

# **Injury and Collision Characteristics That Together Are Suggestive of Diaphragmatic Rupture**

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# History of Diaphragm Injury

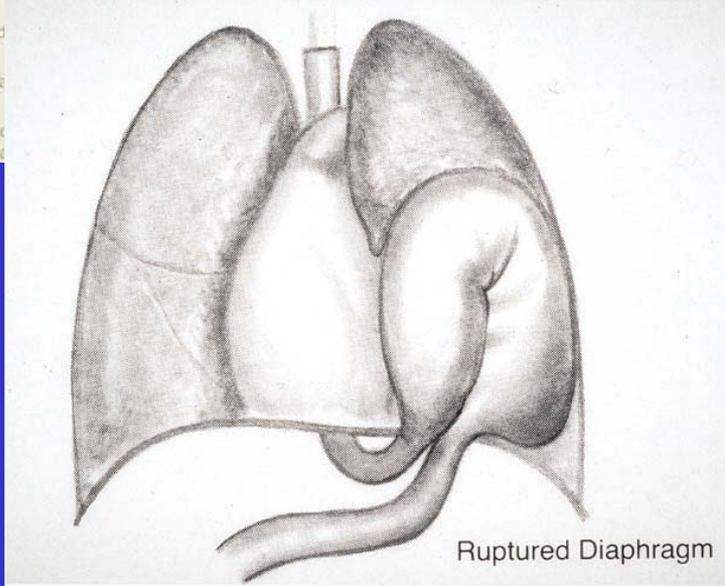
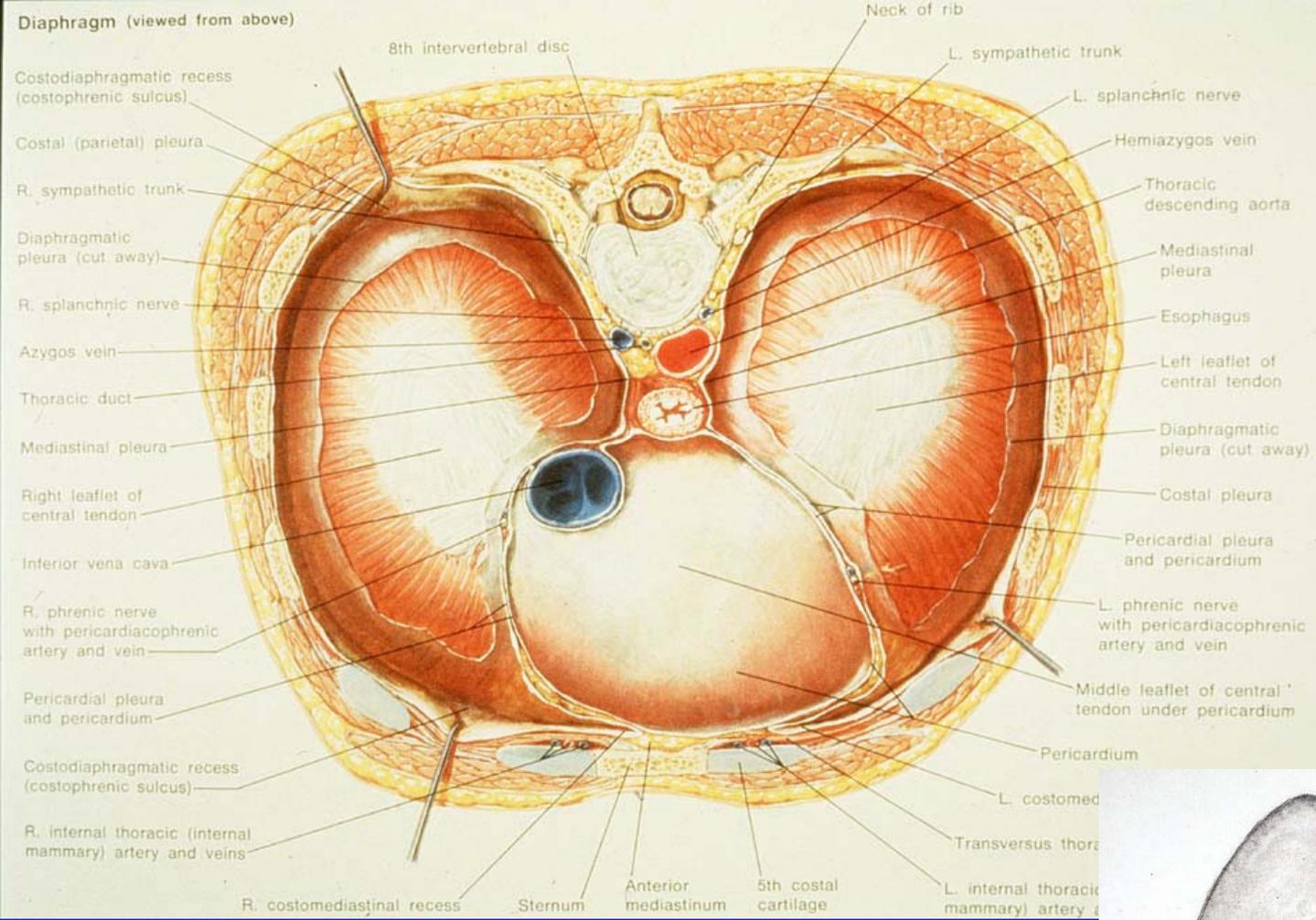
- Diaphragm rupture (DR) first described by Sennertus in 1541
- Bowditch (1853) established the first ante-mortem diagnosis of a traumatic diaphragmatic hernia
- Riolfi (1886) is credited with the first successful repair of a diaphragmatic laceration

