APPLIED BIOMECHANICS

April 16, 2007

Morgan, Lewis & Bockius, LLP
Attn: Molly M. Lane, Esq.
1 Market Spear Street Tower
San Francisco, CA 94105

Re: Matter of Cathy Henderson
Case No. AB30014

Dear Ms. Lane:

In accordance with your request, I have performed a biomechanical analysis of the incident associated with the above-named case. This letter is written to provide you with a summary of my analysis and conclusions on the matter.

Materials reviewed

Materials received / information reviewed in preparation for this report include the following:

- Limited medical records for Brandon Baugh, including 1 lateral view head x-ray
- Autopsy report
- Testimony: Roberto J. Bayardo, M.D.
- Testimony: Sparks P. Veasey, III, M.D.
- Testimony: Kris Lee Sperry, M.D.
- Letter for Executive Clemency by Cathy Henderson
- Investigator measurements of Cathy Henderson

Background

Based on the materials reviewed, it is my understanding that Cathy Henderson was caring for 3-month-old Brandon Baugh in her home. Using a calming technique she had learned from someone else, she was holding Brandon horizontally in her outstretched arm, such that his head was supported by her hand, and spinning in a circle. While spinning, she stepped on a toy on the floor and fell, dropping Brandon during the process. Brandon's body was recovered in a remote area days later, and autopsy demonstrated massive, comminuted fracture of the skull centered over the posterior portion of the left parietal bone and radiating into the upper occipital bone and lower portions of both parietal bones. Extensive subgaleal hematoma was also found over the left parietal and occipital regions of the skull. I have been asked to determine, from a biomechanical perspective, whether these injuries could have occurred as a result of the described drop in the home.

Biomechanical Analysis and Considerations

My assessment of the potential severity of the described drop in this case is based upon calculation of the pre-impact energy, as well as the force and acceleration of the associated

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impact, with comparison of calculated results to data reported in the recent literature for pediatric head injury. Measurements indicate that the height of Ms. Henderson's outstretched hand is 1.2 m (46 in), so this was assumed to be the vertical distance Brandon's head would have traveled prior to impact with the floor. Conservation of Energy requires that the vertical component of the impact velocity would have thus been 4.8 m/s (10.7 mph). The spinning motion was assumed to have occurred at a rate of 0.5 revolutions per second, with the center of rotation around a vertical axis from Ms. Henderson's feet to her head. With Brandon's head 0.71 m (28 in) away from the center of her body, it would have attained a horizontal linear velocity of 2.2 m/s (5 mph) during spinning and would have maintained this velocity upon release until impact with the floor. Given these conditions, the resultant velocity of the head just prior to impact with the floor would have been 5.3 m/s (11.8 mph). While it is unlikely that the momentum associated with this total velocity would have been completely arrested in a single impact, this could have occurred if Brandon's head had struck the floor and base of the wall simultaneously. Calculations of impact severity measures associated with this possibility, as defined by Newton's Law and based on recent data regarding the mechanical response of the human pediatric cadaver head[1], are summarized in Table 1. Values associated with the drop height alone, neglecting the spin velocity, are also provided for comparison. Given Brandon's head mass of 1.5 kg (assuming his head/body mass ratio to be 29%), pre-impact energies associated with these conditions are also provided.

Table 1 Impact severity measures associated with total and drop velocity calculations

	Total Velocity	Drop Velocity Only
Peak Force (kN)	2.3-2.7	1.8-2.4
Peak Linear Acceleration (G)	144-180	122-163
Head Energy (J)	21.0	17.3

