HOW MINOR IS MINOR?
COLLISION FORCES AND INJURY

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OUTLINE

• Trends in low level impact leading to occupants seeking medical treatment
• The physics of collisions
• How crash forces are transmitted to the occupant
• Human tolerance / risks of injury
• Reconstruction methodologies
WHAT ARE THE MOST COMMON MINOR INJURY CRASHES?

- Rear end crashes account for the majority
  - 30% of rear end crashes lead to doctor treatment, only slightly less than property damage only
  - 60% of doctor treatments after crashes are due to rear end crashes
REAR END CRASH NUMBERS OVER TIME

Introduction

of new scheme


Doctor
ED non admission
Claim numbers by severity and legal representation

Minor injuries are increasingly being legally represented

Data for NSW
Source: Sydney Morning Herald, September 10 2016
COMMON QUESTIONS ABOUT REAR-END CRASHES

• What does the evidence say about the speed of the vehicle(s) involved in the crash?

• What occupant motions are likely and what forces were acting on the occupant(s) during the crash

• What injuries might be expected given the severity of the crash?
PHYSICS OF A REAR END CRASH

- Pre-crash phase
- Crash phase
- (Post crash phase)
PRE-CRASH

• Speed
  • Determines initial kinetic energy
  • Determines distance travelled during driver reaction
• Distance
  • With speed, determines the time available for braking
• Braking
  • Duration and level determines speed lost prior to impact
CRASH PHASE

• Momentum and energy
  • Speed and ratio of vehicle mass determines change in velocity / average acceleration levels

• Acceleration of vehicle
  • For the struck vehicle, acceleration defines the severity of the crash

• Occupant response
  • Acceleration, and the characteristics of the occupant’s restraint (seat), determines the response of the occupant and the likelihood of injury.
POST CRASH PHASE

- After the exchange of momentum, vehicles continue to move
- A struck vehicle may go on to strike another vehicle in front
- A second (usually more minor) collision may occur
- Movements of vehicles post crash can indicate the severity of the first crash and hence are a starting point for reconstruction
CRASH PHASE

- crash pulse - delta v - characterises general severity
- Injury mechanisms
  - Seat and seat belt effects
  - Motion of the head and neck
  - Any subsequent frontal collision
SERIOUS INJURY MODES TO THE CERVICAL SPINE
EXPERIMENTAL STUDIES
MOTION OF THE CERVICAL SPINE
MOTION OF THE CERVICAL SPINE

Phase 1

Phase 2

a) b) c)

Phase 1

Phase 2

a) b) c)
WHEN IS INJURY LIKELY TO OCCUR?

- There are three distinct periods that are hypothesised to have the potential to cause injury to the neck
  - Early in the impact event during the head retraction period and leading to the ‘S’ shape of the neck (Phase 2);
  - Due to the impact with the head restraint, if it is poorly positioned with respect to the head and neck at the time of contact (Phase 3);
  - Due to hyperextension for a severe impact with a poorly fitted head restraint or without one (Phase 4); and,
  - During the rebound into the seat belt (Phase 4).
SEATS ARE A FORM OF RESTRAINT

- Seats are a form of restraint, just like seat belts or airbags
  - Allow occupants to ride down an impact
  - Just like all restraints, “slack” degrades performance
  - Just like all restraints, performance is improved if ride-down can occur over the longest distance
- Head rests should be close to the head
- Controlled “collapse” can reduce forces
Find video of thatcham test I put in Cameron
CRASH SEVERITY AND INJURY SEVERITY

• What do we expect to see in rear end crashes with respect to severity?

• Up to 12 km/h change in velocity (i.e. ~ 24 km/h impact speed)
  
  • No motions of the neck outside the normal range

• In 25 out of 767 volunteer tests produced transient soreness for less than one day. Two tests produced soreness for less than 2 weeks.