# Diaphragmatic Injuries - Historical

- **Ambrose Pare (1579)**
  - Description of delayed presentations of 4 patients - herniation involved 2 colons , 2 stomachs
  - Typical patient
    - French artillery captain , chest wound 8 mos. prior
    - colonic obstruction due to diaphragmatic herniation
    - Autopsy : diaphragmatic rent " no larger than the tip of the finger "

# Diaphragmatic Injuries

Defect in the diaphragm does not enlarge with time, but it is the volume of herniated viscera that increases .



Cross-sectional representation of diaphragm injury – inset picture indicating location of diaphragm

# Diaphragmatic Injuries - Kinematics

- Incidence = 2 - 5 % of blunt trauma
- Diaphragmatic rupture results from :
  - compression to lower thoracic area = shearing force
  - MVA - deceleration against seat belts
  - fall from heights
  - explosive increase in intraabdominal pressure

# Modern Diagnosis

- Consensus remains that “high index of suspicion” is critical to making a preoperative diagnosis of Diaphragmatic Rupture (DR)
  - Radiographs have low sensitivity/specificity
  - CT lacks specific findings that relate to diaphragmatic injuries
  - DPL requires associated intra-abdominal injuries to identify DR

# Modern Diagnosis

- As conventional means proved inadequate in detecting Diaphragmatic Rupture (DR), investigators developed alternatives to diagnose DR
  - Peritoneal insufflation (Clay and Hanlon)
  - Peritoneal “irrigation” (Mays and Fallazadeh)
  - Radio isotopic scintigraphy (Armstrong)