The measured and calculated values are given meaning by comparing them to results reported in the literature. While there is a limited amount of scientific data regarding pediatric head injury, results from the few studies that have been conducted, in concert with findings on adults, provide a valuable base of information. In order to better understand the production of skull fracture in infants, Weber[2,3] dropped 50 cadavers, ranging in age from newborn to 9 months, from a height of 0.82 m (32 in). Subjects were dropped horizontally to produce occipital head impact onto a variety of surfaces, including stone tile, thin carpet, foam-backed linoleum, thick rubber pad, and a folded camel hair blanket. Fracture – in the majority of cases, multiple fractures – occurred in all 15 subjects dropped onto one of the first three surfaces. While the production of fracture was much less common, as expected, for the latter two, more padded, surfaces, 5 of the 35 subjects still suffered skull fracture. These results indicate that energy levels associated with these drop heights onto unpadded, or lightly padded, surfaces are more than sufficient to generate complex fracture in the infant skull. Drops onto the stone tile surface correspond to head potential energies of 11-14 J. Reported drops of isolated adult cadaver heads generated fracture at energies ranging from 45-103 J.[4] In addition to these energy considerations, force-acceleration calculations for the infant cadavers tested by Weber suggest

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that the skull of the young infant may fracture at forces below 1.0 kN. Forces producing fracture in large-flat-surface impacts of adult cadaver heads vary widely from 4.7-17.9 kN.[5,6]

While no other studies have produced skull fracture in pediatric cadavers, recent studies utilizing infant crash test dummies provide additional insight. By reconstructing crash tests involving no injury to infants and using engineering scaling techniques, Melvin suggested that a conservative estimate of minor head injury in a 6-month-old infant would be 50 G[7]. In another study, Klinich et al investigated infant head injury criteria by reconstructing three cases, using a CRABI-6 dummy, in which three infants (4-6 months old) had suffered skull fractures as a result of air bag deployments into their rear-facing car seats.[8] One child suffered a simple linear fracture, another resulted in bi-lateral fracture, and the third was complex and depressed. The latter two were fatal. Reconstruction of these cases resulted in peak head acceleration values of 129, 106, and 199 G, respectively, with the non-fatal case surprisingly resulting in a higher value than the fatal, bi-lateral fracture case. These data, coupled with results from simulations of non-injury cases, led the authors to conclude that 85 G was a reasonable value for 50% risk of minor skull fracture for a 6-month-old child, though they stress that their findings are preliminary and that the suggested Injury Assessment Reference Values (IARVs) should be used with caution until more cases can be analyzed. Inconsistencies in results prevented the authors from making recommendations on thresholds for serious injury, but their findings suggest a range between 152 and 217 G.

Comparison of the findings of these studies to the calculated values in Table 1 suggests that the described scenario easily had the potential to produce force, acceleration, and energy levels well above the estimated threshold for minor skull fracture. While thresholds for the serious level of injury seen in Brandon are yet unknown, the calculated values are consistent with a serious level of injury based on the Klinich reconstructions, though, again, the authors note inconsistencies in their findings at this loading level. The described experimental data appear to be in direct conflict with a number of case study collections published during the last three decades[9] concluding that children are not seriously injured in typical household falls. The reasons for differences are not clear, but one logical explanation may be that children most often do not fall in such a way as to expose their heads to the full energy of a fall. If they do, however, the experimental data suggest that the consequences can be severe.

It is important to note here that the calculated values presented in Table 1 are based on simple estimates of the described scenario, particularly in the incorporation of the spinning mechanism. It is possible that I have overestimated its influence, in which case the "Drop Velocity Only" values would be applicable. It may also be the case, however, that the combined spinning fall somehow served to throw Brandon as a result of Ms. Henderson possibly twisting to prepare to

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break her fall, thereby increasing the potential severity of the drop. I have not addressed this in my calculations since it would be speculative to try to quantify. In addition, because the carpet was not available for investigation, my calculations do not account for its possible contribution. While the protective influence of a floor covering is reduced with higher impact velocities, a typical carpet-pad combination in homes today might be expected to reduce the calculated peak acceleration values by 10-20 G under the described conditions for this case.

Based on the materials reviewed, it seems that the reported experimental data were not considered during the trial of Ms. Henderson. With the exception of the Weber studies, this is logical since the other work cited here was published after that time. In addition, Weber published his work in German, so it seems possible that translations were not available to those involved. It also seems possible that Weber's work may have simply been dismissed as an outlier, but the more recent work cited here, including non-fracture drop tests of infant cadaver heads by Prange et al[1], appears to confirm its veracity.

