



Jeremy Colangelo, Charles H. Tator, Benjamin Elkin, Mozghan Khodadadi, Maria Carmela Tartaglia

Background

Concussions caused by motor vehicle collisions (MVC) can lead to more persisting concussion symptoms (PCS) with a longer symptom duration than other causes of concussion¹.

Rear-end collisions were found to be the most common crash type causing concussion in MVC, affecting over 50% of the study population and disproportionately affecting female vehicle occupants².



Many researchers have studied whiplash following rear-end collisions but few have studied concussion in this way³. Previous studies have yet to examine data extracted from the crashed vehicles of patients with concussion and PCS.

Objective

To learn more about how concussions are occurring in rear-end collisions by examining concussed patients' crashed vehicles and extracting event data recorder (EDR) data.

Methods

Clinical concussion data concerning symptomology, demography, and recovery was collected through concurrent retrospective chart review and prospective questionnaire administration.

Two vehicle examinations were conducted involving rear-end collisions in which female occupants sustained concussions, representing the previously defined high-risk population.



Vehicle examinations were performed by MEA Forensic Engineers & Scientists and involved the collection of:

- EDR (or "black box") data
- Seat and head restraint positions
- A 3D scan of the vehicle interior
- Photographs of vehicle damage

Results

Table 1. Demographic, clinical, and crash characteristics of two patients who were concussed by rear-end collisions and whose vehicles were examined.

	Patient 1	Patient 2
Sex	Female	Female
Age at time of crash	37	29
Date of crash	February 11, 2023	February 12, 2025
Persisting concussion symptoms	Headaches, fatigue, anxiety, sensitivity to light and noise, computer screen intolerance, vertigo, tinnitus	Headaches, anxiety, cognitive difficulties, sensitivity to light and noise, computer screen intolerance, eye strain, insomnia, tinnitus, dizziness
Recovery status	Not recovered (November 2025)	Not recovered (December 2025)
Symptom duration	33 months	10 months
Collision type	Low-speed, rear-end collision	Low-speed, rear-end collision
Position in vehicle	Front passenger	Driver
Location	Stopped on highway	Stopped at intersection
Vehicle	2023 Volkswagen Atlas V6	2012 Honda Civic



Figure 1. 3D scan of the vehicle seat (Patient 1).

Conclusions

This analysis shows two cases of low-speed rear-end collisions that caused concussion and persisting concussion symptoms in female vehicle occupants. Safety systems failed to protect the vehicle occupants against concussion in both cases. Our group recommends re-evaluation of vehicle safety systems and further research to characterize concussion in rear-end collisions.

Table 2. Deployment status of vehicle safety systems recorded by the EDR during the rear-end collision (Patient 1).

Pretensioner, Time to 1st Stage Deployment, Driver (msec)	Not Deployed
Belt-Load Limiter, Time to Deployment, Driver (msec)	Not Deployed
Sill-End Pretensioner, Time to Deployment, Driver (msec)	Not Deployed
Frontal Airbag, Time to 1st Stage Deployment, Driver (msec)	Not Deployed
Frontal Airbag, Time to 2nd Stage Deployment, Driver (msec)	Not Deployed
Frontal Airbag, 2nd Stage Disposal, Driver	Not Deployed
Frontal Airbag, Time to 3rd Stage (Vent) Deployment, Driver (msec)	Not Deployed
Frontal Airbag, 3rd Stage (Vent) Disposal, Driver	Not Deployed
Knee Airbag, Time to Deployment, Driver (msec)	Not Deployed
Side Airbag, Time to 1st Stage Deployment, Driver (msec)	Not Deployed
Side Curtain/Tube Airbag, Time to Deployment, Driver Side (msec)	Not Deployed
Pretensioner, Time to 1st Stage Deployment, Front Passenger (msec)	Not Deployed
Belt-Load Limiter, Time to Deployment, Front Passenger (msec)	Not Deployed
Sill-End Pretensioner, Time to Deployment, Front Passenger (msec)	Not Deployed
Frontal Airbag, Time to 1st Stage Deployment, Front Passenger (msec)	Not Deployed
Frontal Airbag, Time to 2nd Stage Deployment, Front Passenger (msec)	Not Deployed
Frontal Airbag, 2nd Stage Disposal, Front Passenger	Not Deployed
Frontal Airbag, Time to 3rd Stage (Vent) Deployment, Front Passenger (msec)	Not Deployed
Frontal Airbag, 3rd Stage (Vent) Disposal, Front Passenger	Not Deployed
Knee Airbag, Time to Deployment, Front Passenger (msec)	Not Deployed
Side Airbag, Time to 1st Stage Deployment, Front Passenger (msec)	Not Deployed
Side Curtain/Tube Airbag, Time to Deployment, Passenger Side (msec)	Not Deployed
Pretensioner, Time to 1st Stage Deployment, 2nd Row, Driver Side (msec)	Not Deployed
Pretensioner, Time to 1st Stage Deployment, 2nd Row, Passenger Side (msec)	Not Deployed
Side Airbag, Time to 1st Stage Deployment, 2nd Row, Driver Side (msec)	Not Deployed
Side Airbag, Time to 1st Stage Deployment, 2nd Row, Passenger Side (msec)	Not Deployed
Rollover Protection System, Time to Deployment, Driver (msec)	Not Deployed
Rollover Protection System, Time to Deployment, Passenger (msec)	Not Deployed
Battery Disconnect, Time to Deployment (msec)	Not Deployed
High-Voltage Battery Deactivation, Time to Deployment (msec)	Not Deployed

