Using Forensics to Make Sense of Pedestrian & Bicycle Accidents

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What Evidence Do You Need?

- Pedestrian struck by a car
- Pedestrian taken to hospital with head injury
- Car driven from scene
- No criminal charges
### Investigation Types

- Investigating Pedestrian Collisions
- Injury Based Analyses
- Nighttime Visibility
- Investigating Bicycle Collisions

### Pedestrian Collisions – The Basics

- Two types of evidence available: witness statements and physical evidence
  - Physical evidence is more accurate, but can be limited
  - Witness statements are often flawed, but may be all that is available
- Can break evidence into three primary categories:
  - Scene
  - Vehicle
  - Pedestrian

### Pedestrian Collisions – The Scene

- The most important evidence and the most volatile
- Sources include Police report, Officer notes or Collision Reconstruction Data, Witness Statements, Photographs, 911 call
  - Contact police to verify where their data comes from.
  - Scene evidence may disappear.
  - Ask specific questions of witnesses and parties.
  - Check all sources for photographs – parties, police, EMS, witnesses, media...
Pedestrian Collisions – The Scene

• What data do we need?
  • Area/Point of Impact
  • Tire Marks (before and after impact)
  • Rest Positions (landmarks)
  • Traffic Signal Information
  • Time of Collision
  • Irregularities (construction, snow banks)
  • Artificial Lighting

Pedestrian Collisions – The Vehicle

• Vehicle Damage
  • Location and extent of damage
  • Height of contact
  • Angle of damage
  • Windshield contact?
  • Roof/Trunk/Side Panel contact
  • EDR (black box)

Pedestrian Collisions – The Driver

• Pre and post-impact vehicle motion
  • Where did vehicle come from?
  • Where was vehicle going?
  • Speed of vehicle?
  • Braking? (before and after)
  • Swerve?
  • How did vehicle get to rest?
Pedestrian Collisions – The Pedestrian

- Basic Personal Data - Age, Weight, Height
- Speed
  - Walk/Jog/Run/Sprint
  - Fitness may be important here
- Direction of Travel
- Clothing
- Full Medical information
  - Pre-existing conditions
  - Any gait problems? (knee operations, cane?)
  - Detailed medicals – nurses notes
- Photographs

Pedestrian Collision Case Study

Vehicle At Rest

Pedestrian At Rest

15 m skid marks

Area of Impact

Vehicle Speed

- Skid Distance = 15 m
  - Dry Asphalt
  - Using a range of friction, vehicle travelling 55 to 65 km/h at start of skids
- Pedestrian Throw Distance = 20 to 23 m
  - Empirical and Theoretical Relationships
Vehicle Speed vs. Throw Distance

Vehicle Speed

- Skid Distance = 15 m
  - Dry Asphalt
  - Using a range of friction, vehicle travelling 55 to 65 km/h at start of skids

- Pedestrian Throw Distance = 20 to 23 m
  - Empirical and Theoretical Relationships
  - Vehicle speed based on projection is 48 to 68 km/h

Pedestrian Motion

- Need to rely on statements
  - Walking or Jogging?
    - Walking ~ 1.65 m/s  Jogging ~ 3.4 m/s

- Pedestrian crossing from left to right
Pedestrian Motion

- Need to rely on statements
  - Walking or Jogging?
  - Walking ~ 1.65 m/s  Jogging ~ 3.4 m/s

- Pedestrian crossing from left to right
- Vehicles stopped in lanes, van first in line
- Pedestrian visible past right side of van for 1.3 s if walking, 0.8 s if jogging
- Consistent with little to no pre-impact braking
Conclusions

- Vehicle travelling between 55 and 65 km/h in a 60 km/h zone
- Pedestrian likely visible for less than 1.3 seconds
- If no sightlines through stopped vehicles, no opportunity for the driver to avoid.
Nighttime Collisions

- Determine when a driver could be expected to detect a pedestrian

- Important evidence to establish:
  - Time of collision
  - Colour of clothing (photos)
  - Headlights of vehicle
  - Artificial illumination
  - Weather
Pedestrians

Poor judges of approach speed
Risky crossing behaviour especially in the rain
Typically assume they can be seen from much farther than is actually the case

How far away can a driver see a pedestrian?

This depends on many factors:

- How old is the driver?
- What side was the pedestrian coming from?
- Are low beams or high beams on?
- What was the pedestrian wearing?
- What was the pedestrian’s background?
- Was there any artificial illumination in the area?
- Was the pedestrian moving?
- Were there any sources of glare?
- What was the weather like?