• Conservatively applied, absolute limit for no initial signs is 8 kph
CRASH SEVERITY AND INJURY SEVERITY

• In very low speed crashes, (under 8 kph change in speed) we do not expect to see forces on the neck and back that are outside the experience of everyday activities

• Vehicle accelerations typically < 3 g

• Forces generated in the neck are often just a few percent of the levels thought to be cause serious injury
REAR CRASH IMPACT FORCES IN CONTEXT

- Series of tests where a passenger vehicle was accelerated by a low speed side-swipe with a truck
- Vehicle accelerations ~ 2 - 3 g
- Head accelerations ~ 4 - 6 g
  - Similar to crowd jostle, chair kick, hop off step, chair plop, sneeze, playground swing
  - Less than falling down, soccer ball strike
One of the great difficulties in explaining reported neck injury severity is that outcomes often do not always reflect crash severity.
### Table 1.1 The Quebec Classification of Whiplash-Associated Disorders

<table>
<thead>
<tr>
<th>Grade</th>
<th>Clinical presentation</th>
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| 0     | No complaint about the neck  
  No physical signs  |
| I     | Neck complaint of pain, stiffness or tenderness only  
  No physical signs  |
| II    | Neck complaint, and  
  Musculoskeletal signs*  |
| III   | Neck complaint, and  
  Neurological signs†  |
| IV    | Neck complaint, and  
  Fracture dislocation  |

* Musculoskeletal signs include decreased range of motion and point tenderness  
† Neurological signs include decreased or absent deep tendon reflexes, weakness and sensory deficits
CRASH SEVERITY AND INJURY SEVERITY

• One of the great difficulties in explaining reported neck injury severity is that outcomes often do not always reflect crash severity

• Some have proposed ‘bio-psychosocial’ models of whiplash injury in order to explain prognoses of whiplash associated disorders
MEASURING RISK FROM ACTUAL CRASHES

Figure 1. Folksam’s two generations of crash pulse recorders. Below is the older Crash Pulse Recorder installed 1992-2007 and above the new Electronic Crash Recorder (ECR) installed from 2008.
SWEDISH FOLKSAM / SAFER CRASH STUDY

- 175 rear end impacts
- Crash pulses were measured
- Participants provided self-reports of injury intensity and duration
CRASH SEVERITY, SYMPTOM DURATION

Figure 26. Mean acceleration and change of velocity for female occupants in rear-end crashes.

Figure 27. Mean acceleration and change of velocity for male occupants in rear-end crashes.
Figure 18. Risk of initial and long-term symptoms with respect to change of velocity.

Figure 19. Risk of whiplash injury with various degrees of WAD with respect to change of velocity.
ASCERTAINING SEVERITY FROM DAMAGE

- Physical evidence after a low level impact is often subtle
- However, the damage caused is a consequence of energy absorption
- If this energy absorption can be estimated, then the speed and severity can be determined
- Ideally this speed can be corroborated from other directions
  - e.g. vehicle accelerated from stationary into rear of vehicle, struck vehicle hit the car in front etc.
ENERGY ABSORPTION

- The energy absorbed in a collision between two vehicles is

$$\Delta E_a = \frac{1}{2} \frac{m_1 m_2}{m_1 + m_2} p^2$$

- where the $m$ denotes the mass of each vehicle, the subscript refers to the car number, and $p$ is the closing speed.
STAGED TESTS

- Known speed, known energy absorption
USING THIS INFORMATION

• Generally describes damage

• Often, subject vehicle model has been tested so a more direct comparison can be made

• Its extremely important to adjust for the differences between the test and the subject crash

• Barrier tests are very stiff and against an unyielding mass
DEFORMATION DISTANCE

• Damaged components usually are nearest the impact surface

• The depth of damage indicates the maximum deformation of the vehicle

\[ s = \sqrt{\frac{2E_a}{K}} \]
Test 4Db

Figure A3.19: Photographs of the test setup for test 4Db.

Figure A3.20: Photographs of damage to the front bumper of the Pontiac Vibe after test 4Db. There was no damage to the Ford F-150 or to the trailer hitch.

Test 4Db

Figure A3.44: Comparison of simulation results based on quasi-static bumper testing and dynamic crash test data for test 4Db.
SPECIAL CASES

- Tow bars can transmit forces forward to the area of a vehicle near the back of the boot. Bumpers can be undamaged but there is deformation away from the impact point.

- Tow bars and bull bars can “sharpen” the impact. This may have some effect on injury risk.
FINAL POINTS

- Rear-end collisions are one of the most common crash types, and associated with WAD
- General principles of momentum and energy can be used to reconstruct them
- For the struck occupant, the seat is the restraint system. Normal restraint principles apply
- Crash severity often very low and disproportionate numbers of claimants require no real medical intervention at the time of injury
FINAL POINTS

• Reasons for WAD appear to be complex, and the literature makes clear that compensation systems do affect rates of WAD.

• Then why do anti-whiplash seats work?
  • The key seems to be the prevention of any initial pain

• If pain is present then for some people, other factors may turn the very minor crash into a big problem