INJURY BIOMECHANICS RESEARCH
Proceedings of the Twenty-fifth International Workshop

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METHODS FOR THE INVESTIGATION OF IMPACT-INDUCED ABDOMINAL INJURIES

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INTRODUCTION

This investigation was initiated to supplement an ongoing effort to design a new dummy abdomen. The literature was reviewed with emphasis on abdominal impact and injury response, and epidemiology and accident investigation data. Particular attention was given to steering-wheel- or steering-column-induced injuries, and restraint-system interaction injuries.

The review of the literature disclosed a number a discrepancies in the existing body of abdominal response data. This prompted a new analysis of data compiled from previous studies, and created the need for a new series of tests. The primary conflicts found within the existing data are associated with rate effects, loading response, and hysteresis characteristics.

The new analysis of the existing data provides possible explanations for the response discrepancies. The new series of tests currently underway is intended to investigate these hypotheses, and attempts to reconcile the discrepancies. The initial focus of this effort is rigid-bar loading of the abdomen. The methods were devised to maximize the ability to approximate human abdominal response when testing human cadavers. The preliminary results appear to confirm some of the original hypotheses.

BACKGROUND

REVIEW OF EXISTING DATA - Many of the studies discussed herein are synopsized in SAE J1460-1 (1995). Most of the studies used human cadavers, and many included alternate treatments of data that were available from other sources.

Cavanaugh et al. (1986) conducted 2.5-cm-diameter rigid-bar impacts using 31.5- and 63.5-kg linear impactors. Twelve unembalmed repressurized human cadavers, eight male and four female, were tested in a free-back seated posture. The average specimen age was 54.7 years, the average mass was 70.3 kg, and the average stature was 167 cm. Impacts were perfromed in two velocity ranges, averaging 6.1 and 10.4 m/s, at the level of L3. Impactor force was measured and deflection was obtained from film. Equal-stress/equal-velocity scaling was applied to the data. Stiffness was found to be proportional to impactor speed and mass, suggesting rate sensitivity. Loading was found to be a simple ramping function while unloading was essentially a vertical line. Peak deflection occurred at approximately 66-percent compression. It was remarked that the results were heavily influenced by the scaling techniques.

Nusholtz et al. (1994) conducted angled semicircular rigid-tube impacts using an 18-kg pendulum. Six unembalmed repressurized human cadavers, three male and three female, were tested in a free-back seated posture. The average specimen age, mass, and stature were 54.4 years, 58.3 kg, and 172 cm, respectively. Impacts were performed in two velocity ranges, averaging 6.0 and 10.0 m/s, at the level of L2. Impactor force was measured and deflection was obtained from film, and corrected-principle-direction acceleration. No scaling technique was applied, and no rate sensitivity was found. It was remarked that the results were influenced by small sample size, biovariabilities, low pendulum mass, and multidimensional loading after the peak force.

Viano et al. (1989) conducted 15.2-cm-diameter rigid-disk impacts using a 23.4-kg pendulum. Unembalmed repressurized human cadavers were tested in a free-back suspended posture (seated with arms above). Sixteen thoracic, fourteen abdominal (7.5 cm below the xiphoid), and fourteen pelvic tests were performed with some cadavers being used in multiple tests. The average specimen age was 53.8 years and the average mass was 67.2 kg. Abdominal impacts in three velocity ranges, averaging 4.5, 6.7, and 9.4 m/s, were performed thirty degrees to the right or left of the midline through the center of gravity of the specimen. Impactor force was measured and deflection was obtained from 3D film analysis. Equal-stress/equal-velocity scaling was applied to the data, which was renormalized for velocity. The response was characterized by an initial stiffness and plateau force. Injury predictors, such as viscous response, were examined.

Stalnaker et al. (1985) compiled and analyzed data from sixteen frontal impacts conducted by Beckman et al. (1971), seventeen right- and left- side impacts conducted by Stalnaker et al. (1971), and two side and seven frontal impacts conducted by Trollope et al. (1973). These studies used vervets, rhesus monkeys, baboons, and squirrel monkeys ranging from 0.53 - 19.40 kg. The tests employed 1.27-, 2.54-, and 5.80-cm-diameter rigid-bar impactors, as well as 5.72 and 7.62-cm x 7.62-cm wedge impactors. The primates were positioned in a free-back seated posture for upper, middle, and lower abdomen tests. The impact speeds ranged from 8.4 - 17.0 m/s. Impactor force was measured and deflection was obtained from film analysis. The force-deflection data were described in terms of a three-stage rise-plateau-rise response. Analysis of the data relied upon linear velocity scaling, and averaging of the data to approximate a human response. The averaging of the data assumed there to be no differences between species, impact region, direction, or pendulum shape.

