The Role of Obesity on Cast Index and Secondary Intervention in Pediatric Forearm Fractures

Kathy M McGurk1*, Ted Samaddar1, William R Barfield1, Robert F Murphy1

1Department of Orthopaedics & Physical Medicine, Medical University of South Carolina, USA

*Corresponding Author: Kathy McGurk, Department of Orthopaedics & Physical Medicine, Medical University of South Carolina, USA; Email: mcgurk@musc.edu

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Abstract

Background: Pediatric forearm fractures are common, and the majority are treated with closed reduction and immobilization. Additionally, the incidence of pediatric obesity is rising. Cast index is a useful metric to assess the quality of a cast mold. This study aims to assess the effect of obesity in obtaining an adequate cast index as a predictor for fracture redisplacement and risk for subsequent intervention after a reduction.

Methods: A retrospective chart review was conducted over a six-year time period on children with a displaced/unstable forearm fracture that underwent reduction and molded long arm casting with >4 weeks follow-up. The cast index was measured on immediate post-manipulation radiographs. Children were divided into three groups according to body mass index (BMI) percentile for age: Underweight (<5th); Normal BMI (5th-85th); Overweight/obese (≥ 85th). Clinical notes and radiographs were reviewed for loss of reduction and secondary intervention.

Results: 84 patients (70% male) qualified for inclusion. Mean age was 7.4 years (Range 3-14 years). Fracture redisplacement and secondary intervention occurred in 8 patients (9.5%). Patient BMI distribution was 5% in the Underweight, 71% in the Normal BMI and 24% in the Overweight/obese groups. The mean cast index in the 8 patients who required a second procedure was significantly higher than those who did not (1.00±0.06 vs 0.83±0.07, P<.001). The mean cast index among the underweight, normal BMI and overweight/obese groups was not statistically different. Obesity was not an independent risk factor for secondary...
intervention. Regression analysis did not correlate increasing cast index with BMI percentile for age.

Conclusion: Cast index continues to be a reliable metric for evaluating the quality of the cast mold and loss of subsequent reduction. In this cohort, it does not appear that BMI plays a significant role in hindering the ability to place a well-molded cast.

Level of Evidence: Prognostic level IV

Keywords

Pediatric; Forearm Fracture, Obesity, Cast Index

Introduction

Recent data highlights that pediatric obesity is on the rise, with reports from the Center for Disease Control and Prevention (CDC) stating that obesity has more than tripled since the 1970s [1]. Now, nearly 30% of children age two to nineteen are considered either overweight or obese [2,3]. Furthermore, a child’s overall fracture risk and severity are directly correlated to increased Body Mass Index (BMI) [4-6]. As forearm fractures are one of the most common injuries in the pediatric population, understanding the impact of obesity on management of forearm fractures is imperative [7-10].

The management of pediatric forearm fractures depends on the age of the patient and magnitude of deformity. Treatment options include non-operative management with closed reduction and immobilization versus operative treatment with stabilization. Most closed pediatric forearm fractures can be treated with closed reduction and placement of a well-molded cast or splint. Operative treatment should be reserved for patients in whom satisfactory alignment cannot be achieved or maintained through closed means [7,10-13].

Loss of reduction is the most common complication following closed treatment of pediatric forearm fractures. Poor casting technique is a frequently cited reason for loss of reduction and subsequent occurrence of further intervention [7,10,14-16]. Principles of forearm casting include interosseous molding, supracondylar molding, appropriate padding, evenly distributed cast material, straight ulnar border, and three-point molding [10]. Furthermore, the Cast Index (CI) is a useful metric to objectively assess cast quality. The cast index is calculated from plain radiographs as the sagittal cast width divided by the coronal cast width at the fracture site, as measured from the inner surface of the cast [15,17,18]. An acceptable CI has previously been described as a ratio <0.70, but has also been reported as high as <0.84 [7,17-20].

The concern regarding a rising population of overweight and obese children is the consequent thicker soft tissue envelope surrounding the osseous structures of the forearm and therefore,
the theoretical difficulty with obtaining an appropriate mold, as evidenced by the CI. This study aims to assess:

1. The ability of CI to predict subsequent intervention after closed reduction and casting
2. The effect of obesity on obtaining an adequate CI
3. If obesity is an independent risk factor for failed initial closed reduction and casting

**Materials and Methods**

After approval by our Institutional Review Board, we retrospectively reviewed the radiographs of all angulated and/or displaced pediatric forearm fractures that underwent closed reduction with long arm fiberglass cast application at a tertiary care pediatric academic medical center over a 6-year period (2011-2016). Skeletally immature patients less than 16 years of age qualified for inclusion. Exclusion criteria included pathologic or open fractures, incomplete data or radiographs, and forearm fractures not treated with molded above elbow cast after manipulation.

All initial injury radiographs were assessed for angulation and displacement. All reductions were performed in the pediatric emergency department under sedation utilizing portable fluoroscopy. Following placement of a long arm bi-valved cast with the elbow in approximately 85-90° of flexion, post-reduction films were obtained. The reduction was deemed satisfactory when there was no evidence of displacement (i.e. <5 mm) in both planes and angulation was corrected to acceptable parameters. All patients followed up in clinic 1 week after manipulation and then every 1-2 weeks for a minimum of 4 weeks.

