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Development and evaluation of a novel smart device-based application for burn assessment and management

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ABSTRACT

We have developed a novel software application that provides a simple and interactive Lund–Browder diagram for automatic calculation of total body surface area (TBSA) burned, fluid formula recommendations, and serial wound photography on a smart device platform. The software was developed for the iPad (Apple, Cupertino, CA) smart device platforms. Ten burns ranging from 5 to 95% TBSA were computer generated on a patient care simulator using Adobe Photoshop CS6 (Adobe, San Jose, CA). Burn clinicians calculated the TBSA first using a paper-based Lund–Browder diagram. Following a one-week ''washout period'', the same clinicians calculated TBSA using the smart device application. Simulated burns were presented in a random fashion and clinicians were timed. Percent TBSA burned calculated by Peregrine vs. the paper-based Lund–Browder were similar (29.53 [25.57] vs. 28.99 [25.01], $p = 0.22$, $n = 7$). On average, Peregrine allowed users to calculate burn size significantly faster than the paper form (58.18 [31.46] vs. 90.22 [60.60] s, $p < 0.001$, $n = 7$). The smart device application also provided 5 megapixel photography capabilities, and acute burn resuscitation fluid calculator. We developed an innovative smart device application that enables accurate and rapid burn size assessment to be cost-effective and widely accessible.

1. Introduction

Accurate burn size assessment is instrumental for initial resuscitation following burn injury. Percent total body surface area (TBSA) burned is calculated to make triage decisions, determine initial fluid resuscitation rates, estimate nutritional formula recommendations and predict prognosis [1]. Inaccurate burn size assessment places patients at risk for inadequate resuscitation among other preventable risks. Numerous methods for calculating TBSA burned have been devised, however the ''Rule of 9s'' and Lund–Browder diagram (LBD) remain the mainstays for burn size assessment despite exhibiting high inter-rater variability [1]. The LBD, introduced in the 1940s, provides a two-dimensional, two-sided figure of an adult human body. Users are instructed to draw in the areas of injury and differentiate between partial- and full-thickness burns. The LBD can be time consuming and susceptible to user

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Abbreviations: TBSA, total body surface area; LBD, Lund Browder diagram; PC, personal computer; SDK, Software Development Kit; ICU, Intensive Care Unit; FDA, Food and Drug Administration; MMA, Mobile Medical Application.

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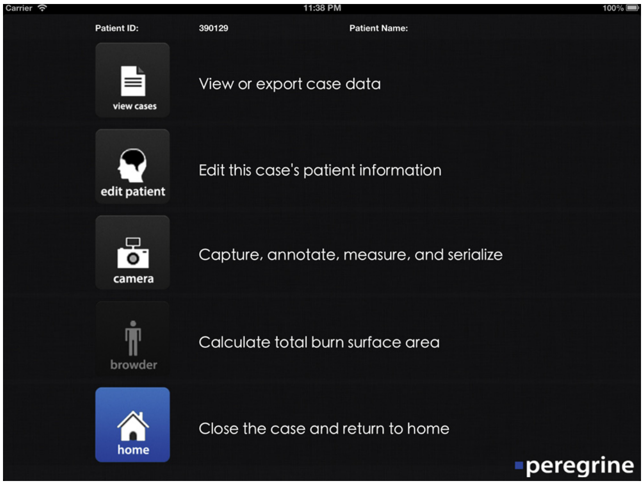

Fig. 1 – Smart device main menu. The figure illustrates the smart device main menu to allow the user to navigate the various features of the application.