Rouhana et al. (1989 and 1990) conducted fifteen impacts on swine cadavers using a controlled-stroke MTS machine. A yolk fixture was used to drive 50-mm lap-belt webbing into the abdomens of the swine cadavers using speeds of 0.2 - 5.3 m/s at the level of L4. The swine cadavers averaged 43.6 kg, and were tested in a supine posture with the back supported. The belt material was initially in contact with the abdomens. Actuator force and deflection were measured, as was belt stretch. The data from a study conducted by Miller et al. (1989) was also reviewed. This investigation involved twenty-five impacts using anesthetized swine averaging 46.1 kg. The data were separated into 3.7- and 6.3-m/s groups and normalized. The swine cadaver and anesthetized swine data were compared to examine the scaling possibilities between human cadavers and living humans. Analysis of the swine data and available human data resulted in the design of a frangible abdomen for use in the Hybrid III dummy.

CURRENT ISSUES - The combined results of the aforementioned studies raise as many questions as they answer. The Cavanaugh data strongly suggest the presence of rate effects, while the Nusholtz data do not. The loading-phase response of the Viano data are different from that of the Stalnaker data, which are different from both the Cavanaugh and Nusholtz datasets. The Viano data are characterized by a hysteresis response, while other data suggest a rapid unloading of the abdomen. Each of these studies involved a different impactor mass, impact location, and impactor shape.

This present study addresses the rate sensitivity, loading phase, and hysteresis response issues in an investigation of mid and upper abdominal impact and injury response. Attention was given to perfusion techniques, such as organ turgor, temperature, and respiration effects. The initial conditions and specimen posture were also a focus of concern.

METHODS

TREATMENT OF EXISTING DATA - Several techniques were employed to bring the existing data to a common basis so that meaningful comparisons could be made. The Nusholtz cadaver data were split into high- and low-speed corridors, and equal-stress/equal-velocity scaling was applied. The Viano cadaver data were averaged within the 6.7- and 9.4-m/s ranges to yield two mean curves.

Upper abdomen tests were eliminated from the Stalnaker primate data, and of the remaining tests, those conducted at 10 m/s, +/- 1.5 m/s were selected for analysis (seven tests). Again, equal-stress/equal-velocity scaling was applied. The data were averaged across all species to obtain the "human" response. Squirrel monkeys accounted for much of the data. Loading-phase stages I, II, and III were generated using 9.6- percent and 27-percent compression break points, and the data were normalized to an abdominal depth of 289 mm. Velocity scaling was used to generate a 6-m/s curve.

The Cavanaugh corridors were plotted to overlay the other reanalyzed datasets. The response of the frangible abdomen of Rouhana was also plotted against the low-speed corridor data.

CURRENT TESTING - The initial focus of this study is on rigid-bar loading using a ballistic pendulum. The pendulum consists of a 48-kg cylindrical, ballistic mass to which a 2.5-cm-diameter rigid-bar impactor is attached by means of a six-axis load cell. A pivoting fork provides the interface between the pendulum and cannon. A conceptual representation of the pendulum is shown in Figure 1. The pendulum is driven through its center of gravity along the tangent to the arc of its swing by a pneumatic cannon. The ballistic mass is suspended by vinyl-jacketed, stainless-steel cables from a support structure that was designed to fit inside an airlock testing area. This configuration is illustrated in Figure 2. The cannon is supported by a sand-filled base (the internal structure is shown in Figure 2) that allows adjustment of the cannon's position and attitude. The specimen is positioned on a large platform. The pendulum support structure and specimen platform are designed such that attachment to the floor in the testing area is not required.

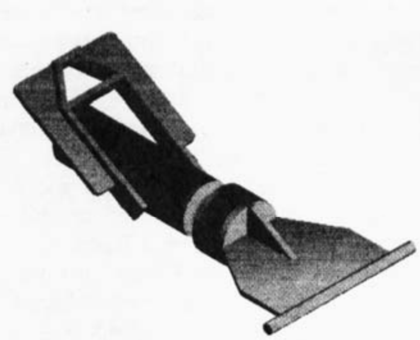

Figure 1. Conceptual pendulum representation.

