

Real World Frontal Impacts Involving Infants and Toddlers

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MOVES Research Team

- Conducts field investigations and research for Transport Canada
 - Collision investigations
 - Investigations of public complaints of safety-related motor vehicle defects
 - Motor vehicle safety research
- Collision investigation studies
 - Air Cushion Restraint Study (ACR9)
 - Special Investigations (ASF7)
 - Pediatric Restrained Occupant Study (PROS)
 - Rear Occupant Protection Study (ROP3)
 - Side Impact Study (SID7)



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**Pediatric Restrained
Occupant Study**

Transport
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Southwestern Collision
Analysis



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Pediatric Restrained Occupant Study

- Injury causation study focused on children
 - Pediatric = 17 years of age and under
- Case notifications
 - LHSC Trauma Program, police and media
- Police and injury data
 - Data collected for all pediatric vehicle occupants that attend LHSC
- Field investigations of severe collisions
 - Transport Canada's real world collision research program

Methodology

- Focus on severe frontal impacts involving restrained children under 2 years of age
- Collisions investigated by the Western MOVES Team and Transport Canada's network of research teams
- Minimum delta-V of 30 km/h
 - Delta-V determined from Event Data Recorder (EDR) when available
 - Delta-V determined from crush analysis when no EDR data
- Comparison of injury severity (AIS) and impact severity (delta-V)

Which impact is more severe?



- Full-frontal crash test into rigid barrier at 50 km/h
- Full-frontal into identical vehicle both at 50 km/h

Abbreviated Injury Scale (AIS)

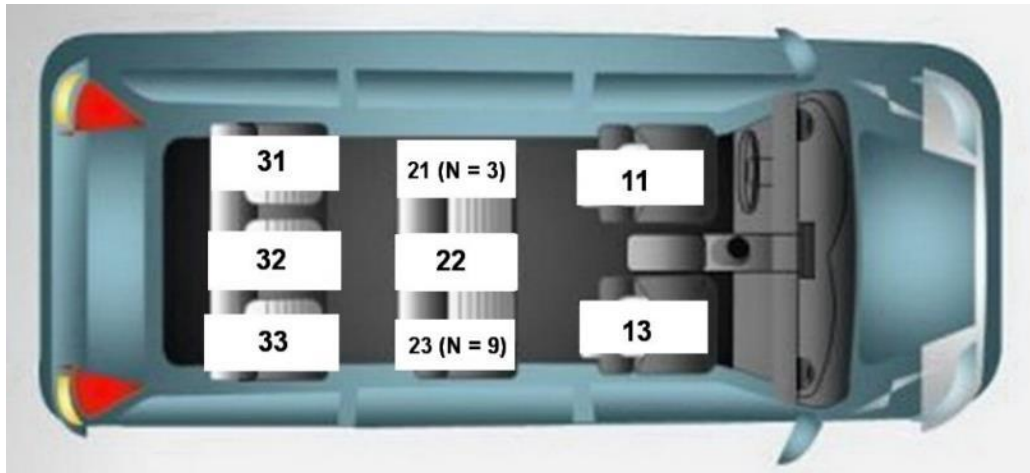
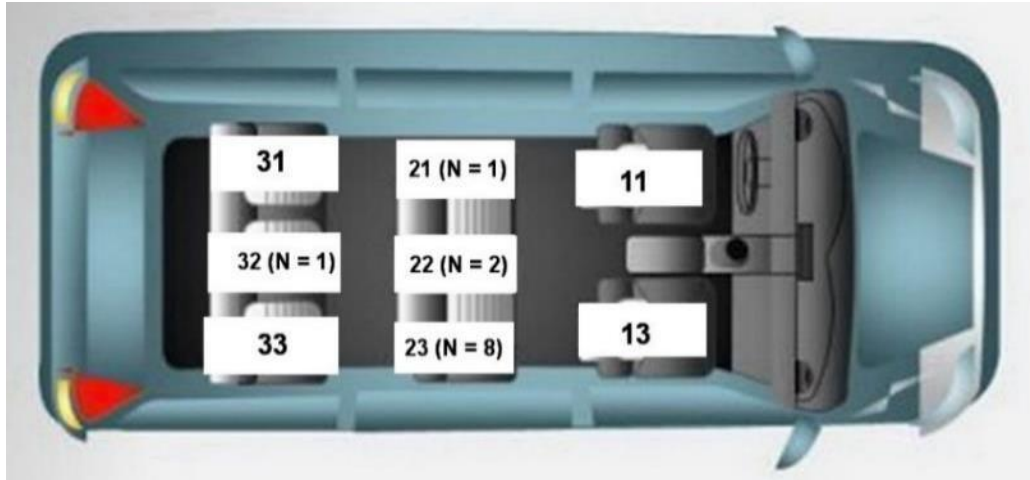
- ❑ Injuries are ranked on a scale of 1 to 6 according to the associated threat to life
- ❑ MAIS = Maximum Abbreviated Injury Scale

