ORIGINAL RESEARCH

3D PED BURN app: A precise and easy-to-use pediatric 3D burn surface area calculation tool

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Abstract

Background and aims: Calculating the precise total burn surface area is crucial when treating burn patients, particularly children. The Lund and Browder chart and Rule of Nines, 2-dimensional diagrams that are widely used, are subject to high interrater variance, and they can severely overestimate the burn area. Previously, the adult 3-dimensional burn area calculation mobile application was developed. Aiming to improve accuracy, a 3-dimensional pediatric burn surface area calculation mobile application ("3D PED BURN") was developed to overcome the limitations of the conventional methods.

Method: Fifteen 3-dimensional pediatric burn surface area models based on detailed anthropometric measurements collected from 85 patients were developed and categorized into four age groups: <1 year; 1–4 years; 5–9 years, and 10–15 years. According to their weight and height, the models in each group were fractionated into large, medium, and small body sizes.

Result: A precise and easy-to-use application was developed based on these data. This application is a promising and more accurate calculation tool for burn surface area in pediatric patients. Its low inter-rater variance makes it reliable for use by various healthcare personnel.

Conclusion: The 3D PED BURN app is a pediatric 3D burn surface area calculation tool that is both accurate and simple to use.

KEYWORDS
body surface area, burns, mobile application

1 | INTRODUCTION

Burns are one of the common major public health problems worldwide, especially among children. According to the World Health Organization, the estimated burn mortality rate worldwide is 180,000 deaths per year, with 20% occurring in pediatric patients. Africa and Southeast Asia have the highest incidence of pediatric burns and maintain a (more than seven times) higher mortality rate than that in high-income countries.[1]

The Lund and Browder chart, the Rule of Palms, and the Wallace Rule of Nines are the most common methods used to determine the total body surface area (TBSA) of both adult and pediatric burn patients. Previous studies have demonstrated that burn surface area is often substantially overestimated using these three conventional methods, particularly the first two.[2–6] Studies have also shown that there is a significant inter-rater variance in burn area estimation using these methods.[7] Since children's body proportions are dynamic in different age groups compared to those of their adult counterparts,[4] it is much more difficult to accurately estimate the TBSA burned in children using these conventional methods.

The most important burn management decisions are based upon a precise assessment of the burn location, TBSA, and depth. Burn area calculation is essential for the estimation of severity and assessment of fluid resuscitation in burn patients. Most of the fluid resuscitation formulas in emergency burn treatments are based on the calculated total surface area burned. Accurate estimation of the TBSA burned is actually the most significant data in each resuscitation formula. Inadequate or excessive resuscitation can lead to increased complications and mortality in burn patients.

To optimize the TBSA burned estimation, computer-aided technologies have emerged. In 2011, the authors applied the 3D scanning technology to develop a "3D Burn Resuscitation" application. It is a free-to-use mobile application for adult burn surface area calculation and has been widely used, especially in Southeast Asia. A validation study has shown that this technology could be useful in improving the efficacy of burn surface area measurement.[8] Aiming to optimize the exactness of burn surface area estimation in children, a "3D PED BURN" application, a 3-dimensional pediatric burn surface area calculation mobile application, was developed to overcome the limitations of these conventional methods.

2 | MATERIALS AND METHODS

2.1 | Design of the system

The study was approved by the institutional review board of our university. Data from 85 normal children who were enrolled in this project were collected. They were categorized into four age groups based on standard growth curve[9]: less than 1 year; 1–4 years; 5–9 years and 10–15 years (Table 1).[10,11] Because patients in the 10–15 years age group had already developed secondary sexual characteristics, they were split into another two groups: boys and girls. According to their weight and height, the participants in each age group were classified as large, medium, or small. Standardized demographic data of all participants were collected.

Twenty-five anthropometric parameters of each participant, such as head circumference, neck circumference, shoulder span, and arm span, were measured and recorded. Based on the collected data, 15 three-dimensional models of different age groups, fractionated by body height and weight, were created (Figure 1).