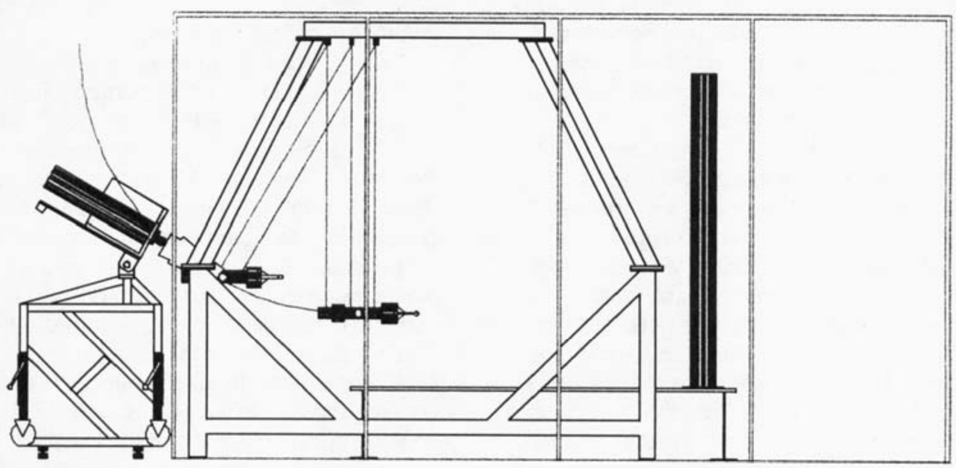

Figure 2. Schematic representation of the abdominal impact testing configuration.

During specimen preparation, foley catheters and compression fittings were used to make bilateral descending perfusion attachments to the carotid arteries and jugular veins. Access to the abdominal aorta was obtained through the right femoral artery. Similarly, access to the inferior vena cava was gained through the right femoral vein. The external iliac artery and vein were perfused on the left side through the left femoral artery and vein. Prior to the perfusion attachments, the vascular system of the cadaver was flushed with approximately 2 liters of normal saline. The cadaver was allowed to reach room temperature. Warm saline was pumped into the right common carotid artery using approximately 28 kPA, and the blood and clots were allowed to exit from the right internal jugular vein. Clot removal was assisted by repeatedly inserting long angled forceps into the superior vena cava. Even the superficial vasculature can be flushed during this procedure. Raising and lowering and massaging of the limbs aided the process. It is thought that use of appropriate perfusion techniques assists in obtaining accurate mechanical and injury responses.

Care was taken to limit the pressure and amount of fluid so as to avoid the accumulation of considerable interstitial abdominal fluids. Champion Millenium Co-Injectanct Beta Factor was added to the saline to help destroy and remove blood clots. This additive has a preservative, but no fixative effect on the tissue. Millenium was selected after evaluating the performance of several additives as part of this study.

Accelerometer mounts were fixed to T1, L3, S1, and the gladiolus via tapered Steinmann pins. Millar pressure catheters were positioned in the stomach, sigmoid colon, abdominal aorta, and urinary bladder. The Millar units were installed through thirty-cc Foley catheters, so that the esophagus, rectum, femoral artery, and urethra could be sealed and/or perfused. The bladder was first evacuated, and then received 250 cc of normal saline. Pretest x-rays were used to verify the instrumentation locations.

Figure 3 illustrates a midabdomen test (GI3) configuration prior to the pendulum being set in the firing position against the pneumatic cannon using an electromagnet. The cadaver is positioned in a seated, upright, free-back posture with the legs extended forward on a curved plastic skid. The height of the skid was adjusted using plastic spacers. The cadaver was dressed in leotards and tights and seated on a thin layer of plastic. The hands were positioned in front of and above the head, to eliminate their direct involvement in the impact. Impact load, acceleration, and moment in the median plane were measured. Anteroposterior and inferosuperior acceleration measurements were made at T1, L3, S1, and the body of the sternum. Dual-marker target masts were fixed to these locations to facilitate kinematic analysis using high-speed film. Overhead and lateral perspectives were filmed at 1000 fps. A contact sensor triggered solid-state timers, visible in each camera field, and provided the data-acquisition system with a synchronizing signal.

A safety harness was buckled around the cadaver under the arms and scapulas. D rings on the harness were positioned above each shoulder and attached to adjustable tie-down assemblies via S hooks. The opposite ends of the tie-down assemblies were attached to a central ring via S hooks. These assemblies have over-center buckles which allowed the posture of the cadaver to be adjusted easily. The central ring was suspended by a swivel snap shackle that was actuated by a remote solenoid through a flexible cable. This shackle was attached to the top and center of the main pendulum and cadaver support structure via a pulley and winch, allowing height adjustments. The overhead camera view was essentially unobstructed. This shackle could be moved forward and backward, up and down, and from side to side, depending on the test conditions and specimen anthropometry. The harness also had a posterior ring to which the belt of a retractable lanyard was latched. This retractor mechanism was fastened to a rigid beam above the test platform.

A cargo net was suspended from this beam using elastic straps and the bottom of the net was attached to the test platform using pear-shaped threaded chain connectors. This rigging was designed to control the cadaver after impact.

