Whiplash injuries from a medical perspective

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anatomy of the human spine

- structured bar
- 24 vertebra (7 cervical, 12 thoracic, 5 lumbar)
- protection of the spinal cord
- shock absorbing function for the brain

7 cervical vertebra

12 thoracic vertebra

5 lumbar vertebra
cervical spine elements

upper Atlas and Axis (C1, C2)

middle C3 to C5

lower C6 to C7
  most frequent site of injury and symptoms

Source: Sobota
Quebec Task Force- Results

- The initial diagnostics and documentation of CSD injuries is insufficient
- Major Problem: different injury classification
- Lit. Analysis of 10,000 Publications shows, that only 400 can withstand a critical View regarding Injury Definition and Comparability
- Improved Medical Injury management (early detection and therapy strategies for chronic cases) important

source: Spitzer et al, SPINE 1995
<table>
<thead>
<tr>
<th>degree</th>
<th>clinical signs</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>NO subjective or objective symptoms of the Cervical Spine</td>
</tr>
<tr>
<td>1</td>
<td>Cervical Spine Symptoms (subjective: pain, stiffness)</td>
</tr>
<tr>
<td></td>
<td>NO objective clinical signs</td>
</tr>
<tr>
<td></td>
<td>MICROLESION</td>
</tr>
<tr>
<td>2</td>
<td>Cervical Spine Symptoms AND</td>
</tr>
<tr>
<td></td>
<td>MUSCULO-SKELETAL SIGNS</td>
</tr>
<tr>
<td></td>
<td>MACROLESION</td>
</tr>
<tr>
<td>3</td>
<td>Cervical Spine Symptoms AND</td>
</tr>
<tr>
<td></td>
<td>NEUROLOGICAL SIGNS</td>
</tr>
<tr>
<td></td>
<td>NEURAL DAMAGE / IRRITATION</td>
</tr>
<tr>
<td>4</td>
<td>Cervical Spine Symptoms AND</td>
</tr>
<tr>
<td></td>
<td>FRACTURE or DISLOCATION</td>
</tr>
<tr>
<td>QTF 1</td>
<td>MICROLESION</td>
</tr>
<tr>
<td>-------</td>
<td>-------------</td>
</tr>
<tr>
<td></td>
<td>single or multiple (ultra-)microskopic lesions</td>
</tr>
<tr>
<td></td>
<td>lesion is too small to cause muscular spasms</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>QTF 2</th>
<th>MACROLESION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Distorsion and soft tissue bleedings (joint capsules, ligaments, tendons and muscles)</td>
</tr>
<tr>
<td></td>
<td>Secundary muscle spasm after soft tissue injury</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>QTF 3</th>
<th>NERVE CELL DAMAGE/ IRRITATION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Injuries of the neural system</td>
</tr>
<tr>
<td></td>
<td>caused by traumatic injury or secondary due to</td>
</tr>
<tr>
<td></td>
<td>Irritation caused by bleeding and inflammation</td>
</tr>
</tbody>
</table>
muscular damage

- muscular sprain/tear
- healing within days/weeks
- leaves scar, but no permanent damage

source: Foreman, Croft, Whiplash Injuries
Williams & Wilkins, Baltimore, 1995
deep muscles of the cervical spine
might be primary site of injury
Musculus semispinalis capitis/cervicis and multifidus
Three stages of Nerval Injury

1. **Neuropraxia**
   - Local demyelisation (neurons intact)
   - Complete recovery

2. **Axonotmesis**
   - Axons interrupted
   - Recovery complete or nearly complete

3. **Neurotomesis**
   - Axons and sheaths both interrupted
   - Recovery never complete

source: Foreman, Croft, Whiplash Injury
Williams & Wilkins, Baltimore, 1995
Suspected Pathology (Spine) I

- Zygapophysial joints
  - synovial impingement
  - hemarthrosis (a)
  - joint capsule rupture/tear (b)
- Intervertebral disc
  - tear of annulus fibrosus (c)
- Upper cervical ligaments
  - tear of anterior ligament (d)

Poorly seen in X-Ray and MRI

Suspected Pathology (Spine) II

- Pressure gradient within spinal channel
  - injury of nerve cells within spinal ganglia (e)

spinal cord within spinal channel
e
space of cerebro-spinal fluid
QTF and gender

Rear-end collisions

Gender - QTF (dv > 10 km/h)

Driver N=92
- Male n=47
- Female n=45

Passenger N=38
- Male n=12
- Female n=26

Source: EU WHIPLASH 1 Project – IFM-GDV
Visual Demonstration I

sled test (Clip) delta v 9,5 km/h
Injury mechanism at rear end collision

Phase 1
Translation and Extension

Phase 2
max Extension

Phase 3
Flexion Rebound
neck muscles during rear crash

sternocleidomastoid muscle and semispinalis capitis muscle show:

potential to influence kinematics and
to be primary site of injury due to eccentric contraction
EMG during volunteer tests, dv 9.5 km/h

- maximum Amplitude of sternocleidomastoid muscle during head/head-restraint contact
- afterwards rising activity of semispinalis capitis muscle reaching Maximum at 200ms (Rebound Phase)
Arguments against dynamic seat test

- *We do not know the injury exactly, so a test does not make much sense*

- We also do also not know the exact lung cancer pathology, but nevertheless **smoking** is a serious risk factor

