

AUGUST 2011

Biomechanics of auto accidents

Injury mechanics and medical opinion combine to form the testimony for injury causation

By John C. Gardiner and Check Y. Kam

To succeed in a personal-injury auto claim, the plaintiffs must prove that the forces applied to them by the defendants' action (or inaction) caused or substantially contributed to their injury. Accident reconstruction engineers commonly quantify the dynamics of an auto accident experienced by the plaintiff whereas medical doctors typically diagnose and treat the plaintiff's injuries.

Historically, individuals from both professions may have offered opinions regarding injury mechanism and causation, but reconstruction engineers often lack formal training in anatomy, physiology and injury mechanics, whereas medical doctors often have no formal training in engineering mechanics, occupant loading, and tissue tolerance to injury. Thus, many accident reconstruction

Copyright © 2011 by the author.
For reprint permission, contact the publisher: **www.plaintiffmagazine.com**



engineers and medical doctors potentially stray outside their areas of expertise when rendering opinions about injury mechanics.

Who's the expert?

Injury biomechanics experts generally have formal training in both engineering mechanics and tissue injury. How this training is acquired can vary. Often injury biomechanics experts have undergraduate engineering degrees with graduate degrees (MS or PhD) in biomechanics, kinesiology, or bio/biomedical engineering with a focus on injury mechanics. Some biomechanics experts have medical degrees combined with degrees in engineering or biomechanics. Whatever combination of degrees is possessed, a biomechanics expert should have formal training in applying engineering principles to the failure of biological tissue. Just as you would expect an engineer analyzing bridge failures to have tested concrete and steel, you should also expect an injury biomechanics expert to have tested biological tissues.

From an engineering or mechanical perspective, an injury biomechanics expert's training includes an understanding of how different parts of the human body react – and interact – to external forces, how stresses and strains develop in tissues during an impact, the failure mechanisms and tolerances of different types of tissues, and the wide variability in the mechanical properties of biological tissue. From a medical perspective, a biomechanical expert's training includes the anatomy and physiology needed to understand medical diagnoses, different injury classification schemes, and the neuromusculature and reflexes that can exacerbate or attenuate the response to externally applied forces. This combination of engineering and medical knowledge is needed to properly understand the biomechanics of injury.

A properly educated biomechanics expert can offer opinions on topics including injury mechanism, accelerations/forces applied to the occupant, occupant motion (kinematics), restraint use and effectiveness, and driver identification. A variety of new technologies and research studies are available to biomechanics experts to assist in their analysis of auto accidents. The following paragraphs will highlight some of the latest tools, testing, and publications that can be used to answer biomechanics questions in auto-accident cases.

Event data recorders

Similar to airplane crash investigators that are able to use information from the "black box" or flight data recorder to answer technical questions, accident reconstruction and biomechanics experts can often utilize on-board devices in automobiles that record information about an accident. In automobiles and trucks, a "black box" is more formally known as an event data recorder (EDR). As the name implies, EDRs are usually only activated by a collision event. Automotive EDRs do not continuously record data during normal driving like an airplane flight data recorder. The National Highway Traffic Safety Administration (NHTSA) defines an EDR as *a function or device installed in a motor vehicle to record technical vehicle and occupant information for a brief period of time before, during and after a crash for the purpose of monitoring and assessing vehicle safety system performance*. The type of information recorded and duration of the recording depends upon the EDR source.

Passenger-vehicle EDRs are usually part of the airbag control module, a small box located under the front seats or near the center console. Nearly all new passenger vehicles have some form of EDR. Recorded information typically includes crash details such as speed change (or delta-V) and may include pre-crash details such as vehicle speed, engine speed, throttle position, brake application, occupant presence, occupant size, seatbelt usage, and seat position. Whether or not this information can be retrieved is another story. Data from most GM, Ford, Chrysler and Toyota vehicles is accessible using publicly available, albeit specialized, electronic tools that many accident reconstruction and biomechanics experts are trained to use. Data from other vehicles is presently only accessible by the manufacturer and data retrieval has been limited in many cases. Other manufacturers will typically only retrieve EDR information for a crashed vehicle in criminal matters (in response to a court order) or in a civil suit in which they are a named defendant. With the accessibility and type of EDR data varying between vehicle makes and models, the NHTSA has introduced new rules (49 CFR 563) to standardize the recorded parameters, trigger thresholds, and access to EDR data for passenger vehicles weighing less than 8,500 pounds. The new rules are currently scheduled to apply starting with model year 2013 vehicles and also require the manufacturers to make the necessary access tools and software available to the public.