Conclusions

Based on the above analysis, it is my opinion that the described fall had the potential to produce a serious injury. Whether or not it could have produced injuries of the severity seen in Brandon Baugh is not clear, but the possibility cannot be ruled out given the current state of knowledge.

If you have any questions, please feel free to contact me at (510) 747-1947.

Sincerely,

Ken L. Monson

Kenneth L. Monson, Ph.D.

Head Impact Calculations

Henderson

Anthropometry

$mass := 5.2 \cdot kg$	Child total body mass (measured)
$age := 0.25 \cdot yr$	Child age
$m_{ratio} := 0.3 - 0.0034 \cdot \frac{12}{yr} \cdot age$	(formula from Head-Body Mass Ratio.xls)
$m_{ratio} = 0.29$	Head / body mass ratio
$len := 25 \cdot in \quad len = 63.5\,cm$	Child height (measured)
$len_{CR} := 42 \cdot cm$	Length from crown to rump (Anthrokids)
$len_{Head} := 14.5 \cdot cm$	Head length (Anthrokids)
$L_{trag} := 9.4 \cdot cm$	Distance from tragion to top of head (Anthrokids)
$H_{cgFrac} := 0.6$	CG height / body height (Anthrokids)
$r_{neck} := 9.5 \cdot cm$	Distance: head cg to C5/C6 (estimated; Prange et al, 2003)

$m_{head} := mass \cdot m_{ratio}$

$m_{head} = 1.507\,kg$

$m_{head} = 3.322\,lb$

Impact Velocity

$H := 46 \cdot in \qquad H = 1.168\,m$ — Head CG height

$E_{phead} := mass \cdot m_{ratio} \cdot g \cdot H \qquad E_{phead} = 17.267\,J$ — Head potential energy

Free Fall: $v_{free} := \sqrt{2 \cdot g \cdot H} \qquad v_{free} = 4.787\,\frac{m}{s} \qquad v_{free} = 10.708\,mph$ — Free-fall impact velocity

Velocity of Head from Spin:

$\omega := 180 \cdot \frac{deg}{s} \qquad r := 28 \cdot in$

$v_{spin} := \omega \cdot r \qquad v_{spin} = 2.234\,\frac{m}{s} \qquad v_{spin} = 4.998\,mph$ — Velocity due to spin

Resultant Velocity

$v_{tot} := \sqrt{{v_{free}}^2 + {v_{spin}}^2} \qquad v_{tot} = 5.283\,\frac{m}{s} \qquad v_{tot} = 11.817\,mph$ — Resultant velocity

$E_{tot} := mass \cdot m_{ratio} \cdot \left(g \cdot H + \frac{1}{2} \cdot {v_{spin}}^2 \right) \qquad E_{tot} = 21.028\,J$ — Head total energy

Impact Force, Skull Deformation and Kinematics

$e_{rest} := 0.0$ Coefficient of Restitution

$t_{surface} := 0 \cdot mm$ Deformation of carpet and pad at peak force predicted below (no information)

Upper Bound - Total Velocity

$tau := 0.006 \cdot sec$ Crush Phase Impulse Duration

$F_p := \frac{2 \cdot mass \cdot m_{ratio} \cdot v_{tot}}{tau}$ $F_p = 2.654 \times 10^3 N$ $F_p = 596.569\ lbf$ Peak Force

$a_p := \frac{F_p}{mass \cdot m_{ratio}}$ $a_p = 179.566\ g$ Peak Accel

Check deformation with Haversine.pxp (Igor Pro)

$def := 15.8 \cdot mm$ Max overall deformation (from Igor Pro)

$def_{Sk} := def - t_{surface}$ $def_{Sk} = 15.8\ mm$ Skull Deformation

$omega_{delt} := \frac{v_{tot} \cdot (1 + e_{rest})}{r_{neck}}$ $omega_{delt} = 55.609 \frac{rad}{s}$ Ang Vel Change

$alpha_p := \frac{a_p}{r_{neck}}$ $alpha_p = 1.854 \times 10^4 \frac{rad}{s^2}$ Ang Acc Peak