- **Neck movement** and **forces** are also significant risk factors

- *If neck movement and forces are reduced, CSD injury logically must also be reduced*
Low Cost car seat
improved car seat
• *Does the dynamic seat test really measure seat performance?*

• *Only real accident analysis* can answer this: Seat test ranking should be comparable to real accident ranking. *Serious basic research with high case numbers necessary*

• Continuous monitoring important
### Rear-End Impact Car Performance Statistics

Injury rates at rear-end collisions divided by manufacturer and type (“Long Term Injuries“ more than 6 weeks)

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Rear end collisions total</th>
<th>With injured</th>
<th>Long-term injured &gt; 6 weeks</th>
<th>rating</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>n</td>
<td>Per 1000</td>
<td>n</td>
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<tr>
<td>B - France</td>
<td>258</td>
<td>13</td>
<td>135</td>
<td>1</td>
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<tr>
<td>F - Germany</td>
<td>378</td>
<td>39</td>
<td>257</td>
<td>8</td>
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<tr>
<td>G - Germany</td>
<td>1087</td>
<td>115</td>
<td>294</td>
<td>25</td>
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<tr>
<td>G - Germany</td>
<td>523</td>
<td>88</td>
<td>433</td>
<td>18</td>
</tr>
<tr>
<td>G - Germany</td>
<td>229</td>
<td>30</td>
<td>380</td>
<td>8</td>
</tr>
<tr>
<td>E - Germany</td>
<td>177</td>
<td>18</td>
<td>400</td>
<td>7</td>
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<tr>
<td>B - France</td>
<td>252</td>
<td>21</td>
<td>328</td>
<td>10</td>
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</tbody>
</table>

lower middle class vehicles

**SOURCE:** IFM-GDV, statistics HuK Coburg Insurance 2000, damages
Injury rates at rear-end collisions divided by manufacturer and type „Long Term Injuries“ more than 6 weeks

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Weight class</th>
<th>Rear end collisions total</th>
<th>With injured n</th>
<th>Per 1000</th>
<th>Long-term injured n &gt; 6 weeks</th>
<th>Per 1000</th>
<th>rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>C- Germany</td>
<td>Upper middle class</td>
<td>90</td>
<td>14</td>
<td>156</td>
<td>2</td>
<td>22</td>
<td>good</td>
</tr>
<tr>
<td>D- Germany</td>
<td>Small car</td>
<td>65</td>
<td>16</td>
<td>246</td>
<td>2</td>
<td>31</td>
<td>good</td>
</tr>
<tr>
<td>E- Germany</td>
<td>Upper middle class</td>
<td>80</td>
<td>18</td>
<td>225</td>
<td>3</td>
<td>38</td>
<td>good</td>
</tr>
<tr>
<td>F- Germany</td>
<td>Middle class</td>
<td>112</td>
<td>20</td>
<td>179</td>
<td>6</td>
<td>54</td>
<td>medium</td>
</tr>
<tr>
<td>G- Germany</td>
<td>Middle class</td>
<td>52</td>
<td>12</td>
<td>231</td>
<td>3</td>
<td>58</td>
<td>medium</td>
</tr>
<tr>
<td>H- Germany</td>
<td>Upper middle class</td>
<td>173</td>
<td>35</td>
<td>202</td>
<td>11</td>
<td>64</td>
<td>poor</td>
</tr>
<tr>
<td>D- Germany</td>
<td>Middle class</td>
<td>211</td>
<td>44</td>
<td>209</td>
<td>14</td>
<td>66</td>
<td>poor</td>
</tr>
<tr>
<td>F- Germany</td>
<td>Middle class</td>
<td>191</td>
<td>52</td>
<td>272</td>
<td>18</td>
<td>94</td>
<td>poor</td>
</tr>
</tbody>
</table>

SOURCE: IFM-GDV, statistics HuK Coburg Insurance 2000, damages
CSD- Long-Term injury

LONG TERM INJURIES SHOULD JUSTIFY HIGH PREVENTION EFFORTS

If recovery takes more than 2 weeks for at least one passenger then for all occupants with CSD:
→ in less than 70 days 50% will recover
→ in 25% recovery will take >6 months
→ in 8% chronic impairment

Time until reduction of earning capacity reaches 0%, all 253 CS-Patients in 208 rear-end impacts (at least one occupant with documented CSD injury suffering for more than 14 days)

Source: W2 Long Term Injury Analysis LMU
Case example FATAL INJURY

seatback collapse after rear-end impact

Child behind driver was killed

*Seatback collapse must be avoided*

Source: FS 90 IFM-GDV
Out of Position (OOP) $\Delta V$ 9.5 km/h
OOP volunteer
comparison Dummy vs. volunteer (OOP)
Outlook

• Volunteers and dummies react differently in OOP

• muscular response and injury need more basic research

• As well higher QTF classes (neurological injury and facet joint injury) advanced research

• Injury Criteria (NIC, Nkm, Rebound Velocity) need improvement and better validation

• Optimisation up to one point must be avoided so different tests should be performed (or one random test)
Outlook

- **Females** are the highest risk group
- **female dummy** should be essential

- Stiffer cars (more aggressive pulse) could compensate the effects from improved seats

- *Do not shoot first (blind) without having a well reflected program and answer questions afterwards*