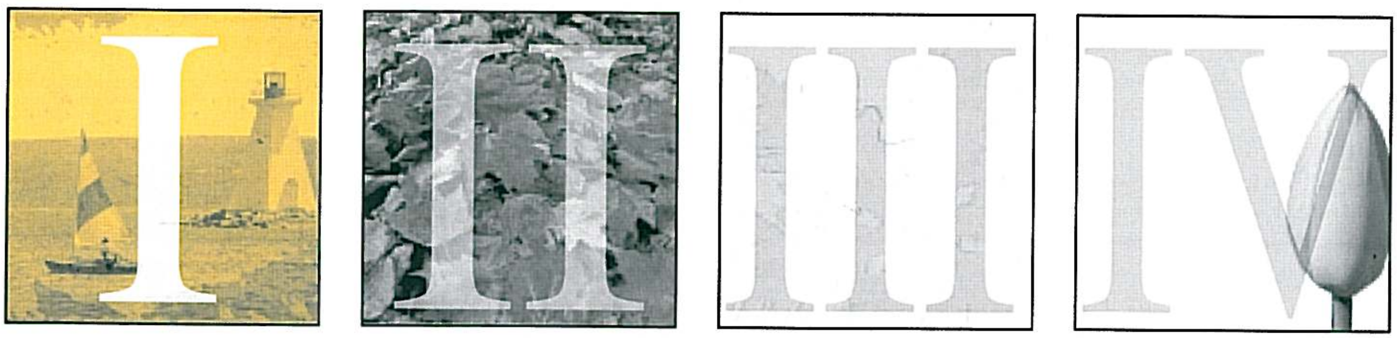
MICHIGAN DEFENSE
QUARTERLY

Volume 26, No. 1 July 2009



IN THIS ISSUE:

MDTC

MICHIGAN DEFENSE TRIAL COUNSEL, INC.

THE STATEWIDE ASSOCIATION OF ATTORNEYS REPRESENTING THE DEFENSE IN CIVIL LITIGATION

Biomechanical Analysis: Counter-Intuitive Insights

By: Jeffrey A. Pike, *Forcon International*

Executive Summary

Biomechanical analysis is a valuable tool in the forensic analysis of injuries. A careful analysis of the details of the injury, in connection with the underlying medical data, will permit the biomechanical expert to provide a coherent and defensible explanation of the extent and nature of the causal connection — or lack of it — between an event and an injury. It is often the case that what might seem to be an obvious connection between an accident and an injury is not supported by the physical evidence. For this reason, biomechanical analysis, which is commonly used by clinicians, safety researchers and others to evaluate risks, can also be of significant assistance to the attorney who is defending a personal injury action.

Jeffrey A. Pike's s professional credentials include: Senior Technical Specialist, Ford Motor Company (retired after 32 years); Adjunct Professor, Wayne State University, Biomedical Engineering Department; Fellow, Society of Automotive Engineers (SAE); Principal Lecturer & Organizer, SAE Seminars on Automotive Safety (24 Years), and invited speaker at conferences in the US (including two White House Conferences), Europe, China, India, Korea and Australia. He has served as a consultant to various agencies, including the Centers for Disease Control (CDC,) National Academy of Sciences, NHTSA and state and local governments. His publications include technical papers, book chapters and three textbooks — *Automotive Safety, Neck Injury,* and Forensic Biomechanics. A fourth book, *Neck Injury Biomechanics* (in press) is the first in a series focused on specific body regions. His additional teaching experience includes guest lectures at MIT, Medical College of Wisconsin, University of Virginia and Harvard Medical School. His educational background includes studies at Polytechnic Institute of New York, New York University and the University of Michigan. His email address is jp@bciconsult.com.

Forensic biomechanics can provide triers of fact, as well as clinicians, government regulators, product developers and safety researchers with an additional methodology for applying reasoned discourse to their decision-making process.[1] The following examples provide instances where the insight provided by biomechanics may be counter-intuitive and therefore, all the more valuable.

Case Study 1: Pre-Existing Condition

The first case study presents a rather straight-forward analysis. The case studies that follow will generally tend to be more complex. The basic scenario involves a 68-year old male driver involved in a frontal motor vehicle impact. He has been diagnosed with a hiatal hernia and the question the expert has been asked to address is "Did the accident cause the hiatal hernia and if not, what was the cause?" A hiatal hernia occurs when abdominal contents migrate upward from the abdomen through the diaphragm into the chest cavity.

