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Relative Risks in Children and Small Females in Trauma: What Have We Learned?

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As late as the second edition of my textbook on whiplash,¹ I cited a 1982 report suggesting that children were at considerably less risk for injury than adults: "In fact," I wrote, "children up to 10 years of age are said to be at one-sixth the risk of neck injury from motor vehicle accidents as are adults"²

In a more recent (1988) Swedish study, Lövsund, et al.,³ analyzed data from the Folksam Insurance Company, one of the largest in Sweden. This data included 2,899 children and 7,169 adults that were involved in rear-impact collisions. The authors found that rear seat passengers were slightly more likely to be injured than front seat passengers (both adults and children) and children were slightly less likely to be injured than adults. This finding is curious in light of several more recent studies that suggest that the front seat position is more dangerous in terms of rear impact crashes. And, due to a likely study design problem that did not account for the now well known (but physiologically, still poorly understood) delay in onset of symptoms, the authors reported risks for injury that were much lower than those reported in the majority of the literature. Notwithstanding these criticisms, this data suggested that children are only slightly less likely to be injured in cervical acceleration/deceleration (CAD) trauma. They were found to be at about two-thirds the risk of adults. However, the long-term consequences in children have not been studied and it would be inappropriate to extrapolate from the data we have on adult outcomes.

A paper that may have come as a welcome relief for all of the doctors over the years who have asked me about this relative risk of injury for children in rear-impact MVC was that of Boyd, et al., which was published last year.⁴ This study focused on 4-16-year-olds presenting, over a period of one year, to ER departments in England. The goal was to compile data on incidence, severity, and clinical outcome. As an aside, there may be a potential bias in using a convenience sample from ER departments due to the fact that only a small percentage of CAD patients are seen at ERs in most municipalities, and this potentially

compromises the study's external validity. However, probably 98 percent of the published outcome studies have used this study design! Another problem that is common is that many who present to the ER do so only out of fear that they may have sustained a serious injury. Some of these persons are not actually injured, and are thus falsely enrolled in these studies. More rightfully, they are merely exposed to whiplash, not afflicted with it. Interestingly, the authors suggested the high incidence of CAD in this group might be due to a positive reporting bias of patients attending the ER-which is possible-although they did not consider the other possible ramifications.

Telephone contact was made with legal guardians and a structured interview was arranged. This took place approximately five days after the crash. Of course, we know nothing of the patients who did not seek care at the hospital. With those graded as (whiplash) grade one or higher, clinical review was also scheduled for 14 days, 28 days, and 56 days post-injury. (This again suggests that some grade zeros were included. A grade zero indicates no injury.) Overall, 105 children were followed (39 percent were front seat passengers; 61 percent rear seat). Of these, 32 percent were involved in frontal crashes, 18 percent in side impacts, and 50 percent in rear impacts. Due to the significant differences in crash mechanics and resulting occupant kinematics, as well as outcomes (i.e., rear impacts are more likely to cause injury and also carry a higher risk of poor outcome than frontal or side impact crashes), I hate to see these mixed studies, but this is another common study design, perhaps due to convenience more than anything else.

The overall incidence of CAD in these children was reported to be 47 percent (49/105), with 60 percent being symptomatic on the day of presentation to the ER. The remainder became symptomatic the next day. It is important to remember that most people become progressively less likely to present to an ER with longer lags in onset of symptoms (i.e., pain arising two days after an injury often seems less of an emergency than pain immediately following an event), so it is quite possible that this sample was biased toward a more immediate onset. Then again, there is no strong correlation with onset and outcome. Slightly more children were female, but the difference was not significant. Almost half (47 percent, or 23/49) of those injured were over the age of 12 years, and the age relationship was found to be significant. This age is also the age usually associated with puberty. Forty were graded as grade one and the remainder as grade two. The average recovery period for the former was 6.4 days, and for the latter, 19.7 days.

The authors, as many have done before, due to the confusing terminology used by the Quebec Task Force on Whiplash-Associated Disorders (QTF-WAD), misquoted the group as reporting a mean time to recovery of 28 days for CAD. In truth, the QTF defined *recovery* as a return to usual activities and did not even

collect data on clinical recovery. The recovery period reported by Boyd, et al. is markedly quicker than has been reported in adult studies, but the follow-up period was quite short and may not be as reliable as those following patients for 6-12 months or more. Unfortunately, studies such as these are rare. It would be helpful to have some type of reliable scaling system with which to compare children (and smaller adults) to those of larger adults, for which a greater body of tissue compliance and tolerance data already exists.