Prior to impact, the cadaver was given a few "full breaths" through a tracheostomy tube. The perfusion device was activated, pumping 13.8-kPa heated normal saline mixed with methylene-blue stain into the arterial system. Fluid returned to the perfusion device through the venous system. The lights were brought up, the cameras started, and the cannon was fired. The pendulum broke free of the electromagnet as the cannon was fired, and computer sampling was triggered shortly afterward. The pendulum then passed through the beams of a laser speed trap mounted outside of the cadaver's knees. Approximately 10 ms prior to the pendulum contacting the abdomen of the cadaver, the shackle suspending the cadaver was released. The cadaver was propelled into the cargo net, and the retractable lanyard ensured that the cadaver remained in the net. The harness and its associated rigging did not interfere with the tests, and the cadaver did not slump prior to the impact. The flight of the pendulum was stable and accurate. Vibration of the pendulum, pendulum support structure, and specimen platform were not discernible. The shock-isolation mounts of the canon base, and the mass of the base limited vibration when the cannon was fired.

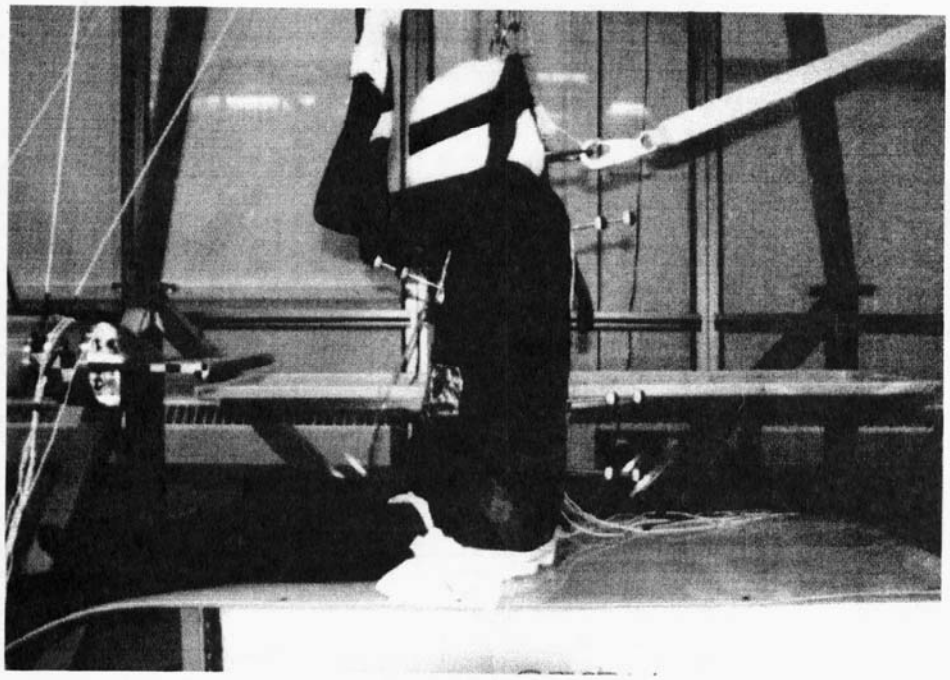

Figure 3. Preimpact conditions for Test GI3.

Table 1 shows the matrix of tests completed thus far. The average age of the specimens is 78, while the average stature and mass are 172 cm and 66 kg, respectively. Both genders are essentially equally represented. Possible future testing calls for upper-abdominal impacts at 6.3 and 9.7 m/s, and mid-abdominal impacts at 3.0 m/s.

RESULTS

Although the experimental methods are the focus of this paper, some preliminary results are available. The existing body of abdominal-impact data was reanalyzed, as previously outlined by first digitizing the published results of the referenced authors' investigations. Only eight points were taken from each curve for this preliminary analysis. Some preliminary results from the current test series are available as well.

EXISTING DATA - Figure 4 shows a comparison of the 10-m/s Cavanaugh corridor and the applicable reanalyses of existing data. Only the loading phases of these datasets are plotted. Although there are discrepancies within the data in terms of curve shape, the data seem to be in general agreement in terms of rate of loading. Figure 5 shows a comparison of the 6-m/s Cavanaugh corridor to the reanalyzed data sets. This shows discrepancies within the data in terms of curve shape and loading rate. With the exception of the Rouhana data, only the loading phases of these data are plotted.

Table 1 Completed Rigid-Bar Test Matrix of Subjects and Conditions

Test	Region	Speed (m/s)	Gender	Age	Stature (cm)	Mass (kg)	Cadaver
GI1	Mid	4.3	female	73	175	36	28594
GI2	Upper	4.3					
GI3	Mid	6.3	male	87	173	73	28682
GI4	Mid	6.3	female	93	165	58	28764
GI5	Upper	6.3	female	65	164	61	28800
GI6	Mid	6.3	male	85	165	91	28838
GI7	Mid	9.7	male	74	181	77	28879
GI8	Mid	9.7	male	71	182	64	28889
GI9	Mid	9.7	female	85	155	51	28942
				79	170	64	Average

