Whiplash Injuries and Low Speed Collisions: Confessions of an Accident Reconstructionist.

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Introduction

Prior to entering private practice, I had been fairly certain that most cases of whiplash were primarily inspired by avarice. In retrospect, I have often reflected on that bias. Where did it come from? It may have evolved to some degree from actually surviving several motor vehicle accidents (MVA) as a youth, but most of the bias, I suspect, was simply cultural. It's not surprising then that plaintiffs in low speed rear impact collisions (LOSRIC) face a challenging medicolegal battle. The fertile soil of juror bias, enriched by the creative, if occasionally disingenuous, testimony of defense experts, along with the recent spate of industrially inspired whiplash research, has provided a growing sense of beleaguerment among plaintiff personal injury attorneys. Fortunately, that immuring feeling of doom is misplaced.

Auto insurance carriers, saddled with a $19 billion annual expense for soft tissue injuries, have taken an expectedly firm stand. Perhaps unyielding, some would argue. With the latest weapon in the arsenal of defense attorneys--the accident reconstructionist--insurers have successfully repudiated many claims, including many valid ones.

Over the years, I've taught thousands of medical and chiropractic physicians the finer points of whiplash biomechanics. Their skilled testimony has no doubt often been crucial in the courtroom. The facts are, after all, overwhelming and irrefragable, and often the only antidote for the preconceived, yet incorrect, notions of the lay public--notions about crash damage and injury potential that are often exploited by defense experts.

In response, defense attorneys developed a new tactic: object to the physician's testimony regarding issues of biomechanics or the physics of the collision. This objection would be based on the fact that the physician is neither an accident reconstructionist nor a biomechanical engineer. The objection is frequently sustained and can be ruinous for the plaintiff, because these discussions are indispensable as a means of realistically portraying whiplash injuries, and because they are woven throughout the plaintiff expert's testimony and will thus serve as the source of repeated and distracting objections and disallowed testimony. The defense accident reconstructionist's testimony that the accident was trivial and could not have resulted in injury serves as the final act of perdition for the plaintiff. Jurors may be unduly impressed by the accident reconstructionist's seeming mathematical precision and occasional references to Newtonian physics.

Having become certified in accident reconstruction through Northwestern University's Traffic Institute, I can now provide an informed view from the bunker: both as a physician and researcher, and as an accident reconstructionist. It was both enlightening and frustrating to find that many of the claims made by accident reconstructionist's in cases I had worked on in the past were patently sophistic and scientifically baseless. In this article I will briefly touch on the realities of accident reconstruction as it relates specifically to LOSRIC and the common whiplash injury.

Accident Reconstruction

The goals of accident reconstruction are as varied as its applications. For example, an accident reconstructionist may be called upon to reconstruct a double fatal MVA occurring on an isolated roadway with no witnesses. Among other things, he/she may be able to determine which driver was at fault, the approximate speeds of the two vehicles, and whether headlights were on at the time of the crash.

As a science, accident reconstruction is based on the part of classical physics known as mechanics. Newton's Laws of Motion form the backbone for the methods used to determine velocity, change of velocity (delta V or ΔV), acceleration, direction of travel, and the timing of events. Using the arsenal of equations available, an accident reconstructionist can also calculate a vehicle's position on a roadway at any given point in time so that, for example, he/she might be able to tell which vehicle entered an intersection first, or whether one driver would have been able to see another vehicle at a specific time--facts that can obviously affect liability. But, as with any science, observations are of crucial importance in accident reconstruction. Without observations, such as measured skid marks or inspection of the nature and extent of damage to the vehicles, an accident reconstructionist can do no more than speculate.

Even when observations are available, some degree of uncertainly is inevitable. For example, when calculating a vehicle's speed before impact, an accident reconstructionist can use an equation that considers the length of skid marks, the coefficient of friction of the road surface, and a resultant drag factor based on the number of wheels skidding. Such equations are referred to as vehicle dynamics equations. For added precision, skid tests can be performed on that roadway with an exemplar vehicle equipped with the same tires. Because this is often impractical, estimates from published tables of different roadway coefficients of friction are used. This, of course, introduces a degree of uncertainty and imprecision into the calculation. Other potential problems with precision are hiding in the shadows as well. Suppose, for example, the driver braked hard for 200 feet before the wheels locked? In that case, the equation will underestimate the speed. What if we thought that all four wheels were skidding, based on poor quality police photographs, when in fact only two wheels actually locked? The equations will then overestimate the vehicle's speed. And what if the police measurements were inaccurate because of rain or poor light conditions?

