Explanation of injury causation in trauma to the lower spine

Saami J. Shaibani *

Visiting Professor of Physics
Department of Physics
Lynchburg College
Lynchburg, VA 24501

and

Principal Research Fellow
Department of Surgery
Temple University/Conemaugh Memorial Hospital
Johnstown, PA 15905

Paper was presented at the 21st Annual Workshop on Human Subjects for Biomechanical Research. This paper has not been screened for accuracy nor refereed by any body of scientific peers and should not be referenced in the open literature.

Abstract

The greater number of degrees of freedom in the articulating structures within the lower spine and pelvis can make their response much harder to model than gross structures such as the head and chest. This places higher demands on the quality of data required by a model and tends to increase the level of detail necessary to produce consistent results. Calculations of the differential motions that occur within the lumbosacral-pelvic complex have been performed to describe the occupant kinematics associated with certain types of trauma. This has provided additional insights that explain the mechanism of injury in cases when there is only limited understanding available from existing diagnostic approaches, which rely on clinical examination and a range of radiological techniques. Other benefits of this approach include the ability to conduct blind studies to generate independent results with the analytical model, the opportunity to obtain dynamic tolerances related to human subjects, and the development of a predictive resource for use in clinical and triage settings.

* Please address all correspondence to Johnstown, PA.

1. Introduction

Much of the initial research into automotive trauma involved full-scale tests with different types of human surrogate, ranging from anthropomorphic test devices (ATDs) to anesthetized primates to human cadavers. These surrogates could only act as an approximation to a real living person and they were subject to a number of constraints, including physical limitations, ethical considerations, viral concerns, and cost. The use of human subjects was confined to low-severity insults on volunteers drawn primarily from the military and research communities. The advent of programmable computers after the end of the 1950s introduced the possibility of being able to replicate physical systems with mathematical models that could be processed by various computing techniques. Among the first such analytical treatments were a number of contributions sponsored by the United States Department of Transportation through its contractor, Calspan Corporation, based in Buffalo, NY.[1-3] (Superscripted numbers in brackets denote references at the end of the paper.) This preliminary effort in the 1960s led to a computer model that was originally known as the Crash Victim Simulation (CVS) program, but later changes to this were referred to as the Articulated Total Body (ATB) program. The history of the CVS/ATB model can be considered to lie in three general categories, each of which loosely coincides with a different decade:

(1) 1970s In a continuation of the work in the 1960s, further progress was made at Calspan with the design of three-dimensional models[4-10] for execution on a mainframe computer. Fortran IV was the programming language employed in this research.

(2) 1980s Technical difficulties prevented the work on mainframe computers from moving out of the research domain, but a big advance took place when the work was transferred onto a minicomputer at the University of Oxford[11-17] where it became an everyday tool. Some new features were added to the model by using the updated language, Fortran 77. Concurrent studies[18-26] were still being performed during this period at Calspan and Wright-Patterson Air Force Base, Dayton, OH.

(3) 1990s After some successful trials on 286 microcomputers, the model was implemented for regular use on 386 microcomputers.[27-28] Similar research related to this was undertaken both in Arlington, VA, and in Dayton, OH.[29-32]

Practical use of the CVS/ATB model has been seen in the naval[33-34] environment in addition to the automotive and aeronautical environments already referred to above. The first applications of the model concentrated on head and chest injuries because these formed the basis of early legislative activity,[35-41] but there has been more recent attention to other body regions,[42-51] such as the legs, neck, and spine. Results from the model are usually compared with government standards, other tolerances, or clinical scores[52-57] to determine the effectiveness and reliability of the analytical techniques inherent in the model. The reader is referred to previous work for more details regarding this.[44, 49]

2. Methodology

CASE REPORT

A 39-year-old law enforcement officer was driving his midsize patrol car at approximately 32 kilometers per hour (kph) [20 miles per hour (mph)] when it was struck by a pickup truck that appeared suddenly from a parking lot on his right. (These vehicles are labeled "#1" and "#2", respectively, in Figure 2.1.) The nominal direction of impact was 60°, as measured clockwise from the forward direction of the struck vehicle. The law enforcement officer was 168 centimeters [5 feet 6 inches] in height, 75 kilograms [170 pounds] in weight, and he was correctly wearing a three-point seat belt. As a result of the impact, he experienced pain in the vicinity of the lumbar spine and the pelvis, but there was no complaint of injury to the head, neck or chest or to the upper or lower extremities.

All initial clinical examinations suggested no fractures or dislocations, and neither roentgenograms or other radiographs revealed any abnormalities. Several clinicians confirmed this in their assessments that the trauma was limited to a muscle strain. This was contradicted by the unusual persistence of pain, and upon yet further examination it finally emerged that there was an instability in the right side of the sacroiliac joint. The delay in detecting both the nature and the extent of this trauma prevented the correct treatment and management strategy from being instituted in a timely manner, thus compromising the recovery of the patient.