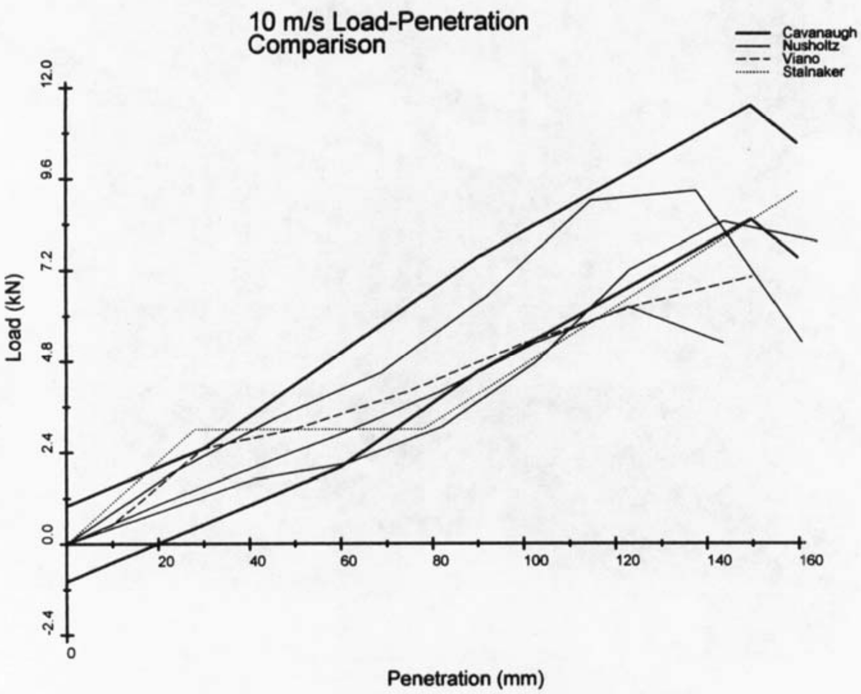

Figure 4. Comparison of the high-speed Cavanaugh corridor and reanalyses of existing data sets.

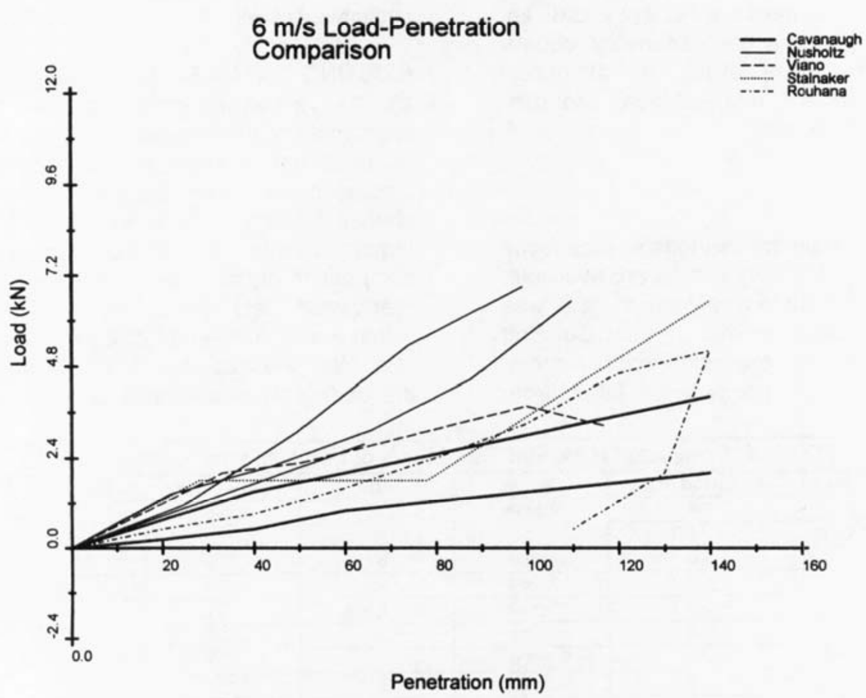

Figure 5. Comparison of the low-speed Cavanaugh corridor and reanalyses of existing data sets.

CURRENT TESTING - Figure 6 shows a typical sequence (Test GI3) for a 6.7-m/s midabdomen impact. Figure 6a shows the moment of pendulum contact with the abdomen, and Figure 6d shows the moment of maximum pendulum penetration into the abdomen. Currently, autopsy data and preliminary force-penetration data are available from Test GI3 and Test GI4 only.

During autopsy of cadaver 28682 (GI3), the spleen, stomach, kidneys, and mesentery were found to be uninjured. Bilateral fractures of the sixth ribs were found due to CPR received by the subject prior to death. Bilateral fractures of ribs 7, 8, and 9 were found, and could have resulted from contact with the pendulum as the cadaver bent forward during the later part of the impact. A 9-cm transverse tear of the left side of the diaphragm was found, as was a 10-cm tear of the cecum. The right lobe of the liver had a 7.5-cm tear anteriorly and a 9-cm tear along the posterior surface, as shown in Figure 7. The tears were inferosuperior. During autopsy of cadaver 28764 (GI4), the spleen, stomach, kidneys, bowel, and mesentery were found to be uninjured. Bilateral midclavicular (anterior auxiliary line) fractures of ribs 6, 7, 8, 9, and 10 were noted, but probably resulted from contact with the pendulum as the cadaver bent forward during the later part of the impact. The liver sustained a 3.5-cm transverse posterior tear of the left lobe, and an 11-cm tear of the anterior surface of the capsule of the right lobe.