Nighttime Visibility – Experimental Data

Average detection distances for young drivers (18 to 30 years)

Nightime: White left: 81m
White right: 66m
Dark left: 32m
Dark right: 58m
Nighttime Visibility – Experimental Data

Average detection distances for old drivers (65 years or more)

White right: 60m
Dark right: 24m
Dark left: 20m
White left: 35m

Nighttime Visibility – Experimental Data

Average detection distances for unalerted older drivers

White right: 31m
Dark right: 12m
White left: 18m
Dark left: 10m

Nighttime Visibility

What if the incident scene is substantially different than the available experimental data?

- Find the time on the current date which has the same ambient light as the date of incident
- Recreate the scene as closely as possible including weather
- Measure the luminance contrast of the pedestrian
- Calculate the Visibility Level for the driver
Nighttime Visibility

Illuminance Meter

Spot Luminance Meter

What do we measure?

Luminance of target and background

Visibility Modelling

Visibility Modelling: Graph showing relationship between visibility and longitudinal distance from observer to target.
Pitfalls of Photography

- Objects can be made to look bright (or dark) in any lighting conditions by selecting camera settings:
  - 1/2s – f/5.6 – ISO 100
  - 1s – f/5.6 – ISO 100
  - 5s – f/5.6 – ISO 100

Nighttime Pedestrian Impact

- Woman jogging on an unlit rural road
- Struck by full size pickup and fatally injured

Could driver have seen pedestrian in time to avoid?

Scene Information

- No tire marks – vehicle equipped with ABS
- Debris gives rough area of impact
- Pedestrian comes to rest at side of road
- Throw distance from debris suggests vehicle speed of 70 to 90 km/h.

- Vehicle equipped with an event data recorder (black box)
EDR data

- EDR data says vehicle travelling at 83 km/h (82 to 87 km/h)
- Does last throttle point equate to reaction?
  Throttle change occurs as little as 0.1 seconds before impact

Nighttime Visibility

- Police measured a visibility distance of 72 m.
- Corrected for expectancy – 36 m.
- Average test subject detection – 48 m

- At 83 km/h, driver would travel 48 m in about 2 seconds
- Driver would travel 36 m in 1.5 seconds
- 50th percentile response time to a hazard directly in front of a driver is 1.1 seconds
- Average driver would have less than a second to brake

What is Biomechanics?

- Application of mechanical principles to the human body
- Injury biomechanics – how are injuries caused?
Injury Biomechanics

- Question: Is there a causal relationship between the injury and the event?
- Answer: Compare the required force to the applied force

Injury Biomechanics

- Mechanism – type of force
- Magnitude of force

Injury Biomechanics - Applications

Could this injury be caused by this collision?
Are the injuries from another event?
Pedestrian travel direction?
Vehicle speed?

Hypothetical situations
Injury Biomechanics - Qualifications

Engineer
- Reconstruction
- Impact severity
- Anatomy
- Physiology
- Injury mechanics

Biomechanist
- Anatomy/Physiology
- Occupant loading
- Injury mechanics
- Tissue tolerance

Physician
- Diagnosis
- Treatment
- Collision mechanics
- Occupant loading
- Tissue tolerance

Impact Velocity Distribution

Pedestrian Deaths vs. Speed

Chances of survival
- ≤30km/h more than 90%
- ≥45km/h less than 50%
Pedestrian Crash Data Study

- 552 detailed crashes involving pedestrians in six major U.S. cities (2005)

Body Orientation

- Lateral: 24%
- Anterior / Posterior: 21%
- Other: 5%

Leg Orientation

- Other: 24%
- Apart Lateral: 5%
- Together: 6%
- Stance: 69%

Pedestrian crossing roadway

Pedestrian Impact Sequence

- Lower Extremity Contact
- Wrap Around Front End
- Head Strike

Rotation from Leg Orientation

- Struck limb forward led to a clockwise rotation to the posterior side.
- Struck limb back led to a counter-clockwise rotation to the anterior face.
Post Impact Kinematics

