Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.JournalofSurgicalResearch.com

Association for Academic Surgery

Comparison of the Lund and Browder table to computed tomography scan three-dimensional surface area measurement for a pediatric cohort

R. Wolfgang Rumpf, PhD,[a] *William CL. Stewart, PhD,*[a] *Stephen K. Martinez, MS,*[b] *Chandra Y. Gerrard, BS,*[b] *Natalie L. Adolphi, PhD,*[b] *Rajan Thakkar, MD,*[c] *Alan Coleman, MD,*[c] *Adrian Rajab,*[a] *William C. Ray, MS, PhD,*[a,*] *and Renata Fabia, MD*[c]

[a] *The Battelle Center for Mathematical Medicine at The Research Institute at Nationwide Children's Hospital, Columbus, Ohio*

[b] *Radiology-Pathology Center for Forensic Imaging, University of New Mexico Health Sciences Center, Albuquerque, New Mexico*

[c] *Burn Center, Nationwide Children's Hospital, Department of Pediatric Surgery, Columbus, Ohio*

ARTICLE INFO

Article history:
Received 1 February 2017
Received in revised form
14 July 2017
Accepted 10 August 2017
Available online xxx

Keywords:
Burn estimation
Lund and Browder
Total body surface area
Pediatric

ABSTRACT

Background: Treating burns effectively requires accurately assessing the percentage of the total body surface area (%TBSA) affected by burns. Current methods for estimating %TBSA, such as Lund and Browder (L&B) tables, rely on historic body statistics. An increasingly obese population has been blamed for increasing errors in %TBSA estimates. However, this assumption has not been experimentally validated. We hypothesized that errors in %TBSA estimates using L&B were due to differences in the physical proportions of today's children compared with children in the early 1940s when the chart was developed and that these differences would appear as body mass index (BMI)-associated systematic errors in the L&B values *versus* actual body surface areas.
Materials and methods: We measured the TBSA of human pediatric cadavers using computed tomography scans. Subjects ranged from 9 mo to 15 y in age. We chose outliers of the BMI distribution (from the 31st percentile at the low through the 99th percentile at the high). We examined surface area proportions corresponding to L&B regions.
Results: Measured regional proportions based on computed tomography scans were in reasonable agreement with L&B, even with subjects in the tails of the BMI range. The largest deviation was 3.4%, significantly less than the error seen in real-world %TBSA estimates.
Conclusions: While today's population is more obese than those studied by L&B, their body region proportions scale surprisingly well. The primary error in %TBSA estimation is not due to changing physical proportions of today's children and may instead lie in the application of the L&B table.

* *Corresponding author*. The Research Institute at Nationwide Children's Hospital, The Battelle Center for Mathematical Medicine, Research Building 3, 575 Children's Crossroad WB5141, Columbus, OH 43215. Tel.: +1 614 355-5645; fax: +1 614 355-5898.
E-mail address: Ray.29@osu.edu (W.C. Ray).

http://dx.doi.org/10.1016/j.jss.2017.08.019

Introduction

Effective burn treatment depends on accurate assessment of the severity of the injury and the proportion of total body surface area (TBSA) affected. Inaccurate assessment of the percentage of the TBSA (%TBSA) affected by burns compromises immediate treatment choices and long-term outcomes. Unfortunately, even burn experts admit that initial burn assessments can contain frequent and significant errors related to the use or application of current modalities.[1] Previous studies have shown that the average error in using Lund and Browder (L&B) charts to assess pediatric burns of varying ages averaged between 12.4% and 17.8% of TBSA with some cases as high as 154%.[2]

Accurate initial %TBSA estimation is critical. Fluid resuscitation volumes are typically calculated based on the initial % TBSA value, and errors can lead to serious complications. Although it is commonly acknowledged that initial resuscitation with an insufficient volume can lead to complications, overresuscitation can also lead to serious complications up to and including mortality.[3,4] Furthermore, recent studies have shown that overresuscitation can lead to a greater, rather than lesser, requirement for fluids later in treatment.[5] Therefore, fluid adjustments after an initial phase of improper fluid resuscitation (caused by an error in calculation) while feasible is a less ideal course than initial accurate resuscitation.