The medical records indicate that the driver had no complaints at the scene, but three days afterward he went to an emergency room as a walk-in, complaining of neck and abdominal pain. Upon examination, he was found to have no abdominal bruising. Ultrasound imaging revealed a hiatal hernia.

Biomechanical Analysis. Photographs of the vehicle showed minor frontal damage, no steering wheel rim deformation and no airbag deployment. The consultant concluded that biomechanically, the hernia did not appear to be causally related to the accident. Furthermore, the consultant cited a statistic that hiatal hernia is present in 60% of males who are 60 years old and older[2] and therefore concluded that to a reasonable degree of biomechanical certainty, the hernia was pre-existing and not attributable to the subject accident.

Case Study 2: Three Vehicle Chain Impact

As the name implies this case study involves three vehicles that are lined-up and facing in the same direction. The front-most vehicle is vehicle 1 (V1), the middle vehicle is vehicle 2 and the rear-most vehicle is vehicle 3. There is general agreement that there was at least one impact involving the front of V3 and the rear of V2 and at least one impact involving the front of V2 and the rear of V1 (*i.e.* V3 rear-ended V2 and V2 rear-ended V1) [Figure 1].

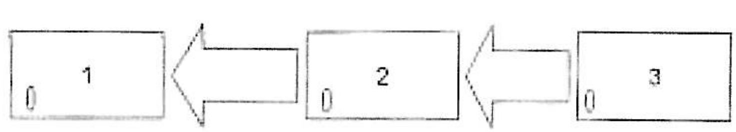


Figure 1. Three-Vehicle Chain Impact

Head injury may be produced by a contrecoup mechanism, that is, an impact to the rear of the head may produce an injury to the front of the brain.

The medicals indicate that the driver of Vehicle 2 (D2) was examined in the emergency room found to have forehead bruising and closed head injury consisting of minor contusions to the frontal poles of the brain. There are differing accounts regarding which vehicle impact occurred first. According to the driver of V3, V2 hit V1 and then V3 hit V2; whereas according to the driver of V2, V3 hit V2 and then knocked V2 into V1. The driver of V1 reports that he was parked (and unbelted) and does not know if V3 hit V2 before or after V2 hit V1. His statement contains the quotation that "all he knows is that V2 hit his vehicle while he was stopped" and that he was injured. The experts were asked to address which impact caused the closed head injury sustained by D2.

Biomechanical Analysis – Expert A. Expert A (consulted by D3) opined as follows: The medical records report bruising to the front of the head and contusion to the front of the brain, so the CHI was caused by forward head motion and impact involving the front of the head and this in turn was produced by an impact involving the front of the vehicle (V2 into V1). Thus the impact of V2 into V1 was the significant impact regarding D2's brain injury, and the impact of V3 into V2 was insignificant regarding D2's brain injury. Furthermore, with regard to injury causation, the sequence of the impacts (*i.e.* did V2 into V1 occur before V3 into V2) does not matter.

Biomechanical Analysis – Expert B. Expert B (consulted by D2) provided an opinion that was not only quite different form Expert A, but also appeared at first to be counter-intuitive. Photographs of vehicle damage showed that the V3/V2 impact was much more severe than the V2/V1 impact. There was considerably more vehicle damage to the front of V3 and the rear of V2 than to the front of V2 and the rear of V1. This more severe impact would be expected to produce the more abrupt head motion and to move the head of D2 rearward.

Head injury may be produced by a contrecoup mechanism, that is, an impact to the rear of the head may produce an injury to the front of the brain. [Figure 2] This is especially true for the frontal poles of the brain [Figure 3], which overlie some jagged bony surfaces of the skull interior [Figure 4]. Thus, it was the V3 into V2 impact that caused the brain injury for D2 and the V2 into V1 impact was insignificant with regard to the brain injury.

No bruising to the back of the head was reported in the medical records, either because it was covered by the driver's hair or because the head impacted with the padded head restraint. In any event, the rearward motion was sufficient to abrade the frontal poles. In this instance, the forehead bruise was incidental and the significant impact was to the rear of the head.