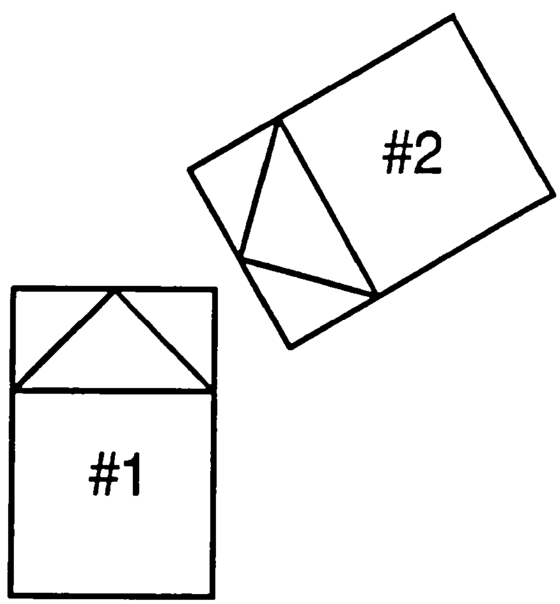

Figure 2.1 *Positions of struck vehicle #1 and striking vehicle #2 at impact*

The damage profiles of both vehicles were assessed to determine reasonable estimates for the primary change in speed Δv for the struck vehicle, and consistent values of about 24 kph [15 mph] were derived with a principal direction of force that was close to 45°. Additional information was obtained from a visit to the scene of the accident with the law enforcement officer, who was also present on a separate occasion when an inspection was conducted of the interior of the struck vehicle. His presence for the latter was particularly helpful because he demonstrated his driving posture and the associated location of the seat, and this allowed very reliable measurements of the passenger compartment geometry to be made for use in calculations with the CVS/ATB model. Data collected for this first set of circumstances are referenced in this study by the label N12CC301.

The same general approach outlined here was followed for all the other accidents considered during this research; however, special attention was paid to the above case for two reasons: first, only slight or moderate injuries might have been expected in what did not appear to be a very severe impact for a restrained occupant, and second, the debilitating trauma that actually occurred was not identified during conventional clinical examinations.

Although the main emphasis of this study was on possible trauma to the lower spine, other body regions were evaluated to provide a more complete picture of the impact event. For example, it is important to match a predicted non-injury with a known non-injury even in the simplest of circumstances because the success of this comprehensive analysis in doing so will then reinforce the confidence in results that suggest a significant probability of injury.

3. Results

Standard injury measures[56] for the head and chest are called the head injury criterion (HIC) and the chest severity index (CSI), respectively, and values derived for these by the CVS/ATB model are reported in Table 3.1(a) for the original case outlined in the previous section. The table also contains the parameters F(UN) and F(LN), which describe the maximum forces in newtons (N) [pounds (lb)] experienced in the anterior-posterior direction at the upper neck (near the C1 and C2 vertebrae) and at the lower neck (near the C6 and C7 vertebrae).[44, 49] All four values point to a low probability of injury to any region in the upper body, in agreement with what was reported by the occupant himself.

The remaining body regions that are of interest here can be represented by various structures within the lower torso, which encompasses the lower vertebrae and the pelvic complex. Although these regions do not have well-defined human tolerance data in the same manner as those in Table 3.1(a), the anterior-posterior (A-P), left-right (L-R), and superior-inferior (S-I) components of the maximum resultant force are listed in Table 3.1(b) as suitable indicators.

Table 3.1

Response calculated by CVS/ATB model for restrained occupant subjected to insult with Δv = 24 kph (15 mph) at θ = 45°

(a) upper part of body

body region	injury measure	value
head	HIC	202
upper neck	F(UN)	453 N (102 lb)
lower neck	F(LN)	475 N (107 lb)
chest	CSI	49 g

(b) components of the maximum resultant forces within lower torso [in kN (lb)]

body region	A-P	L-R	S-I	resultant
lumbar spine	− 8.97	− 5.44	− 4.52	11.42 (2568)
sacral spine	− 10.47	− 6.21	− 4.21	12.88 (2896)
left hip	− 6.58	− 3.66	+ 3.60	8.35 (1877)
right hip	+ 8.06	− 5.05	− 3.29	10.07 (2264)

The magnitude of the values for the lumbar spine (LS) and the sacral spine (SS) in Table 3.1(b) can be contrasted with the results for other insults in Table 3.2. (For a typical seated occupant, it should be noted that F(LS) = 0.30 kN [68 lb] and F(SS) = 0.32 kN [72 lb] when there is no insult.)