Charts were retrospectively reviewed for demographic data consisting of age, gender, height, weight, bones involved, location and outcome data including loss of reduction and whether secondary intervention was undertaken. For purposes of this study, the cast index was measured on the immediate post-reduction bi-valved cast films. CI was measured as ratio a/b in which ‘a’ is the internal cast width in the lateral view and ‘b’ is the internal cast width in the AP view at the fracture site [12]. We also stratified the patients into groups based on their BMI percentile for age, as follows: Underweight (<5th %ile); Normal BMI (5th-85th %ile); Overweight/obese (≥85th %ile). The decision to proceed with secondary intervention was determined based on individual surgeon preference and interpretation of well-established guidelines [12,13,17,29].

Interobserver variation was determined by having two authors independently calculate the CI in our data set. Intra-observer variability was determined by having one of the author’s repeat CI calculations of the data set 4 weeks after initial measurement. We used the Pearson correlation coefficient to determine correlation. The mean CI in the group requiring secondary procedures and the weight stratified groups were recorded and compared. The primary variable
of interest was the BMI percentile for age and the main outcomes were CI and secondary intervention due to redisplacement. Paired, two-tailed student's t-tests were performed to analyze statistical differences between means in the groups of continuous data; p<0.05 was deemed significant. For categorical data, the Chi-square test was used. Statistical analysis was performed using IBM SPSS® software v. 24 (Chicago, Illinois).

**Results**

Over our study period, we identified 84 patients who met inclusion criteria with displaced and/or angulated forearm fractures that underwent closed reduction and long arm casting. Mean age was 7.4 years (range 3-14 years), and 59 (70%) were male. After stratifying the children into weight groups based on BMI percentile for age, 4 were in the underweight category (5%), 60 were in the normal weight category (71%), and 20 were in the overweight/obese category (24%). The mean cast index for the study group was 0.86±0.01 (range 0.63-1.18). The mean cast index among the underweight, normal weight, and overweight/obese groups were not found to be statistically different (Table 1). Additionally, regression analysis did not show that increasing BMI percentile for age was an independent risk factor for increased CI.

Occurrence of secondary intervention occurred in a total of 8 patients (9.5%): 6/59 males and 2/25 females. The mean cast index in these 8 patients who required a second procedure was 1.00±0.06, which was significantly higher than the mean cast index in the children who did not have a secondary procedure (0.83±0.07, p <0.001, Table 2). Of these 8 patients requiring secondary intervention, 3 underwent repeat closed reduction in the operating room, 3 underwent elastic nailing, and 2 underwent open reduction and internal fixation (Table 3). A representative example of a patient who a poor cast index that ultimately re-displaced and required flexible nailing is shown in Fig. 1. All secondary interventions were performed between 1 and 3 weeks of initial injury.

Mean initial angulation for all fractures was 25°. The mean initial angulation for patients requiring a secondary intervention was 18.78° as compared to 25.71° in group that did not require re-intervention, which was not statistically significant (p >0.05, Table 2).

Pearson's correlation coefficient was used to compare repeat measurements to original measurements. Analysis of both inter and intra-observer measurements showed high agreement and that CI could be reproduced reliably. There was good intra-observer (r=0.98) and inter-observer (r=0.93) agreement for the CI in the study group and the observed differences were less than two standard deviations in magnitude.
Table 1: Cast index by BMI percentile for age.

<table>
<thead>
<tr>
<th>Factor</th>
<th>No 2nd Intervention Group</th>
<th>2nd Intervention Group</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Age (years)</td>
<td>7.21</td>
<td>9.38</td>
<td>NS</td>
</tr>
<tr>
<td>Gender</td>
<td>53M : 23F</td>
<td>6M : 2F</td>
<td>NS</td>
</tr>
<tr>
<td>Initial Mean Angulation (°)</td>
<td>25.71</td>
<td>18.78</td>
<td>NS</td>
</tr>
<tr>
<td>Mean Redisplacement (°)</td>
<td>4.43</td>
<td>15.76</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Mean CI</td>
<td>0.83</td>
<td>1</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

CI: Cast Index; NS: Not Significant

Table 2: Patients with no secondary intervention vs. with secondary intervention.