Complicating matters, an accident reconstructionist will typically need to employ a sting of calculations, each subsequent formula often depending on values calculated from the last, in order to answer the critical question in any particular case. Thus, if a single calculation is inaccurate, the succeeding derivations will likewise be unreliable. To counter this problem, accident reconstructionist's will generally calculate a range of answers based specifically on the uncertainties present. Thus, their final range of results will usually contain the true values for speed, acceleration, times, vectors of travel, and other details. Often, these ranges will be fairly broad, such as a calculated pre-impact speed of from 63.5 mph to 74.0 mph. The important thing to consider here is that, if the calculations are accurate, the probability of the true speed falling outside this admittedly broad range is quite low. Consequently, if the maximum speed limit were 55 mph, these figures would be sufficient to establish liability.

Another method used to determine impact velocity relies on the assessment of crush damage to the involved vehicle. By measuring the degree of intrusion at a number of points, an accident reconstructionist can calculate, based on formulas that have been developed for this purpose, the approximate impact velocity that would have been necessary to cause that amount of damage. There are a number of limitations in using this method; particularly in dealing with new vehicle types that have not been sufficiently crash tested, and in assessing offset collisions involving both hard and soft areas of the vehicle. Nevertheless, the Barrier Equivalent Velocity (BEV), as it is known, is a viable method for estimating collision speeds. However, in primarily elastic collisions, where very little crush occurs, these equations become unreliable.

In order to satisfy certain federal motor vehicle safety standards that require a standard of crashworthiness at higher speeds (for example, offset barrier 30 mph collisions), manufacturers produce vehicles that behave relatively stiffly at lower speeds. As a result, significant amounts of energy can be transferred to occupants in low speed collisions where no permanent property damage occurs. The popular allegorical of "no crash, no cash" has no basis in fact.

Accident Reconstruction in LOSRIC

One of the more useful methods of analyzing same-direction, and specifically for our application, rear impact collisions, is the conservation of momentum equation. This equation is based on Newton's teachings and states, simply, that momentum is always conserved. The total momentum after the collision is the same as the total momentum before the collision. Thus, the sum of the products of the two vehicles' velocities and their weights (masses, to be more accurate) before the collision will be same as after the collision. And, in the example of a moving vehicle that strikes another stationary vehicle, if we have been able to calculate pre-impact velocity for the moving vehicle using vehicle dynamics equations, and if we know the weights of both vehicles, we can calculate the post-impact velocities of both using the conservation of momentum equation.

Unfortunately, in the cases of the low speed collisions frequently evaluated by accident reconstructionist's, there either are no skid marks or else they are not measured. Nor is the amount of vehicle damage sufficient to employ BEV formulas. Police reports often appear to be no more than make-work, with little in the way of tangible details provided. The police are loath to cordon off traffic merely to measure skid marks in minor traffic accidents and figures given are frequently only visual estimates.

Damage photographs of the involved vehicles, normally taken by claims representatives or insurance estimators, are usually provided to accident reconstructionist's months after the cars themselves have been repaired. Damage to important structures, such as bumper isolators and internal bumper or subframe components, is often not documented and typically not photographed, leaving the accident reconstructionist with very little to analyze. For example, bumper isolators that are frozen and nonfunctional behave drastically different from those that are functional. Occupant kinematics may be significantly affected. These unknown factors reside inside the black box of accident reconstruction.

Witness statements are notoriously unreliable in LOSRIC. After all, usually one or both parties was not paying sufficient attention to prevent the accident. And very few drivers can accurately estimate impact speed, especially when the vehicle is rapidly decelerating at the moment of impact. Surprisingly though, many accident reconstructionist's will rely on such nebulous evidence in their calculations, apparently to propitiate their patrons rather than face them with the honest confession that there is insufficient data from which to base any calculations.

To illustrate the degree of variation possible in these calculations, let me provide a case I was recently involved with as a chiropractic (not accident reconstructionist) expert for the plaintiff. Each side hired accident reconstructionists. This was a false start rear impact collision with the plaintiff driving a Honda and the defendant driving a larger Thunderbird. When a traffic signal that both drivers had been waiting at changed, they both proceeded. The woman driving the Honda had to abruptly stop again for traffic and the man in the Thunderbird did not notice her sudden stop and struck her from the rear.

The chief point of contention between the two accident reconstructionists was the amount of ground covered by the Thunderbird before impact because, with this information and using equation 1, an accident reconstructionist can estimate the impact speed of the Thunderbird. From this he/she can estimate the change in velocity and acceleration of the Honda.

$$Ve = \sqrt{Vi^2 + 2ad} \qquad \text{eq. 1}$$

where:
Ve = ending (i.e., impact) velocity
Vi = initial velocity
a = acceleration in ft/sec^2
d = distance in ft

Relying on witness' statements, the defense accident reconstructionist estimated the distance to have been about 8 ft, while the plaintiff accident reconstructionist estimated the distance to have been about 25 feet.