Table 3.2

Comparison of maximum resultant forces in lower spine from various insults

input data reference	severity kph (mph)	type of restraint	angle (deg)	F(LS) kN (lb)	F(SS) kN (lb)
N25L40P1	3 (2)	0	210	0.40 (90)	0.43 (96)
N26D8301	3 (2)	3	180	0.68 (153)	0.68 (153)
N4DMC301	3 (2)	3	180	0.61 (136)	0.65 (145)
N25L43P1	3 (2)	3	210	0.49 (111)	0.49 (109)
N6DMC301	5 (3)	3	180	1.14 (256)	1.13 (254)
N45L40P1	6 (4)	0	210	0.65 (146)	0.69 (155)
N46D8301	6 (4)	3	180	1.51 (340)	1.72 (387)
N8DMC301	6 (4)	3	180	1.30 (292)	1.59 (357)
N45L43P1	6 (4)	3	210	0.59 (132)	0.59 (133)
N07GT201	8 (5)	2	210	1.58 (355)	1.44 (323)
N05TC301	8 (5)	3	150	1.29 (290)	1.74 (391)
N05TC3P1	8 (5)	3	210	1.29 (291)	1.74 (391)
N66D8301	10 (6)	3	180	1.13 (255)	1.77 (397)
N1BLT301	16 (10)	3	330	0.73 (165)	0.77 (173)
N12CC301	24 (15)	3	45	11.42 (2568)	12.88 (2896)

A graphical complement to the data in Table 3.1 appears in Figure 3.1, which is a subset of an animated sequence on video tape[58] that was produced by a recent addition to the CVS/ATB model, known as the SJSFLMPC program.[44, 49] The sequence identifies the change in occupant motion throughout the impact event, and the main features illustrated in it can be summarized thus: a translation of the body towards the striking vehicle is followed by a rotation of the right side of the upper torso about the shoulder belt, thus creating a differential rotation of the upper torso with respect to the lower torso; this anticlockwise rotation along the spine is aggravated by the limited motion in the lower torso allowed by the lap belt, and the overall effect is the production of imbalances that are biased to the right side of the pelvis.