AIS Score	Injury
1	Minor
2	Moderate
3	Serious
4	Severe
5	Critical
6	Unsurvivable

Results

- Collisions (N = 25) involved 25 children (13 F / 12 M) under 2 years
 - 13 infants aged 1 to 12 months (6 F / 7M)
 - 12 toddlers aged 1 year (> 12 months) (7 F / 5 M)
- Severe frontal impacts
 - Delta-V ranged from 30 km/h to 84 km/h
 - Average delta-V of 49 ± 14 km/h
 - No intrusion into rear occupant compartment (survivable collisions)
- Two fatalities and 6 children admitted to hospital with serious injuries
 - Minor injuries (N = 10) and no injuries (N = 7)

Seating Positions



Infant Cases
(N = 12 / 1 Unknown)

Average of 3 to 4
occupants per
vehicle

Toddler Cases
(N = 12)

Infant Case Summary (< 12 months)

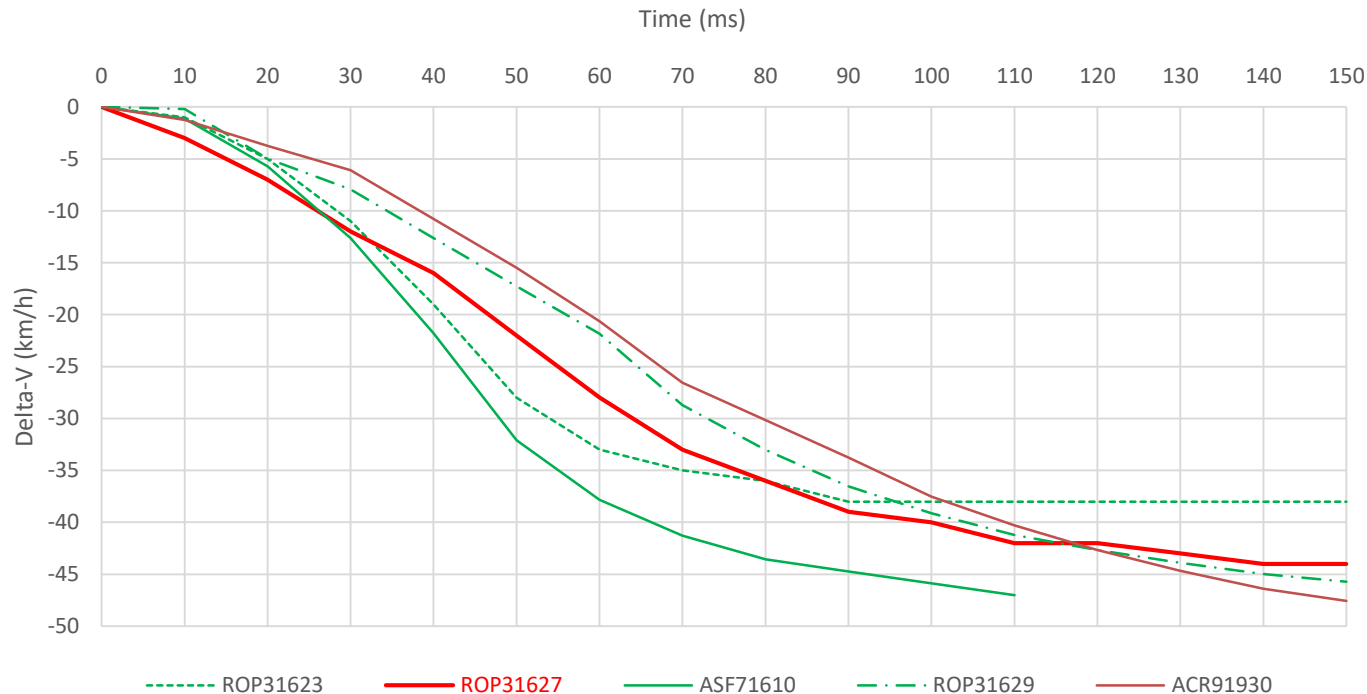
CASE	MONTHS	GENDER	INFANT SEAT	DELTA-V (KM/H)	INJURY SEVERITY	MAIS- HEAD	MAIS- CERV	MAIS- THORAX	LOWER EXTREMITY
ROP31626	11	MALE	UNKNOWN	30	NO INJURY	0	0	0	N
ROP31902	1	FEMALE	REMOVEABLE BASE	30	NO INJURY	0	0	0	N
ROP31623	9	FEMALE	UNKNOWN	39	MINOR	1	0	0	N
ASF71606	3	MALE	REMOVEABLE BASE	41	NO INJURY	0	0	0	N
ROP31627	2	MALE	BASE NOT USED	46	FATAL	5	0	0	UNKNOWN
ASF71610	5	MALE	REMOVEABLE BASE	47	MINOR	UK	UK	UK	UNKNOWN
ROP31633	9	MALE	CONVERTIBLE	50	NO INJURY	0	0	0	N
ROP31629	10	MALE	CONVERTIBLE	54	NO INJURY	1	0	0	N
ACR91930	7	FEMALE	UNKNOWN	58	ADMITTED	UK	UK	UK	UNKNOWN
ASF61911	9	FEMALE	CONVERTIBLE	60	MINOR	1	0	0	N
PROS1603	2	FEMALE	REMOVEABLE BASE	62	ADMITTED	5	1	3	FEMUR FRACTURE
ASF71620	7	FEMALE	REMOVEABLE BASE	67	FATAL	5	3	0	THIGH BRUISES
ASF61913	4	MALE	REMOVEABLE BASE	84	ADMITTED	4	0	0	FEMUR FRACTURE