PCDS Avoidance Maneuvers

<table>
<thead>
<tr>
<th>Variable #</th>
<th>Avoidance Maneuver</th>
<th>Frequency</th>
<th>Percentage</th>
<th>Cumulative</th>
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<tbody>
<tr>
<td>4</td>
<td>Brake (Lockup Unknown)</td>
<td>6</td>
<td>1.1%</td>
<td>1.1%</td>
</tr>
<tr>
<td>3</td>
<td>Brake (Lockup)</td>
<td>82</td>
<td>15.6%</td>
<td>16.7%</td>
</tr>
<tr>
<td>2</td>
<td>Brake (No Lockup)</td>
<td>142</td>
<td>27.0%</td>
<td>43.7%</td>
</tr>
<tr>
<td>6</td>
<td>Brake and Steer Left</td>
<td>42</td>
<td>8.0%</td>
<td>51.7%</td>
</tr>
<tr>
<td>9</td>
<td>Brake and Steer Right</td>
<td>26</td>
<td>4.9%</td>
<td>56.7%</td>
</tr>
<tr>
<td>1</td>
<td>No Avoidance</td>
<td>207</td>
<td>39.4%</td>
<td>95.0%</td>
</tr>
<tr>
<td>98</td>
<td>Tumbling/Rolling</td>
<td>2</td>
<td>0.4%</td>
<td>95.4%</td>
</tr>
<tr>
<td>5</td>
<td>Releasing Brakes</td>
<td>1</td>
<td>0.2%</td>
<td>95.6%</td>
</tr>
<tr>
<td>6</td>
<td>Steering Left</td>
<td>11</td>
<td>2.1%</td>
<td>97.7%</td>
</tr>
<tr>
<td>7</td>
<td>Steering Right</td>
<td>6</td>
<td>1.1%</td>
<td>98.8%</td>
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<tr>
<td>10</td>
<td>Accelerating</td>
<td>1</td>
<td>0.2%</td>
<td>100.0%</td>
</tr>
<tr>
<td></td>
<td>TOTALS</td>
<td>526</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Application of the Brakes

\[ V_i \]

\[ V_f = 0 \]

Initial Impact  Trajectory Phase  Tumbling/Rolling  Pedestrian Throw Distance
No Application of Brakes

<table>
<thead>
<tr>
<th>Initial Impact</th>
<th>Trajectory Phase</th>
<th>Tumbling/Rolling</th>
</tr>
</thead>
</table>

Injury Distribution

**Top 10 Most Frequent Injuries**

1. Brain-Cerebrum Injury
2. Tibia Fractures
3. Fibula Fractures
4. Head-Loss of Consciousness
5. Pelvis Fractures
6. Rib Fractures
7. Femur Fractures
8. Humerus Fractures
9. Cervical Spine Injury
10. Lung Injury

Pedestrian Impact Risk

- **Head injury** is the major cause of death
- **Torso injuries** are generally minor except for impacts involving SUV’s, trucks and vans
- **Leg injuries** are the most frequent and usually the most disabling pedestrian injury
Injury vs. Vehicle Geometry

**Sedans, Coupes**
- Head injuries
- Leg injuries
- Tib/Fib fractures
- Knee injuries

**SUV, Trucks, Vans**
- Thoracic injuries
- Abdominal injuries
- Pelvic injuries
- Femur fractures

*Function of vehicle geometry, pedestrian height, and impact speed.*

Vehicle Profile Comparison

Lower Extremity Injury Mechanism

- Direct Impact Trauma
- Valgus bending
- Induced bending
Tibial Fracture Patterns

Fracture Types

Type A3: low energy, minimally displaced

Type C2: pedestrian struck by automobile

25 mph Impact, Struck Leg Back
Sedan vs. SUV Comparison

Pedestrian Orientation Case

Incident: Pedestrian collision
Impact Speed: 36 km/h
Diagnosis: Pelvic fracture / bilateral pubic rami
Material: Medical Information
Issue: Was pedestrian crossing or walking along highway?

Injury Mechanism
Injury Analysis - Crossing highway

Load from the side – pubic rami fracture

Injury Mechanism

Load from behind – pubic rami separation, but no fracture

Injury Analysis - Walking along highway
Report Conclusion

Based on injury pattern, crossing highway at impact more likely than walking along highway

Bicycle Collisions

- Similar to pedestrian collisions
- Extra information to collect:
  - Bicycle specifications (size, tires, gears)
  - Rider experience and ability
  - Lights and reflectors
  - Rider clothing (reflective?)
  - Helmet use
  - Bicycle damage
  - Bicycle computer?
  - Slope of roads

Rider Ability

- Bicyclist likely travelling faster than a pedestrian – avoidance
  - Harder for driver to avoid if bicycle crosses vehicle path
  - Easier for driver to avoid if bicycle travelling in same direction
Lights and Reflectors

- Location of lights and reflectors important
- Most lights and reflectors not visible from side
- Motion can greatly increase detection distance at night
- Pedal reflectors or retroreflective strips on a rider's shoes or pants can significantly increase visibility
Cyclist Impacts

Bicycle Helmet Testing

Questions?