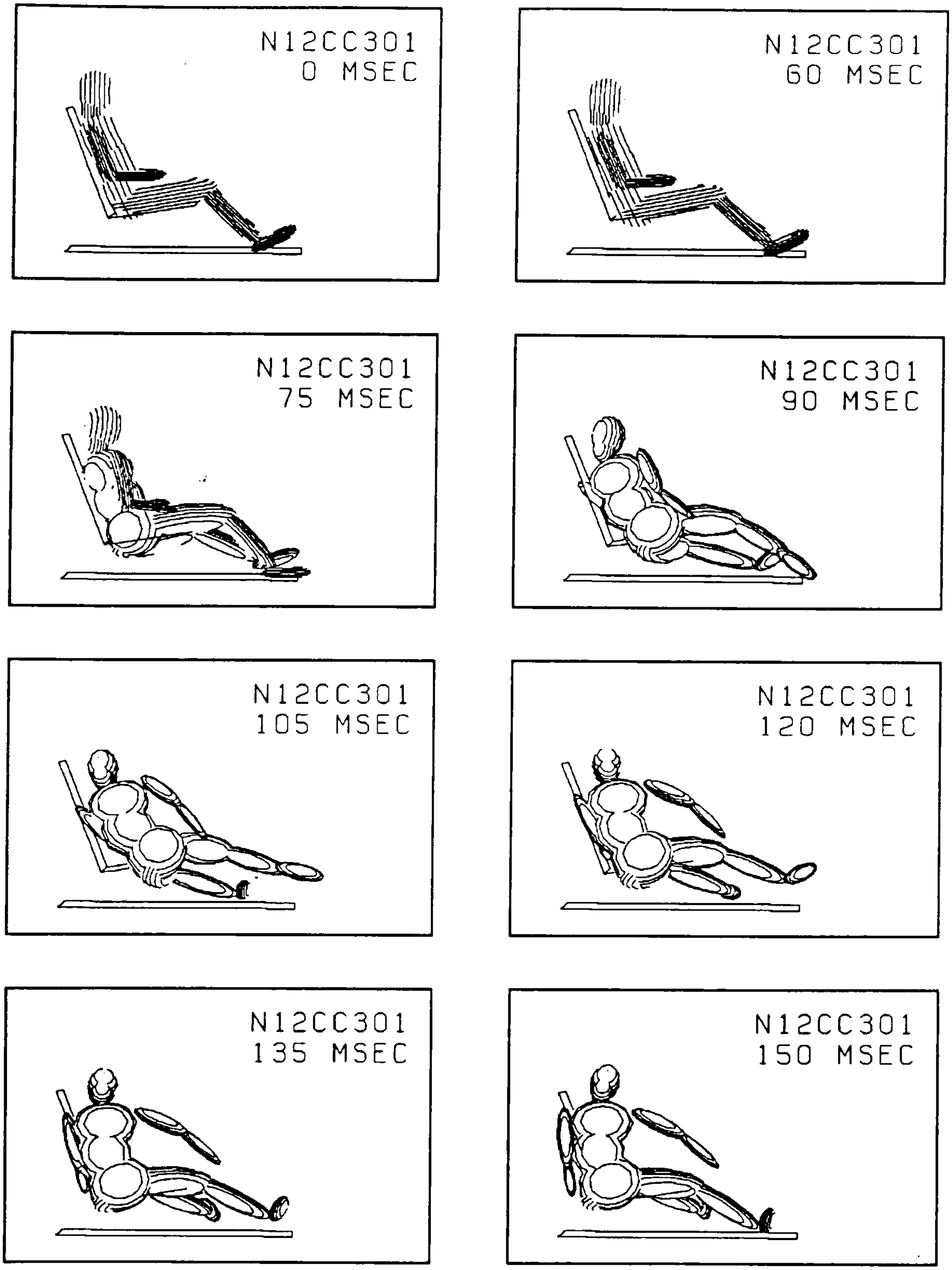

Figure 3.1 *Selected output from SJSFLMPC for CVS/ATB input data N12CC301*

4. Discussion

The following treatment is not intended to be an exact exercise; indeed, this would be almost impossible because so many of the parameters involved necessarily lie within a range of numbers rather than as single, precise values. Confounding factors, such as age and gender, will also introduce some variation. Taken together, these and other issues will inevitably produce some simplifications and approximations, but the overall effect should not change the basic outcome by a great amount. With this proviso in mind, the results from the previous section can be now explained by the analysis set forth below.

It is clear from the calculated values in Table 3.1(a) that the law enforcement officer in the case study that was presented in Section 2 had a low probability of head, neck, or chest injury. This finding agrees with the known non-occurrence of injury to these body regions and, although such a result might be expected to be a fairly simple one to prove, the ability of the CVS/ATB model to identify non-injury correctly is still an important achievement.

In the absence of any quantifiable data for human tolerances in the lower spine, it might be helpful to look at the values of F(LS) and F(SS) in Table 3.1(b) by invoking the values in Table 3.2. If a nominal level of about 0.85 kN (190 lb) is accepted as a tolerance threshold for the cervical spine,[56] then the more substantial structures of the lumbar and sacral spines would appear to have values higher than this rather than lower. Now, all of the results in Table 3.2 (except the repeated value of N12CC301) are below 2 kN (450 lb), and each of these has been independently found to constitute a low probability of trauma to the lower spine. The implication that any threshold would have to be above 2 kN (450 lb), say, to explain this would obviously be consistent with the tolerance being at least 0.85 kN (190 lb).

It would not be surprising if the tolerance for the lower spine occurred somewhere in the increase from 2 kN (450 lb) to between 11 and 13 kN (2500 and 2900 lb) seen for N12CC301. The amount of latitude in these numbers points to there being

(a) a higher probability of injury to the lumbar spine and the sacral spine

for N12CC301 than for all the non-injury cases. Similar arguments cannot be made for the other two parts of the lower torso, namely the left and right hips, because they are not vertebral structures like the cervical, lumbar, and sacral spines. In fact, the different type of structure involved in the hips would not be likely to make comparisons any easier.

Once it has been accepted that all plausible tolerance levels for the lower spine have been exceeded, the qualitative approach to explaining the injury mechanism can be upgraded to a semi-quantitative analysis. The asymmetry in the values of the maximum resultant forces F(LH) and F(RH) on the left and right hips, respectively, suggests that there is

(b) a higher probability of injury to the right side of the pelvis

than the left.

When deductions (a) and (b) are combined together with the animated sequence of images recorded on video tape,[58] the final appraisal emerges as a simple summary:

> There is a high probability of injury to the right side of that place where the spine meets the pelvis; in other words, a disruption to the sacroiliac joint caused by an anticlockwise rotation of the sacrum with respect to the right ilium.

This evaluation was derived without the benefit of many relevant medical records because the author did not want to be influenced or biased by the opinions of others. As it turned out, this was a wise decision because the trauma went undetected by several physicians, whose observations could have been very misleading if they had been considered. The neatness and directness of the above evaluation is satisfying, but it should not detract from the high level of effort involved in obtaining it.