TABLE 1 Summary of the distribution of the research participants

Participant group	Variable	Mean ± SD
Group 1 (Aged <1 year, 15 patients)	Age and range	5.62 ± 2.96 months
	Weight and range	6.80 ± 0.96 kg
	Height and range	67.9 ± 6.61 cm
Group 2 (Aged 1–4 years old, 15 patients)	Age and range	2.16 ± 0.98 years
	Weight and range	14.30 ± 6.44 kg
	Height and range	85.76 ± 9.13 cm
Group 3 (Aged 5–9 years old, 15 patients)	Age and range	8.17 ± 1.24 years
	Weight and range	34.16 ± 11.04 kg
	Height and range	129.23 ± 11.66 cm
Group 4 (Males, aged 10–15 years old, 15 patients)	Age and range	12.22 ± 1.21 years
	Weight and range	48 ± 26.76 kg
	Height and range	144.2 ± 20.82 cm
Group 5 (Females, aged 10–15 years old, 15 patients)	Age and range	11.82 ± 1.20 years
	Weight and range	45.77 ± 30.16 kg
	Height and range	141.64 ± 12.77 cm

FIGURE 1 3D burn model from patient's data
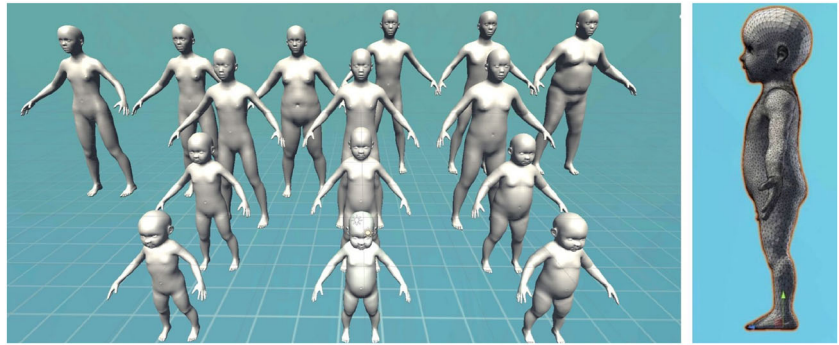
FIGURE 2 Completing data on baseline characteristics

The study was approved by the institutional review board of the Faculty of Medicine, Chulalongkorn University, Bangkok, Thailand, IRB No. 622/61. The principles outlined in the Declaration of Helsinki were followed. Informed consent was obtained from the patients.

3 | RESULTS

A "3D PED BURN" software application (app) for smartphones based on detailed anthropometric measurements collected from 85 patients was developed for Apple's App Store and Google's Play Store. This application is for calculating an estimated TBSA in percentage and square centimeters, total fluid replacement, and total calorie requirement. Being able to paint on the screen of a smartphone allows each user to draw the injured surfaces directly on a body diagram. This 3D model could be magnified, rotated, and zoomed in for specific and detailed painting. These more advanced techniques potentially allow for a more accurate burned area calculation.[12]

After completing all required patient's information, a proper 3D model is selected (Figures 2 and 3).[13,14] The "paint mode" is then selected and the burn depth chosen. The partial-thickness burn depth is represented in blue while the full-thickness is represented in red. Painting could be done with different sizes of pen or brush. Wrongly placed color could be easily erased and repainted. The 360-degree

rotation mode enables the user to freely rotate the selected 3D model around *x*- and *y*-axes. Zoom in and out can be achieved by a pinch-to-zoom gesture on the screen. These gestures allow for a more detailed painting and provide access to difficult-to-approach areas (such as the palm, sole, inner arm and thigh, flank area, and vertex of the head) that could not be accessed in the 2-dimensional charts; this eventually results in more precise calculation of the burned area.

Subsequently, the pixels from the screen converted to TBSA in square centimeter by the application. Overlapping painting would be detected and corrected to prevent over-calculation. The total burned area would finally be displayed n percentage and square centimeter. These data are used to calculate resuscitation fluid and calories requirement.

