Rear row frontal airbags and their interaction with rear-facing and forward-facing child restraint systems (CRS)

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ABSTRACT – Airbags that deploy in front of the occupant are being implemented for rear row passengers. This study explores frontal sled tests with Mercedes-Benz S-Class rear row airbags for a 3-year-old Hybrid III in rear-facing (RF) and forward-facing (FF) child restraint systems (CRS). Compared to a baseline no-airbag condition, the RF CRS with airbag showed reduced injury metrics in the head (HIC), chest, and neck. There was an increase in head resultant acceleration. For FF CRS, the airbag was beneficial for neck metrics but was not beneficial for acceleration-based metrics in the head and chest. These data offer generally encouraging outcomes in cases where a driver may neglect to disable the rear row airbag for child occupants. More data are needed from a wider variety of conditions to broadly determine the risks or benefits of rear row airbags for children.

INTRODUCTION

Frontal airbags are a critical safety feature for adults even though they have historically posed a threat to children. As test protocols expand to include rear row passengers (IIHS 2025), new safety innovations such as airbags are being added to rear row seating positions often occupied by children. Mercedes-Benz S-Class vehicles feature a frontal airbag which deploys from the back of the front row seat. Current instructions suggest this “rear airbag” should be disabled for certain passengers, especially those in rear-facing child restraint systems (RF CRS) or forward-facing (FF) children with short legs resting near the deployment zone of the airbag. Disabling the airbag requires the driver to observe the “Rear airbag indicator lamp” in the overhead control panel and then navigate to the airbag controls via the multimedia system. Drivers who do not familiarize themselves with this unique feature may neglect to disable it for child passengers. Examining how these rear row frontal airbags interact with children in CRS will provide a baseline understanding to ensure the safety of children in current and future transportation modes. The objective for this work was to perform frontal sled tests with rear row airbags for the 3-year-old Hybrid III in RF and FF CRS and compare outcomes to a baseline condition without the airbag.

METHODS

Rear airbags for the 2024 Mercedes-Benz S-Class were purchased from a Mercedes dealership. The Consumer Reports test buck (reinforced 2010 Ford Flex second row seat) was set up with the blocker plate adjusted to an angle of 22.3 degrees and the airbag module mounted on the blocker plate at a height of 27.4 mm from the rear row seating surface. These geometric targets were calculated from a publicly available video of the Mercedes-Benz rear airbags (The Car Expert, 2020). Initial distances between the blocker plate and CRS were approximately 48 mm for RF (top of shell) and 256 mm for FF (front of base). The padding was removed from the blocker plate to accommodate airbag module attachment. The padding was replaced for the baseline (no airbag) tests. The airbag trigger time was set to 10 ms after sled fire. Tests were conducted at the Federal Motor Vehicles Safety Standard (FMVSS) No. 213 frontal pulse (approximately 23.4 g and 47.5 kph). The Evenflo Sonus 65 convertible CRS was tested in RF and FF modes, both with and without the airbag for a total of four tests. The CRS was replaced after each test. All were installed with lower anchors. The top tether was used for FF tests. The Hybrid III 3-year-old anthropomorphic test device (ATD) was the occupant for all tests. Data were collected at 20,000 Hz and processed according to SAE J211. High speed video was collected at 1,000 fps. Injury metrics were compared between baseline and airbag conditions.

RESULTS

The baseline RF CRS loaded into the blocker plate on the upper portion of the CRS shell (Figure 1, 55 ms). The ATD’s head did not contact the blocker plate directly. In the airbag test, the airbag deployed underneath the head area of the RF CRS and prevented it from contacting the blocker plate (Figure 1, 55 and 150 ms). The RF CRS rebounded slightly rearward but came to a natural stop midway through its rotation and did not contact the back of the rear row seat structure (Figure 1, 400 ms).

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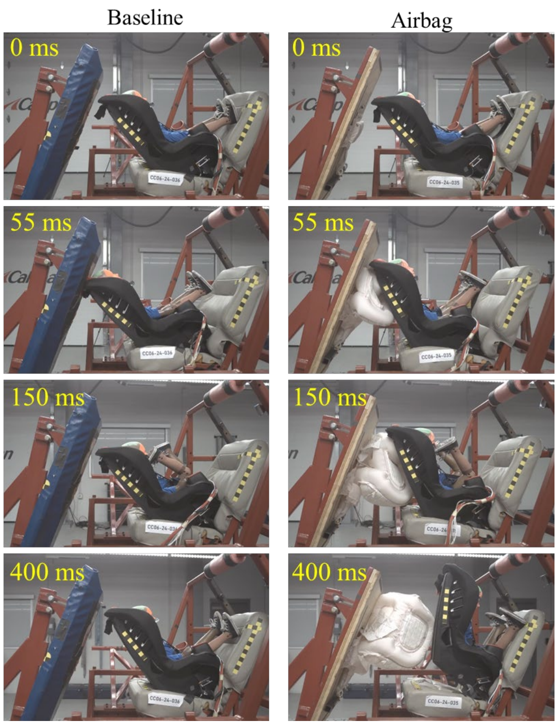

Figure 1: Time progression of baseline and airbag test kinematics with RF CRS.

Injury metrics for RF CRS are summarized in Table 1. Most metrics decreased with the airbag compared to baseline. The exceptions were head resultant acceleration and upper neck flexion moment. However, both metrics were far below injury assessment reference values (IARVs), so the large percent differences are likely not clinically relevant.

For the baseline FF CRS, the ATD's head flexed forward but did not contact the blocker plate (Figure 2, 90 ms). In the airbag test, the airbag deployed without obstruction in front of the ATD (Figure 2, 53 ms) and the ATD's head loaded into the lower middle section of the airbag (Figure 2, 90 ms).