The normal acceleration of a passenger car is generally accepted to be about 4.8 ft/sec^2. A rapidly accelerating vehicle's acceleration may be 9.7 ft/sec^2. [Note: By comparison, a funny car's acceleration will exceed 50 ft/sec^2.] Here again, we must calculate a range of possible answers using eq 1. Using a conservative acceleration value (4.8 ft/sec^2) and a conservative intervehicle distance (8 ft), we calculate an impact velocity of 8.7 ft/sec, or 6 mph. At the other range of the scale, using a less conservative acceleration factor of 6 ft/sec2 and the longer initial intervehicle distance of 25 ft, we come up with a figure of 11.7 mph--nearly double the other estimate. And, using a regression equation that I developed (1 p17), we could calculate an acceleration to the head of the occupant of up to 16 g--certainly sufficient to cause neck injury and/or mild traumatic brain injury in some occupants.

The defense accident reconstructionist estimated the ΔV of the Honda to be about 2-3 mph (ΔV will be less than the impact velocity if the struck vehicle has any mass). Consequently, the value of acceleration calculated was about 1 g which, as the accident reconstructionist quickly pointed out in court, is about the energy experienced with plopping into a chair. This can be calculated with equation 2:

$$\mathbf{a} = v/t \qquad \text{eq. 2}$$

where
$\mathbf{a}$ = acceleration in ft/sec^2
v = change in velocity (ΔV) in ft/sec
t = time in seconds

A ΔV of 3 mph equals about 4.4 ft/sec; the typical time for these collisions is about 120 to 300 msec, so t = about 0.2 sec:

$\mathbf{a}$ =4.4/0.2, or 22 ft/sec^2

Since 1 g is equal to 32.2 ft/sec^2, 22 ft/sec2 equals about 0.7 g. But again, this is the <u>average</u> or mean acceleration of the vehicle. <u>Peak</u> accelerations to the occupant's head occurring during that 200-300 msec time frame have been measured in 5 mph crash tests using human volunteers to be many times higher. And it is the peak acceleration that we are most concerned with when assessing the potential for human injury. In the same vein, one can easily drown fording a river with an average depth of 3 ft. This is another case where measures of central tendency (e.g., mean, median, and mode) are less helpful than the maxima.

When accident reconstruction is misused

It is a common practice to report figures for velocity and acceleration with pretentious accuracy. For example, a velocity calculation presented in such a narrow range as, say, 2.0 to 3.0 mph should raise an immediate red flag. With the meager and unreliable data typically available in LOSRIC, we can rarely justify a more narrow impact velocity estimate than, say, 2-10 mph. Consequently, estimations for other parameters, such as acceleration are likewise imprecise.

As mentioned earlier, accident reconstructionists frequently report velocity and acceleration parameters for the vehicle and fail to consider the known variances between vehicles and their occupants. Moreover, the reported figures represent mean rather than peak figures. Equations such as eq. 2 tell us only the average vehicle acceleration for the entire time of the event. In order to know the exact acceleration at any given time we would have to develop a derivative using the differential calculus. Perhaps more definitive, of course, are the actual instrumented human volunteer crash tests clearly demonstrating human head accelerations 2-3 times higher than the vehicle in low speed crashes.

In testifying, many accident reconstructionists cite references of crash test and other experiments of McConnell et al. (2,3), Szabo et al. (4), West et al. (5), and Allen et al. (6). These are frequently mischaracterized so as to portray low speed impact collisions as trivial and entirely benign through the application of logically unscripted and muzzy-headed comparisons between experimental studies and real world motorists. Yet it is nearly impossible to extrapolate the findings of these limited studies to real world occupants for a number of reasons: 1. The experimental subjects are almost universally male, while epidemiological data tells us that females are injured more frequently and more severely. Thus we would be forced to commit scientific blasphemy to extrapolate beyond the data to include females or to theorize about accidents involving different speeds or conditions; 2. The experiments employ very small numbers of subjects who are cognizant of the impending collision and otherwise healthy, whereas recent studies have shown that a lack of awareness of impending impact is associated with 15 times the risk of poor outcome (7); and the unfavorable effects of preexisting degenerative changes have also been reported (8,9). While researchers attempt to downplay the awareness problem, its effect is always with us to an unknown degree; 3. Other variables, such as the out-of-position-occupant, have also been found to influence outcome negatively (10-15), yet volunteers are usually well positioned.

Finally, although several authors have reported temporary mild injuries resulting from these tests, none have reported any chronic injuries, a fact that contrasts quite sharply with the 40 or so outcome studies that have been published over the past 40 years. A meta-analysis of these studies shows that about 50-60% of those injured in rear impact collisions will have some degree of permanent pain; about 10% will become disabled (1 p74,16 p 325). From this disparity we can only conclude that either: 1. Some essential element in experimental design that would allow researchers to accurately simulate real world accident conditions is lacking in these studies, or 2. Long-term symptoms may have been present, yet unreported, in some of the volunteers, or 3. Whiplash really is one big hoax.

