Rami Hashish, PhD
NATIONAL BIOMECHANICS INSTITUTE AND ADJUNCT CLINICAL FACULTY AT THE UNIVERSITY OF SOUTHERN CALIFORNIA

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The interplay of accident-reconstruction and biomechanics experts

THESE EXPERTS CAN DETERMINE ACCIDENT DYNAMICS AND THE ENSUING POTENTIAL FOR INJURY TO A SPECIFIC PERSON

There were 6.3 million police-reported motor-vehicle collisions in 2015, resulting in 2.44 million injured occupants and 35,092 fatalities – a 7.4 percent rise from the previous year. (NHTSA) Despite the staggering numbers, there is consistent debate whether collisions, particularly those of the "low speed" variety, can result in injury. The debate seemingly intensifies – at least from a litigation perspective – when functional independence declines and medical bills rise. The (multi) million-dollar question thus remains: Did the motor-vehicle collision (MVC) cause the injury?

When attempting to determine the ever-elusive injury question, legal teams from both sides of the debate spend exorbitant fees on experts to help scientifically ascertain the answer with a reasonable degree of certainty. Experts commonly relied upon include those in medicine, accident reconstruction, and biomechanics. Despite variable educations, skill-sets, and backgrounds, these experts occasionally provide opinions across the scope of the other's discipline(s), and in doing so, overextend their own relative expertise(s). Whereas the medical expert is best suited to determine injury causation, it is the role of the biomechanics expert to determine injury potential. In doing so, the biomechanics expert typically relies on findings provided by the accident reconstructionist.

Considering the debate surrounding the potential of spinal intervertebral disk injury from motor-vehicle collisions, let's deliberate on the following case to better understand the role of the respective experts:

> A 45-year-old female with pre-existing scoliosis, but who is otherwise asymptomatic, is rear-ended when traversing through a slowing intersection. Seemingly because of the first impact, she collides with the vehicle in front of her. Following the collisions, she reports of neck pain and weakness to her right wrist. The symptoms limit her ability to drive, exercise, and work. Following one year of visits to pain management specialists, chiropractors and physical therapists, her pain and radicular symptoms maintain. Accordingly, her orthopedist suggests fusion to her C6-C7 vertebrae.

Injury causation

A three-step systematic approach to determine injury causation was proposed by Dr. Michael Freeman and colleagues. As part of this approach, the treating practitioner is to determine whether (1.) There is biologic plausibility for the injury; (2.) There is a temporal association between the collision and symptom onset; (3) There is a lack of a more probable explanation of the symptoms. If all three criteria are met, these authors contend that, from a medical perspective, intervertebral disc

injury "can result from any MVC regardless of magnitude." (Freeman, Centeno and Kohles)

Assuming all three criteria are met in the example case, a medical expert may deduce that the radicular symptoms experienced by the occupant are indeed caused by the collision in question. However, lacking the educational framework, as well as sufficient case evidence to deduce accident dynamics and experienced forces, the medical practitioner is likely ill-suited to ascertain whether the injury in question was more likely caused by the first or second impact.

Considering the systematic approach to deducing causation, it is evident that a traditional biomechanics expert is unqualified to determine causation as they often lack the clinical skills to assess the patient, deduce temporality of symptoms, and/or interview the patient to determine competing causes for the symptoms. Yet, using their background in physics, engineering, and anatomy, the biomechanics expert – in conjunction with the findings from the accident reconstruction – is seemingly perfectly suited to deduce injury mechanisms and potential across the two impacts.

Injury risk

The biomechanics expert is to utilize the available evidence to assess injury plausibility. The first step in determining injury

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risk, is to understand the dynamics of the collision in question – a role typically commissioned to the accident reconstructionist. The second step is to utilize the provided findings and apply them to the specific case and patient facts to determine injury potential.

Accident reconstruction

Experts in traffic crash reconstruction use the laws of physics and engineering principles to determine the dynamics of a collision, including pre- and post-impact traveling speeds and trajectories. As part of the analysis, these experts aim to assess contributing factors to a collision, such as vehicle speeds and integrity, roadway conditions, and scene geometry.

A systematic multifactorial approach is required to adequately investigate collision dynamics. Factors considered during the reconstruction include, but are not limited to, scene geometry and photographs, legal testimony, skid/tire marks, roadway gouges, and vehicle specifications and fidelity. Accordingly, it is customary for investigations to include scene and/or vehicle inspections.