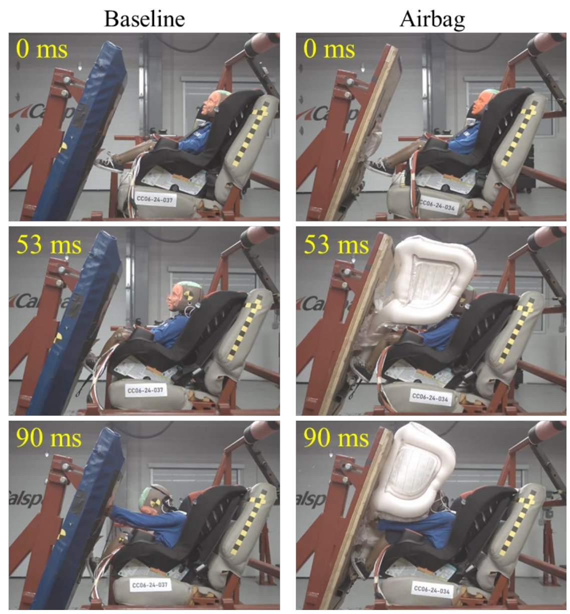

Figure 2: Time progression of baseline and airbag test kinematics with FF CRS.

Injury metrics for FF CRS are summarized in Table 1. The head and chest metrics increased but the neck metrics decreased with the airbag compared to baseline.

Table 1: RF and FF CRS injury metrics. IARVs are from Mertz et al. 2016 unless otherwise noted.

		RF CRS			FF CRS		
	IARV	Base-line	Air-bag	Difference (%)	Base-line	Air-bag	Difference (%)
Head resultant acceleration, g	175	62.1	74.5	+12.5 (+20.1%)	50.8	59.7	+8.9 (+17.5%)
HIC15	568	333	179	-154 (-46.2%)	171	275	+104 (+60.8%)
HIC36	1000*	442	236	-206 (-46.6%)	285	462	+177 (+62.1%)
Chest resultant acceleration, g	92.0	61.2	50.0	-11.2 (-18.3%)	42.9	49.7	+6.8 (+15.9%)
Upper neck shear (+Fx), N	1070	446	240	-206 (-46.2%)	283	247	-36 (-12.7%)
Upper neck tension (+Fz), N	1430	1254	601	-653 (-52.1%)	385	167	-218 (-56.6%)
Upper neck flexion moment (+My), Nm	42.0	2.0	11.6	+9.7 (+480%)	127	103	-24 (-18.9%)
Lower neck tension (+Fz), N	1430	1155	454	-701 (-60.7%)	1755	1472	-283 (-16.1%)
Nij (upper neck)	1.00	0.73	0.38	-0.35 (-47.9%)	1.88	1.57	-0.31 (-16.5%)

*FMVSS 213 limit

DISCUSSION

For many injury metrics, the rear row airbag appeared beneficial for the RF CRS occupant compared to baseline (Table 1). Although HIC15 and HIC36 were lower with the airbag, the absolute maximum head resultant acceleration was higher with the airbag. This is indicative of a short-duration head acceleration peak that occurred during airbag deployment near the back of the ATD's head. However, this peak (74.5 g) was low compared to the IARV for head resultant acceleration (175 g). Overall, these results suggest that the airbag deployed relatively gently and vented appropriately when it contacted the RF CRS.

These outcomes for RF CRS should be interpreted with caution due to the limitation of using a single condition as a baseline comparison. In the baseline, the RF CRS baseline test contacted the blocker plate, which may have artificially increased some of the baseline injury metrics. The structure of the blocker plate and starting distance between the blocker and the RF CRS could affect how the ATD responds (Maltese et al. 2025). The airbag prevented contact against the blocker plate, which eliminated this variable from the setup. More data are needed from a larger variety of configurations to determine whether the airbag would endanger other RF CRS occupants. Considerations should include RF CRS which are required to touch the back of the front row seat during normal driving and those that are installed incorrectly or loosely.

The FF CRS occupant appeared to load into the airbag as designed for an adult occupant. The airbag reduced several neck metrics. Acceleration-based metrics in the head and chest were increased with the airbag, although all these metrics were still below IARVs and FMVSS 213 limits. More information is needed for FF CRS occupants and/or booster and belt seated child occupants to determine what factors influence injury outcomes for this population of children. Variations in seated height and posture could significantly affect how children's heads and torsos interact with the rear row airbag.

The airbag's current design requires drivers to recognize situations with child passengers when the airbag should be disabled and then manually complete that task. A system that automatically suppresses when there is a child in the rear row would reduce the risk of a driver neglecting this duty.

Limitations of this study include: small sample size with no repeated tests, only one type of CRS tested with one size of occupant, one type of vehicle seat bench used, and the mounting of the airbag to a blocker plate rather than a realistic vehicle seat. These preliminary test outcomes should never override the airbag manufacturer's current recommendations, which are to disable the airbag for RF CRS occupants and for FF CRS and/or shorter children whose legs are near the deployment point on the back of the seat.

CONCLUSION

For the Mercedes-Benz rear row airbags, injury metrics suggest benefits for the RF CRS occupant compared to the baseline condition where the RF CRS contacted the blocker plate. For FF CRS, the rear row airbag was beneficial for most neck metrics compared to baseline but was not beneficial for acceleration-based metrics in the head and chest. These data offer generally encouraging outcomes for child occupants in a scenario where a driver may neglect to disable the airbag. However, more data are needed from a wider variety of conditions to broadly determine the risks or benefits of these airbags for children. Manufacturers' instructions should always be followed for situations where children might interact with airbags.

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