# Modern Diagnosis

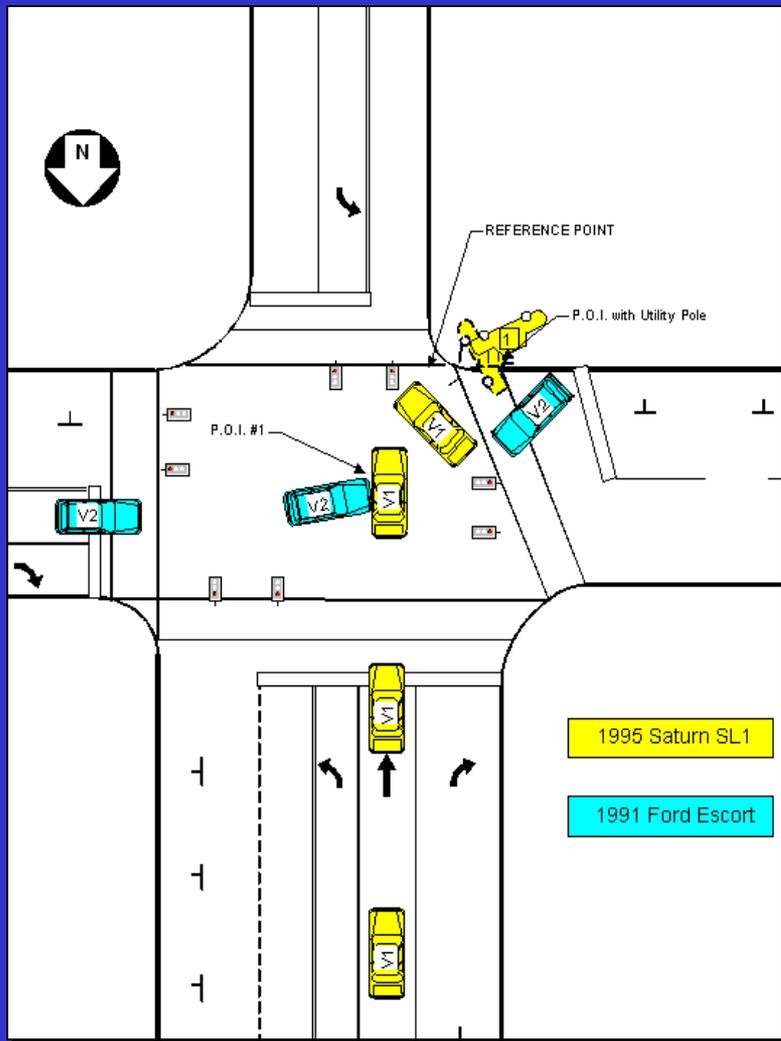
- Despite the numerous diagnostic approaches to DR, the majority of injuries are found during operation for other injuries
  - Guth AA, et al. Am J Surg. '95
- Thus, as the current trend moves towards non-operative management of solid organ injury following blunt trauma, the early identification of DR will become more difficult

# Hypothesis

**Combining information gained at the scene of a motor vehicle collision (MVC) with specific injuries identified early during the primary and/or secondary survey can predict a Diaphragmatic Rupture**

# Case 1

- 24 year old restrained driver of 1995 Saturn SL
- Near-side collision with Ford Escort
- Extrication time of 15 minutes using Hurst tool to remove door
- Transported by ground ambulance



**CASE VEHICLE**  
**CASE SUBJECT**  
**OPPOSING VEH.**  
**TIME OF CRASH**  
**ROAD COND.**  
**RESTRAINTS**

1995 Saturn SL 1  
 Driver  
 1991 Ford Escort  
 10:30 a.m. / daylight  
 Dry asphalt  
 Lap/shoulder belts  
 Deployed frontal airbag

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**POSTED SPEED LIMIT = 30 mph**

**Case vehicle travel speed = 30 mph**  
**Opposing vehicle travel speed = 30 mph**



Photographs of intersection and  
resting stop of vehicles



Post-crash photos of subject vehicle, indicating points of impact, and protrusion

**1995 Saturn SL1**



**INTRUSIONS**

|                 |              |
|-----------------|--------------|
| Left door panel | 20 cm (8 in) |
| Left sill       | 20 cm (8 in) |
| Left 'B' pillar | 14 cm (6 in) |
| Left kick panel | 8 cm (3 in)  |

|           |                   |
|-----------|-------------------|
| Wheelbase | 260 cm (102 in)   |
| Curb wt.  | 1054 kg (2324 lb) |
| PDOF      | 300 Degrees       |
| CDC       | 10 LYEW3          |
| Delta-V   | 26 km/h (16 mph)  |