As part of the reconstruction, experts may rely on one or more of the following methods of analysis:

EDR

Many new vehicles nowadays are equipped with an onboard Electronic Data Reorder (EDR). The EDR tracks crash information, including vehicle traveling speed pre-collision, seatbelt use/non-use, airbag deployment, and delta-v (i.e., the change in vehicle velocity following impact). EDRs, however, do not always record data for low-impact collisions and may only record longitudinal (and not lateral) delta-v's. Bosch is arguably the world leader of Crash Data Retrieval (CDR) products. The entry CDR Diagnostic Link Connector Kit includes most components needed to retrieve EDR from many vehicles readily sold in the U.S. and Canada.

Crush analysis

In a crush analysis, the amount of crush damage to the respective vehicles is analyzed through a 3D scan of the vehicle, direct measurements (e.g., via tape measure) and/or still photographs. By assessing the crush depth, length, and angulation of impact, the amount of crush energy, and accordingly, the delta-v, can be calculated. Scans are also often taken of the scene to better understand relative geometries. Rendering a 3D model may provide more accurate crush measurements than either direct measurements or still photographs, and serve as a visually appealing trial exhibit.

Momentum analysis

The law of conservation of momentum states that for a collision occurring between one object and another, the total momentum of the two objects before the collision is equal to the total momentum of the two objects after the collision. Utilizing this principle, and considering previously published research, findings from the crush analysis, and/or testimony regarding traveling velocities, the delta-v of vehicles can be ascertained.

Software

Experts are increasingly performing accident reconstruction analyses via readily available software, such as PC Crash. Such collision and trajectory simulation tools allow for a robust analysis of vehicle dynamics and creation of animations that can serve as trial exhibits.

Upon establishing the dynamics of the accident, the expert shall form opinions with a reasonable degree of accident reconstruction certainty. Typical opinions pertain to the area of impact, traveling speeds, closing velocity (i.e., the relative difference in speeds between vehicles at impact), delta-v's, and/or the Principal Direction of Force (PDOF; i.e., directionality of impact). These opinions are to be provided thereafter to the biomechanist.

Biomechanics

Equipped with the accident reconstruction report/findings, the biomechanics expert aims to deduce occupant dynamics and compare applied forces to established injury tolerances.

An example systematic approach is as follows:

Review of medical records

As the biomechanics expert will not opine on injuries, but rather injury potential, the specific diagnoses by the evaluating and treating clinicians are to be determined from the medical records. It is also imperative for the biomechanist to have a thorough understanding of the patient's past medical history and physical condition to ascertain whether he/she was at an altered risk for injury relative to the general populous.

Accident reconstruction

Reviewing the findings of the accident reconstruction, the biomechanics expert extracts information pertinent to injury. Such information includes the area of impact, vehicle delta-v, crash pulse duration and PDOF. While many are familiar with the established relation between delta-v and injury (Gabauer and Gabler), what may be less understood is the influence of crash pulse duration. Crash pulse duration for traditional (non-rollover) collisions typically ranges from 80-200ms. A shorter duration indicates that the forces of the collision are applied to the body over a short time period, suggesting a higher potential for injury.

Testimony review

With a clear understanding of the medical records and accident reconstruction in tow, aim is placed upon "filling the gaps" with the available testimony. When reviewing depositions, unsurprisingly the fundamental goal is to extract any potential factors that may have contributed to injury. These include, but are not limited to, the occupant's positioning within the vehicle (e.g., neck position, arm position, feet position), whether (and where) they hit any aspect of the inside of the vehicle upon impact, and seat-belt use/misuse.

Kinematics and kinetics analysis

Considering previously published research and crash test data, the findings from the medical records, accident reconstruction, and testimony review, the general kinematic trajectory of the occupant,

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as well as the forces applied to/experienced by the occupant can be ascertained with a reasonable degree of biomechanical certainty. When conducting a force analysis, it is critical that the biomechanics expert examine all potential forces, such as those from the collision, internal impact(s) (e.g., between the occupant and the inside of the vehicle), the seatbelt, airbag, and intrinsic muscle contraction forces.

Injury mechanisms and tolerances

Injury mechanisms for the diagnosed injuries are determined via a literature review. The dynamics experienced by the occupant are then compared to known injury mechanisms. Considering known mechanisms, it is of great importance that the biomechanics expert does not relegate the analysis simply to experienced forces. Rather, the rate at which forces are applied (commonly referred to as the 'loading rate') and the directionality of those forces (as indicated by the movement of the occupant) should be considered. Indeed, Wang et al. demonstrated that static biomechanical analyses may underestimate the loads experienced to the spine by 30-60 percent relative to more dynamically applied forces (Wang et al.), whilst various research studies have shown that multiplanar movements may expose the spine to a heightened risk of disc injury relative to pure sagittal plane (i.e., flexion/extension) movement.

