Background / Significance

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. These conceptual factors are shown visually in Figure 1.

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 one (least severe) to seven (most severe).

Methods

- Biomedical IRB -> Exempt Review (#1205-4154M)
- Review of adverse event 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
- Pertinent information extracted (age, height, mass, gender, fall description, MERP)
- Resulted in n=12 usable cases for MERP
- Contact velocity and contact force computed
- HIC value computed using:

\[
\frac{1}{(t_2 - t_1)^{2.5}} \int a(t)dt \]  

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

- System center of mass location modeled using:
  - HumanCAD v1.2 (NexGen Ergonomics)
  - AnthroKids Anthropometric data base (open access)
  - Centers for Disease Control growth charts

Two postures modeled: 1) standing, 2) lying

Descriptive statistics: contact velocity, force, HIC15

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 HIC15 and MERP were r=0.333 (upright) and r=0.045 (lying). The correlations between HIC15 and age were r=0.129 and r=-0.061 for upright and lying, respectively (Figure 2).

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>HIC15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upright Posture</td>
<td>Mean 6.63</td>
<td>4.59</td>
<td>204.8</td>
</tr>
<tr>
<td></td>
<td>sd 0.24</td>
<td>0.16</td>
<td>17.8</td>
</tr>
<tr>
<td>Lying Posture</td>
<td>Mean 6.09</td>
<td>4.22</td>
<td>165.6</td>
</tr>
<tr>
<td></td>
<td>sd 0.22</td>
<td>0.15</td>
<td>14.1</td>
</tr>
</tbody>
</table>

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 HIC15 values.

Figure 1. Word cloud representation of fall risk model [4] factors associated with current investigation.

Figure 2. Correlation between HIC15 and age for two modeled fall positions (n=33).

Conclusion

Results suggest little to no relationship between HIC15 values and MERP scores assigned to each fall or age. This outcome suggests a need for a more objective measure of injury severity for infants and children.

The HIC15 values calculated for these pediatric falls were generally in the range of those reported for adults (130-519) which resulted in a headache or dizziness for the adults [3]. In most adult head impacts, HIC15 (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 health care delivery relative to follow-up care, reduce waste by eliminating unnecessary tests and enhance the efficiency and effectiveness of healthcare delivery for children.

Acknowledgements

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References

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