Lower Bound - Total Velocity

$tau := 0.0075 \cdot sec$ Crush Phase Impulse Duration

$F_p := \frac{2 \cdot mass \cdot m_{ratio} \cdot v_{tot}}{tau}$ $F_p = 2.123 \times 10^3 N$ $F_p = 477.255\ lbf$ Peak Force

$a_p := \frac{F_p}{mass \cdot m_{ratio}}$ $a_p = 143.653\ g$ Peak Accel

Check deformation with Haversine.pxp (Igor Pro)

$def := 19.8 \cdot mm$ Max overall deformation (from Igor Pro)

$def_{Sk} := def - t_{surface}$ $def_{Sk} = 19.8\ mm$ Skull Deformation

$omega_{delt} := \frac{v_{tot} \cdot (1 + e_{rest})}{r_{neck}}$ $omega_{delt} = 55.609 \frac{rad}{s}$ Ang Vel Change

$alpha_p := \frac{a_p}{r_{neck}}$ $alpha_p = 1.483 \times 10^4 \frac{rad}{s^2}$ Ang Acc Peak

Upper Bound - Drop Velocity

$tau := 0.006 \cdot sec$ Crush Phase Impulse Duration

$F_p := \frac{2 \cdot mass \cdot m_{ratio} \cdot v_{free}}{tau}$ $F_p = 2.405 \times 10^3 N$ $F_p = 540.586\ lbf$ Peak Force

$a_p := \frac{F_p}{mass \cdot m_{ratio}}$ $a_p = 162.716\ g$ Peak Accel

Check deformation with Haversine.pxp (Igor Pro)

$def := 14.4 \cdot mm$ Max overall deformation (from Igor Pro)

$def_{Sk} := def - t_{surface}$ $def_{Sk} = 14.4\ mm$ Skull Deformation

$omega_{delt} := \frac{v_{free} \cdot (1 + e_{rest})}{r_{neck}}$ $omega_{delt} = 50.39 \frac{rad}{s}$ Ang Vel Change

$alpha_p := \frac{a_p}{r_{neck}}$ $alpha_p = 1.68 \times 10^4 \frac{rad}{s^2}$ Ang Acc Peak

Lower Bound - Drop Velocity

$tau := 0.008 \cdot sec$ Crush Phase Impulse Duration

$F_p := \frac{2 \cdot mass \cdot m_{ratio} \cdot v_{free}}{tau}$ $F_p = 1.803 \times 10^3 N$ $F_p = 405.44\ lbf$ Peak Force

$a_p := \frac{F_p}{mass \cdot m_{ratio}}$ $a_p = 122.037\ g$ Peak Accel

Check deformation with Haversine.pxp (Igor Pro)

$def := 19.1 \cdot mm$ Max overall deformation (from Igor Pro)

$def_{Sk} := def - t_{surface}$ $def_{Sk} = 19.1\ mm$ Skull Deformation

$omega_{delt} := \frac{v_{free} \cdot (1 + e_{rest})}{r_{neck}}$ $omega_{delt} = 50.39 \frac{rad}{s}$ Ang Vel Change

$alpha_p := \frac{a_p}{r_{neck}}$ $alpha_p = 1.26 \times 10^4 \frac{rad}{s^2}$ Ang Acc Peak

May 11, 2007

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Background

Based on the materials reviewed, it is my understanding that Cathy Henderson was caring for 3-month-old Brandon Baugh in her home. Using a calming technique she had learned from someone else, she was holding Brandon horizontally in her outstretched arm, such that his head was supported by her hand, and spinning in a circle. While spinning, she stepped on a toy on the floor and fell, dropping Brandon during the process. Brandon's body was recovered in a remote area days later, and autopsy demonstrated massive, comminuted fracture of the skull centered over the posterior portion of the left parietal bone and radiating into the upper occipital bone and lower portions of both parietal bones. Extensive subgaleal hematoma was also found over the left parietal and occipital regions of the skull. I have been asked to determine, from a biomechanical perspective, whether these injuries could have occurred as a result of the described drop in the home.