Infant Cases

- Two infants were fatally injured and 3 were admitted to hospital with serious injuries
 - Age range of 2 to 7 months
- At least 4 of the 5 seriously / fatally injured were seated in rear-facing infant carriers (ie. not convertible seats)
 - In 1 case type of infant seat was unknown (removed)
- Interaction with unrestrained cargo (N=1) and an unrestrained occupant (N=2) was observed in 2 of the 5 cases

Delta-V of Impacts Involving Infants

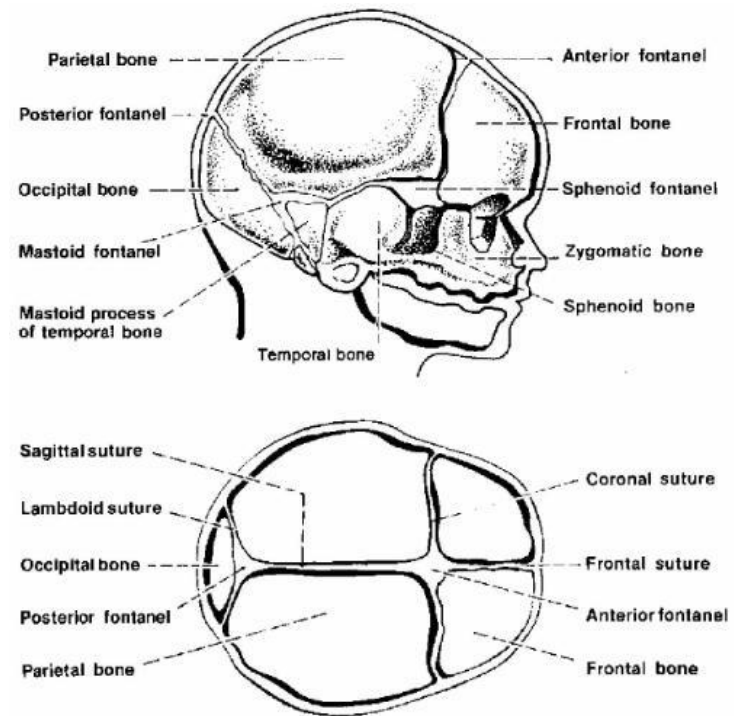
- Delta-V ranged from 30 to 84 km/h (51 ±15 km/h)
- Delta-V ranged from 46 km/h to 84 km/h in serious injury cases



Recorded Longitudinal Delta-V (Age < 1 Year)

Infant Cases: Head Injuries

- At least 4 of 5 seriously injured infants sustained severe head trauma (MAIS-4 or greater)
 - In 1 case the infant was admitted to hospital but injuries not reported
- Head injuries due to contact with the car seat shell, seatback or center console
- Injuries to the femurs or thighs occurred in 3 of the serious head injury cases
 - Injury source likely harness loading



Toddler Case Summary (> 12 Months)

CASE	MONTHS	GENDER	CAR SEAT TYPE	DELTA-V (KM/H)	INJURY SEVERITY	MAIS-HEAD	MAIS-CERV	MAIS-THORAX
ROP31902	22	MALE	CONVERTIBLE	30	NO INJURY	0	0	1
ACR81825	18	FEMALE	CONVERTIBLE	31	MINOR	0	0	1
PROS1612	19	FEMALE	CONVERTIBLE	32	MINOR	0	0	0
ASF71913	uk	FEMALE	REAR-FACING INFANT	36	MINOR	1	0	0
ACR91920	uk	FEMALE	CONVERTIBLE	49	MINOR	0	0	1
ACR81609	18	FEMALE	CHILD SEAT	50	ADMITTED	0	2	0
ACR81855	uk	MALE	CONVERTIBLE	50	MINOR	0	0	1
ROP31628	uk	MALE	CONVERTIBLE	50	MINOR	1	0	0
ROP31620	15	FEMALE	CONVERTIBLE	56	ADMITTED	1	4	1
ASF61224	17	MALE	CONVERTIBLE	50	NO INJURY	0	0	0
ASF61347	uk	FEMALE	CONVERTIBLE	69	MINOR	1	0	0
ROP31909	uk	MALE	CONVERTIBLE	78	ADMITTED	7	0	0