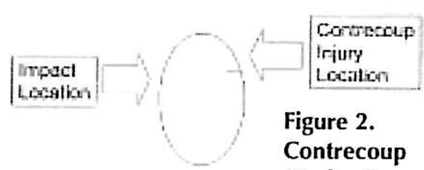


Figure 2. Contrecoup Mechanism

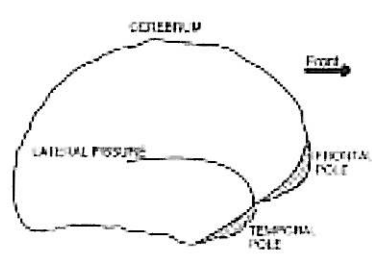


Figure 3. Frequent Brain Laceration and Contusion Sites[3]

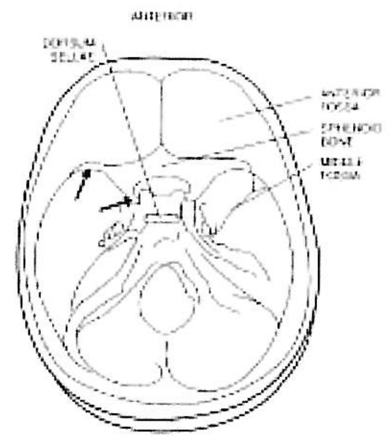


Figure 4. Interior of the Skull[4]

Case Study 3: "Slip and Fall"

This case involves a man who slipped and fell from a height of about 3 feet and landed on his head. He sustained brain and spine injury. He was hospitalized, but only survived for about one day. The consultant was asked to address whether the fall would have been survivable if the floor had been softer (conformed to an optional guideline that specified a flooring surface that was about ¼ less stiff).

Biomechanical Analysis. The initial approach might be along the lines of a common sense view that the softer the impact surface, the better. However, biomechanical analysis may lead to a different conclusion in a particular case. The medical record from the treating neurosurgeon [Figure 5] makes the assessment that the patient had chronic spinal stenosis, a chronic — and hence preexisting — narrowing of the bony canal in which the spinal cord resides. This in turn would make the cord susceptible to compression injury, which in turn would compromise its function. The neurosurgeon noted stenosis from C2 down to C5 — this includes the region of the

ASSESSMENT:
At this point, I believe this patient had some type of injury to the brain and possibly the upper cervical spinal cord. Again, he had chronic stenosis essentially from C2 down through C5 or so. Apparently, he was relatively asymptomatic prior to this injury except for some neck aching pain. I believe at the scene, he probably was apneic for a period of time and probably suffered a hypoxic/anoxic brain injury. I think the prognosis is poor. There is certainly not an obvious surgical lesion with regards to the brain.

Figure 5. Neurosurgical Report

spinal cord that regulates breathing and so this is a reasonable mechanism for the man's breathing to have been compromised and for this in turn to diminish blood supply to the brain, or in the neurosurgeon's words, "he probably was apneic for a period of time and probably suffered a hypoxic/anoxic brain injury." He also noted that he did not find any "surgical lesion" (thereby ruling out such head impact injuries as skull fracture or hematoma).

In another note (not shown) the neurosurgeon also described a fracture of C5 and this would be consistent with a so-called diving-type injury, i.e. the type of neck injury that is sometimes produced when a swimmer dives into shallow water.[5] A CT of this injury is provided [Figure 6]. Note that the injury includes a vertebral body which is fractured essentially in half (arrow).

Based on the above discussion, the biomechanical expert concluded that the brain was not directly injured by the force of the mechanical impact with the ground; rather, the ground merely served to stop the motion of the head. It was the momentum of the "falling" torso and limbs that fractured the cervical spine and thereby injured the region of the spinal cord that controls breathing and this in turn disrupted the brain's oxygen supply. Thus, the tissue of the brain was not injured by the impact force per se and so, a somewhat softer flooring surface would not be expected to affect this injury mechanism or to mitigate the outcome.

Case Study 4: "Impact Speed vs. Injury."

This case study is entitled "Impact Speed v. Injury." In this example, the expert is asked to address a question with a seemingly-obvious answer: If an impact between two vehicles had occurred at a lower speed, how would that have affected the injury severity?