5. Conclusions

The traditional strengths of the CVS/ATB model are usually considered to be the assessment of major trauma to the head and chest. Other applications of the model have included the study of the neck and spine, as well as the legs. With the increased power and ready availability of microcomputers, a large number of permutations can be processed in short periods of time and so free up mental and intellectual resources to address unusual cases like the one tackled during this research. It was a daunting prospect to overcome the non-trivial nature of the trauma involved, but this has been rewarded by the tremendous encouragement gained from being able to conduct the work efficiently and effectively.

With the same level of care and attention, there is no reason why the model should not be invoked for even more ambitious projects. The measure of success evidenced by this paper should be viewed as a vote of confidence that other, more difficult challenges can be undertaken and resolved.

Acknowledgments

The author wishes to extend his thanks and appreciation to Bernie Ankney, Jim Coil, Cecil Knox, Jack Kolff, Scott Magley, Lee Miller, Ed Mulligan, and Rick Schroeder.

"Truly my soul waiteth upon God: from him cometh my salvation. He only is my rock and my salvation; he is my defence; I shall not be greatly moved." [59]

"That if thou shalt confess with thy mouth the Lord Jesus, and shalt believe in thine heart that God hath raised him from the dead, thou shalt be saved." [60]

References

1. McHenry, R.R. & Naab, K.N., "Computer simulation of the automobile crash victim — A validation study." Report YB-2126-V-1R, Calspan Corporation, Buffalo, NY, July 1966.

2. Segal, D.J. & McHenry, R.R., "Computer simulation of the automobile crash victim — Revision No. 1." Report VJ-2492-V-1, Calspan Corporation, Buffalo, NY, March 1968.

3. Kidd, E.A., "Development of physical and analytical simulating of the automobile crash victim." Report VJ-2554-V-1, Calspan Corporation, Buffalo, NY, December 1970.

4. Bartz, J.A., "A three dimensional computer simulation of a motor vehicle crash victim." Report VJ-2978-V-1, Calspan Corporation, Buffalo, NY, July 1971.

5. Fleck, J.T., Butler, F.E. & Vogel, S.L., "An improved three-dimensional computer simulation of motor vehicle crash victims." Report ZQ-5180-L-1, Calspan Corporation, Buffalo, NY, 1974.

6. Fleck, J.T., Butler, F.E. & Vogel, S.L., "An improved three-dimensional computer simulation of crash victims — Volume 1: Engineering manual." Publication DOT HS 801 507, U.S. Department of Transportation, Washington, DC, April 1975. [Available through National Technical Information Service, Springfield, VA 22161, via Accession No. PB-241 692.]

7. Fleck, J.T., Butler, F.E. & Vogel, S.L., "An improved three-dimensional computer simulation of crash victims — Volume 2: Model validation." Publication DOT HS 801 508, U.S. Department of Transportation, Washington, DC, April 1975. [Available through National Technical Information Service, Springfield, VA 22161, via Accession No. PB-241 693.]

8. Fleck, J.T., Butler, F.E. & Vogel, S.L., "An improved three-dimensional computer simulation of crash victims — Volume 3: User's manual." Publication DOT HS 801 509, U.S. Department of Transportation, Washington, DC, April 1975. [Available through National Technical Information Service, Springfield, VA 22161, via Accession No. PB-241 694.]

9. Fleck, J.T., Butler, F.E. & Vogel, S.L., "An improved three-dimensional computer simulation of crash victims — Volume 4: Programmer's manual." Publication DOT HS 801 510, U.S. Department of Transportation, Washington, DC, April 1975. [Available through National Technical Information Service, Springfield, VA 22161, via Accession No. PB-241 695.]

10. Fleck, J.T. & Butler, F.E., "Development of an improved computer model of the human body and extremity dynamics." Report AMRL-TR-75-11, Armstrong Medical Research Laboratory, Wright Patterson Air Force Base, Dayton, OH, July 1975. [Available through National Technical Information Service, Springfield, VA 22161, via Accession No. ADA014816.]

11. Shaibani, S.J., "A uniform input data convention for the Cal 3-D Crash Victim Simulation." Report 1419/82, Oxford University Engineering Laboratory, England, July 1982. [Available through NTIS, Springfield, VA 22161, via Accession No. N8316575.]

12. Shaibani, S.J., "Application of the Cal 3-D CVS program to evaluate the equilibrium position of an Euler-jointed Alderson Part572." Report 1426/82, Oxford University Engineering Laboratory, England, August 1982. [Available through NTIS, Springfield, VA 22161, via Accession No. N8316576.]

13. Shaibani, S.J., "Review of CVS work conducted at Oxford University between June 1982 and September 1982." Report 1427/82, Oxford University Engineering Laboratory, England, September 1982.

14. Shaibani, S.J., "The modelling of occupant response in collisions of Δv = 30 mph with different principal directions of force from 0° to 30°." Report 1456/83, Oxford University Engineering Laboratory, England, February 1983.