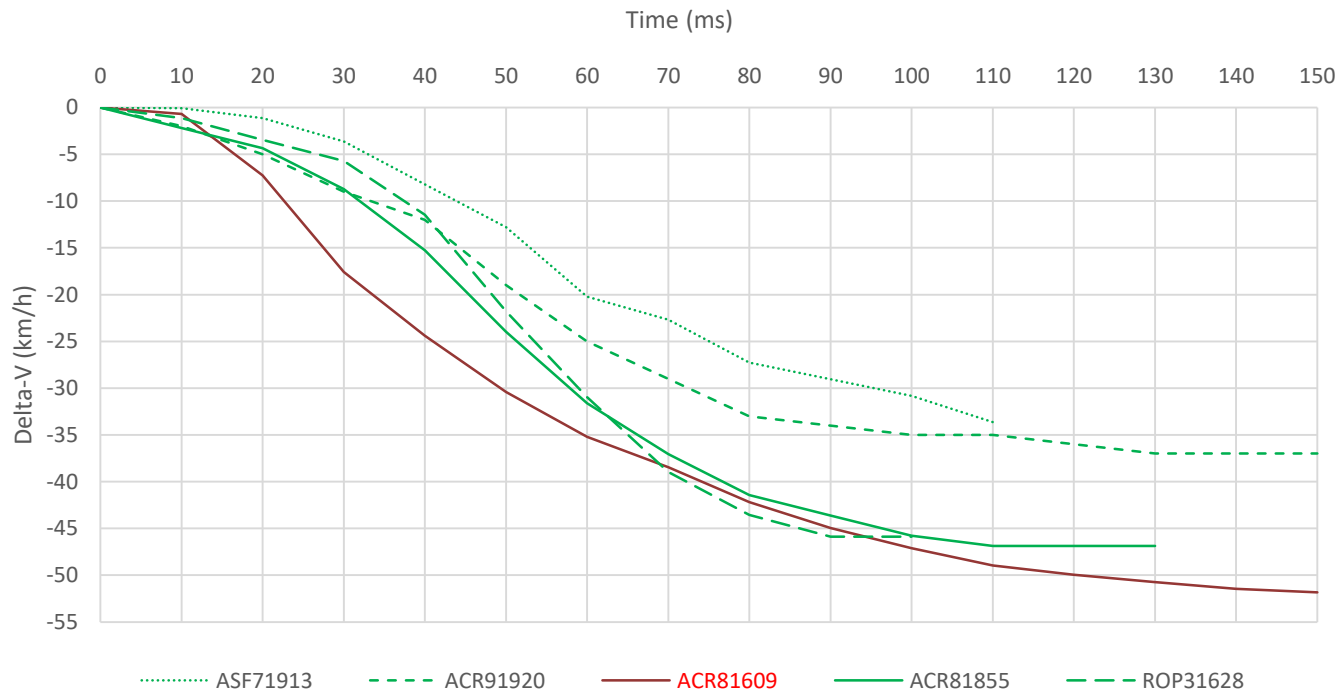
- Nine of the 12 toddlers sustained no injuries or minor injuries
 - Three toddlers were admitted to hospital with serious injuries
- At least two of the toddlers that were admitted sustained cervical spine injuries
 - A 15-month-old female sustained an AIS-4 cervical spine injury with permanent disability (ROP3-1620)
 - In one case injuries were unknown
- Only 1 of the 12 toddlers was seated rearward facing
 - All 3 toddlers that were admitted to hospital were seated forward-facing



Toddler Cases

Delta-V of Impacts Involving Toddlers

- Delta-V ranged from 30 km/h to 78 km/h (48 ± 14 km/h)
- Delta-V ranged from 50 km/h to 78 km/h in serious injury cases



Recorded Longitudinal Delta-V (Age = 1 Year)

CASE STUDIES



ROP3-1627

2012 Chevrolet Equinox 4-Dr SUV

Delta-V: 46 km/h (EDR overall at 195 ms)

