

## Injuries of Abdominal Organs

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### ABSTRACT

*The paper deals with the mechanical properties of the selected abdominal organs. The target of the study is to present the methodology and results of mechanical properties measurements and to prove the differences between fixed and unfixed specimens. The results could be used for the definition of biomechanical criteria limiting the tolerance level. It can be used for frontal and side crashes, and for the pedestrian collisions.*

### INTRODUCTION

The approval tests of the vehicles include the passive safety features evaluation. The biomechanical criteria, especially of the head and the thorax are quite sophisticated. The attention given to the abdomen seems to be lesser than importance of the real abdomen injuries during car accidents (Kovanda, 1999). These injuries may have very serious consequences, which are life threatening – they can involve heavy bleedings, peritonitis or serious metabolic dysfunctions. The most relevant injuries are liver ruptures followed by bleeding into peritoneal cavity, ruptures of the spleen with comparable consequences as the liver ruptures. In about 20% of cases the spleen injuries are followed by so called “two step splenic rupture,” when the spleen tissue is filled by intrasplenic hematoma and then after some time internal pressure of growing hematoma disrupts the capsule of the spleen leading to intraperitoneal bleeding. Therefore we focused our effort on these organs. The injuries of other organs like kidneys, pancreas, stomach, duodenum and intestines can lead to the bleedings, heavy dysfunctions, peritonitis, etc. Nevertheless the analysis of their mechanical properties is not within the scope of this study. The aim of this study was to use the measurements of hepatic and partly splenic capsule of fixed and non-fixed human cadaveric material and to compare them with real loads and existing criteria. The widely used criterion APF (Abdominal Peak Force) is maximum of measured three peak forces in abdominal area. This criterion is used for side crash by EC95 regulation. This study can open the discussion about complexity of this evaluation.

### METHODS

The mechanical properties of the material include many characteristics, nevertheless the one dimensional stiffness can give rich information about the material using simple tearing machine and it is easily repeatable. The selected organs i.e. hepatic and splenic capsule, were tested from 50 individuals. The specimens were taken from Charles University, the 2<sup>nd</sup> and 3<sup>rd</sup> Medical Schools, Departments of Anatomy, Department of Pathology and Forensic Medicine. The samples from fresh cadavers

(41 cadavers) were tested 24-36 hours post mortem, before the test they were stored in the fixative solution by 4° C. The fixed material (9 cadavers) was embalmed for anatomical research 3-12 month before the tests (Stingl, 2000).

#### **Comparison of fixed and unfixed liver**

The mechanical stiffness of the human liver was tested for different age groups. In each age (from 49 to 84 years) were tested from 1 to 3 specimens. Large differences between obtained strength were detected. The reasons are following:

- 1) the tearing machine is designed for material with much higher stiffness, therefore the measurements run on the lower end of range
- 2) the measurement of the cross-section area is often uncertain
- 3) the speed of loading is not adjustable
- 4) the failure was sometimes quite close to the fixed end
- 5) the maximal force and loss of stability do not correlate well.

For these reasons, only part of the results were accepted.

#### **Comparison of fixed and unfixed spleen**

Spleen was tested parallel to the liver tests, but there were only few specimens available. The same problems appeared during the measurements. The spleen is even more fragile and therefore the influence of not-suitable tearing machine is even higher.

#### **Loading in the liver area during car crash**

The load of the right hypochondrial region was tested during the sled test with middle car crash parameters. The initial speed of frontal impact was 56km/h. The acceleration is presented on Figure 3.

## **RESULTS**

The mean-values of measured strain of material are following:

liver unfixed  $\sigma = 0.198 \pm 0.034$  MPa

liver fixed  $\sigma = 0.145 \pm 0.020$  MPa

The age dependency of the result is not proved. The Figure 1 shows the age dependency of unfixed material, the Figure 2 for fixed material.

Note, the results of measurement of spleen are following:

spleen unfixed  $\sigma = 0.147$  MPa

spleen unfixed  $\sigma = 0.223$  MPa

The number of specimens available was lower than for liver, therefore the relevance of the results is not very high and only mean values are presented.

