Simulated predictors of organ dysfunction in accident casualties

Olaf Schedler[1], Torsten Haase[4] , Stefan Koch[2], Claus König[3]

[1]Helios Clinic Bad Saarow, emergency room and rescue medicine, Pieskower Straße 33, 15526 Bad Saarow

[2]Helios Clinic Bad Saarow, Institute for Pathology, Pieskower Str. 33, 15526 Bad Saarow

[3]BTU Cottbus-Senftenberg, Faculty 6, Engineering mechanics and numeric methods, Konrad-Wachsmann-Allee 2, 03046 Cottbus

4 Naemi Naemi-Wilke-Stift Clinic, Guben

Abstract: After surviving a traffic accident, a total of 17% die during further hospitalisation. Valuable were the variables of the Quick Test and Base Excess (BE), which are essentially dependent on Liver function. Finite-Element-Methods (short FEM) are established digital development tools within product design, which are put into numeric solvable form to evaluate organ packages and their dynamics. The solution of the analysis achieve a useable prediction quality if the influencing variables are known. Goal of this project is to perform a detailed accident analysis using numerical simulation techniques and to identify prognostic predictors of invisible and diagnosable injuries in order to reduce the mortality of accident victims after surviving a traffic accident.

Keywords: accident research, FEM, THUMS, Organ histology, Intracellular mechanical damage, Energy Equivalent Speed (EES), Abbreviated Injury Scale (AIS), Microscopy, morphology, histology, morphometries

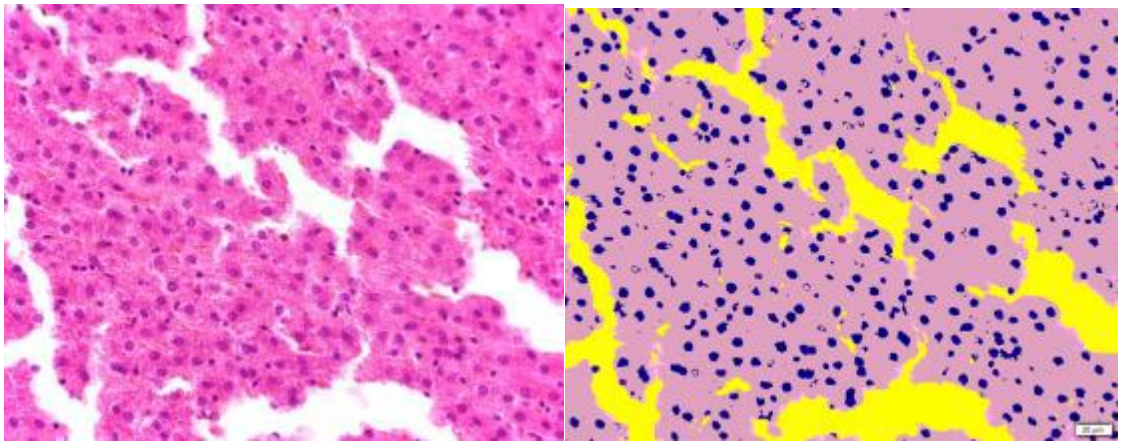
Preface: A major focus in accident research lies on analysing the cause of accidents and estimating the amount of energy the accident event has on the human body. The conveyed accident energy (Energy Equivalent Speed EES) correlates with the frequency and severity of the injury (ISS). In the primary fatality, the accident energy was above the biomechanical stability of the organs or organ groups, so that death occurred at the scene of the accident. Therefore it is indispensable to analyse the accident energy (EES) transferred to the survivors or injured in the course of the accident in order to determine the prediction or frequency and severity of the organ damage.

After surviving a traffic accident (n=12.5000) 16, 9% die during their hospitalisation. 49, 3% of all fatalities die within the first 24 hours. Another 15, 6% died between 24h and 72h after the accident occurred. 35, 1% died after 72h or later. Prognostically valuable were the variables: resuscitation, severe multiple injuries (ISS $\geq$24), Quick Test (TZW), Base Excess (BE) Abbreviated Injury Scale (AIS) of the pelvis = 5, mass transfusion $\geq$ 10 red cell concentrates, AIS Head $\geq$ 3 and blood pressure at the accident site < 90 mmHg. For rescue medicine, the correlation between mechanical effects (EES) and medical findings (AIS, TZW, BE) is of outstanding importance, especially in regard to the abdomen.

