HEAD IMPACT BIOMECHANICS IN PEDIATRIC PATIENT FALLS

Nancy A. Ryan-Wenger, PhD, RN, FAAN[1] and Janet S. Dufek, PhD, FACSM[2]

[1] Research Institute Center for Innovation in Pediatric Practice; Nationwide Children's Hospital, Columbus, OH

[2] Department of Kinesiology and Nutrition Sciences; University of Nevada, Las Vegas; Las Vegas, NV

The Problem

Patient falls are medical errors that have captured the attention of health care quality, regulatory, and third party payers.

Despite hospital-wide fall prevention programs, patients continue to fall with some regularity from their beds, cribs, chairs, and examination tables.

Falls that involve head to floor contact are of greatest concern because of the potential for concussion.

Unless there is loss of consciousness or skull fracture, the majority of hospitalized children are not examined or followed after discharge for signs of traumatic brain injury after a fall in the hospital.

MERP Index of Harm

Quality Improvement staff use the national **MERP Index**[1] to assign the level of medical error and corresponding patient harm to each fall event.

- Harm is defined as "impairment of the physical, emotional, or psychological function or structure of the body and/or pain resulting therefrom"
- **Scores range from 1 (capacity to cause error, no harm) to 9 (error that contributed to or caused patient death).**

HIC Concussion Potential

A measure of harm more sensitive than MERP scores is the **head injury criterion (HIC)**[2-3] which is a function of head acceleration rate and the duration of head-surface contact. It is a quantitative estimate of the potential for concussion or traumatic brain injury from an impact.

According to the Federal Motor Vehicle Safety Standards and Regulations,[4] **age-related HIC_{15} threshold levels for head injury/concussion are:**

- 5 years to adults: 700
- >2 to 5 years: 570
- 1 to 2 years: 390
- <1 year: 225

Purpose

The primary purpose of this study was to evaluate the head injury potential of pediatric patients who fell and made head to floor contact.

The secondary purpose was to compare hospital-assigned levels of harm to each fall event with calculated head injury potentials.

Methods

- Biomedical IRB –> Exempt Review (#1205-4154M)
- Review of adverse event reports and medical records for 49 young children who experienced a fall during hospitalization
  - > 48.3 ± 52.6 m/o
  - > 97.8 ± 28.7 cm;
  - > 19.5 ± 19.4 cm)
- Falls from crib, bed, chair, table or couch modeled for each child (Figure 1)
- **All falls resulted in head-to-floor contact**
- **Flooring consisted of commercial-grade vinyl-covered concrete**
- Pertinent information extracted (age, height, mass, gender, fall description, MERP)
- Contact velocity and contact force computed as Conservation of Energy: $PE_i = Ke_f$
- HIC_{15} value computed using:

$$\{[1/(t2-t1)\int_{t1}^{t2}[a(t)dt]^{2.5}(t2-t1)\}_{max}$$

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

- Correlation: HIC_{15} with MERP scores

Results

- **Fall Height Range:**
  > 72 cm (couch, chair, bed) to 149 cm (crib)
- **Fall Time Range:**
  > 0.14 – 1.26 s (average = 0.43 s)
- **Head Impact Force Range:**
  > 2.0 – 6.9 times bodyweight
- **HIC_{15} Range:**
  > 26.4 – 1302.1
- **14.3% (n=7) children experienced HIC_{15} scores exceeding the threshold for their age**
- MERP Index of Harm Score:
  - > 3: No harm (n=10)
  - > 4: No harm based on monitoring or intervention (n=36)
  - > 5: Temporary Harm (n=2)
  - > 8: Intervention necessary to save life (n=1)
- **Spearman Correlation (HIC_{15} and Harm Score):**
  r = - 0.251; p = 0.041

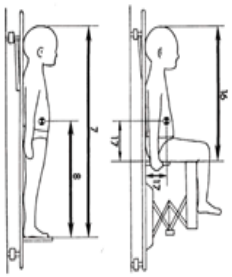

Figure 1. Exemplar anthropometric model of center of gravity location used to determine fall height. Each fall case was modeled to fit the child using their age, height, weight and gender.

Acknowledgements

Partially supported by the President's Faculty Opportunity Award (#2221-272-76MH)[2], University of Nevada, Las Vegas and the American Nurses Foundation (#2350-257-736T).[1]

Discussion

Most pediatric patient falls are not preventable

Children fall from their beds, cribs, tables, chairs or couches **in less than one second.**

Hospital-assigned levels of harm do not reflect the potential for head injury.

Parents of children with HIC_{15} scores >threshold for age should have received parent instructions about **signs and symptoms of concussion and follow-up care.**

Hospitals must **focus on minimizing fall-related injuries** when fall prevention interventions are unsuccessful.

Conclusions

Two components of HIC_{15} calculations are height of the fall and the **surface coefficient of restitution**, or "stiffness," which reflects the amount of energy absorbed by the floor-person system.

Research shows that floor mats significantly attenuate head injury potential by absorbing some of the force of the fall.

Height-adjustable hospital cribs would be a good investment to protect our most vulnerable infants and toddlers.

References

1. National Coordinating Council for Medical Error Reporting and Prevention, 2001. Retrieved from: http://www.nccmerp.org/types-medication-errors.
2. Child Health Corporation of America, 2009. Retrieved from: http://chca.com/index_no_flash.html,
3. Cory CZ et al. *Forensic Sci Int*, 123, 89-106, 2001.
4. Federal Motor Vehicle Safety Stamdards and Regulations. Retrieved from www.nhtsa.gov; 2015.