3.1 | Verification

After obtaining informed consent, three pediatric burn patients were enrolled for the application verification. A flexible, sterile, non-adhesive, transparent plastic sheet was patched on each burn, wound, and the burned area was precisely marked. These marked sheets were scanned to create an image file and the area (in centimetres) was measured using the ImageJ™.[15] The whole-body
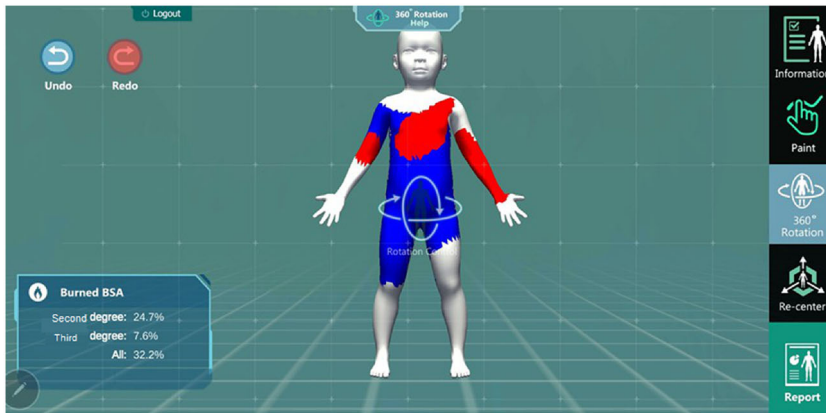
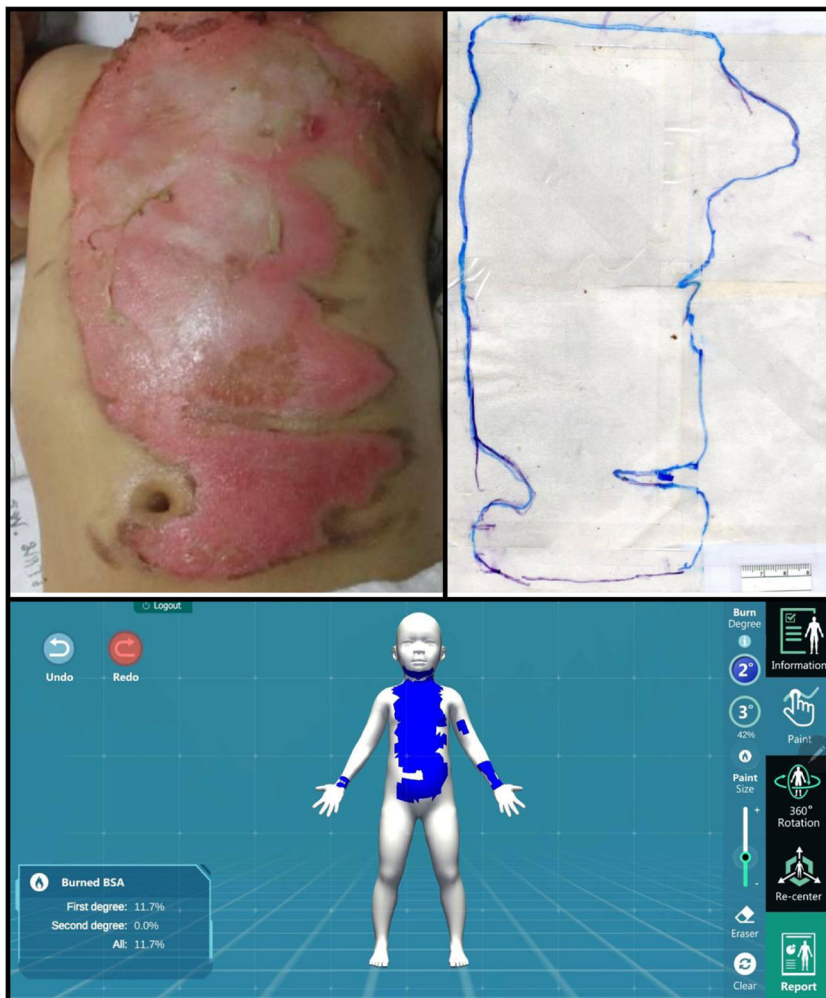**FIGURE 3** An example of burned areas painted on the model

**FIGURE 4** Application verification in burn patients

surface area of both patients was calculated using the Mostellar formula. For the total burned surface area in percentage (%TBSA), the test areas (in cm) were divided by the whole-body surface areas (in cm). The burn injuries were 11.43%, 18.32%, and 20.71% TBSA, respectively (Figure 4).