Table 3. EDR data describing vehicle activity for the 5-second time interval preceding the crash (Patient 1).

Time (sec)	Engine RPM (rpm)	ABS activity	Stability Control	Steering Input (deg)	Speed, Vehicle Indicated (MPH [km/h])	Accelerator Pedal (%)	Service Brake Activation
-5.0	1,152	No ABS Activity	No ESC Activity	0	29 [46]	0	On (Driver)
-4.5	1,088	No ABS Activity	No ESC Activity	0	27 [44]	0	On (Driver)
-4.0	1,216	No ABS Activity	No ESC Activity	0	24 [39]	0	On (Driver)
-3.5	1,024	No ABS Activity	No ESC Activity	-2	21 [33]	0	On (Driver)
-3.0	1,152	No ABS Activity	No ESC Activity	-2	16 [26]	0	On (Driver)
-2.5	1,024	No ABS Activity	No ESC Activity	-2	12 [20]	0	On (Driver)
-2.0	768	No ABS Activity	No ESC Activity	-2	7 [12]	0	On (Driver)
-1.5	768	No ABS Activity	No ESC Activity	-2	4 [7]	0	On (Driver)
-1.0	768	No ABS Activity	No ESC Activity	-2	2 [4]	0	On (Driver)
-0.5	768	No ABS Activity	No ESC Activity	-2	1 [1]	0	On (Driver)
0.0	768	No ABS Activity	No ESC Activity	-2	0 [0]	0	On (Driver)

Both concussions occurred from low-speed rear-end collisions. One patient experienced a speed change of 11 km/h during the crash and no vehicle safety systems were deployed; the other patient was involved in a crash that was not severe enough to trigger the event data recorder, implying a speed change of less than 8 km/h.