Airbag controllers generally monitor for frontal collisions as well as lateral collisions in vehicles equipped with side airbags. When these controllers measure a collision pulse greater than a preset threshold, they will activate or "wake up" in preparation for a possible airbag deployment. If the controller decides the collision is sufficiently severe, the airbags are deployed. If the collision is not severe enough, no airbags are deployed. In both cases, the decision as to whether or not the collision is a deployment or non-deployment event is made within tens of milliseconds. Both event types activate the EDR function within the airbag module and collision information is recorded.

If the collision pulse is less than the threshold to "wake-up" or is in a direction not monitored by the airbag module, no collision data is recorded. For example, rear-end impacts do not typically result in event data being recorded for the struck vehicle (except for some Toyota vehicles) but data would likely be recorded for the striking vehicle. Sometimes no data is recorded in seemingly severe lateral collisions because the system may not monitor for lateral impacts and the frontal portion of the deceleration is not sufficiently severe.

Copyright © 2011 by the author.
For reprint permission, contact the publisher: **www.plaintiffmagazine.com**



After an airbag deployment, the EDR will permanently lock any data in memory, and it cannot be overwritten. Additionally, the airbag control module is a single-use item so it must be replaced if the vehicle is repaired. In cases involving airbag deployment, the data may be uploaded and saved for later analysis. Alternatively, the actual airbag control module may be physically removed and preserved as evidence for any legal proceedings as it is no longer a useful part of the vehicle. If the vehicle is repaired before the data is accessed, repair shops will usually dispose of the modules and evidence will be lost.

In the case of a non-deployment event, collision data is not stored permanently and it may be erased or overwritten. How and when the event is overwritten is manufacturer dependent but generally occurs after a subsequent collision event or a preset number of ignition cycles. In cases involving minor collisions where the airbags have not deployed, there still may be useful data available but it must be accessed as soon as possible. [Check the September 2009 issue of *Advocate* for an article authored by David King containing a more detailed description of event data recorders and their potential applications in your auto accident cases.]

Soft-tissue injuries in rear-end impacts

Soft-tissue neck sprains and strains, commonly referred to as whiplash injuries, are the most common auto-accident injuries treated in US hospital emergency departments. For some individuals, these complaints resolve after a short period of time but for others the complaints may result in long-term disability. Due to the prevalence of these injuries, decades of research have been performed to understand how these injuries occur (injury tolerance) and what may be done to prevent them (improved vehicle or seat designs). Research studies have used a variety of approaches including human volunteers, cadavers, crash test dummies, animal models, and computer simulations.

One of the biggest questions and controversies surrounding those that suffer long-term whiplash-related neck pain is determining the anatomical source of that pain. Research projects attempting to determine the physiological source of neck pain have focused on the facet joints, spinal ligaments, intervertebral discs, vertebral arteries, dorsal root ganglia, and neck muscles. The findings of these studies suggest different anatomical sources may be the source of pain for different individuals and that the pain source may differ in short-term vs. long-term complaints. Of the anatomical sites listed above, research has most strongly linked the cervical facet joints with chronic whiplash pain.

There are two facet joints between each pair of cervical vertebra from C2 to C7. The facet joint is a synovial joint enclosed by a thin, loose ligament known as the facet capsule. The motion of the cervical facet joints during whiplash-like impacts have been characterized in both human volunteers and cadaveric specimens (Cusick et al. *Spine*. 2001; Kaneoka et al. *Spine*. 1999; Pearson et al. *Spine*. 2004). Based on documented joint motion, two mechanisms of facet joint injury have been proposed: pinching of the synovial fold and excessive strain of the capsule. Ono et al. (*Stapp Car Crash Conference*. (1997) and Kaneoka et al. (1999) observed that the cervical vertebrae rotate about a higher instantaneous center during a whiplash exposure than during normal voluntary motion and proposed that this abnormal motion compresses the posterior facet surfaces together, pinching the synovial fold. Excessive facet capsule strain during whiplash has been demonstrated by numerous groups which may explain whiplash injury in some individuals (Luan et al. *Clin Biomech* 2000; Pearson et al. *Spine* 2004; Yang and King. *Pain Res Manag* 2003; Yoganandan et al. *Accid Anal Prev* 2002). Also, head-turned postures can double peak capsule strain during simulated whiplash loading (Siegmund et al. *Spine* 2008).

