



Evaluating the “cushion effect” among children in frontal motor vehicle crashes[☆]

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ARTICLE INFO

Article history:

Received 17 January 2018

Accepted 1 February 2018

Key words:

Analytic morphomics

Trauma

Abdominal injury

Pediatric surgery

ABSTRACT

Background: The “Cushion Effect,” the phenomenon in which obesity protects against abdominal injury in adults in motor vehicle accidents, has not been evaluated among pediatric patients. This work evaluates the association between subcutaneous fat cross-sectional area, quantified using analytic morphomic techniques and abdominal injury.

Methods: This retrospective study includes 119 patients aged 1 to 18 years involved in frontal impact motor vehicle accidents (2003–2015) with computed tomography scans. Subcutaneous fat cross-sectional area was measured and converted to age- and gender-adjusted percentiles from population-based normative data. Multivariable analysis determined the risk of the primary outcome, Maximum Abbreviated Injury Scale (MAIS) 2+ abdominal injury, after adjusting for age, weight, seatbelt status, and impact rating.

Results: MAIS 2+ abdominal injuries occurred in 20 (16.8%) of the patients. Subcutaneous fat area percentile was not significantly associated with MAIS 2+ abdominal injury on multivariable logistic regression (adjusted Odds Ratio, 0.86; 95% CI, 0.72–1.03; $p = 0.10$).

Discussion: The “cushion effect” was not apparent among pediatric frontal motor vehicle crash victims in this study. Future work is needed to investigate other analytic morphomic measures. By understanding how body composition relates to injury patterns, there is a unique opportunity to improve vehicle safety design.

Level of Evidence: Prognosis Study, Level III.

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The “Cushion Effect” is the phenomenon in which obesity serves as a protective factor against abdominal injuries and a risk factor for lower extremity injuries following frontal motor vehicle crashes (MVC) among adults [1–3]. It is hypothesized that central adiposity absorbs energy from the impact of airbag deployment, serving as a “cushion.” Conversely, the extremities are not motion-limited by airbag deployment, thus extremities with greater mass generate greater momentum; this is hypothesized to result in an increased incidence of lower extremity injuries among obese adults [2]. From this observed phenomenon, the field of analytic morphomics emerged to describe the motor vehicle occupant beyond traditional demographic factors (i.e. age, gender, height, and BMI). Analytic morphomic techniques objectively quantify the

morphological features of a biological system in three-dimensional space using standard cross-sectional images [4–6]. Among adults in frontal MVCs, morphomic measurements were more highly associated with abdominal injury than traditional demographic factors, and were most informative when morphomic, demographic, and vehicle factors were combined [7].

Motor vehicle accidents are the leading cause of death among U.S. children ages 5–24 years, representing a major national public health problem [8]. Pediatric crash victims often suffer more frequent and severe multisystem organ injuries as compared to their adult counterparts [9–11]. Historically, physical surrogates of children for crash test modeling have relied on isolated anthropometric measures or single subjects [12–15], with recent efforts seeking to create more diverse and realistic models [16]. Analytic morphomic techniques have been used to develop a morphometric model of intraabdominal solid organ growth relative to the ribcage [17], but no studies to date have evaluated the cushion effect among pediatric patients.

To examine cushion effect in pediatric patients, we studied a population of children and adolescents in frontal MVCs who underwent computed tomography (CT) cross-sectional imaging at the University of

Abbreviations: MAIS, maximum abbreviated injury scale; CT, computed tomography; PRAMP™, Pediatric Reference Analytic Morphomics Population; AIS, Abbreviated Injury Scale; aOR, adjusted odds ratio; CI, confidence interval; MVC, Motor Vehicle Crash.

[☆] Funding: PZ wants to acknowledge the grant support from NIH K01 DK106296.

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Michigan. We hypothesized that subcutaneous abdominal adiposity would have a significant negative association with abdominal injuries and positive association with extremity injuries based on the Maximum Abbreviated Injury Scale (MAIS), even after correction for patient demographics and vehicle factors.

1. Methods

This study was approved by the University of Michigan Institutional Review Board (HUM00041441).

1.1. Patient population

The study population included 119 patients, ages 1 to 18 years, admitted to the University of Michigan following frontal impact MVC from 2003 to 2015. Retrospective data collection was performed to obtain seatbelt status, impact rating, and injury severity. Crash impact rating was obtained from crash reports (UD-10) and rated as moderate or severe. Patients were excluded for missing data, fatality (owing to lack of autopsy data), pregnancy and age less than one year.