**1991 Ford Escort**

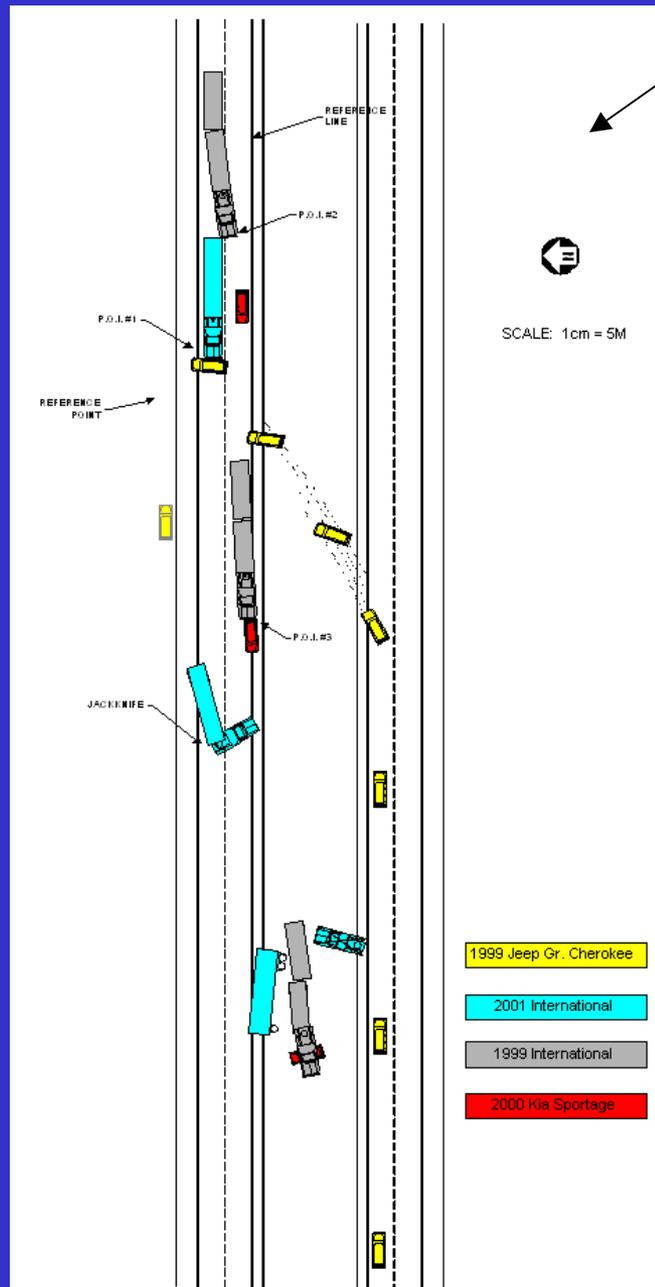
# Case 1 Injuries

- Ruptured left diaphragm
- Grade IV splenic laceration
- Left superior/inferior pubic rami fractures
- Left sacral fracture

## Case 2

- 60 year-old female restrained driver of a 1999 Jeep Grand Cherokee
- Far-side impact by a 2001 International trailer truck
- Frontal airbag deployed

Graphic indicating pattern of vehicle travel and post-impact



**CASE VEHICLE**  
**CASE SUBJECT**  
**OPPOSING VEH.**  
**TIME OF CRASH**  
**ROAD COND.**  
**RESTRAINTS**

1999 Jeep Gr. Cherokee  
Driver  
2001 International  
2:00 p.m. / daylight  
Wet asphalt  
Lap / shoulder belts  
Deployed frontal airbag

**POSTED SPEED LIMIT = 70 mph**

**Case vehicle travel speed = 70 mph**  
**Opposing vehicle travel speed = 60 mph**



Eastbound path of travel for Jeep Cherokee

# 1999 Jeep Grand Cherokee 4-door 4x2 (Post Crash)



Wheelbase 269 cm (106 in)  
Curb wt. 1775 kg (3913 lb)  
PDOF +70 degrees  
CDC 02RDAW6  
BE 79 km/h (49 mph)