Following the aforementioned approach, consider our case study

Medical records: The subject female was diagnosed with C6-C7 radicular symptoms, yet there is debate from the treating clinicians and IME whether her disc protrusion is acute. Her past medical history was remarkable for scoliosis indicating to a heightened potential for disc injury (i.e., and thus, theoretically lower injury tolerance). At the time of the collision, she presented with a fresh one-inch gash above her right eyebrow.

Accident reconstruction: The accident reconstruction revealed a closing velocity for the first impact (i.e., rear-end) of 23 mph and a forward delta-v of 17 mph. This impact was described as a full-overlap rear-end (i.e., the frontal aspect of the impacting vehicle perfectly overlapped with the rear aspect of the subject vehicle). The closing velocity for the second (i.e., frontal) impact was 14 mph with a rearward delta-v of 13 mph. There was greater crush damage to the front passenger side of the subject vehicle, with a PDOF of ~15°.

Testimony review: At the time of the collision, the occupant claims that while her back was resting on the seat-back, her seat was pulled fully forward. She cannot recall whether she impacted any aspect of the inside of the vehicle as she lost consciousness. She further testifies that she was wearing her seatbelt, which was confirmed by the accident reconstructionist in their analysis of seatbelt use.

Kinematics and kinetics analysis: Previously published research indicates that during a rear-end impact, the occupant initially moves rearward into the seatback before moving forward thereafter; forward motion is ultimately arrested by the seatbelt. In the subject collision, there was a secondary frontal impact, which, according to the accident reconstruction analysis, likely occurred within 500-600ms following the rear-end collision. Considering that the duration of occupant motion to a rear-end is on the order of 400-600ms (McConnell et al.), the secondary frontal impact likely caused the occupant to experience a relatively immediate jerk forward as she was returning to her baseline position. The jerk forward likely consisted of clockwise rotation and right lateral side bending as indicated by the PDOF.

The gash above the occupant's eye further indicates that she may have impacted some internal aspect of the vehicle. This is confirmed by a vehicle inspection, which revealed blood residue on the driver console. The movement of the head towards the direction of the driver console is consistent with the anticipated kinematic trajectory. The ability for the head to come into contact with the console was likely made more possible by the occupant's (fully-forward) driver seat position (among other factors).

From the findings of the accident reconstruction – namely the delta-v, PDOF, and crash pulse duration – the longitudinal and lateral g-forces involved in the collision are ascertained. Utilizing previous research, as well as biomechanical modeling, the g-forces experienced by the head and neck can also be determined. As a form of validation testing, calculated force estimates are compared to findings reported in crash tests of similar severity.

Injury mechanisms and tolerances: Tolerance for cervical disc prolapse to compressive and shear forces has previously been quantified. (Boden et al.; Duma, Kemper and Porta; Kleinberger et al.) By considering the pre-collision health of the occupant, their kinematics prior and in response to the collision, the crash pulse duration and viscoelastic properties of human tissue, and comparing the forces experienced by the occupant in the subject collision to such 'tolerance' limits, the risk for injury is determined with a reasonable degree of biomechanical certainty. Considering the totality of the findings, it is opined that 1) The rear-end collision was not sufficient in severity to initiate cervical radicular symptoms to the occupant; but 2) The frontal collision was sufficient in severity to initiate cervical radicular symptoms to the occupant.

Through using case facts, peer-reviewed research, and established scientific processes, methods, and calculations, the accident reconstruction and biomechanics experts can determine accident dynamics and injury potential. In the example case, the biomechanical analysis helps support, and provide rationale to the causation opinion provided by the medical provider. Such a multidisciplinary approach engenders a better understanding of the accident and injuries in question, and in doing so, may help you win your case.

(***Author's note:*** *The scenario described above is purely theoretical and does not reflect the opinions of the author, or any companies or institutions with which he is affiliated*

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including, but not limited to, the National Biomechanics Institute and the University of Southern California.)

Dr. Rami Hashish is a Principal at the National Biomechanics Institute and Adjunct Clinical Faculty at the University of Southern California. *Dr. Hashish holds his PhD in Biomechanics, Doctorate of Physical Therapy, Diploma in Traffic Crash Reconstruction for the Forensic Engineer, and is a Certified Slip & Fall Tribometrist. Dr. Hashish specializes in assessing accident dynamics and determining injury risk and mitigation across a variety of settings, including motor vehicle accidents, slip, trip, and fall events, workplace environments, and athletic participation. To secure Dr. Hashish as an expert, please visit www.nationalbi.com or email info@nationalbi.com.*

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