15. Shaibani, S.J. & Digges, K.H., "Analytical reconstructions of front seat passenger response in a road accident." Report 1457/83, Oxford University Engineering Laboratory, England, March 1983.

16. Digges, K.H. & Shaibani, S.J., "Analytical reconstructions of driver response in a road accident." Report 1458/83, Oxford University Engineering Laboratory, England, April 1983.

17. Shaibani, S.J., "The reconstruction of vehicle occupant response in road traffic accidents." Film made at Computing Teaching Centre, University of Oxford, England, 1983. [Presented at Seventeenth International Workshop on Human Subjects for Biomechanical Research, Washington, DC, October 4, 1989.]

18. Butler, F.E. & Fleck, J.T., "Advanced restraint system modeling." Report AFAMRL-TR-80-14, Air Force Aerospace Medical Research Laboratory, Wright Patterson Air Force Base, Dayton, OH, May 1980. [Available through National Technical Information Service, Springfield, VA 22161, via Accession No. ADA088029.]

19. McConville, J.T., Churchill, T.D., Kaleps, I., Clauser, C.E. & Cuzzi, J., "Anthropometric relationships of body and body segment moments of inertia." Report AMRL-TR-80-119, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Dayton, OH, 1980. [Available through National Technical Information Service, Springfield, VA, under accession number ADA097238.]

20. Fleck, J.T., Butler, F.E. & DeLeys, N.J., "Validation of the Crash Victim Simulator — Volume 1." Report ZS-5881-V-1, Calspan Corporation, Buffalo, NY, and Publication DOT HS 806 279, U.S. Department of Transportation, Washington, DC, 1982. [Available through National Technical Information Service, Springfield, VA 22161, via Accession No. PB-86212420.]

21. Fleck, J.T., Butler, F.E. & DeLeys, N.J., "Validation of the Crash Victim Simulator — Volume 2." Report ZS-5881-V-2, Calspan Corporation, Buffalo, NY, and Publication DOT HS 806 280, U.S. Department of Transportation, Washington, DC, 1982. [Available through National Technical Information Service, Springfield, VA 22161, via Accession No. PB-86212420.]

22. Fleck, J.T., Butler, F.E. & DeLeys, N.J., "Validation of the Crash Victim Simulator — Volume 3." Report ZS-5881-V-3, Calspan Corporation, Buffalo, NY, and Publication DOT HS 806 281, U.S. Department of Transportation, Washington, DC, 1982. [Available through National Technical Information Service, Springfield, VA 22161, via Accession No. PB-86212420.]

23. Fleck, J.T., Butler, F.E. & DeLeys, N.J., "Validation of the Crash Victim Simulator — Volume 4." Report ZS-5881-V-4, Calspan Corporation, Buffalo, NY, and Publication DOT HS 806 282, U.S. Department of Transportation, Washington, DC, 1982. [Available through National Technical Information Service, Springfield, VA 22161, via Accession No. PB-86212420.]

24. Leetch, B.D., & Bowman, W.L., "Articulated total body (ATB) "View" package software report, Part I, Programmer's guide." Report AMRL-TR-81-111, Volume I, Aerospace Medical Research Laboratory, Wright Patterson Air Force Base, Dayton, OH, June 1983. [Available through National Technical Information Service, Springfield, VA 22161, via Accession No. ADB075161.]

25. Leetch, B.D., & Bowman, W.L., "Articulated total body (ATB) "View" package software report, Part II, User's guide." Report AMRL-TR-81-111, Volume II, Armstrong Medical Research Laboratory, Wright Patterson Air Force Base, Dayton, OH, June 1983. [Available through National Technical Information Service, Springfield, VA 22161, via Accession No. ADB075162.]

26. Baughman, L.D., "Development of an interactive computer program to produce body description data." Report AFAMRL-TR-83-058, Air Force Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Dayton, OH, 1983.

27. Shaibani, S.J., "The SJSATBPC package: mainframe-quality results with the Crash Victim Simulation in the microcomputer environment." Seventeenth International Workshop on Human Subjects for Biomechanical Research, Washington, DC, October 4, 1989, pp 1-20, U.S. Department of Transportation, Washington, DC.

28. Shaibani, S.J., "The development of the SJSATBPC microcomputer package to obtain mainframe-accuracy with the Crash Victim Simulation analysis of occupant kinematics." Engineering Sciences Paper C42, 42nd Annual Meeting of American Academy of Forensic Sciences, Cincinnati, OH, February 19-24, 1990.

29. Engin, A.E. & Chen, S., "Human joint articulation and motion resistive properties." Report AAMRL-TR-87-011, Armstrong Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Dayton, OH, 1987.