Mertz, et al.⁵, recently developed injury tolerance corridors based on human subject testing. And at least one other recent paper⁶ has suggested that these tolerance corridors may be quite overstated. However, there are limitations with that particular study: the forces are primarily calculated based on occupant kinematics using cadavers as subjects and classical physics (i.e., dynamics) to arrive at occipital load values. The results could be criticized in a number of ways:

1. Cadavers typically are older and frail, often with relatively advanced degenerative disease and-particularly in cases of those who died from terminal illnesses in hospitals-markedly osteoporotic. (This point is seldom addressed in studies of this kind.)
2. The material properties of their tissues may have been affected by embalming or refrigeration.
3. They have no resting or reflexive muscular tone or response.
4. The calculations are subject to systematic error and the precision of the method has not been determined.

Having said all of that, and setting aside the issue of the accuracy of these tissue trauma thresholds or tolerances (which can also be criticized on the basis of their relatively imprecise derivation), one comes to yet another problem: Since they are all derived from adult male test subjects, how can we scale them to apply to smaller women and children?

The most common method has been to use simple geometric scaling, the practical application of which is to merely decrease the tissue tolerances in direct proportion to the size of the occupant and/or size of the

tissues of interest (ligaments, tendons, etc.). The problems inherent in such a procedure include variations in tissue material properties with age. In very young children, skeletal structures are neither fully developed nor ossified. And the greater range of motion in the spine can also affect the relative strains on the different hard and soft tissues. Anulus fibers also are known to vary over the years (and no, it isn't "annulus" as many believe; the only other person that I have noticed to spell this term correctly is Nick Bogduk). As a result of this, it is expected that more reasonable scaling factors could be derived if these varying tissue properties were also taken into account, and that is the subject of a recent paper by Yoganandan, et al.⁷

Specifically, these authors developed scaling regression equations for cartilage; disc; spinal ligaments; vertebrae; spinal cord; and muscle; and the more familiar geometry that can be obtained for various tissues by digitizing CT or MRI scans. They also derived scaling factors for tension, extension moment, compression, and flexion moment. For example, for compression, the important tissues would be cartilage, vertebrae, and disc, not ligaments, muscles, and spinal cord. These latter elements, however, would be factors, for example, in a tensional scaling.

For the purposes of this analysis, the authors considered that there are no material property differences based on gender, but admitted that this is a potentially risky assumption based on differences between bone density as adults age. (For pregnant women, this is even more likely to be true, at least for ligaments during the second and third trimester.) Previous scaling attempts between adults and children have been based on the calcaneal tendon. This limits one to tension and extension loading scaling. A merit of the current study is that it allows for determination of loading mode-dependent scale factors for all four modes. Table 1 below provides a comparison of values obtained through the calcaneal tendon method and the current study's method. The numbers represent proportions of the 50th-percentile male, which has a value here of 1.00. A small (5th-percentile) female has about 50 percent of the tolerance to extension, for example, of a 50th-percentile male based on either method.

Age (in years)	Based on calcaneal tendon material property		Based on spinal component material property			
	Tension	Extension	Tension	Extension	Compression	Flexion
1	0.24	0.14	0.248	0.141	0.239	0.137
3	0.34	0.22	0.302	0.187	0.291	0.182
6	0.46	0.31	0.369	0.248	0.355	0.242
5 th female	0.63	0.50	0.630	0.501	0.630	0.501
50 th male	1.00	1.00	1.000	1.000	1.000	1.000

Table 1: External and spinal component tension, child-to-adult comparison of values.

From this table, it can be seen that very young children are likely to have much greater vulnerability to trauma than adult males.

This data should be helpful in considering the relative impact of motor vehicle trauma between adult males, females, and children in terms of tissue vulnerability. It does not necessarily follow, however, that these values are equivalent to the differential risk for injury, since there are many other conditions to account for, such as the relative fit of safety systems, differential restraint types between front and rear seats, etc. For example, kids more often ride in rear seats, which are generally safer than front seats. They tend also to have smaller backsets because of this - also reducing their risk of injury. Back seats in many cars still do not have shoulder harnesses and this also would decrease the injury risk in the case of a rear impact. And children have a greater cervical range of motion, less lifetime injury history, and virtually no degenerative disease. These are factors that also contribute to injury risk and outcome.

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