Considering the prognostic parameters Blood coagulation and the metabolic components, it is obvious that the influencing factors of the internal organs, which were not recognizable by whole-body CT-Scan within the first 72h, must be present. In order to carry out the parameter

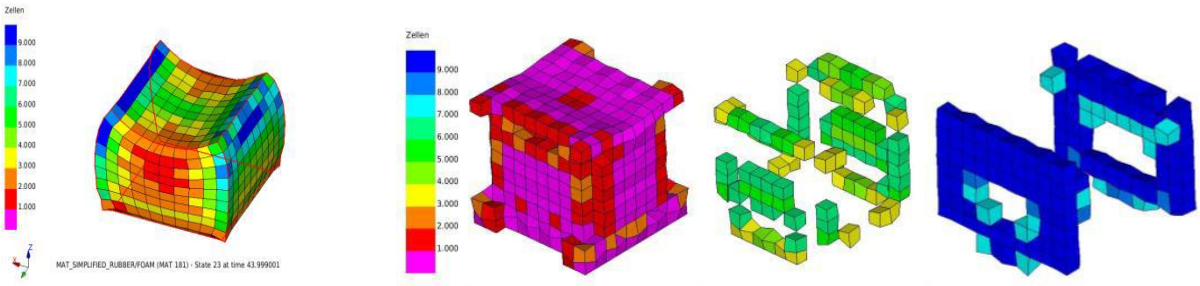
programming of the FEM on the organic model, titrated organic load tests were carried out without complete loss of structure. The mechanically strained organ parts were subsequently processed into histologically usable objects and morphometrically analysed with regard to cell nucleus counts, extravascular fluid spaces and organ assemblies. Illustration 1 depicts the morphometric data in reference to histologic morphometries.

Illustration 1: Morphological examination (Normal cell left, compressive stress right, 40x magnification)



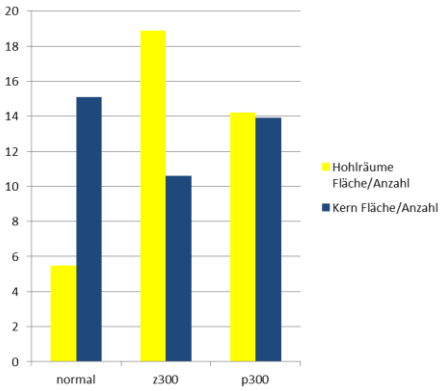
Simulation methods, such as Finite-Element-Method (short FEM), are established development tools in product development. They are based on physical principles which have been transformed into a numerically solvable form. The solutions of the analysis (e.g. deformations) achieve a considerable prediction quality with knowledge of the influencing variables. The Total Human Model for Safety (THUMS) developed by TOYOTA represents the anatomical geometry and the biomechanical properties of the human body. The main area of application is the simulation of the kinematics of the human body as well as the evaluation of stress and strain distributions. With the improvement of the model structure (e.g. Model version 4.0), further analysis, such as the assessment of injury mechanisms, are conceivable, provided that a suitable mathematical description of the material behaviour is available. The task of the tests is to implement a basic structure of liver parenchyma morphology in the FEM system. For this purpose, the determinants of the morphometry performed were calculated with the THUMS, depending on the different energy loads (tension, compression) and loaded by means of standardized energy amounts from accident research.

Illustration 2: simulated cell damage model in the liver FEM with fractionation (0-3, 4-7, 8-10 cells)



The results of the morphometry show that there is no change in the number of nuclei in the context of energy contribution effects on the organ system (pressure/pull). This fulfils the criterion of structural consistency. The number of extracellular and extravascular cavities and the area proportion of extravasals in the histological-microscopic examination area change significantly under compressive and tensile loads. Illustration 3 shows the ratio of the correlation area to number as a measure of organ function restriction

Illustration 3: cell nucleus fraction and area fraction changes under tension (z) and pressure (p)



The aim of this project is to perform a detailed accident analysis using numerical simulation techniques and to find out the prognostic predictors of invisible and/or diagnosable injuries in order to reduce the mortality of accident victims after surviving traffic accidents. The correlation between mechanical action and medical findings, especially with regard to the organs, is of outstanding importance. In this project first results are presented, which have a histological morphometric correlation of organ dysfunction and can therefore be used as calculable determinants of FEM simulation. The simulated analysis can clarify which energetic components were distributed to the organ-FEM liver and give indications for a functional restriction of the organs as a fraction of the abnormal cells. The knowledge of the relevant predictors enables a quick identification of high-risk patients, a first orienting assessment of the prognosis, a targeted and prioritized shock therapy.

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THUMS: Organs, Bone structure, Skin