The preliminary force-penetration data from representative tests GI3 and GI4 are shown in Figure 8. Both of these tests were conducted at approximately 6.3 m/s. The penetration data were obtained from film analysis, and were filtered per SAE channel class 180 Hz. The force data were filtered using a 165 Hz, 4th-order-Butterworth profile. Equal-stress/equal-velocity scaling was applied to each dataset. Figure 8 also shows the low-speed Cavanaugh corridor, generated from rigid-bar impacts of cadaver abdomens. This corridor results from +/- one standard deviation of averaged data from tests at different speeds, and does not represent the maximum and minimum boundaries of the data. The data from both tests GI3 and GI4 agree well with this corridor.

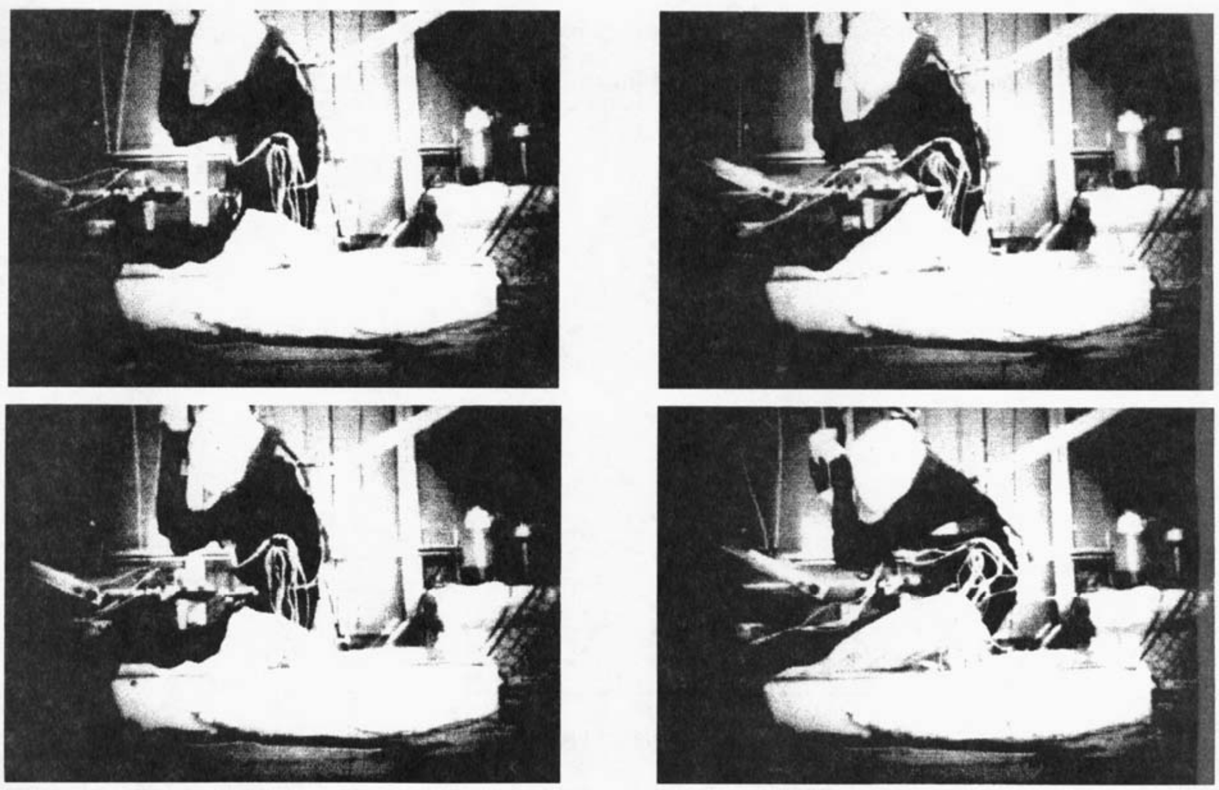

Figure 6. A typical 6.7-m/s midabdomen impact, from contact (upper left) to maximum penetration (lower right).

Figure 7. A liver laceration experienced by Cadaver 28764 from Test GI3.