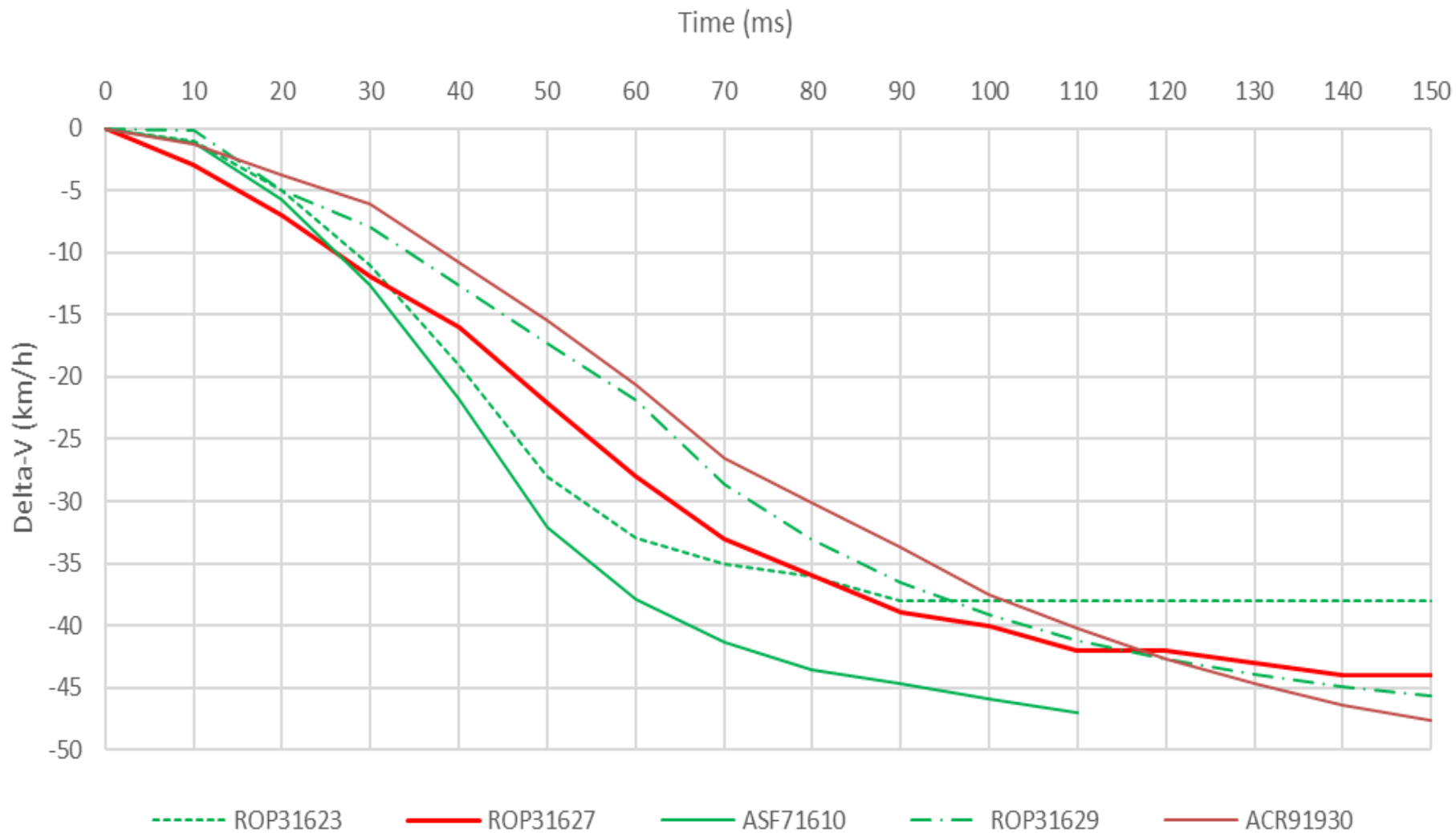
11: 38-yr-F, Lap/torso/front+curtain airbag, MAIS-1

13: 70-yr-M, Lap/torso/front+curtain airbag, No injuries

21: 68-yr-F, Unrestrained, MAIS-3

22: 7-week-M, Rear-facing infant carrier/lap/torso, MAIS-5 (FATAL)

23: 6-yr-F, Lap/torso/booster, MAIS-2



Recorded Longitudinal Delta-V (Age < 1 Year)



ROP3-1627

- The 7-week-old male passenger (58 cm / 5 kg) was fatally injured
- Cause of death was blunt force trauma to the head
 - Possibly due to contact with the centre console
- Infant carrier handle was upright and was heavily deformed
 - Contact with unrestrained left rear passenger



DEFORMATION

Post-crash inspection of car seats can reveal important information about usage and loading



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PROS-1603

2011 Dodge Grand Caravan 4-Dr Minivan

Delta-V: 62 km/h (Calculated from EDR data)

11: 38-yr-M, Lap/torso/front+knee airbag, MAIS-1

13: 34-yr-F, Lap/torso/front airbag, MAIS-3

21: 2-month-F, Rear-facing infant carrier/ removeable base/LATCH, MAIS-4

23: 2-yr-F, Forward-facing CRS/LATCH, MAIS-1

PROS-1603

The 2-month-old female was air-lifted to hospital with major injuries:

- Subdural hemorrhage (AIS-4)
- Intraventricular hemorrhage (AIS-3)
- Multifocal subarachnoid hemorrhage (AIS-3)
- Cerebral parenchymal contusions (AIS-3)
- Pulmonary contusions (AIS-3)
- Fracture of T2 lamina extending to T2 facet (AIS-3)
- Extensive calvarial fractures (AIS-2)
- Left parietal skull fracture (AIS-2)
- Bilateral frontal skull fractures (AIS-2)
- Fracture of right femur 100% displaced (AIS-2)
- Extensive facial fractures (AIS-1)
- Cervical ligamentous injuries (AIS-1)
- Scalp hematoma (AIS-1)





ASF7-1620

2014 Volkswagen Jetta TDI 4-Dr Sedan

Delta-V: 67 km/h (Calculated)

11: 30-yr-F, Lap/torso/front + curtain airbag, Major injuries

23: 7-month-F, Rear-facing infant carrier/removable base, MAIS-5 (FATAL)



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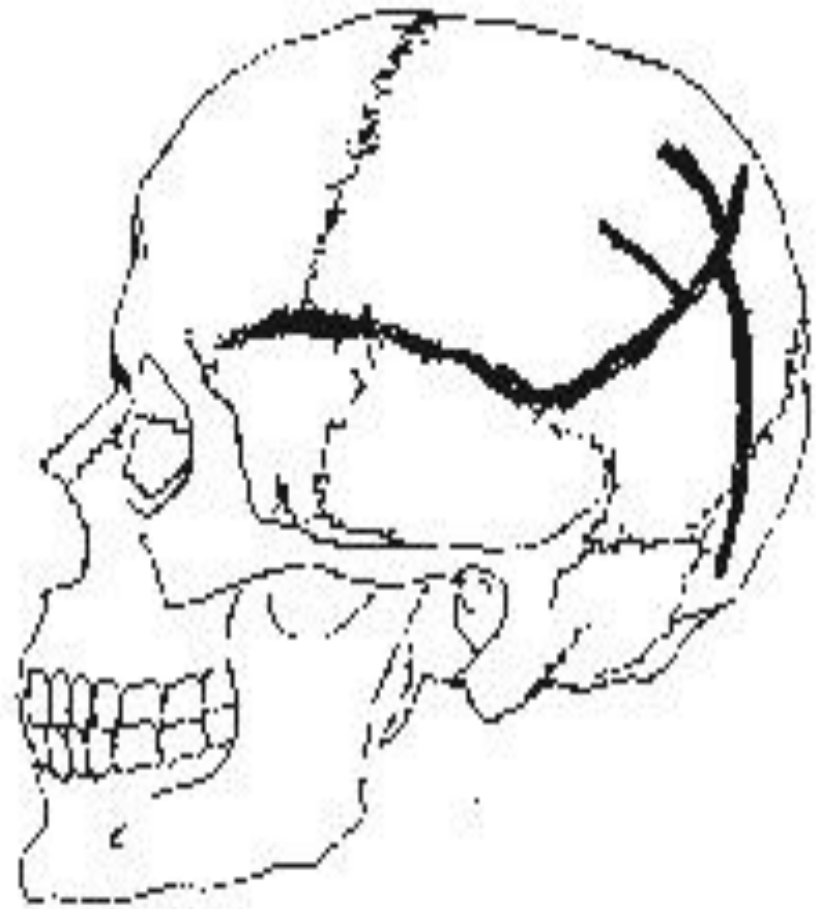
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The 7-month-old female infant (7.8 kg / 64 cm) was of average mass and below average length and her head circumference was well above average. She sustained the following injuries:

- Widespread axonal damage of cerebrum (AIS-5)
- Bilateral cerebral epidural and subdural hemorrhages (AIS-5)
- Bilateral cerebral intraparenchymal hemorrhages (AIS-5)
- Bilateral cerebral lacerations (AIS-4)
- Intraventricular hemorrhage (AIS-4)
- Bilateral cerebral subarachnoid hemorrhages (AIS-3)
- Severe hypoxic-ischemic neuronal injury (AIS-3)
- **Bilateral cerebral contusions (orbitofrontal and inferior temporal) (AIS-3)**
- Diffuse brain swelling (AIS-3)
- Cervical spinal epidural, subdural and subarachnoid hemorrhages (AIS-3)
- **Bilateral skull fractures involving temporal, parietal and occipital bones (AIS-2)**
- Bilateral optic nerve and optic nerve sheath hemorrhages (AIS-2)
- **Cervical spinal nerve and nerve sheath hemorrhages (AIS-2)**
- Bilateral scalp hemorrhage (AIS-1)
- Symmetrical diagonally-oriented linear bruises on the upper medial thighs consistent with the car seat harness straps (AIS-1)