30. Obergefell, L.A., Fleck, J.T., Kaleps, I. & Gardner, T.R., "Articulated total body model enhancements. Volume 1: Modifications." Report AAMRL-TR-88-009, Armstrong Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Dayton, OH, January 1988.

31. Obergefell, L.A., Gardner, T.R., Kaleps, I. & Fleck, J.T., "Articulated total body model enhancements. Volume 2: User's guide." Report AAMRL-TR-88-043, Armstrong Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Dayton, OH, January 1988.

32. Gross, M.E., "The GebodIII program user's guide and description." Report AL-TR-88-043, Armstrong Laboratory, Wright-Patterson Air Force Base, Dayton, OH, March 1991.

33. Hirsch, A.E., Shaibani, S.J. & Nguyen, T.T., "Response of seated and standing manikin during shock trials on U.S.S. Mobile Bay (CG53) and U.S.S. Roosevelt (CVN71)." Report NBDL-89R005, Naval Biodynamics Laboratory, New Orleans, LA, 1989. [Available from National Technical Information Service, Springfield, VA 22161, via Accession No. ADA212586.]

34. Shaibani, S.J. & Hirsch, A.E., "The design of a database structure to predict and manage naval personnel injuries." Chi Associates Report, CAI, Arlington, VA, November 1989.

35. Federal Register, 31, 15212, Washington, DC, December 3, 1966.

36. Federal Register, 32, 2408, Washington, DC, February 3, 1967.

37. Federal Register, 35, 16927, Washington, DC, November 3, 1970.

38. Federal Register, 36, 4600, Washington, DC, March 10, 1971.

39. Federal Register, 37, 12393, Washington, DC, June 23, 1972.

40. Federal Register, 37, 22871, Washington, DC, October 26, 1972.

41. Federal Register, 42, 34299, Washington, DC, July 5, 1977.

42. Shaibani, S.J., "Energy management in the distribution of injuries incurred by automotive occupants under different types of restraint condition." Engineering Sciences Paper C13, 42nd Annual Meeting of American Academy of Forensic Sciences, Cincinnati, OH, February 19-24, 1990.

43. Shaibani, S.J., "Distribution of injuries received with different types of seat-belt use." Film made in Arlington, VA, 1989. [Presented at 42nd Annual Meeting of American Academy of Forensic Sciences, Cincinnati, OH, February 19-24, 1990.]

44. Shaibani, S.J., "Disparate cervical trauma in low severity insults." Nineteenth International Workshop on Human Subjects for Biomechanical Research, San Diego, CA, November 17, 1991, pp 43-80, U.S. Department of Transportation, Washington, DC.

45. Shaibani, S.J., "Variations in neck injuries produced by similar loads." Film made at the Department of Mathematics, Liberty University, Lynchburg, VA, 1991. [Presented at Nineteenth International Workshop on Human Subjects for Biomechanical Research, San Diego, CA, November 17, 1991.]

46. Shaibani, S.J., "Calculation of the forces in the cervical spine as a measure of injury." Engineering Sciences Paper C20, 44th Annual Meeting of American Association of Forensic Sciences, New Orleans, LA, February 17-22, 1992.

47. Shaibani, S.J., "Injury mechanisms in impacts with minimal vehicle deformation." Engineering Sciences Paper C16, 44th Annual Meeting of American Academy of Forensic Sciences, New Orleans, LA, February 17-22, 1992.

48. Shaibani, S.J., "Determination of injury thresholds from increments in impact forces." Film made at Department of Mathematics, Liberty University, Lynchburg, VA, 1992. [Presented at 44th Annual Meeting of American Academy of Forensic Sciences, New Orleans, LA, February 17-22, 1992.]

49. Shaibani, S.J., "Assessment of cervical trauma in posterior insults." Twentieth International Workshop on Human Subjects for Biomechanical Research, Seattle, WA, November 1, 1992, pp 29-42, U.S. Department of Transportation, Washington, DC.

50. Shaibani, S.J., "Evaluation of cervical spine response to lateral and rear impacts." Engineering Sciences Paper C26, 45th Annual Meeting of American Academy of Forensic Sciences, Boston, MA, February 15-20, 1993.

51. Shaibani, S.J., "Role of physics in the analysis of trauma." Film made at Temple

University/Conemaugh Memorial Hospital, PA, 1993. [Presented at Trauma Symposium, Conemaugh Memorial Hospital, Johnstown, PA, September 24, 1993.]

52. McElhaney, J.H., Roberts, V.L. & Hilyard, J.F., "Handbook of Human Tolerance." Japan Automobile Research Institute, Ibaraki, Japan, 1976.

53. American Association for Automotive Medicine (AAAM), "The Abbreviated Injury Scale, 1980 Revision." AAAM, Morton Grove, IL, 1980.