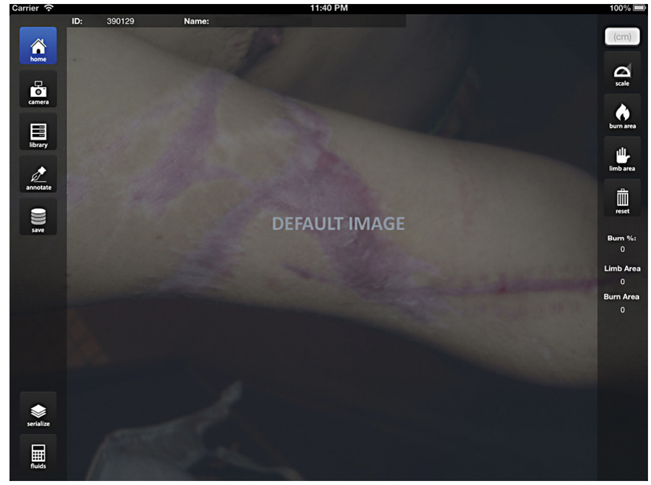

Fig. 2 – Smart device photography mode. The figure illustrates the photography mode to enable the user to photograph burn wounds.

error, especially for untrained users [1]. Alternatively the "Rule of 9s", developed by Pulaski and Tennison in 1947, is a faster but less accurate method of determining percent TBSA [1,2]. New computer-based diagrams, which offer increased accuracy, are available however they are often proprietary, prohibitively expensive, and/or not compatible with electronic health record systems. Moreover, these computer-based programs require either a large desktop personal computer (PC) or a laptop computer, many of which are unable to be sanitized without damage. Smart devices serve as an innovative and portable solution for accurate burn size assessment due to their inherent mobility, ease of use, excellent battery life, electronic security, and ability to be protected by a sealed chemically robust case without impeding functionality [3,4].

Building upon prior work with the innovative smart device application "BurnBookApp" [5], which enabled consistent serialized imaging of burn wounds, our study objective was to develop a new smart device-based application, dubbed "Peregrine" for burn size assessment, wound photography, and fluid rate calculations.

2. Materials and methods

2.1. *Software*

The Apple (Cupertino, California) iOS Software Development Kit (SDK) based on the Objective-C programming language was used to develop Peregrine. The application was programmed for the iPad (Apple, Cupertino, CA) smart-device platform, specifically the iPad 3rd Generation (5MP Camera, 16GB flash storage, 1GB RAM, 802.11 WiFi, iOS 5.0). Peregrine includes an interactive LBD, serial photography system, wound measurement tool, and a Parkland/maintenance fluid calculator. QuatzCore-2D framework and iOS 5 UIKit libraries were heavily used. Specifically, the QuartzCore-2D framework was utilized to calculate the total burn surface area on the LBD as well as provide a number of functions used in the masking and setup of drawing layers for the application. UIKit library functions were used for the general usage of the application, such as being able to save, load, and export patient case data, as well as rendering a number of views to display images and calculations. The photography system utilized a similar semitransparent image overlay to facilitate consistent serial wound images as reported previously [5]. Fluid calculation was based on the Parkland Formula and established methods for determining maintenance rates. The goal was to pursue an innovative approach to burn care by developing a smart device-based application to calculate burn size, photograph wounds, and calculate fluid formula recommendations for resuscitation.

When the application opens, a "BrowderModel" object is instantiated and the LBD TBSA calculation initiates. This object parses information from a plist file (a iOS specific XML file type) that defines various shapes drawn within the front and rear images of the LBD, and instantiates the relationships between a specific limb face and its counterpart on the other side of the body (e.g., the front and back of the arm). The plist has its definitions generated through a calibration process in which the programmer selects corners of various aspects within the LBD and inputs body surface area percentages respective to the paper LBD. The programmer then colors in every area of the digital LBD, and sets the value to an expected 100% burn area value per limb. The calculation of burn area for a limb is established by first masking the image in accordance to the predefined points. Then the image is traversed point by point using the Quartz framework functions to determine the number of burned points vs. unburned points by analyzing the RGB values at each point. This data is also stored in the plist file. In calculating the TBSA on the application's LBD, a process similar to the aforementioned calibration is employed. A cross section of the image containing the limb is cropped and then masked. The image is analyzed pixel by pixel for the number of 'burned' pixels and a percentage is calculated against the value stored in the plist. This TBSA value is then used in calculating the Parkland formula, which is input as [%TBSA burned $\times$ weight (kg) $\times$ 4 mL].