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Table 1 Impact severity measures associated with total and drop velocity calculations

	Total Velocity	Drop Velocity Only
Peak Force (kN)	2.0-2.5	1.8-2.4
Peak Linear Acceleration (G)	137-172	122-163
Head Energy (J)	19.2	17.3

The measured and calculated values are given meaning by comparing them to results reported in the literature. While there is a limited amount of scientific data regarding pediatric head injury, results from the few studies that have been conducted, in concert with findings on adults, provide a valuable base of information. In order to better understand the production of skull fracture in infants, Weber[2,3] dropped 50 cadavers, ranging in age from newborn to 9 months, from a height of 0.82 m (32 in). Subjects were dropped horizontally to produce parieto-occipital head impact onto a variety of surfaces, including stone tile, thin carpet, foam-backed linoleum, thick rubber pad, and a folded camel hair blanket. Fracture – in the majority of cases, multiple fractures – occurred in all 15 subjects dropped onto one of the first three surfaces. While the production of fracture was much less common, as expected, for the latter two, more padded, surfaces, 5 of the 35 subjects still suffered skull fracture. These results indicate that energy levels associated with these drop heights onto unpadded, or lightly padded, surfaces are more than sufficient to generate complex fracture in the infant skull. Drops onto the stone tile surface correspond to head potential energies of 11-14 J. Reported drops of isolated adult cadaver heads generated fracture at energies ranging from 45-103 J.[4] In addition to these energy considerations, force-acceleration calculations for the infant cadavers tested by Weber suggest

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break her fall, thereby increasing the potential severity of the drop. I have not addressed this in my calculations since it would be speculative to try to quantify. In addition, because the carpet was not available for investigation, my calculations do not account for its possible contribution. While the protective influence of a floor covering is reduced with higher impact velocities, a typical carpet-pad combination in homes today might be expected to reduce the calculated peak acceleration values by 10-20 G under the described conditions for this case.

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Conclusions

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If you have any questions, please feel free to contact me at (510) 747-1947.

Sincerely,

Ken L. Monson

Kenneth L. Monson, Ph.D.

Head Impact Calculations

Henderson

<u>Anthropometry</u>

$mass := 5.2 \cdot kg$ — Child total body mass (measured)

$age := 0.25 \cdot yr$ — Child age

$m_{ratio} := 0.3 - 0.0034 \cdot \frac{12}{yr} \cdot age$ — (formula from Head-Body Mass Ratio.xls)

$m_{ratio} = 0.29$ — Head / body mass ratio

$m_{head} := mass \cdot m_{ratio}$

$len := 25 \cdot in$ $\quad len = 63.5\,cm$ — Child height (measured)

$m_{head} = 1.507\,kg$

$len_{CR} := 42 \cdot cm$ — Length from crown to rump (Anthrokids)

$m_{head} = 3.322\,lb$

$len_{Head} := 14.5 \cdot cm$ — Head length (Anthrokids)

$L_{trag} := 9.4 \cdot cm$ — Distance from tragion to top of head (Anthrokids)

$H_{cgFrac} := 0.6$ — CG height / body height (Anthrokids)

$r_{neck} := 9.5 \cdot cm$ — Distance: head cg to C5/C6 (estimated; Prange et al, 2003)

<u>Impact Velocity</u>

$H := 46 \cdot in$ $\quad H = 1.168\,m$ — Head CG height

$E_{phead} := mass \cdot m_{ratio} \cdot g \cdot H$ $\quad E_{phead} = 17.267\,J$ — Head potential energy

Free Fall: $v_{free} := \sqrt{2 \cdot g \cdot H}$ $\quad v_{free} = 4.787 \frac{m}{s}$ $\quad v_{free} = 10.708\,mph$ — Free-fall impact velocity

Velocity of Head from Spin:

$\omega := 180 \cdot \frac{deg}{s}$ $\quad r := 20 \cdot in$

$v_{spin} := \omega \cdot r$ $\quad v_{spin} = 1.596 \frac{m}{s}$ $\quad v_{spin} = 3.57\,mph$ — Velocity due to spin

