Abdominal Twin Pressure Sensors for the Assessment of Abdominal Injuries in Q Dummies: Status

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Outline

Context

Development status

Sensor and dummy availability
Summary of previous tests and behavior
Candidate Injury criteria and risk curves

Perspectives

Remaining needs, shortcomings & integration
Importance and need for test procedure

References
Context

• Abdominal injuries commonly injured in (older) children
  – At higher risk than adults (CASPER, Javouhey et al. 2006, and others)

• Configuration: mainly belt loading in frontal impact
  – Submarining, pre-submarining (misuse, relaxed posture, etc), submarining and jackknifing (e.g. Arbogast et al. 2007)
  – Phenomenon can be on/off = loading/no loading
  – Includes no CRS or CRS with or without evident misuse (CASPER, Beillas et al. 2012)

• Aims of protection strategy: move at least some injured children to the non/less injured category
  – Different tools could address the problem incl. ergonomics, education and of course better CRS and cars

• Here: Evaluation of CRS performance by impact testing. Requires:
  1) Instrumented dummy to evaluate risk/loading to the abdomen
  2) Test procedure, representing a situation where children are injured (abdomen loading high on dummy). Better CRS reduce the load…
1) Abdominal instrumentation: Abdominal Pressure Twin Sensors (APTS) V2

- Child: V1; **CASPER: V2**
- Soft cylindrical bladder filled with oil, subminiature pressure sensor in cap
- Implanted in dummy abdominal block
  - Q3 and Q6, Q10: D=50mm, L=135mm
  - Q1.5 (design ongoing: D=35mm, L=100mm)
1) APTS V2: abdomen integration

- holes drilled in full abdomen (abdomen held in plaster)
  - Limitations: friction? Tolerance? → discussions with Humanetics for integration in mold

- Attachment: Velcros used at the bottom to prevent the upward migration of the sensors
- Friction: use of baby powder → better control (not requiring to maintenance) would be better. Sock?
Abdominal compression with belt:
Mid abdomen, 1m/s, (biofidelity Corridor conditions)
Q10 (Beillas et al., 2012a)

Pressure response: mostly linear against penetration or force (midabdo, 1m/s, belt loading)

Pressure response (1m/s, belt loading): sensitivity is reduced towards pelvis and thorax

Similar results for Q3 (Beillas et al., 2012b) and Q6 (not published yet)

Limitations: Only one abdomen/sensor pair for each dummy

Pressure levels are relatively low
Isolated abdomen in compression (Q3, Q6, Q10)

- Objective: simplified test that could be used for calibration/certification...
- Belt, bars, etc
- E.g. Q3/Q6: Less force out than in dummy but pressure vs. penetration not affected
e.g. Q10 tests: two abdomens
- Old (1410g drilled)
- New (1050g drilled)

Tests setups are different: only for order of magnitude
Comparison with sled test conditions

- Q3 and Q6 abdo compression obtained by tracking (n=3)
  - Hard stop reached on one test…
- Belt load projected based on angle to compute force
- Velocity: around 1m/s (average).

(Speed is average compression between 5 and 60ms)

1 raised anchor
2 light rod
3 targets
Compressive response: Comparison between dummies and configurations

- Normalization? → compression in front of spine
  - Used for human models (Beillas & Berthet, 2011)
Compressive response: conclusions

- APTS V2 effects:
  - Q3, Q6: response unaffected; Q10: stiffens
  - Corridors: Q3, Q6: ok. Q10: which abdomen?

- Pressure seems more related to compression/penetration than force (which is dependent on load path…)
  - Could be used to transfer criteria between dummies

- Seems possible to use isolated abdomen with sensors to characterize response + calibration
  - Pressure reached over 1bar
  - Exact setup to select: (probably 3 levels: pressure cell in pressure tank, isolated bladder, bladders in abdomen)
Sled testing

• Numerous sled tests conducted with APTS V2:
  – Q3: Ifsttar, TUB, Dorel, TRL, …, various positions and CRS
  – Q6: Ifsttar
  – Q10: Dorel (Beillas et al., 2012a), JAMA members, TRL
  – Planned: TUB (Q3), TME (Q6), Others (Q10), TRL, …
  – Reconstructions (Q3 or Q6): Ifsttar, TUB, Fiat, Idiada, LAB…
  – Many more tests with APTS V1
Examples of sleds