## INTRUSIONS

|                      |               |
|----------------------|---------------|
| Right door panel     | 82 cm (34 in) |
| Right 'B' pillar     | 64 cm (25 in) |
| Right sill           | 75 cm (30 in) |
| Right roof side rail | 49 cm (19 in) |
| Center console       | 20 cm (8 in)  |



*2001  
International  
trailer  
Truck (Post  
Crash)*

# Case 2 Injuries

- Ruptured left diaphragm
- Grade III splenic laceration
- Right superior/inferior pubic rami fx
- Right SI diastasis
- Left rib fx with pulmonary contusion

# Common Characteristics Between Case 1 and Case 2

| Crash Characteristics |                      |                   | Patient Injuries  |           |
|-----------------------|----------------------|-------------------|-------------------|-----------|
|                       | $\Delta V$<br>(km/h) | Intrusion<br>(cm) | Splenic<br>Injury | Pelvic Fx |
| Case 1                | 26                   | 20                | Yes               | Yes       |
| Case 2                | 79                   | 82                | Yes               | Yes       |

# Hypothesis

**We propose that combining information gained at the scene of an MVC with specific injuries identified early during the primary and/or secondary survey can be used to predict the presence of a Diaphragmatic Rupture**

# Methods – Data Source

- National Automotive Sampling System (NASS) data, 1995-1999

*National probability sample of passenger vehicles that would be involved in police-reported tow-away crashes*

# Methods – Study Population

- Front seat occupants (Driver or Passenger) wherein a partial or complete vehicle inspection was conducted
- Inclusion was further limited by requiring associated injuries
  - Abdominal Injury (Abbreviated Injury Scale (AIS)  $\geq 2$ )
  - Thoracic Injury (AIS  $\geq 3$ )

# **Methods – Definitions**

Primary outcome of interest

**Diaphragm Rupture**

**AIS Code 440604.3**

# Methods – Definitions

## *Selected measures of interest*

### Associated Injuries

-Pulmonary contusion

-Thoracic aortic injury

-Splenic injury

-Rib fractures

-Hepatic injury

-Pelvic fracture

# Methods – Definitions

## *Selected measures of interest*

- Collision Characteristics
  - Direction
    - Frontal
    - Rearward
    - Nearside Lateral
    - Far side Lateral
  - Measured Intrusion
  - Change in velocity at time of collision ( $\Delta V$ )