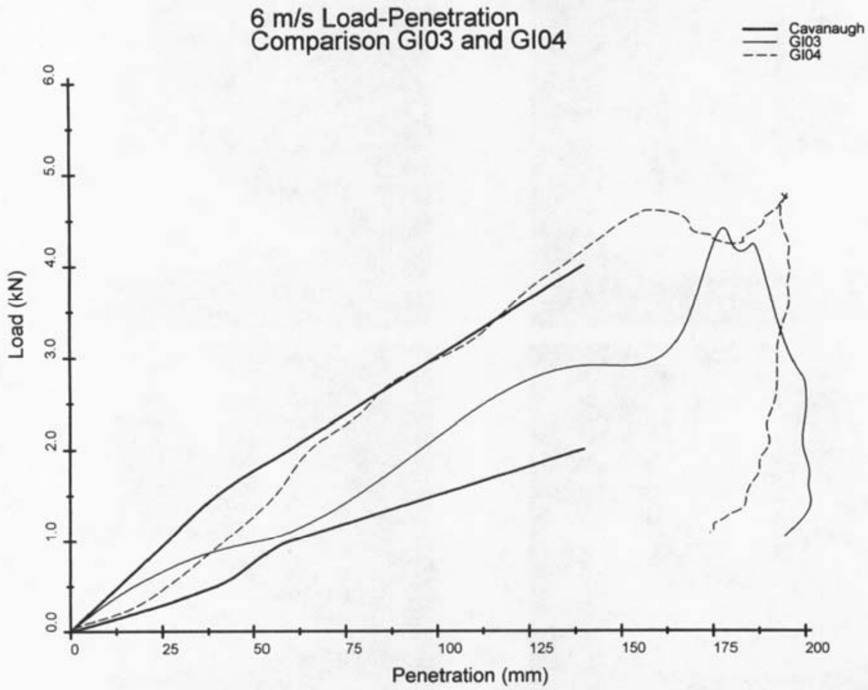

Figure 8. Comparison of the low-speed Cavanaugh corridor and preliminary analyses of GI3 and GI4 data.

DISCUSSION AND CONCLUSIONS

EXISTING DATA - It is hypothesized that previously observed rate effects, whether of a viscous or mass-recruitment nature, are dependent upon the relative impactor/subject masses involved. If the impactor mass is relatively small compared to the effective mass of the struck region of the subject, the response of the subject may not be indicative of the response that would be observed in an actual crash event. It is thought that because the impactor used in the Nusholtz tests was relatively low in mass and the impactor used in the Cavanaugh tests was of relatively high mass, the Nusholtz data did not show rate effects whereas the Cavanaugh data did show these effects.

It is also postulated that differences in the type of loading-phase response depend on impactor shape. Both the Nusholtz and Cavanaugh data resulted from tests using a round rigid-bar impactor, and the loading-phase responses were very similar ramp functions. The rigid-disk impacts conducted by Viano produced an initially steep loading followed by a plateau. This might be attributed to the much larger impactor surface area involved in the tests, as compared to the Nusholtz or Cavanaugh tests. Similarly, the wedge-shaped impactors used by Stalnaker produced a three-stage, rise-plateau-rise response, which also differs from the Nusholtz and Cavanaugh data.

Furthermore, it is thought that the differences in hysteresis depend on impact location. The Viano data exhibit a pronounced hysteresis, while the other datasets suggest a rapid unloading of the abdomen. The region of impact and the size of the impactor resulted in the ribs being involved in the test response. This rib involvement may have contributed to restorative forces required to generate a hysteresis response. Since the abdomen by itself is rather incapable of providing this type of restorative force, the unloading is a rapid drop of force level in the purely abdominal impacts.

CURRENT TESTING - The methods designed for use in this study have produced promising results so far. The flight of the pendulum is smooth and stable, and the release of the cadaver seems to be timed appropriately. The motion of the cadaver after pendulum contact is well constrained, and the level of impact is easily controlled.

The preliminary data shown for Test GI3 and Test GI4 agree well with the low-speed Cavanaugh corridor. This agreement is particularly good considering that this Cavanaugh corridor results from plus-or-minus one standard deviation from the mean of the test data, not actual maximum or minimum curves. Although the low-speed corridor is the corridor for which there are the most discrepancies between existing data sets, the current test results reinforce confidence in this corridor. Because the current tests fall within this corridor, it is thought that rate effects may exist. It is anticipated that the faster test will fall within the high-speed Cavanaugh corridor, similar to the existing data sets. These data also suggest that the previously described assumptions regarding impactor shape and location may also be correct, as these tests were conducted using similar conditions as the Cavanaugh tests, and the results are similar.

After the higher speed impact data have been analyzed and the upper abdominal tests have been conducted, it is hoped that most, if not all, of the discrepancies within the existing body of abdominal-impact response data will be reconciled. The focus of the testing will then shift from rigid-bar impacts to restraint system loading and mapping of abdominal response to rigid-disk loading of seven of the nine classical abdominal regions. It is hoped that this work will provide meaningful contributions to the design of an improved surrogate abdomen for use in anthropomorphic test devices.