Current modalities for determining %TBSA rely on tables of historic average body statistics. One of the most common approaches of %TBSA estimation uses L&B tables.[6] Created in 1944, the L&B tables contain schematics of the body for different age ranges. These schematics are then divided into a set of zones with corresponding %TBSA percentages. The caregiver must add the percentages from each zone that the burn involves to determine the overall %TBSA. The hand is commonly considered to be 1% of the TBSA and thus facilitates estimation of smaller or irregular areas.

As today's population tends to be increasingly obese compared with the population in 1944,[7-10] it is reasonable to assume that errors in %TBSA estimates stem from the failure of "one-size-fits-all" tables to account for modern body morphometrics. However, errors can also arise from "user error" in the application of the tables, independent of the quantitative accuracy of the tables themselves.

To test the hypothesis that errors in %TBSA estimates stem from the divergence of L&B table values from population reality at the extremes of body mass index (BMI), we compared quantitatively acquired and measured %TBSAs using full-body computed tomography (CT) scans, with L&B-predicted %TBSAs for the same regions, across a morphometrically diverse group of recently deceased cadaveric pediatric subjects. Because full-body CT data are a scarce resource and because we were solely interested in estimating how large an impact BMI could have on %TBSA estimates, we focused on subjects that were extreme BMI outliers, in both the upper and lower tails of the BMI distribution. We anticipated that these individuals would display errors in their zonal %TBSA measurements that were comparable to, or larger than, errors commonly observed in % TBSA estimates with burn victims.

The results of these comparisons were surprising and suggested that large errors observed in the actual application of the L&B tables in real subjects are not primarily due to errors in the L&B tables. To preliminarily examine the alternative hypothesis that large errors in the application of L&B may be user errors rather than systematic errors in the tables, we examined the results of previous burn unit training exercises conducted at Nationwide Children's Hospital (NCH), in which clinicians were given refresher training in the use of L&B tables for estimating burn %TBSA values and then tested on their accuracy with mock victims.

The result of this analysis demonstrates that the distribution of user errors when clinicians attempt to apply the L&B tables to an individual (mock) victim is strikingly similar to the distribution of errors seen across burn victims.

Combined, our two results call into question the utility of attempts to contemporize the L&B tables and instead suggest that efforts should be directed toward improving user training, or improving the usability of the tables, rather than the data within them.

Methods and materials

CT scans

Full-body CT scans of 13 complete pediatric cadavers were obtained from the University of New Mexico (UNM). They were selected from cases with no disfigurements from the New Mexico Office of the Medical Investigator, which is funded to acquire and archive CT scans of cadavers through a "Utility of Post-Mortem CT" grant from the National Institute of Justice. The scans included individuals aged between 9 mo and 15 y. Age-matched pairs were chosen when available, attempting to include each extreme of the BMI range. CT scan data were assembled and segmented in OsiriX (Pixmeo SARL, Bernex, Switzerland)[11] to construct three-dimensional surface models of the skin isosurface (Fig. 1A), which were subsequently exported to MeshLab (Visual Computing Lab, CNR-ISTI, Piza, Italy)[12] for editing to remove nonbody artifacts (Fig. 1B). CT scans of two of the subjects were subsequently rejected from the study because of difficulties in producing an adequately clean surface model. The morphometric characteristics of the final 11 cadavers are shown in Table 1.

TBSA and fractional surface area calculations

To gain insight into user-to-user variations in the application of the L&B table (such as between different user's choices regarding the boundaries of anatomic regions like the palm), surface area calculations were carried out independently by two groups—one at NCH in Columbus, Ohio, and one at the UNM School of Medicine. Both groups calculated the (overall) TBSA for each of the 11 complete cadaver skin isosurface models using the surface area calculation function in MeshLab.

Each group then divided the cadaver models, again using MeshLab, into discrete regions based on an L&B diagram (Fig. 2). Some canonical L&B regions were combined into single region