Resultant Velocity

$v_{tot} := \sqrt{v_{free}^2 + v_{spin}^2}$ $\quad v_{tot} = 5.046 \frac{m}{s}$ $\quad v_{tot} = 11.288\,mph$ — Resultant velocity

$E_{tot} := mass \cdot m_{ratio} \cdot \left(g \cdot H + \frac{1}{2} \cdot v_{spin}^2 \right)$ $\quad E_{tot} = 19.186\,J$ — Head total energy

Impact Force, Skull Deformation and Kinematics

$e_{rest} := 0.0$ Coefficient of Restitution

$t_{surface} := 0 \cdot mm$ Deformation of carpet and pad at peak force predicted below (no information)

Upper Bound - Total Velocity

$tau := 0.006 \cdot sec$ Crush Phase Impulse Duration

$F_p := \frac{2 \cdot mass \cdot m_{ratio} \cdot v_{tot}}{tau}$ $F_p = 2.535 \times 10^3 N$ $F_p = 569.837\ lbf$ Peak Force

$a_p := \frac{F_p}{mass \cdot m_{ratio}}$ $a_p = 171.52\ g$ Peak Accel

Check deformation with Haversine.pxp (Igor Pro)

$def := 15.8 \cdot mm$ Max overall deformation (from Igor Pro)

$def_{Sk} := def - t_{surface}$ $def_{Sk} = 15.8\ mm$ Skull Deformation

$omega_{delt} := \frac{v_{tot} \cdot (1 + e_{rest})}{r_{neck}}$ $omega_{delt} = 53.117 \frac{rad}{s}$ Ang Vel Change

$alpha_p := \frac{a_p}{r_{neck}}$ $alpha_p = 1.771 \times 10^4 \frac{rad}{s^2}$ Ang Acc Peak

Lower Bound - Total Velocity

$tau := 0.0075 \cdot sec$ Crush Phase Impulse Duration

$F_p := \frac{2 \cdot mass \cdot m_{ratio} \cdot v_{tot}}{tau}$ $F_p = 2.028 \times 10^3 N$ $F_p = 455.869\ lbf$ Peak Force

$a_p := \frac{F_p}{mass \cdot m_{ratio}}$ $a_p = 137.216\ g$ Peak Accel

Check deformation with Haversine.pxp (Igor Pro)

$def := 19.8 \cdot mm$ Max overall deformation (from Igor Pro)

$def_{Sk} := def - t_{surface}$ $def_{Sk} = 19.8\ mm$ Skull Deformation

$omega_{delt} := \frac{v_{tot} \cdot (1 + e_{rest})}{r_{neck}}$ $omega_{delt} = 53.117 \frac{rad}{s}$ Ang Vel Change

$alpha_p := \frac{a_p}{r_{neck}}$ $alpha_p = 1.416 \times 10^4 \frac{rad}{s^2}$ Ang Acc Peak

Upper Bound - Drop Velocity

$tau := 0.006 \cdot sec$ Crush Phase Impulse Duration

$F_p := \frac{2 \cdot mass \cdot m_{ratio} \cdot v_{free}}{tau}$ $F_p = 2.405 \times 10^3 N$ $F_p = 540.586\,lbf$ Peak Force

$a_p := \frac{F_p}{mass \cdot m_{ratio}}$ $a_p = 162.716\,g$ Peak Accel

Check deformation with Haversine.pxp (Igor Pro)

$def := 14.4 \cdot mm$ Max overall deformation (from Igor Pro)

$def_{Sk} := def - t_{surface}$ $def_{Sk} = 14.4\,mm$ Skull Deformation

$omega_{delt} := \frac{v_{free} \cdot (1 + e_{rest})}{r_{neck}}$ $omega_{delt} = 50.39 \frac{rad}{s}$ Ang Vel Change

$alpha_p := \frac{a_p}{r_{neck}}$ $alpha_p = 1.68 \times 10^4 \frac{rad}{s^2}$ Ang Acc Peak

Lower Bound - Drop Velocity

$tau := 0.008 \cdot sec$ Crush Phase Impulse Duration

$F_p := \frac{2 \cdot mass \cdot m_{ratio} \cdot v_{free}}{tau}$ $F_p = 1.803 \times 10^3 N$ $F_p = 405.44\,lbf$ Peak Force