ASF7-1620



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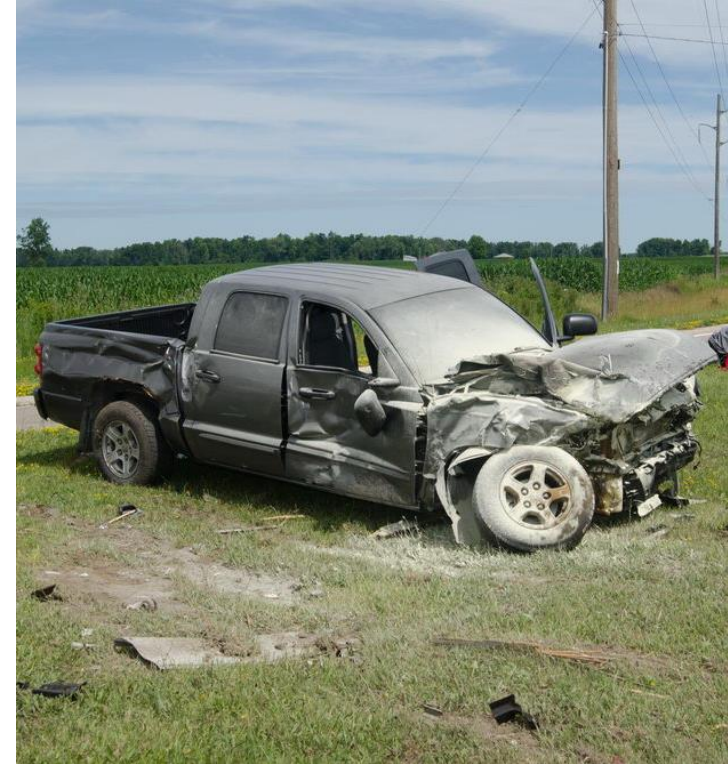


ASF7-1620

- The back of the infant's skull likely hit the rear of the right front seatback and was compressed
 - The sides of the skull were areas of outward bending and were subject to tensile forces leading to fractures
- The contusions on the brain were distributed on the front (bilateral orbitofrontal and inferior temporal)
 - Contrecoup injuries occurring opposite the impact site
- The head injury led to diffuse brain swelling and lack of blood flow causing hypoxia-ischemia
- Hemorrhages in the cervical cord area were consistent with a hyperextension mechanism as the head was accelerated back

Discussion

- The frontal impacts examined in this review involved high delta-Vs and extensive vehicle damage
 - Most frontal impacts are less severe
- The majority of children in this series were not injured or sustained minor injuries
 - None of the children were ejected
- Infants and toddlers receive a high level of occupant protection when properly restrained in a child safety seat



ROP3-1633

9-Mo Male

No injury

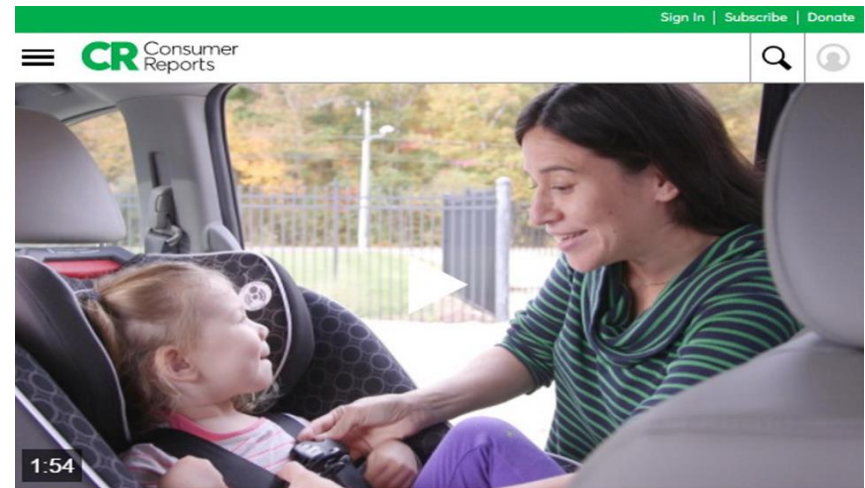
Head Injuries



- At least four infants seated in rear-facing infant carriers sustained severe head injuries due to interior contact
- Frontal crash tests conducted by Transport Canada found that infant or rear-facing infant seat contact with the interior often resulted in elevated head responses
- The current dynamic testing requirement for rear-facing child seats does not model severe real world frontal impacts where interior contact is predictable

