adult patients from a medical respiratory ICU (MRICU), surgical trauma ICU (STICU) or neuroscience ICU (NSICU) to describe the relationship between backrest elevation, tissue interface pressure and skin integrity (Grap et al., 2016). The study was approved by the university Institutional Review Board (IRB) and informed consent was obtained from the subject's legally authorized representative (LAR). Because the parent study included use of a pressure mapping system that may enhance skin moisture, exclusion criteria included patients who had significant skin moisture risk as determined by the Braden scale of "constantly moist" (Braden and Bergstrom, 1987). Subjects were enrolled in the study within 24 hours of airway intubation and sacral HFUSs were obtained daily for up to seven days. Data were collected from February 2010 through May 2012.

Measures

High frequency ultrasound scans

Sacral tissue was evaluated using a high (20 MHz) frequency ultrasound dermal scanning system (EPISCAN, Longport, Inc, Glen Mills, PA). The EPISCAN settings on all images were as per manufacturer's recommendation for sacral scans and were consistent to insure uniformity of measurement between images: size – 512 × 1024; TGC srt = 0%; pos = 16.0; depth = 10.2 mm; TGC = 10%; gain = 20%. However, in this critically ill population, it was not possible to obtain scans in the prone position as recommended by the manufacturer, rather HFUS sacral images were obtained in patient side-lying positions as close to a side-lying, 90° lateral rotation as possible, based on the clinical condition of the patient. All sacral scans were therefore obtained in the lateral position with the subject turned from 60 to 90°.

Tissue characteristics (dermal thickness, dermal density)

Use of HFUS to evaluate tissue injury has indicated that patterns of fluid accumulation or edema within dermal and hypodermal tissue may be early indicators of tissue injury (Helvig and Nichols, 2012; Quintavalle et al., 2006; Andersen and Karlsmark, 2008; Ryan et al., 2001). Changes in dermal and hypodermal thickness (in millimeters) and dermal and hypodermal layer density (median signal intensity distribution) may reflect tissue inflammation (Timar-Banu et al., 2001). EPISCAN HFUS software-generated measurements include measures for layer thickness and layer density (Moghimi et al., 2010a; Moghimi et al., 2011; Laurent et al., 2007). Layer thickness is a measure of the width of the layer (dermal and hypodermal), therefore in non-chronic skin conditions, as inflammation and edema increases, layers become thicker (Timar-Banu et al., 2001). In this study we evaluated only sacral dermal thickness as a measure of inflammation. Three thickness measurements were obtained for each image and the average of the three were used in the analysis. Inter-rater reliability of the three measurements was excellent with an average deviation of 0.03 mm over all subjects and a range from 0 to 0.92 mm.

Dermal density measured in this study is the median signal intensity distribution of the image. Colours represent the intensity of the signal reflected from the tissue and therefore the structure of the tissue. Statistical analysis of the colour distribution may detect subtle changes that cannot be reliably detected by the visual assessment of the images. The median intensity (or colour) is the intensity/colour at the center of the distribution profile (Longport, 2007). Dermal density may decrease as fluid accumulates since the tissue would appear less dense in the ultrasound image (Lucas et al., 2014). Use of HFUS in the evaluation of tissue injury then is dependent on accurate measures (dermal and hypodermal layer thickness, dermal and hypodermal layer density) that may reflect changes or injury in the dermis or hypodermis layers. However the evaluation for this study focused only on the dermal layer as the hypodermal depth can reach beyond the limits of useful HFUS evaluation. Therefore the median signal intensity distribution was used as our measurement of dermal density.

HFUS visual evaluation

To assure process standardization and consistency between the two HFUS image evaluators, serial comparisons and evaluations of results occurred regularly. To select the best HFUS image for evaluation, all sacral images per patient per day were independently rated by each evaluator based on our previously published evaluation process (Grap et al., 2015). In that process we evaluated 241 HFUS sacral images in three analyses from the first 40 subjects for agreement between the two expert evaluators using criteria for overall image quality. We found agreement was good to substantial and is reported in detail elsewhere (Grap et al., 2015).

When inconsistencies occurred, an agreed upon best image per patient per day was selected and used for evaluation. The best image for one patient in succession in order of patient day was then aligned on the computer monitor to facilitate recognition of changes from day to day in both edema and tissue change. Images were visually evaluated based on change from the previously available image and then gauged on the presence of edema as well as tissue change per patient per day and categorized as: normal; injury with no change; injury and improving; injury and worsening.