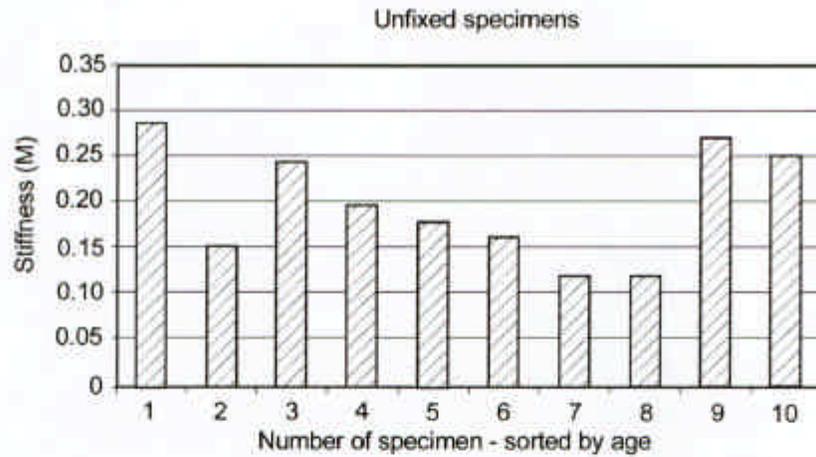


Figure 1. Age dependency of unfixed liver strain (age from 49 to 84 years vs. MPa).

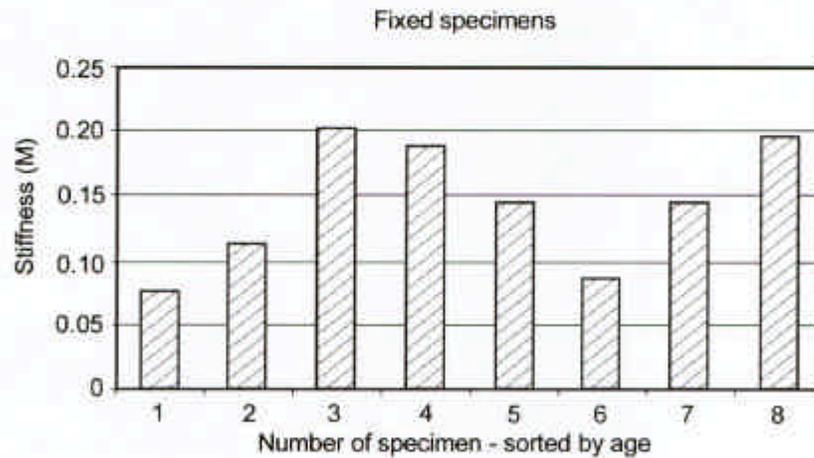


Figure 2. Age dependency of fixed liver strain (age from 49 to 84 years vs. MPa).

The sled test results show the acceleration in the hypochondrial region measured on the Hybrid III dummy.

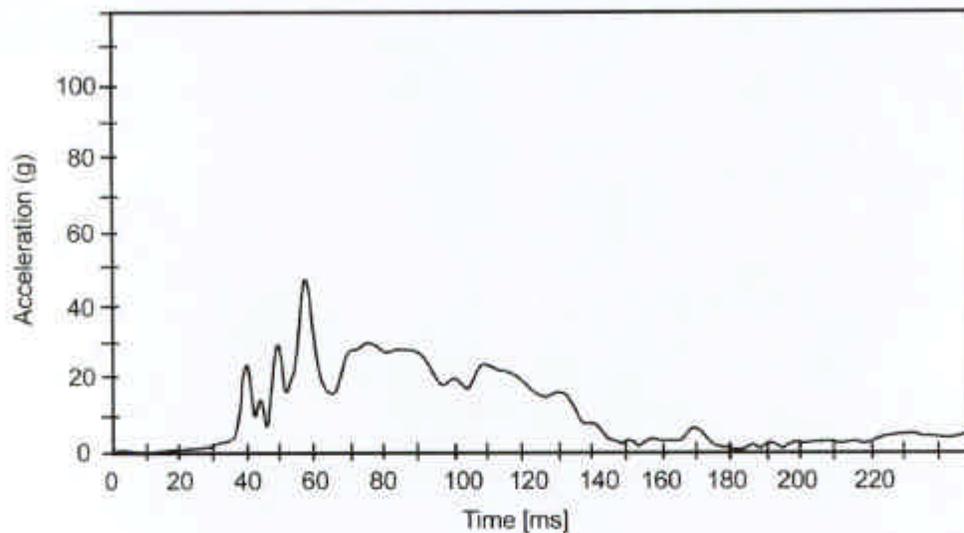


Figure 3. Acceleration measured in hypochondrial area (time in ms vs. acceleration in g).

### CONCLUSIONS

The presented results show, that the difference between mechanical properties of fixed and unfixed organs is not substantial, the age dependency was not proved. The shift of middle value can be detected and the fixed specimens can be used for further research. The obtained strength of liver tissue seems to correspond well with the dynamic loadings measured during the sled test. The simple calculation gives the estimation, that during the deceleration peak there is the stress in the liver area on the level about 0.1 MPa. The resulting dynamic force is roughly one half of limit force done by EC95 test. The liver seems to be protected enough from the mechanical point of view. The open question is the overloading done by blood overpressure during the crash and the development of the shock wave in the tissue.

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