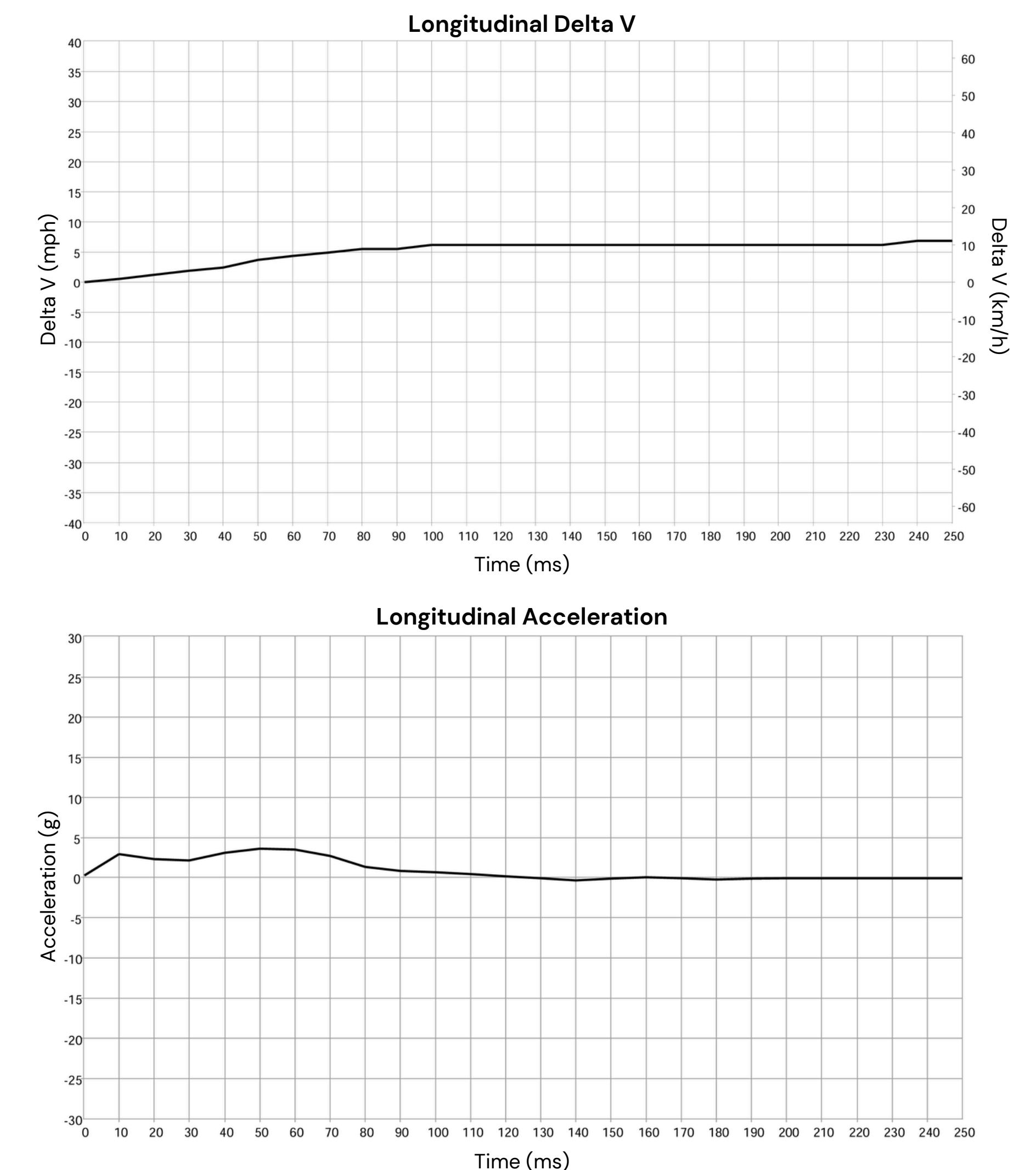


Figure 2. Crash pulse data showing the longitudinal delta-V and acceleration measured by the vehicle's EDR (Patient 1).

References

1. Tator CH, Moore C, Buso C, Huszti E, Li Q, Prentice EB, Khodadadi M, Scott OFT, Tartaglia MC. Cause of Concussion With Persisting Symptoms Is Associated With Long-Term Recovery and Symptom Type, Duration, and Number in a Longitudinal Cohort of 600 Patients. *Journal of Neurotrauma*, 2024. 41(11-12): 1384-1398.
2. Tator CH, Scott OFT, Elkin BS, Prentice EB, Muhammad U, Khodadadi M, Li Q, Huszti E, Tartaglia MC. Analysis of Concussions with Persisting Symptoms Caused by Motor Vehicle Crashes in 136 Vehicle Occupants Shows that Females Are Vulnerable Road Users. *Journal of Neurotrauma*, 2025. 42(11-12): 916-928.
3. Elkin BS, Elliott JM, Siegmund GP. Whiplash Injury or Concussion? A Possible Biomechanical Explanation for Concussion Symptoms in Some Individuals Following a Rear-End Collision. *The Journal of Orthopaedic and Sports Physical Therapy*, 2016. 46(10): 874-885.