- Q3 repeatability (Beillas et al. 2012b)
- Limitation: the only test found for repeatability in sled and no reproducibility

<table>
<thead>
<tr>
<th>Test number</th>
<th>APTS version</th>
<th>Peak Pressure (bar)</th>
<th>Average of max (bar)</th>
<th>CV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q3_37</td>
<td>V2</td>
<td>2.13 2.20 2.20</td>
<td>2.32</td>
<td>4.4%</td>
</tr>
<tr>
<td>Q3_38</td>
<td></td>
<td>2.39 2.12 2.39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q3_40</td>
<td></td>
<td>2.22 1.77 2.22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q3_45</td>
<td></td>
<td>2.26 2.13 2.26</td>
<td></td>
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</tr>
<tr>
<td>Q3_46</td>
<td></td>
<td>2.42 2.17 2.42</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q3_47</td>
<td></td>
<td>2.41 2.26 2.41</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Examples of sleds

• Resistance-durability
  – Q10 JAMA: sensor line disconnection (needed re-soldering)
  – Extreme loading: Q6 sled issue (63 km/h instead of 50km/h → hard stop): 7 bars, 8kN lap belt, no damage
• Otherwise: no failure, no damage since V2 manufactured

→ need to further reinforce wiring (new attachment design ongoing for APTS Q1.5)
Examples of sleds

- Abdominal load detection: Objective of most tests and reconstructions...e.g.
  - Q3: Casper reports
  - Q6: LAB tests (V1) (Beillas et al. 2012b)
  - Q10: mainly belt under the arm (Beillas et al. 2012a, JAMA tests)

<table>
<thead>
<tr>
<th>Test Description</th>
<th>Max. (bar)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard, ISOFIX CRS</td>
<td>0.31</td>
</tr>
<tr>
<td>Relaxed posture, no CRS</td>
<td>1.23</td>
</tr>
<tr>
<td>Standard posture, seat reclined, no CRS</td>
<td>1.23</td>
</tr>
<tr>
<td>Relaxed posture, feet on front seat, ISOFIX</td>
<td>1.33</td>
</tr>
<tr>
<td>Leg folded, belt under arm, no CRS</td>
<td>1.85</td>
</tr>
<tr>
<td>Standard posture, belt above armrests, ISOFIX</td>
<td>2.33</td>
</tr>
</tbody>
</table>

Normal: Max: 0.83 bar

Misuse (belt under arm): Max: 1.82 bar
• 2 declared as valid, 1 invalid (injury mechanism not reproduced: no abdominal loading=normal restraint kinematics)

All Reconstructions summarized in Beillas et al. 2012b
Reconstructions & risk curves

- Full reanalysis (Beillas et al., 2012b): 8 cases removed (loading mechanisms, sensor malfunctions, invalid at car level) → 19 cases (12 Q6, 7 Q3) kept

- Max Pressure and Pressure rate based $P_{\text{max}}*(dP/dt)_{\text{max}}$, $(dP/dt)_{\text{max}}$: all predictors of injury (pressure rate correlated with pressure); even narrower confidence interval for rate based

- Max pressure: same trends for Q3 scaled and Q6, Q3 and Q6, and Q6.
  - CFC180 seems good choice for filter

- Q3 (scaled) points have higher pressures than Q6 points at the same AIS
  - But only 1 AIS3+ for Q3…
Reconstructions & risk curves: Discussion and conclusions

- Important limitations:
  - Lack/limited overlap surprising (Sampling? Ncases? Limited submarining?...), Inherent limitations of reco.
  - Confidence interval very sensitive to individual points but limit (50% risk) relatively stable
  - Scaling between dummies? (Q3/Q6, and now Q10)

→ Confidence intervals and risk curves to be considered cautiously. Observation of dummy and instrumentation performance in a set of realistic test conditions that are believed to correspond to real accidents

→ New: Based on recent results: dummy scaling could be attempted based on penetration. No particular reason to scale Q3/Q6 based on response.
Summary and perspectives:
Remaining issues and open questions for sensors