According to the police report, this was a two-vehicle impact with Vehicle 1 stopped in a cross-walk and facing North and Vehicle 2 heading east and impacting the driver side of Vehicle 1. The driver of Vehicle 2 (D2) suffered severely comminuted pelvic fracture and died shortly after arriving by EMS at the emergency room. Two accident reconstructionists studied the case. Their calculations produced two very close values for the impact speed, ranging from 55 to

AIS	SEVERITY
0	NONE
1	MINOR
2	MODERATE
3	SERIOUS
4	SEVERE
5	CRITICAL
6	MAXIMUM INJURY (VIRTUALLY UNSURVIVABLE)

Figure 7. AIS Levels[7]

AIS	Approx. Fatality Rate
1	.0
2	.1
3	1.
4	10.
5	50.

Figure 8. AIS vs. Approximate Fatality Rate

58 mph. The biomechanic was asked to address the effect on D2's injury if the impact speed had been 54 mph.

The Abbreviated Injury Scale (AIS) is a well-established, widely used methodology for assigning a relative ranking or severity to different injuries. It is based on the likelihood that a given injury will be survivable and in fact, aggregates injuries into one of 6 levels, designated AIS1

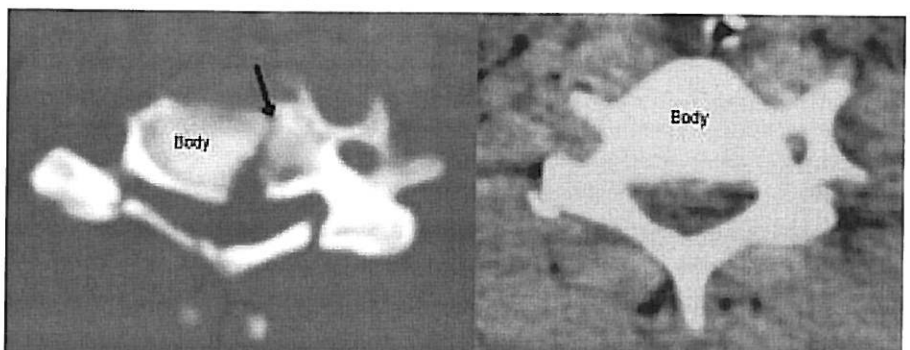


Figure 6. CT showing vertebral fracture (left) and no fracture (right)

through AIS6, which correspond to increasing severity [figure 7] and decreasing likelihood of survival[6] [figure 8].

Biomechanical Analysis. The expert discusses that the fracture was not a hairline or minimal fracture, but rather a severely comminuted fracture. Therefore, even if the speed (and hence the energy) of the impact were somewhat reduced, the resulting injury would still be expected to be a comminuted fracture (although somewhat less comminuted than the original fracture.) Thus, the AIS rating, which does not specify degree of comminution, would stay the same and so the fractures in the two scenarios — original and lower speed, would have the same AIS and hence the same probability of fatality.

Thus, if the impact speed were lowered to 54 mph (and hence the vehicle was traveling within the 55mph speed limit) the outcome would not have changed. This analysis can also be quantified as follows: the AIS specifies six levels of injury and so, on the average, about 55mph/6 = 9.2 mph/injury level. Thus, a change of less than about 9 mph would be expected to stay within the same injury severity. Again, this is not to say that there would be no change in the impact and the injury, but rather, that the change would not be clinically significant with regard to the likelihood of survival.

Conclusion

Biomechanical injury analysis can apply an established, well-regarded methodology, used by professionals in a variety of fields including product development, health care and safety regulations, to address such issues as: did an injury occur, was it caused by a particular event and if not, what was the cause? In some instances, the answers to these questions are not the same as might be initially thought.

Endnotes

1. Pike JA (2008): Forensic Biomechanics: using medical records to study injury mechanisms, SAE, Warrendale.
2. Braunwald E (1987): Harrison's Principles of Internal Medicine, 11 Ed., McGraw-Hill, p.1238.
3. Pike JA (1990): Automotive Safety: anatomy, injury, testing & regulation (SAE, 1990).
4. Note 3.
5. Pike JA (2002): Neck Injury: the use of x-rays, CT's and MRI's to study crash-related injury mechanisms, SAE, Warrendale.
6. Ulman MS (1986): Evaluation of the AIS as a measure of probability of death, Proc. 1986 IRCOBI Conf, Zurich.
7. The Abbreviated Injury Scale (1990): Association for the Advancement of Automotive Medicine, Des Plaines.