$a_p := \frac{F_p}{mass \cdot m_{ratio}}$ $a_p = 122.037\,g$ Peak Accel

Check deformation with Haversine.pxp (Igor Pro)

$def := 19.1 \cdot mm$ Max overall deformation (from Igor Pro)

$def_{Sk} := def - t_{surface}$ $def_{Sk} = 19.1\,mm$ Skull Deformation

$omega_{delt} := \frac{v_{free} \cdot (1 + e_{rest})}{r_{neck}}$ $omega_{delt} = 50.39 \frac{rad}{s}$ Ang Vel Change

$alpha_p := \frac{a_p}{r_{neck}}$ $alpha_p = 1.26 \times 10^4 \frac{rad}{s^2}$ Ang Acc Peak

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EDUCATION

Ph.D. **University of California, Berkeley**, Mechanical Engineering, 2001

Mechanical and Failure Properties of Human Cerebral Blood Vessels
Committee: Werner Goldsmith (chair), Tony M. Keaveny, Jeffrey C. Lotz, Marian C. Diamond

Major Fields: Biomechanics, Solid Mechanics

M.S. **Brigham Young University**, Mechanical Engineering, 1997

Magnitudes and Mechanisms of Planar Restitution in Motor Vehicle Collisions
Advisor: Geoffrey J. Germane

B.S. **Brigham Young University**, Mechanical Engineering, 1995

AWARDS / HONORS

National Institutes of Health Career Development Award, 2006-2011

Guaranteed Financial Support, 1997/98, Mechanical Engineering, UC Berkeley

Magna Cum Laude, 1995, Brigham Young University

Brigham Young University Trustees Scholar, 1989 (four years full tuition)

RESEARCH EXPERIENCE

Assistant Adjunct Professor (Aug 06 – present)
Department of Neurological Surgery, University of California, San Francisco

Assistant Research Scientist (Oct 04 – July 06)
Department of Neurological Surgery, University of California, San Francisco

Research Fellow (Dec 01 – Aug 05)
Department of Mechanical Engineering, University of California, Berkeley

Visiting Post-doc (Dec 01 – Sept 04)
Department of Neurological Surgery, University of California, San Francisco

Graduate Student Researcher (Aug 97 – Dec 01)
Department of Mechanical Engineering, University of California, Berkeley

Research Assistant (May 95 – Aug 97)
Department of Mechanical Engineering, Brigham Young University

RESEARCH INTERESTS

- Biomechanics of injury, particularly traumatic brain injury. Pediatric head injury, accidental and intentional.
- Role of cerebral vessels in the structural response of the brain. Vascular mechanotransduction and remodeling.
- Physical experimentation, computational modeling for investigation of soft tissue mechanics, head injury.
- Automobile collision mechanics. Safety.

TEACHING / MENTORING EXPERIENCE

Laboratory Supervisor (Sep 06 – present)
Department of Neurological Surgery, University of California, San Francisco

Undergraduate Research Supervisor (Aug 97 – present)
Department of Mechanical Engineering, University of California, Berkeley

Graduate Student Instructor (Aug 97 – Dec 00)
Department of Mechanical Engineering, Department of Bioengineering, University of California, Berkeley

- Engineering Mechanics II (Dynamics)
- Introduction to Bioengineering
- Mechanical Behavior of Engineering Materials
- Intermediate Dynamics

Teaching Assistant (Aug 95 – Apr 97)
Department of Mechanical Engineering, Brigham Young University

- Machine Design
- Applied Thermodynamics

PROFESSIONAL SERVICE

Ad Hoc Reviewer
Accident Analysis & Prevention
Biomechanics and Modeling in Mechanobiology
Journal of Biomechanics
Neuropathology and Applied Neurobiology

PUBLICATIONS / PRESENTATIONS / GRANTS

Manuscripts

Goldsmith, W., Monson, K. L., 2005. On the state of head injury biomechanics – past, present, and future. Part 2: Physical experimentation. *Critical Reviews in Biomedical Engineering* 33(2):105-207.