- **Durability**: reinforcement of cable needed → design ongoing
- **Integration**: discussions with Humanetics for Q10
  - Reservations in mold, mounting procedure/friction control needed…
- **Compressive response**: Q3, Q6 ok. Q10: need some clarification
- **Calibration**: out of dummy procedure tested → needs to be finalized
- **R&R**: limited testing performed for sled… (ok otherwise)
- **Detection of abdominal loading**: ok (Reco and sleds):
  - Typically <1 bar when pelvis loaded, >1 when abdomen loaded
  - Limited experience for Q10 (only 2 misuse tested)…
- **Criteria and Risk curves**: candidate available based on accident
  reconstructions for Q3 and Q6 (with limitations).
  - Pmax CFC180 (around 1.1-1.3 bar depending on hyp.)
  - No curve for Q10: scaling based on compression?
- **Other**: ongoing work on Q1.5, Thor + Simulation of sensors to help scaling
2) Test procedure

- Improved CRS (here: booster), evaluated by impact testing require:
  1) Instrumented dummy to evaluate abdominal risk
  2) Test procedure, representing a situation where children are injured (and the abdomen loading is high on the dummy)

- Note: 2) is really important.

- E.g. Sled testing on Q10 (Dorel)
  (Beillas et al. 2012a)

<table>
<thead>
<tr>
<th>Q10</th>
<th>R44</th>
<th>NPACS</th>
<th>5xboosters</th>
<th>normal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>no CRS</td>
<td>no CRS</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>booster</td>
<td>belt under arm</td>
</tr>
<tr>
<td>ADAC</td>
<td>Golf body</td>
<td>5xboosters</td>
<td>normal</td>
<td></td>
</tr>
</tbody>
</table>
E.g. Sled testing on Q10: normal vs. no CRS

<table>
<thead>
<tr>
<th>Seat</th>
<th>Cfg</th>
<th>Peak press. (bar)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Booster1 (Isofix)</td>
<td>1</td>
<td>0.83</td>
</tr>
<tr>
<td>Booster2 (Isofix)</td>
<td>1</td>
<td>0.73</td>
</tr>
<tr>
<td>Booster3 (inflatable)</td>
<td>1</td>
<td>0.78</td>
</tr>
<tr>
<td>Booster4 (Backless)</td>
<td>1</td>
<td>1.02</td>
</tr>
<tr>
<td>No CRS</td>
<td>1</td>
<td>0.44</td>
</tr>
<tr>
<td>Booster1 (Isofix, Misuse)</td>
<td>1</td>
<td>1.82</td>
</tr>
<tr>
<td>Booster5 (Isofix)</td>
<td>1</td>
<td>0.65</td>
</tr>
<tr>
<td>Booster1 (Isofix)</td>
<td>2</td>
<td>0.54</td>
</tr>
<tr>
<td>Booster2 (Isofix)</td>
<td>2</td>
<td>0.96</td>
</tr>
<tr>
<td>Booster5 (Isofix)</td>
<td>2</td>
<td>0.51</td>
</tr>
<tr>
<td>Booster4 (Backless)</td>
<td>2</td>
<td>0.57</td>
</tr>
</tbody>
</table>

Config 1=Bench, Config 2=Body in white
Note:
dummy
Q10 vs P10
2) Test procedure

• Improved CRS evaluated by impact testing require:
  1) Instrumented dummy to evaluate abdominal risk
  2) Test procedure, representing a situation where children are injured (and the abdomen loading is high on the dummy)

• E.g. Sled testing on Q10 (Dorel) (Beillas et al. 2012a)
  – abdo not loaded w/o CRS on NPACS → not injurious. But no CRS leads to higher risk in real world. No Protection.
    • Cause: Dummy behavior? Bench? Anchor position? Other?
  – Any CRS is ok, no differentiation → Are there good and bad CRS for the abdomen?
    • Injury with CRS and no detected misuse (CASPER, Beillas et al. 2012)
    • Differentiation is the objective of a test procedure for CRS. Otherwise enforcing usage is enough.

→ Test procedure seems inappropriate for the goal…
References and acknowledgements

- CASPER project reports (WP1), under review...

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