Sixteen healthcare personnel took part in this application verification, including medical students, nurses, general practitioners, and surgical residents. A 3D pediatric burn application and the three conventional methods of burn estimation: Rule of Nines, Lund and Browder chart, and Rule of Palms were used to estimate the burned area. None of the participants had ever encountered the 3D pediatric burn application. The application was downloaded and installed on each participant's smart-phone, and a brief power-point-based tutorial was carried out on the day of the evaluation.

TABLE 2 3D Burn Ped application versus conventional methods

	Patient no. 1, 11.43%		Patient no. 2, 18.32%		Patient no. 3, 20.71%	
Rule of Palms (%)	14.0 ± 1.3	+2.57	19.4 ± 1.6	+1.17	20.0 ± 1.7	−0.71
Rule of Nines (%)	14.0 ± 1.1	+2.57	20.2 ± 2.4	+1.88	24.0 ± 2.0	+3.29
Lund and Browder chart (%)	8.6 ± 0.74	−2.83	16.6 ± 1.2	−1.72	18.0 ± 2.3	−2.71
3D Burn app (%)	11.0 ± 0.83	−0.43	18.5 ± 2.55	+0.18	21.0 ± 2.94	+0.29

FIGURE 5 The summary page of burn area, calories, and guidelines for resuscitation
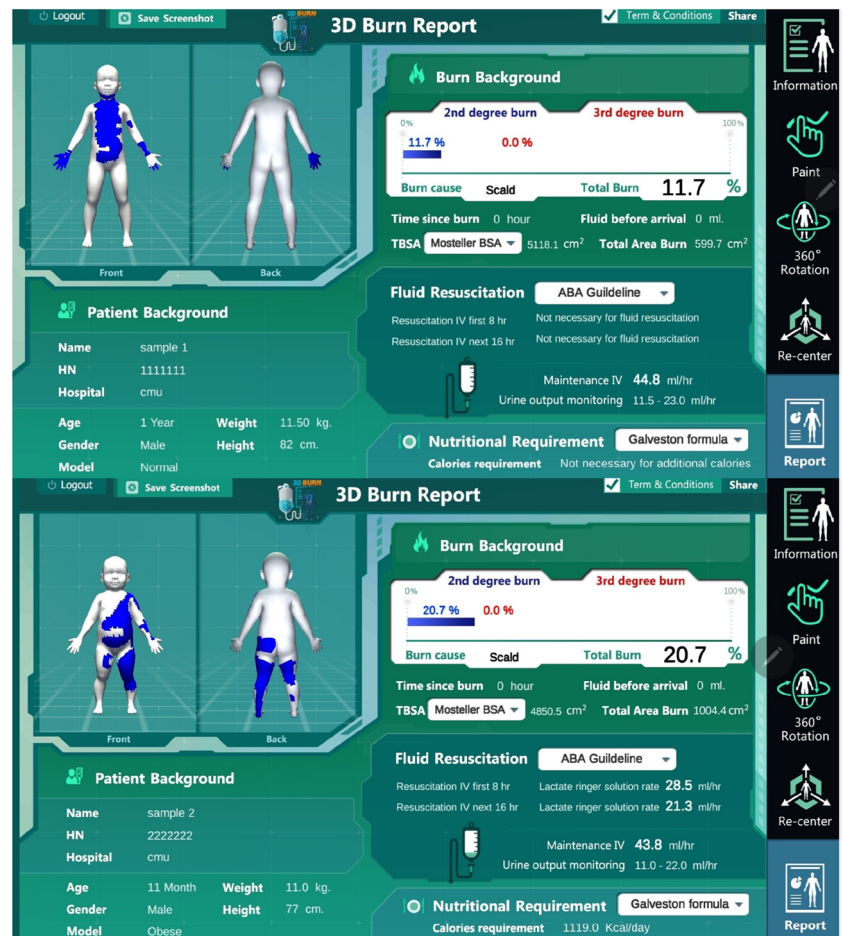
The data collected from the 16 participants that had assessed all verification scenarios demonstrated that the 3D pediatric burn application was more accurate in estimating the burned area than the three other conventional methods. A low interrater variation was also seen among participants; greater in the Rule of Palms and Nines, lower in the Lund and Browder chart, and the lowest inter-rater variance in the 3D Burn app (Table 2).