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Gender</th>
<th>Location/Type</th>
<th>BMI %ile</th>
<th>Cast Index</th>
<th>2nd Intervention*</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>M</td>
<td>MBB</td>
<td>15.9</td>
<td>0.96</td>
<td>EN</td>
</tr>
<tr>
<td>14</td>
<td>M</td>
<td>MBB</td>
<td>16</td>
<td>1.11</td>
<td>ORIF</td>
</tr>
<tr>
<td>9</td>
<td>M</td>
<td>DBB</td>
<td>19.4</td>
<td>0.98</td>
<td>CR</td>
</tr>
<tr>
<td>9</td>
<td>M</td>
<td>PBB</td>
<td>50.3</td>
<td>0.97</td>
<td>CR</td>
</tr>
<tr>
<td>7</td>
<td>M</td>
<td>MBB</td>
<td>56.5</td>
<td>0.97</td>
<td>CR</td>
</tr>
<tr>
<td>4</td>
<td>F</td>
<td>PBB</td>
<td>56.6</td>
<td>0.99</td>
<td>EN</td>
</tr>
<tr>
<td>6</td>
<td>F</td>
<td>PBB</td>
<td>75</td>
<td>0.93</td>
<td>EN</td>
</tr>
<tr>
<td>13</td>
<td>M</td>
<td>MBB</td>
<td>91.8</td>
<td>1.09</td>
<td>ORIF</td>
</tr>
</tbody>
</table>

MMB: Midshaft Both Bone; DBB: Distal Both Bone; PBB: Proximal Both Bone; En: Elastic Nails; ORIF: Open Reduction Internal Fixation; CR: Closed Reduction in operation room

*All secondary intervention was within 1-3 weeks of initial injury

Table 3: Summary of patients with secondary intervention.
Figure 1: Case of a 6 year old female (BMI percentile 75, normal) who sustained a proximal both bone forearm fracture and underwent closed reduction and casting with a cast index of 0.93 (a, b). Ultimately, the fracture re-displaced (c,d) and required placement of elastic nail (e,f).

Discussion

While the health effects of childhood obesity are commonly linked to the cardiovascular and endocrine systems, providers must be aware of the relationship of obesity to pediatric musculoskeletal health. Risk of fracture secondary to low-impact trauma is greater in obese children and has been associated with lower bone density, poor diet, sedentary lifestyle, and greater propensity to fall due to altered gait mechanics and poor balance [6,21-25]. Previous metabolic and biomechanical studies have shown that excess fat accumulation impedes skeletal development and increases the peak force transmitted through an arm during a fall, thus contributing to increased fracture incidence amongst obese children [23,25].

Although there is significant variability in what truly defines loss of reduction in the literature, rates are cited anywhere from 7.3% to 32.3%, which encompasses all variations of pediatric...
forearm fractures [4,7,16,18,21,26-30]. In the present study, we defined loss of reduction as any redisplacement that resulted in secondary intervention based on surgeon discretion. This definition yielded a secondary intervention rate of 9.5% amongst all our patients.

Predictors of loss of reduction include older age, lack of anatomic reduction immediately post-manipulation magnitude of deformity at the time of fracture, initial magnitude of displacement, more proximal fractures and poor casting technique as evidenced by the cast index, Canterbury index, padding index, or 3-point index [4,16,26-30]. Furthermore, we chose to evaluate the Cast Index (CI) as it has the advantage of being easy to perform, quick, and reproducible, with concomitantly high inter- and intra-observer reliability [18]. The CI is, in essence, a marker for a well-molded cast.

Chess et al., initially described the cast index in 1994 in a population of 761 fractures. These authors found that re-angulation at follow-up was related to poor cast molding, as reflected by a high cast index, set at 0.70 based on previous anthropometric studies [15]. Subsequent studies have examined the utility of the cast index as a predictor of loss of reduction and have yielded similar results [16-19]. Debnath et al., calculated the mean CI for patients that required a secondary intervention was 0.92±0.08 as compared to 0.77±0.07 for the patients that did not require secondary intervention [17]. Kamat et al., found that in patients with CI <0.8, the displacement rate was 5.58% whereas in patients with CI >0.81, the displacement rate was 26% [18]. We found that the mean cast index in our patients that required a secondary intervention was significantly higher than those who did not (1.00±0.06 vs 0.83±0.07, P<.001), independent of both BMI and magnitude of initial deformity.

Over further detail in the aforementioned studies is the effect of a patient’s weight on the adequacy of cast application. For instance, Debnath et al., found higher CI in patients aged <5 and >10 and owed it to the fact that these age groups have excess subcutaneous fat and therefore increased difficulty with cast molding [17]. In a similar fashion, Kamat et al., noted the lack of inclusion of patient weight measurements as a potential weakness in their study [18]. The results of our present study disprove the idea that subcutaneous fat inhibits an adequate reduction as we found no significant difference in CI amongst the underweight, normal BMI, and overweight/obese groups. Additionally, regression analysis did not correlate increasing cast index with BMI percentile for age.

Our study has several limitations, including those inherent to retrospective reviews, lack of long-term follow-up, and relatively small sample size. Additionally, we chose to include in this study all fractures broadly categorized as forearm fractures, which included isolated radius or ulna fractures or both bone fractures at any level, which could result in differing results if these were analyzed separately. Finally, the initial reductions were performed by multiple orthopedic residents of varying skill levels thereby possibly affecting the quality of reduction and cast molding.
**Conclusion**

In conclusion, we found that cast index is both a reproducible and reliable method of objectively critiquing a cast and ultimately of predicting failure of treatment. The mean cast index for patients who required secondary intervention was significantly higher than those patients that did not require secondary intervention (P<.001). Additionally, we found that obesity does not preclude a well-molded cast with an acceptable cast index and moreover is not an independent risk factor for failed closed reduction.

**References**