1.2. Morphometric analysis

Analytic morphomic measures were performed on anonymized computed tomography (CT) scans using custom semiautomatic image-processing algorithms written in MATLAB 2013a (MATLAB 2013a, Mathworks Inc., Natick, MA) as previously described [7]. Subcutaneous fat area was measured as the cross-sectional area (in mm²) at the L4 vertebral level between the skin and fascia meeting fat density thresholds of CT intensity between -205 and -51 HU (Fig. 1). Each measure was converted to the corresponding age- and gender-adjusted percentile using PRAMP™ growth curves, which are age- and gender-based percentile curves derived from a cohort of 2500 representative US children [18] (Fig. 2).

1.3. Injury severity

Injury severity was evaluated by the Abbreviated Injury Scale (AIS), which represents the assessment of life-threatening injuries at the time of first medical evaluation. It ranges from 0 to 6 and is divided into an MAIS for each body region. MAIS for each body region was previously determined using hospital charts and radiologic review of injuries. The primary outcome was moderate to serious abdominal injury as defined by MAIS greater than or equal to 2. Our secondary outcome was moderate to serious extremity injury (MAIS 2+).

1.4. Statistical analysis

Statistical analyses were performed using R (<http://www.r-project.org>, version 3.2.1) [19]. Univariate descriptive characteristics were used to examine patient characteristics. Bivariate analysis was performed using Wilcoxon–Mann–Whitney test to compare subcutaneous fat cross-sectional area percentile among patients with and without MAIS 2+ abdominal injury and, secondarily, extremity injury. A multivariable logistic regression model was estimated to examine the relationship between MAIS 2+ injury and subcutaneous fat area percentile, controlling for patient and crash characteristics.

2. Results

We identified 119 eligible pediatric patients admitted to the University of Michigan from 2003 to 2015 after frontal MVC. MAIS 2+ abdominal injury was identified in 20 patients (16.8%) and MAIS 2+ extremity injury in 37 patients (31.1%). Descriptive characteristics are shown in Table 1. There were no significant differences between groups. Subcutaneous fat area was measured and converted to age- and gender-adjusted percentile, with 48.3% of patients below the 50th percentile and 51.6% above the 50th percentile.

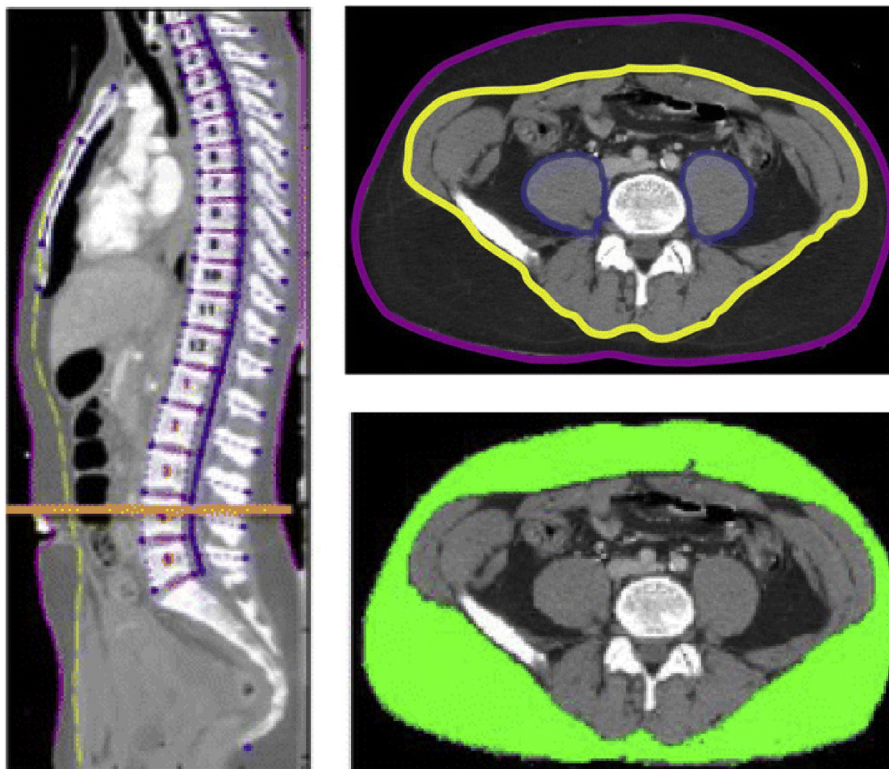


Fig. 1. Analytic morphomics. First, the spinal column is semiautomatically defined (left) to define the global coordinate system. The skin and fascial envelope are defined circumferentially (top right) and the cross-sectional area between the skin and fascia meeting defined thresholds is calculated (bottom right).

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