ACKNOWLEDGMENTS

This work was conducted by the University of Michigan Transportation Research Institute Biosciences Division and was carried out in accordance with the practices outlined by the Anatomical Donations Program of the University of Michigan Medical School.

Necropsy assistance and pathology analysis was provided by Dr. Kanu Virani, consulting forensic pathologist. The contributions of Thomas A. Jeffreys, Anthony G. King, and other UMTRI staff are greatly appreciated.

The work covered by this report was financed by GM pursuant to an agreement between GM and the U.S. Department of Transportation.

REFERENCES

Cavanaugh, JM; Nyquist, GW; Goldberg SJ; King, AI (1986) Lower Abdominal Tolerance and Response. *Proceedings of the 30th Stapp Car Crash Conference*, pp. 41-63. SAE, Warrendale, PA.

Nusholtz, G; Kaiker P (1994) Abdominal Response to Steering Wheel Loading. *Proceedings of the 14th International Technical Conference on Enhanced Safety of Vehicles*, pp. 118-127. U.S. Department of Transportation, Washington, DC.

Rouhana, SW; Jedrzejczak, EA; McCleary, JD (1990) Assessing Submarining and Abdominal Injury Risk in the Hybrid III Family of Dummies: Part II Development of the Small Female Frangible Abdomen. *Proceedings of the 34th Stapp Car Crash Conference*, pp. 145-173. SAE, Warrendale, PA.

SAE J1460-1 Report (1995) *Human Mechanical Impact Response Characteristics-Dynamic Response of the Human Abdomen*. SAE, Warrendale, PA.

Stalnaker, RL; Ulman MS (1985) Abdominal Trauma-Review, Response, and Criteria. *Proceedings of the 29th Stapp Car Crash Conference*, pp. 1-16. SAE, Warrendale, PA.

Viano, DC; Lau, IV; Asbury C; King, AI; Begeman, PC (1989) Biomechanics of the Human Chest, Abdomen, and Pelvis in Lateral Impact. *The 33rd Annual Proceedings for the Advancement of Automotive Medicine*, pp. 367-382. AAAM, DesPlaines, IL.

DISCUSSION

PAPER: **Methods for the Investigation of Impact-Induced Abdominal Injuries**

PRESENTER: Warren Hardy, University of Michigan Transportation Research Institute (UMTRI)

QUESTION: Guy Nusholtz, Chrysler Corporation

Just a few quick questions. After you've done pressurization, are you checking through the different organs to see how much profusion you got?

ANSWER: Yes, and actually later this afternoon, we will have some slides to show exactly what the extent of the profusion is.

Q: Is deflection measured by film analysis?

A: Yes, in this case, this was a quick and dirty film analysis for deflection measurement.

Q: The last question is, "Is the cadaver suspended at all times or do you release them during the impact?

A: It is released when the pendulum gets to about four inches or so away from contact.

Q: OK. Thank you.

Q: Peter Orner, Internal Medicine and Biomechanics

I've had several cases where there was abdominal injury. You mentioned a cecal tear, but that was with some sort of bar which, from a standpoint of a real world accident, is sort of a contrivance. I understand what you are doing; you are looking for tissue properties. At the very end of your list, you mentioned about examining some of the injury characteristics of the viscera. One problem that comes up, that I've seen, is the differentiation of mesentery tears from bursts of the small bowel at both ends. Ilial perforations are common and they often, at least to my understanding, indicate different methods of application of the traumatic force. I was just wondering if you could explain what happens when there is trauma to the mesentery where the bursts are hydrostatic, which doesn't necessarily locate the point of application of force, but just says that there was a filled organ which burst.

A: Right. Well, this is something that we'll be watching for in the future as we do this. We have many more tests planned.

Q: That would be neat if you could shed some light on that because that comes up fairly often.

A: OK.

Q: John Cavanaugh, Wayne State University

Warren, based on your extensive look at the literature, aside from the tests that we did at Wayne State about ten years ago, would you say that it does look like there are rate dependent corridors, or is it too preliminary?

A: Perhaps it is a bit too preliminary but I think, based on some assumptions and some observations, I would lean toward a rate dependent response effect. Whether that is based on mass recruitment or a viscoelastic effect I can't really say right now, but I have a feeling that perhaps we may see something along those lines. I think it is very early to come out and say something like that because the data are particularly varied.

Q: The tests we ran were over ten years ago so it is a little bit hard to remember exact injuries. I do recall, we did get rib fractures at higher levels than the level of impact, and it looks like you did in this case too so it is an interesting phenomenon.

A: Yes. We haven't had the opportunity to really look into the injuries that we've seen so far and say, "well, we think this is happening because of this." As a matter of fact, most of these slides were generated just a couple of days ago. So, this is all very fresh. We need a little more time to think about it.

Q: Thank you.