Monson, K. L., Goldsmith, W., Barbaro, N. M., Manley, G. T., 2005. Significance of source and size in the mechanical response of human cerebral blood vessels. *Journal of Biomechanics* 38(4): 737-744.

Monson, K. L., Goldsmith, W., Barbaro, N. M., Manley, G. T., 2003. Axial mechanical properties of fresh human cerebral blood vessels. *Journal of Biomechanical Engineering* 125(2): 288-294.

Zhang, L., Bae, J., Hardy, W. N., Monson, K. L., Manley, G. T., Goldsmith, W., Yang, K. H., King, A. I., 2002. Computational study of the contribution of the vasculature on the dynamic response of the brain. *Stapp Car Crash Journal* 46: 145-163.

Monson, K. L., Goldsmith, W., Barbaro, N. M., Manley, G., 2000. Static and dynamic mechanical and failure properties of human cerebral vessels. In: *Crashworthiness, Occupant Protection, and Biomechanics in Transportation Systems 2000*, ASME. Ed. by H. F. Mahmood, S. D. Barbat, and M. R. Baccouche. AMD v. 246 / BED v. 49: 255-265.

Monson, K. L., Germane, G. J., 1999. Determination and mechanisms of motor vehicle structural restitution from crash test data. In: *Accident reconstruction: Technology and Animation IX*, SP-1407 and *1999 Transactions* 108, Section 6 (*Journal of Passenger Cars*), Part 1, pp. 249-271. SAE Paper No. 1999-01-0097.

Abstracts / Presentations

Monson, K., Sparrey, C., Cheng, L., Van Ee, C., Manley, G. Head exposure levels in pediatric falls. Accepted for presentation at the 25th Annual National Neurotrauma Symposium, July 30-Aug 1, 2007, Kansas City, MO.

Krasnokutsky, M. V., Barnes, P. D., Monson, K. L., Ophoven, J. Spinal cord injury without radiographic abnormality – a mimic of nonaccidental injury. Presented at Society of Pediatric Radiology, April 2007, Miami, FL.

Monson, K. L., Barbaro, N. M., Manley, G. T. Multiaxial response of human cerebral arteries. American Society of Biomechanics Annual Meeting, September 6-9, 2006, Blacksburg, VA.

Monson, K. L., Hashimoto, T. Temporal correlation between mechanical properties and MMP-9 expression during hemodynamically-induced vascular remodeling. Poster at NCMRR Biennial Training Workshop, NICHD, NIH. December 5-6, 2005, Rockville, MD.

Monson, K. L. The structural role of vasculature in traumatic brain injury. Presentation at the 2nd Annual Northern California Neurotrauma Spring Symposium, University of California, 2003, San Francisco, CA.

Monson, K. L. Static and dynamic mechanical and failure properties of human cerebral blood vessels. Poster at the Nineteenth Annual National Neurotrauma Symposium, 2001, San Diego, CA. Abstract: *Journal of Neurotrauma* 18(10): 1125.

Monson, K. L. Static and dynamic mechanical and failure properties of human cerebral vessels. Presentation at the 9th ASME Symposium on Crashworthiness, Occupant Protection, and Biomechanics in Transportation, 2000 ASME International Mechanical Engineering Congress and Exposition, Orlando.

Awarded Grants

Vascular Mechanotransduction in Traumatic Brain Injury (PI), 1K25HD048643-01A1, Apr 2006 – Mar 2011, National Institute of Child Health and Human Development, National Institutes of Health.

Vascular Biomechanics in Traumatic Brain Injury (PI: Geoff Manley), R49 CE000460, Sept 2004 – Aug 2007, Centers for Disease Control and Prevention.

Biomechanical Properties of Human Cerebral Vessels (PI: Geoff Manley), R49/CCR 919722, Oct 2001 – Sept 2004, Centers for Disease Control and Prevention.

Biomechanics Training (PI: Werner Goldsmith), 1998-2001, San Francisco Injury Center, Centers for Disease Control and Prevention.

Apr-07