Rear-Facing Convertible Car Seats

- Three infants ranging in age from 9 to 10 months seated in rear-facing convertible car seats were not seriously injured
 - Delta-Vs ranged from 50 to 60 km/h
- **Consumer Reports** found a lower incidence of dummy head contact with the seatback in rear-facing convertible car seats
 - The longer shells and shape of the convertible seats increased space between the head and seatback



Why You Should Buy a Convertible Car Seat Sooner Rather Than Later

Rear-facing convertible seats provide added protection from head contact compared to infant seats

Recline Angle Challenges

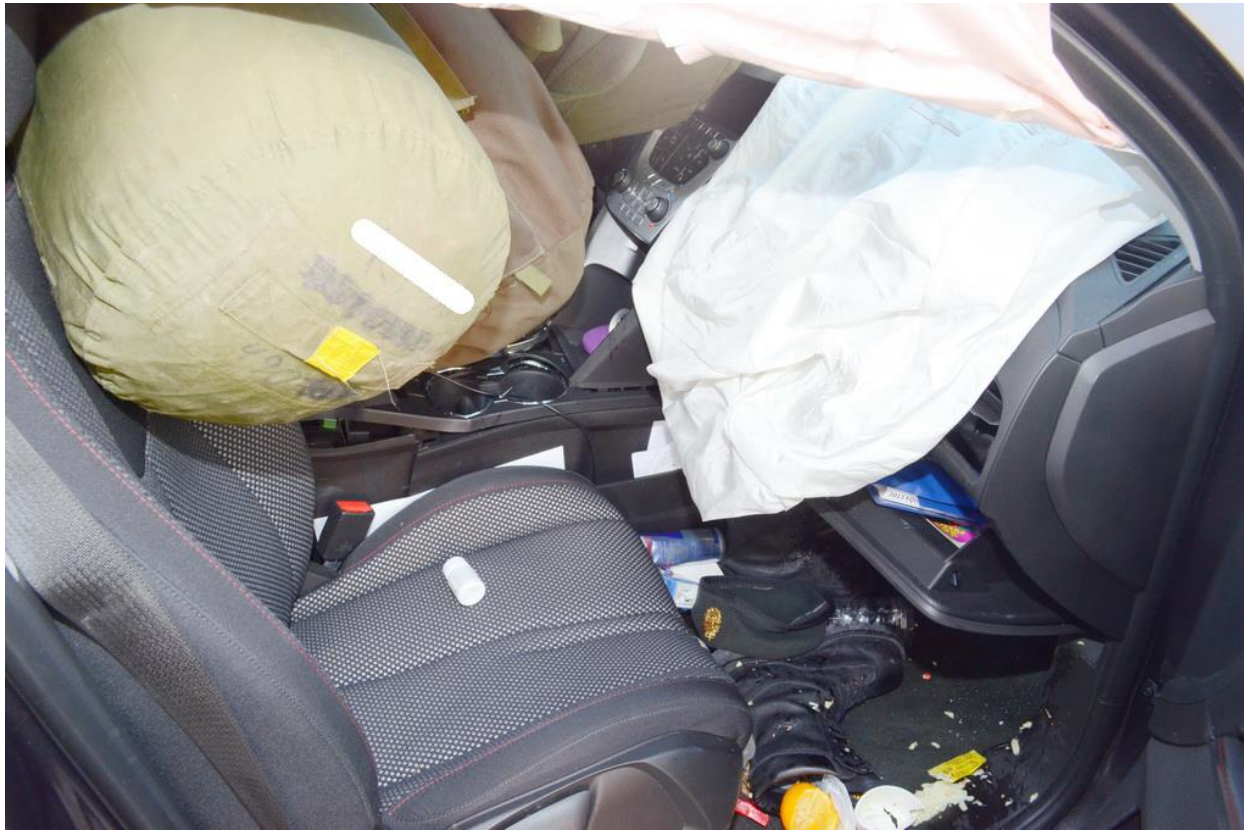


- In a frontal impact, it is desirable to have the forces restraining the rearward-facing infant or toddler distributed over the back of the car seat
- If the seat is over-reclined the forces will be transferred to the harness and the child's shoulders and neck
- The recline angle must be sufficient to prevent the infant's head from dropping forward which could result in airway restriction.

Conclusions

- Rear-facing child safety seats do provide excellent protection in frontal impacts
- But at least four infants seated in rear-facing infant carriers sustained severe head injuries probably due to interior contact
- There may be a lower risk of head injury for infants properly restrained in rear-facing convertible car seats
- The dynamic testing requirement for rear-facing child seats does not model severe real world frontal impacts where interior contact is predictable
- Toddlers seated in forward-facing car seats were at increased risk for cervical spine trauma in the present study

Occupants and cargo must be properly restrained *especially when travelling with vulnerable child passengers*



Acknowledgments



**SPECIAL THANK YOU TO
WEST REGION OPP
COLLISION RECONSTRUCTION**