54. Society of Automotive Engineers (SAE), "Human Tolerance to Impact Conditions as Related to Motor Vehicle Design — SAE J885 APR 80." SAE, Warrendale, PA, April 1980.

55. American Association for Automotive Medicine (AAAM), "The Abbreviated Injury Scale, 1985 Revision." AAAM, Morton Grove, IL, 1985.

56. Society of Automotive Engineers (SAE), "Human Tolerance to Impact Conditions as Related to Motor Vehicle Design — SAE J885 JUL 86." SAE, Warrendale, PA, July 1986.

57. American Association for Automotive Medicine (AAAM), "The Abbreviated Injury Scale, 1990 Revision." AAAM, Morton Grove, IL, 1990.

58. Shaibani, S.J., "Mapping of whole body to identify injury patterns." Film made at Temple University/Conemaugh Memorial Hospital, PA, 1993. [Presented at Twenty-First International Workshop on Human Subjects for Biomechanical Research, San Antonio, TX, November 10, 1993.]

59. The Holy Bible, Psalm 62, verses 1 and 2, The King James Version, 1611.

60. The Holy Bible, The Epistle of Paul the Apostle to the Romans, Chapter 10, verse 9, The King James Version, 1611.

DISCUSSION

PAPER: **Explanation of Injury Causation in Trauma to the Lower Spine**

SPEAKER: Saami J. Shaibani, Lynchburg, VA

QUESTION: Peter A Orner, MD State of California

Did this get by you on the CT scans or are you talking about a reducible diastasis of the SI joint. The diastasis pulling apart. Nothing else broken. Missed on CT and MRI?

A: Yes.

Q: How was it picked up?

A: The physician who diagnosed the injury incorrectly was a physiotherapist. It is an area of medicine that I wasn't familiar with up until then. We don't have it as well defined back in Europe as we do here and he explained to me and I spent a couple of days in his office as he was manipulating patients, finding out what hurt and where and it is amazing how just some slight adjustments within the pelvic structure can cause tremendous relief of pain and I was manipulating his patients, not that I can do anything and seeing is believing. Being able to spend as much time as I did with a police officer and with that diagnosing physician, really gave the insights that otherwise you would not have been able to get from conventional medical records.

Q: I guess the problem I'm having is that's an anatomic diagnosis and gee whiz, you can get down to a couple of millimeters, certainly on any MRI. You should be able to see some dissymmetry in the joint. I have a hard time understanding how you got a spontaneously reducing unilateral diastasis of the SI joint that is not connected to MRIs. Was it ever proven on an MRI or any objective study?

A: I think all the radiography was ambiguous at best.

Q: Even after the physiatrist made his diagnosis.

A: Yes.

Q: So this is purely a clinical diagnosis.

A: Yes, it is.

Q: As opposed to something verified by showing asymmetry in the joints.

A: If you look at the way the patient presents himself, it is very obvious clinically.

Q: Thank you

Q: Guy Nusholtz, Chrysler Motors

It appears that from the tone and the way it's presented, it appears that all of the medical capabilities, a MRI, catscans, and the other methodology are not quite as good for diagnosing injuries as CVS and that we should abandon that type of approach and just stick to visual imaging to determine what type of injuries we might have.

A: I would propose possibly another hypothesis in that the CVS just randomly, every once in a while, you are going to produce a phenomenon like this, where it appears to predict what the injury actually is, and therefore, you can choose one case and pull it out of maybe millions, billions, trillions and say "ah, ha, see this is the situation."

Q: You prefaced your remarks, Guy, by saying "it seems." That was not my intent. Nothing will replace the very sophisticated medical technologies that exist out there. They are important diagnostic tools. All I'm saying is that if you have good data and that's what makes this case different, this is not a run of the mill case where you have to estimate this, you have to approximate that. I was able to spend a lot of time with the occupant of the vehicle, with his vehicle and get an intimate sense of what was going on. Most of the time, that's not going to be the case and I'm not saying that CVS "proved" the injury here. All I'm saying is that it gave us some kind of insight. There are severe limitations to CVS. No doubt about it. All I'm saying is that if you are able to spend the time and the effort and go through the permutations that you think are reasonable then maybe something emerges from that consistent and agrees with what at least one physician found.

Q: I'm just a little bit concerned here that there is almost too much dependence.

A: Alright. But your point is well taken, Guy. It would never be a conventional diagnostic modality with all the other ones out there which are so good. It's just something might supplement or compliment whatever is going on. If a physician says you're not sick, then who are you to say that you are almost and if you look at the personal circumstances involved with this police officer, he went through an awful lot of grief. One incidental benefit of this is that his daughters are now babysitters for my baby so there is a great personal benefit so see what CVS can do for you. So if you need a babysitter, use CVS.