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Evidence to collect in vehicle collisions with pedestrians/bicycles

**Scene**
- Area or point of impact
- Rest positions – vehicle, bicycle, pedestrian/rider, debris
- Tire marks – vehicle and bicycle
- Traffic signal information – pedestrian and vehicle signals
- Location of other vehicles on road
- Sightline obstructions
- Time of collision
- Weather and road conditions
- Light sources
- Road features that may affect bicycle or pedestrian path
- Temporary irregularities – (e.g., snowbank, construction)

**Vehicle Damage**
- Detailed photographs of vehicle damage, scuff, marks, etc.
- Location of front end damage – height, width, depth
- Hood and windshield contacts
- Side mirror, roof or trunk contacts
- Event data recorder (black box)
- If hit and run, vehicle type?

**Bicycle**
- Bicycle – make, model, year, size, prior condition
- Location and extent of damage
- Brakes – manufacturer, brake type, condition
- Handlebars – type and alignment
- Tires – condition, tire style, pressure
- Seat height
- Number of gears; in what gear was bicycle?
- Location of all lights and reflectors.
- Were lights on? Continuous or flashing?
- Helmet type, age and damage
- Onboard computer? – GPS data, speed, cadence

**Driver Evidence**
- Speed of vehicle
- Lane of travel, lateral lane position
- Pre-impact braking or swerve?
- Was vehicle braked all the way to rest?
- When and where was pedestrian first observed?
- Distractions (e.g., cell phone/PDA/GPS Navigation)

**Pedestrian**
- Personal data – age, height, weight
- Speed – walk, jog or run
- Direction of travel
- Clothing and footwear – colour, fabric, reflective elements – photographs
- Pre-existing gait problems or injuries?
- Detailed medical information – location of abrasions, bruises, lacerations
- Photographs of injuries
- Reaction to vehicle? – movement?, jump? arms out?

**Rider**
- Helmet use? Proper adjustment?
- Reflective clothing?
- Pre-collision actions – sprinting?, drinking/eating?
- Experience level
- Body and hand positions
- Leg length
- Distance ridden on current trip
- Purpose of trip – training, commute, casual ride
- Riding solo or in a group? Formation?
DENNIS CHIMICH, MEA FORENSIC ENGINEERS & SCIENTISTS

Dennis Chimich is a principal and senior biomechanical engineer with MEA Forensic Engineers & Scientists. Dennis has performed more than 1500 injury biomechanics investigations. He has been co-investigator of several research studies including whiplash biomechanics, occupant kinematics, helmet effectiveness and slip and fall. He has published papers in peer-reviewed journals on these areas as well as on the biomechanics of knee ligament injuries. Dennis is a registered professional engineer in British Columbia, Ontario and Alberta and has been qualified to give expert evidence as a Biomechanical Engineer in the field of Injury Biomechanics in the Supreme Court of British Columbia, the Court of Queen’s Bench in Alberta, and the Superior Court of the State of Washington.
CRAIG WILKINSON, MEA FORENSIC ENGINEERS & SCIENTISTS

Craig Wilkinson is a senior engineer with MEA Forensic Engineers & Scientists and has over 10 years of forensic engineering experience. Craig has performed more than 1000 investigations, participated in over 1500 crash and vehicle dynamics tests, published 7 research papers on the accuracy of event data recorders and frequently lectures on this and other collision reconstruction topics at conferences in Canada and the United States. Craig is a registered professional engineer in Ontario and British Columbia and has been qualified to give expert evidence as a Mechanical Engineer in the field of Accident Reconstruction in the Supreme Court of British Columbia and the Ontario Superior Court of Justice.
Patricia Armstrong joined the firm in 2001 and is an associate practising in Lindsay Kenney’s Vancouver office.

Patricia has many years of experience in insurance defence litigation on behalf of the Insurance Corporation of British Columbia. While working as in-house counsel for ICBC she was involved in the development of numerous defence strategies, including the low velocity impact program and the auto-immune defence strategy. Patricia specializes in complex medical issues including the defence of brain injury, chronic pain, fibromyalgia, PTSD and psychological claims, as well as auto-immune claims of various types. She has extensive trial experience in Judge alone and jury trials.

Patricia has been a faculty member of numerous Law Society Continuing Education courses as well as those of the Canadian Defence Lawyers Association and has attended numerous international conferences.

PROFESSIONAL AFFILIATIONS & MEMBERSHIPS

- Canadian Bar Association
- British Columbia Bar Association
- Canadian Defence Lawyers Association, board member