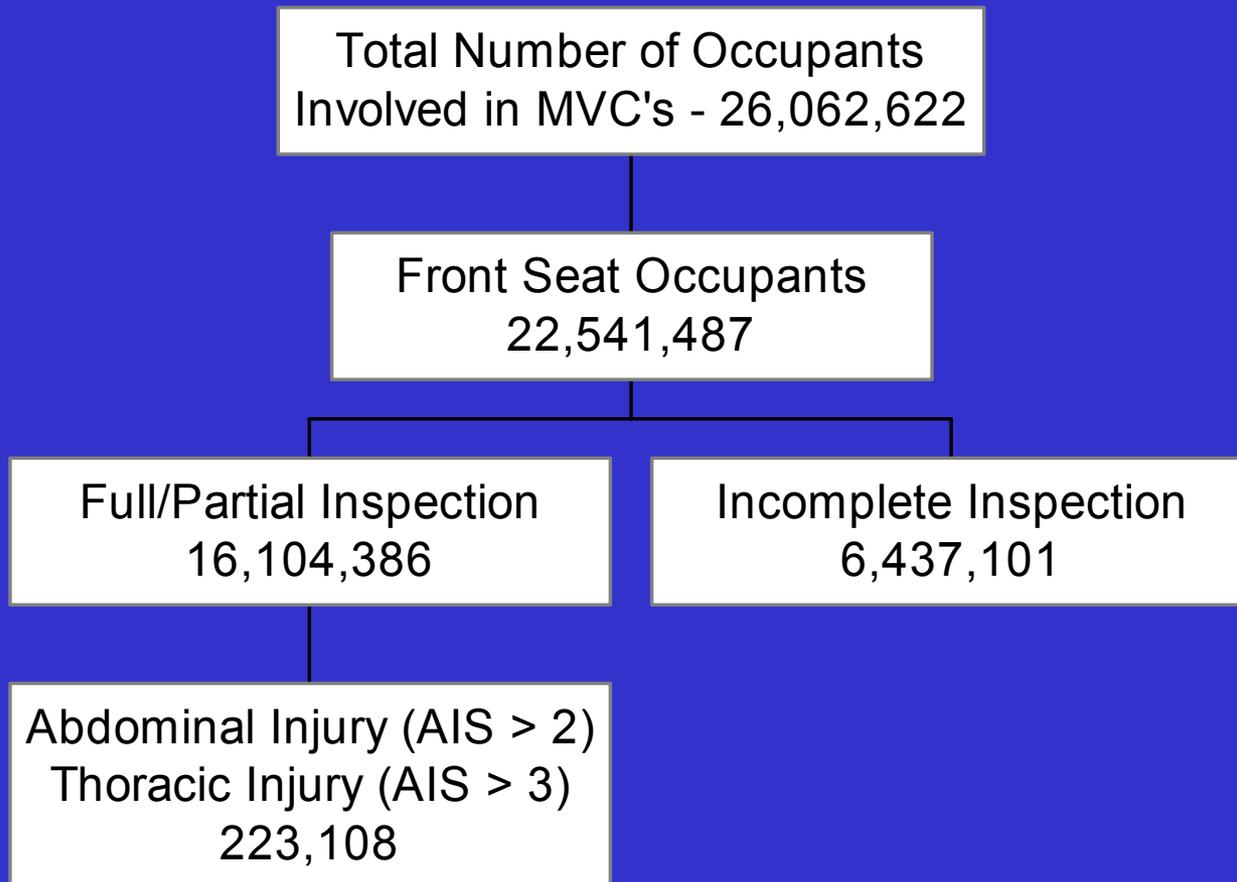
# Methods – Statistical Analysis

## *Analyses conducted using weighted data*

- Calculate and compare the DR risk by measured compartment intrusion,  $\Delta V$  and the presence of associated thoraco-abdominal injuries
- Risk ratios (RRs) and 95% confidence intervals (CIs) calculated using SUDAAN (version. 8.0).

# Results

## *Final Study Population*



Total number of **Diaphragmatic Ruptures** identified – 8,031

# Results

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|                           | Diaphragm Rupture | No Diaphragm Rupture | p-value |
|---------------------------|-------------------|----------------------|---------|
| Gender, <i>No. (%)</i>    |                   |                      |         |
| <i>Male</i>               | 3,473 (43.2)      | 108,367 (50.4)       | 0.6587  |
| <i>Female</i>             | 4,558 (56.8)      | 106,710 (49.6)       |         |
| Age, <i>Mean (SD)</i>     | 43.3 (21.5)       | 39.1 (18.9)          | 0.0282  |
| ISS, <i>Mean (SD)</i>     | 40.2 (20.1)       | 21.4 (16.0)          | 0.0002  |
| Mortality, <i>No. (%)</i> | 4,073 (50.7)      | 39,101 (18.2)        | 0.0016  |

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# Results

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|                                      | Diaphragm<br>Rupture | No<br>Diaphragm<br>Rupture | p-value  |
|--------------------------------------|----------------------|----------------------------|----------|
| <hr/>                                |                      |                            |          |
| Seating Position, <i>No. (%)</i>     |                      |                            |          |
| <i>Driver</i>                        | 6,951 (86.6)         | 164,989 (76.8)             | 0.1110   |
| <i>Passenger</i>                     | 1,080 (13.5)         | 49,916 (23.2)              |          |
| Delta-V (kph), <i>Mean (SD)</i>      | 50.3 (17.2)          | 36.4 (15.9)                | < 0.0001 |
| Max Intrusion, <i>cm., Mean (SD)</i> | 70.6 (27.8)          | 52.3 (29.0)                | < 0.0001 |
| <br>                                 |                      |                            |          |
| Seatbelt use, <i>No. (%)</i>         |                      |                            |          |
| <i>Yes</i>                           | 4,154 (51.7)         | 113,420 (52.7)             | 0.8468   |
| <i>No</i>                            | 3,876 (48.3)         | 101,657 (47.3)             |          |