4 | DISCUSSION

The most important burn management decisions, especially in children, are based on a precise assessment of the burn location, TBSA, and depth.[1,5] Many computer-aided technologies have emerged aiming to overcome the limitations of the conventional methods and improve the accuracy of burn surface area estimation. Current mobile phone technology allows substantially better rendering than the computer workstations created over a decade ago.[12,16,17] Fluid resuscitation is directly related to the burn size by most formulaic estimates. Overestimation of burn surface area and a significant interobserver variation among various healthcare personnel are the main problems of the 2D conventional methods.[7] Studies have shown that overestimation is observed more in patients with small, scattered burn areas than in those with a single, large burn area.[17] Over-resuscitation leads to serious complications including burn wound edema.

A free-to-use 3D pediatric burn surface area calculation mobile application was developed to overcome these limitations. The availability of mobile smartphones among physicians and allied healthcare personnel enables the easy use of this software

application. The advantages of using a mobile 3D computer-aided calculation over the 2D estimation charts are obvious. In early fluid resuscitation, this software application may lower the risk of over or underestimation of burn wounds by less experienced personnel. A 3D diagram, patient's information, fluid resuscitation, and caloric requirement guidelines can be generated and stored in the database of each patient. Therefore, this makes it possible to manage burn databases on an institutional or national scale (Figure 5).[18]

The other smartphone apps for calculating TBSA applications were designed for general burn patients, but the pediatric burn surface area is more complicated and sensitive because of the proportion of surface area and age that changes every year from childhood to maturity. Therefore, a precise and easy-to-use 3D pediatric burn surface area calculation mobile application was developed and is a promising and accurate calculation tool for burn surface area estimation in pediatric patients and it is free downloadable "3D ped burn resuscitation" from Google Play Store for Android devices and from the App Store for iOS devices. Its low interobserver variability makes it more reliable for use by different healthcare personnel. The fact that we only tested mild to moderate burns (<20% TBSA) is a limitation of our study. Due to a lack of patients in the COVID-19 era, a high severity burn (>20% TBSA) was not included in this study, but we intend to publish another article to validate this application in different burn severity and across other applications. However, further studies with larger populations in a controlled setting are required.

AUTHOR CONTRIBUTIONS

Jiraroch Meevassana: Conceptualization; data curation; methodology; project administration; validation; visualization; writing—original draft; writing—review and editing. **Piyamit Sumonsriwarankun**: Conceptualization; data curation; investigation; methodology; visualization; writing—review and editing. **Poonpissamai Suwajo**: Formal analysis; validation; writing—review and editing. **Kasama Nilprapha**: Data curation; formal analysis; software; writing—review and editing. **Pasu Promniyom**: formal analysis; investigation; visualization; writing—review and editing. **Seree Iamphongsai**: Funding acquisition; validation; writing—review and editing. **Pornthep Pungrasmi**: Funding acquisition; project administration; visualization; writing—review and editing. **Sirachai Jindarak**: Formal analysis; funding acquisition; resources; writing—review and editing. **Tanasit Kangkorn**: Formal analysis; investigation; visualization; writing—review and editing. **Apichai Angspatt**: Data curation; methodology; resources; software; supervision; validation; writing—original draft; writing—review and editing.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The datasets that support the study's findings are included in the supplementary file.

TRANSPARENCY STATEMENT

All authors have read and approved the final version of the manuscript. Prof. Apichai Angspatt had full access to all of the data in this study and takes complete responsibility for the integrity of the data and the accuracy of the data analysis. Prof. Apichai Angspatt affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

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