Diffuse Axonal Injury (DAI): Injury Mechanisms and Tolerance Criteria

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Introduction

Diffuse Axonal Injury (DAI) occurs when the brain is subjected to strain, e.g. caused by rapid change of head motion (direct impact, inertial loading), and represents widespread microscopic damage of the axons due to the resulting brain tissue shear strain. Previous studies have examined this particular intracranial lesion in clinical surveys, animal experiments, real accidents, and computer(FE)-simulations. However, for a better understanding of DAI there is still the need of extended basic data, both to complete knowledge of significant injury mechanisms, and, in particular, to develop tolerance criteria. To contribute to that task is the objective of this real accident study.

Material and Methods

16 fatalities are included in this DAI study, all selected from autopsy cases investigated at the Munich University Institute for Legal Medicine in 1995 – 1999. Selection criteria were defined as follows: (1) Determination of relevant physical head loading parameters must be possible; (2) Acute DAI is included only; (3) Cases showing primary vascular lesions with relevant haemorrhage are excluded. Each case selected was subject to an extensive microscopic neuropathological examination, in particular detecting DAI location and frequency. “Brain maps” were developed to illustrate this DAI location and frequency in order to identify significant injury mechanisms related to causative head loading parameters determined by accident reconstruction.

Results and Discussion:

Diffuse Axonal Injury (DAI) was examined in 16 real fatal accidents. The findings suggest that DAI in the brain stem and in the medulla oblongata occurs in cases exposed to axial linear acceleration of the head (±g_z), while this location of DAI is uncommon in cases subjected to head impact loading in the transversal plane (±x frontal and occipital, ±x lateral).

DAI in the corpus callosum region is caused when rotational head acceleration around vertical z-axis is predominant. Shear forces due to extensive skull deformation and tensile forces, in particular parietal, are causing DAI in the hemispheres.

Head loading parameters determined in this study indicate for DAI the following tolerance curves:

(1) Linear (mean) acceleration 120g for short duration (10 ms) and 72 g for longer duration (> 20 ms, cf. Figure 1, related to the Wayne State University Tolerance Curve WSTC).

(2) Rotational (mean) acceleration 12,000 rad/s² for short duration (10 ms) and 6,000 rad/s² for longer duration (> 20 ms, c.f. Figure 2).