Motorcycle helmets

Despite a mandatory helmet law in California and most other states, questions often arise concerning motorcycle helmets and their relationship to a head or brain injury that occurred in an accident. Attorneys litigating cases in which such an injury is alleged to have occurred may face issues such as a plaintiff's comparative fault for not wearing an appropriate helmet or a helmet manufacturer's potential liability for failing to give adequate instructions regarding the use of the manufacturer's product. Often, analysis of these cases by a biomechanical expert follows a relatively simple line of reasoning: Was a helmet being worn (properly)? Was the helmet approved for motorcycles? Would a helmet (or better helmet) have reduced the injuries sustained by the plaintiff in the accident?

Though each case is different, the analytical approach is often similar. First, the motorcycle helmet that the plaintiff was wearing (or claims to have been wearing) at the time of the accident is inspected along with a thorough review of the motorcyclist's medical records that describe the sustained injuries. This information is combined with data from the scientific literature regarding injury tolerance and helmet effectiveness to answer the relevant questions. In some cases, full-scale impact tests of exemplar helmets may be needed to reconstruct the severity of the head impact and to assess whether a helmet defect may have been present. Research has clearly shown that not all helmets are created equal and that different helmets offer differing levels of protection.

Pedestrian impacts

When it comes to auto accidents, pedestrians are by far the most vulnerable road users. Unlike occupants within vehicles or on motorcycles/bicycles, pedestrians do not have the luxury of having protective equipment such as seatbelts, airbags, and/or helmets. Pedestrians often receive debilitating or fatal injuries even after relatively low speed collisions.

Copyright © 2011 by the author.
For reprint permission, contact the publisher: **www.plaintiffmagazine.com**



When investigating pedestrian-vehicle collisions, it is important to gather as much information as possible. Important details include the injuries to the pedestrian, the damage to the vehicle (indicating contact from head or other body parts), evidence left on the roadway (skid marks, debris, blood or other biological tissues), EDR download (if available), and the final rest positions of the pedestrian and vehicle.

Injury alone is usually not sufficient to determine vehicle impact speed. However, by combining information such as the rest position and impact location determined by physical evidence on the roadway, an estimate for the speed at impact can be established. Subsequently, the injuries can then be evaluated to see if they are consistent or inconsistent with the calculated impact speed. In addition, the location and type of injuries can be analyzed along with the damage to the vehicle to establish the pre-impact orientation and speed of the pedestrian relative to the vehicle.

Conclusions

Much like other scientific disciplines, the field of biomechanics is constantly evolving. New scientific tools are available such as EDRs that allow trained experts to obtain vital information about an auto accident such as vehicle speed, impact severity, seatbelt use, and seat position. New biomechanical research is published every year containing new data on injury tolerance, occupant kinematics, restraint effectiveness, and other biomechanics measures that may be vital to your case. Biomechanical experts have a duty to stay current with research and rely on the most up to date published literature. It is far too common of an occurrence to see forensic experts relying on "old" research that supports their opinion despite the existence of new peer-reviewed research that refutes the earlier research.

Attorneys, just like experts, benefit by understanding the science of auto accidents and keeping up to date on the latest research. The more educated you are concerning the scientific principles that govern fields such as injury biomechanics, the better you will be equipped to evaluate your cases and cross-examine opposing experts. In all cases, documentation and preservation of evidence is essential. The latest technologies and research are useless for a biomechanics expert evaluating an auto accident if the EDR has been thrown away or a damaged seatbelt replaced.



Gardiner

John C. Gardiner (PhD, PE) is a Principal and Senior Biomechanical Engineer in the Orange County, California office of MEA Forensic Engineers and Scientists. *MEA Forensic is a multi-disciplinary forensic investigation firm with additional offices in Vancouver, British Columbia and Toronto, Ontario. Dr. Gardiner has a BS degree in Mechanical Engineering, a PhD in Bioengineering, and is licensed as a Professional Mechanical Engineer by the State of California. He is responsible for conducting investigations to assess injury mechanics in cases involving automobile collisions, falls, and sports injuries.*



Kam

Check Y. Kam (MS, PE) is a member of MEA Forensic's Injury Biomechanics group. Mr. Kam is licensed as a Professional Mechanical Engineer in California and holds a BS degree in Aerospace Engineering and a MS degree in Mechanical Engineering. Mr. Kam has special expertise in vehicle-pedestrian collisions developed over years of research and he has several publications in that area.

Copyright © 2011 by the author.
For reprint permission, contact the publisher: **www.plaintiffmagazine.com**