The most important of these crash test studies are those of McConnell et al. (2,3). They demonstrated that, for their group of healthy adult male volunteers, the threshold for soft tissue injury was about a 5 mph ΔV exposure. In all likelihood, the presence of known risk factors (e.g., female gender, having the head turned at impact, lack of awareness, use of seatbelt and shoulder harness, etc.) will drop this threshold significantly, thus rendering the accident reconstructionist an unnecessary novelty in LOSRIC since, on the one hand he/she cannot predict the actual collision velocities with any meaningful precision and, on the other hand, because knowing the precise impact velocity value would be meaningless anyway, since we do not, as yet, have any satisfying way of associating collision velocities and human pathology.

This should be self-evident when one considers that, in a given accident, some occupants are injured (or even killed), while others are unscathed. Certainly, knowing the precise impact velocity or acceleration would not have allowed us to make any reasonable predictions for outcome. In fact, it is fantasy to expect that we will ever discover <u>the</u> specific crash parameters that cause injury when the human variable is so very complicated. And this, of course, brings us back to medicine because it is ultimately the purview of the physician (D.C., D.O., or M.D.) to determine the veracity of the patient's complaints and the extent of their impairment.

It's been my experience that many accident reconstructionists and biomechanical engineers will rather unabashedly venture into the field of medicine, arrogantly opining that an occupant should not, or could not, have been injured in a given collision. It is clear to me, after many years of research and clinical experience, and a thorough familiarity with the literature, that such forecasting abilities are as scientifically baseless as astrology. In truth, depending on risk factors present, injury is possible in very low speed collisions.

The work of Allen et al. (6) deserves special note. These researchers attached accelerometers to human subjects and had them simply plop into chairs. Measuring spikes of acceleration within the ranges of those recorded by other researchers in human volunteer crash testing at low speeds, Allen et al., employing an unqualified extrapolation, suggested, in essence, that LOSRIC are no more dangerous than plopping into a chair. The primary fault in this comparison lies in the duration of the acceleration and the ΔV experienced by the chair plopper. In the crash victim the duration of acceleration is long (300 msec or so) and the ΔV is significant. As a result, the head and neck are moved violently and injury sometimes results. In contrast, the lack of appreciable ΔV, coupled with the very brief duration of acceleration (less than 10 msec) in chair plopping probably explain why physicians so rarely treat chair injuries. Unfortunately, comparisons of LOSRIC and chair plopping, while scientifically flawed and purely sophistic in nature, can sway a scientifically unsophisticated jury--particularly one lacking the benefit of reasonable counter testimony. For a more in-depth discussion of these studies see references 1, 16, and 19.

What about damage?

Earlier I alluded to the fact that using vehicle crush damage as a yardstick of injury potential is invalid. Large epidemiological studies have shown that nearly 80% whiplash injuries occur at crash speeds below about 12 mph (7,15). Other studies have shown that the threshold of damage for many passenger cars ranges from 8.5 mph to over 12 mph (2-5,17,18). Clearly then, a large percentage of real injuries occur in the absence of significant vehicle damage. Paradoxically, when significant damage does occur to the vehicle, the occupant is spared much of the energy that is used up in that crushing of metal and mechanical failure of the seat back. And, in fact, Foret-Bruno et al. have reported that the injury rate for crashes below 9.3 mph was 36%, whereas the rate above 9.3 mph dropped to 20%, probably because the collisions become more plastic at higher speeds (13). These relationships are illustrated in Figure 1.

Summary

Although the trend to employ accident reconstructionists to analyze LOSRIC and predict occupant injury has become popular in recent years, in most cases accident reconstruction cannot accurately or scientifically be applied to LOSRIC for a number of reasons. Although accident reconstruction is a valid science and honorable profession, it is clear that some accident reconstructionists are less concerned with the science of whiplash and less familiar with the scientific method than others. Logical and scientific violations are common among accident reconstructionists. Many accident reconstructionists have little or no background in science philosophy, physics, or human anatomy or physiology. And many are grossly unfamiliar with the whiplash and related literature. Research has shown that the threshold for injury to healthy adult males, under ideal conditions, is a 5 mph ΔV rear impact--a threshold that almost certainly is lower under a variety of real world conditions. Vehicle damage thresholds hover in the same range and epidemiological studies show that the majority of whiplash injuries occur at or below this vehicle damage threshold, thus laying to rest any notions that vehicle damage analysis can be used to gauge human injury potential. With luck, this fable will soon be no more than an historical footnote; evidence of a once distinct boundary between health science and the industry of health care.

Note: I have spared the reader the risk of turning to stone after gazing upon most of the formulas mentioned in this article. The subjects of accident reconstruction and LOSRIC are covered in more detail for the interested reader elsewhere (1,19,20), as is the general subject of whiplash (16).

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