INTRODUCTION

It has been estimated that 30% of hospital falls result in serious injury to the patient [1]. The occurrence of pediatric patient falls in the hospital or medical clinic environment has been estimated to range from 1.2-10.8% of hospitalized children [2], with most children falling on their head [3]. Current procedures to characterize, minimize or eliminate fall occurrence are not uniform among health care facilities. Furthermore, fall treatment protocols following pediatric patient falls are non-standard and are even sometimes overlooked. A theoretical fall risk model has recently been introduced [4] and is the first to consider the triad of child human factors, environmental human factors and biomechanical factors as they relate to fall occurrence and injury potential. It was not the intent of this model to address the severity of falls when they do occur, which is of concern relative to administering appropriate follow-up care for the patient.

Presently, no criteria exist which associate the dynamics of a fall with injury severity for pediatric patients. The current study embraced the head injury criterion (HIC), a measure borrowed from the automotive industry, as a means of assessing potential bounds for injury severity, versus the Medical Error Prevention and Error scoring (MERP) value. The MERP rating scale, used in clinical settings, is a qualitative system with scores ranging from 1 (least severe) to 7 (most severe). Scores are assigned based upon the known facts of the fall and subjective reported recall. HIC values are dependent upon the system (person) and the mechanics of the fall scenario and are thus bound theoretically from zero to infinity. In most adult head impacts, HIC_{15} (collision Δ velocity modeled to be 15ms) values greater than 1000 suggest some level of head injury. Understanding the severity of the fall can potentially lead to policy change in healthcare delivery relative to follow-up care, reduce waste by eliminating unnecessary tests, and enhance the efficiency and effectiveness of healthcare delivery for children. Thus, the purpose of this study was to retrospectively calculate the head injury criteria (HIC) values for pediatric patient falls and correlate these values to documented injury severity (MERP) scores. This was done to assess the effectiveness of the current standard of fall injury severity (MERP score) relative to fall mechanics in an attempt to quantify fall severity. A second purpose was to examine the relationship between child ages and associated HIC_{15} values in an attempt to scale the values obtained from pediatrics to adult values.

METHODS

Adverse event report records for 33 young children (76.8 ± 2.2 cm, 10.4 ± 4.8 kg, 16.0 ± 10.1 m/o) who experienced falls while admitted to a pediatric hospital were examined. Pertinent information including age, height, mass, gender, fall description and qualitative injury severity score (MERP) were extracted from the records. Of the total number of cases, only 12 records had a MERP score recorded.

For each fall incident, an HIC value was computed. First, the child’s center of gravity was modeled based upon age, gender, anthropometrics and fall scenario in order to accurately represent fall height. Several sources were used to estimate system center of gravity location including the anthropometric data base built into HumanCAD v1.2 (NexGen Ergonomics) software, AnthroKids Anthropometric Data Base (open access), and the Centers for Disease Control growth charts. Each fall was modeled for two positions, upright and lying, to
simulate the child either climbing or rolling out of the hospital crib. Contact velocity and contact force were computed and an HIC\textsubscript{15} (15 ms deceleration time independent of system deformation [3]) value computed using the following equation:

\[
\text{HIC} = \left( \frac{t_2 - t_1}{t_2 - t_1} \int_{t_1}^{t_2} a(t) \, dt \right)^{2.5}
\]

\[
\text{HIC}_{15} = a(t)^{2.5}
\]

where \(a\) is acceleration (in units of gravity) and \(t\) is contact time (0.015 s).

Descriptive statistics were computed for contact velocity, force and HIC\textsubscript{15} for the two modeled postures (n=33). The HIC\textsubscript{15} value was correlated to the MERP score (n=12) to address the primary study purpose. In addition, the HIC\textsubscript{15} value was correlated to age (n=33) to address the secondary study purpose.

RESULTS AND DISCUSSION

The demographic characteristics of the 33 cases evaluated reflected a very homogenous study sample. All falls occurred from a standard hospital crib (1.90m). The vertical COG location ranged from 1.92-2.47m (2.24±0.16m) and 1.57-2.01m (1.98±0.13m) for upright and lying postures, respectively. Descriptive modeled fall data are given in Table 1. The correlations between HIC\textsubscript{15} and MERP were \(r=0.333\) (upright) and \(r=0.045\) (lying). The correlations between HIC\textsubscript{15} and age were \(r=0.129\) and \(r=-0.061\) for upright and lying, respectively (Figure 1).

Table 1. Mean and standard deviation values for two modeled fall positions.

<table>
<thead>
<tr>
<th>Model</th>
<th>Contact Velocity (m/s)</th>
<th>Contact Force (bodyweight)</th>
<th>HIC\textsubscript{15}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upright Posture</td>
<td>Mean</td>
<td>6.63</td>
<td>4.59</td>
</tr>
<tr>
<td></td>
<td>sd</td>
<td>0.24</td>
<td>0.16</td>
</tr>
<tr>
<td>Lying Posture</td>
<td>Mean</td>
<td>6.09</td>
<td>4.22</td>
</tr>
<tr>
<td></td>
<td>sd</td>
<td>0.22</td>
<td>0.15</td>
</tr>
</tbody>
</table>

Results suggest little to no relationship between HIC\textsubscript{15} values and MERP scores assigned to each fall or age. The HIC\textsubscript{15} values calculated for these pediatric falls were generally in the range of those reported for adults (135-519) which resulted in a headache or dizziness for the adults.

CONCLUSIONS

This study explored the application of a unique approach to quantify the head injury severity of pediatric patient falls. The model is limited in that the fall was modeled as a rigid body. The homogenous nature of the falls (environment, child morphology) led to the inability to discriminate fall severity. A standard (adult) collision time (15ms) was used in this study. Modeling the falls with individualized parameters (skull deformation and/or floor surface) could provide additional insight into injury severity. Additionally, an alternative severity measure, such as the Abbreviated Injury Scale, may be a more appropriate correlate to HIC\textsubscript{15} values.

REFERENCES


ACKNOWLEDGEMENTS

Partially supported by the President’s Faculty Opportunity Award (#2221-272-76MH), University of Nevada, Las Vegas and the American Nurses Foundation (#2350-257-736T).