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# Results

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| Organ Injured   | DR<br>No., (%) | No DR<br>No., (%) | RR<br>(95% CI) |
|-----------------|----------------|-------------------|----------------|
| Pulm contusion  | 3,611 (45.0)   | 68,446 (31.8)     | 1.8 (1.1- 2.8) |
| Rib fracture    | 5,214 (64.9)   | 121,064 (56.3)    | 1.4 (1.0- 2.2) |
| Thoracic aorta  | 1,225 (15.3)   | 8,794 (4.1)       | 4.2 (1.8-10.1) |
| Spleen          | 4,324 (53.9)   | 38,186 (17.8)     | 5.4 (2.5-11.8) |
| Liver           | 2,777 (34.6)   | 40,564 (18.9)     | 2.3 (0.9- 5.7) |
| Pelvic fracture | 3,344 (41.6)   | 32,530 (15.1)     | 4.0 (2.4- 6.7) |

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# Results

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| <i>Direction</i> and<br><i>Magnitude</i> of<br>Intrusion | DR<br>No., (%) | No DR<br>No., (%) | RR<br>(95% CI) |
|--|----------------|-------------------|----------------|
|--|----------------|-------------------|----------------|

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## *Lateral*

|         |              |                |           |
|---------|--------------|----------------|-----------|
| < 30 cm | 3,355 (41.8) | 162,830 (75.7) | 4.3       |
| ≥ 30 cm | 4,676 (58.2) | 52,248 (24.3)  | (2.5-7.6) |

## *Frontal*

|         |              |                |           |
|---------|--------------|----------------|-----------|
| < 30 cm | 6,351 (79.1) | 179,785 (83.6) | 1.4       |
| ≥ 30 cm | 1,680 (20.9) | 35,293 (16.4)  | (0.3-7.1) |

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# Results

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| <i>Combined Characteristics</i>  | DR<br>No., (%) | No DR<br>No., (%) | RR<br>(95% CI) |
|--|----------------|-------------------|----------------|
| Intrusion $\geq 30$ cm or $\Delta V \geq 40$ kph                                 | 6,724 (83.7)   | 109,205 (50.8)    | 5.0 (3.1-8.2)  |
| Spleen injury, Pelvic fracture or Intrusion $\geq 30$ cm                         | 6,857 (85.4)   | 91,625 (42.6)     | 7.9 (4.7-13.1) |
| Spleen injury, Pelvic fracture or $\Delta V \geq 40$ kph                         | 7,039 (87.7)   | 107,457 (50.0)    | 7.1 (3.5-11.7) |
| Spleen injury, Pelvic fracture, $\Delta V \geq 40$ kph or Intrusion $\geq 30$ cm | 7,297 (90.9)   | 132,119 (61.4)    | 6.2 (2.7-14.4) |

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| Combined Characteristics   | Sensitivity | Specificity |
|--|-------------|-------------|
| Intrusion $\geq 30\text{cm}$ or Delta-V $\geq 40\text{kph}$                                  | 83.7        | 49.2        |
| Spleen Injury, Pelvic Fracture or Intrusion $\geq 30\text{cm}$                               | 85.4        | 57.4        |
| Spleen Injury, Pelvic Fracture or Delta-V $\geq 40\text{kph}$                                | 87.7        | 50.0        |
| Spleen Injury, Pelvic Fracture, Intrusion $\geq 30\text{cm}$ or $\Delta V \geq 40\text{kph}$ | 90.9        | 38.6        |

# Conclusions

- Vehicular intrusion or  $\Delta V$  combined with specific injuries that are diagnosed early during the resuscitative phase following blunt trauma are highly suggestive of diaphragmatic rupture
- Clinical “index of suspicion” for DR should be heightened when these injuries are diagnosed following a MVC with intrusion  $\geq 30$  cm or  $\Delta V \geq 40$  kph