IV. DISCUSSION

Structural Performance

The biggest differences between left- and right-side results were observed for the Forester, RAV4, and Rogue. Two of these models, the RAV4 and Rogue, incorporated engagement and energy-absorbing structures on the left side that were not present on the right side, shown in Fig. 18. The left- and right-side differences in the Forester were due to different materials (likely steel type or material thickness) used in components around the occupant compartment doorframe. The other models had similar intrusion measurements in both left- and right-side tests, even if right-side intrusion was generally somewhat greater than on the left side. Though limited to two vehicles, results for both the visibly asymmetric RAV4 and Rogue suggest that the lack of visible small overlap structures on the right side is an indicator of reduced structural performance on that side compared with the left side. These differences cannot simply be explained as test variation. These vehicles experienced 26 to 34 cm differences in intrusion from the left to right side, much greater than the 8 cm level of repeatability established by Mueller *et al.* [13].

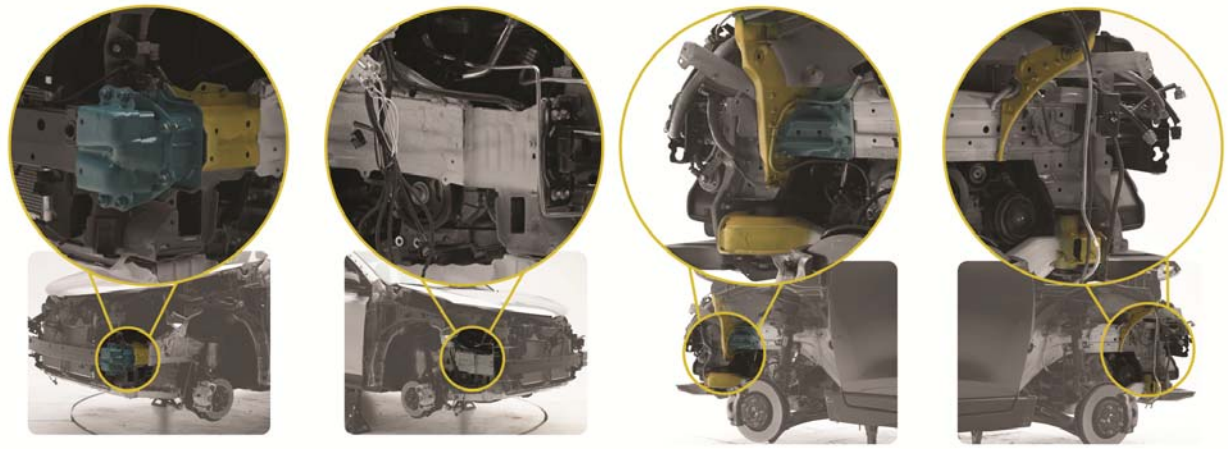

Fig. 18. Visual differences between driver- and passenger-side structures for Toyota RAV4 (*left*) and Nissan Rogue (*right*).

At the same time, results from visually symmetric vehicles show that such assessments do not guarantee comparable performance in left- and right-side impacts. The Encore performed well in the right-side test, with the greatest structural variation of only 8 cm between the left and right sides. In contrast, the greatest structural variation between the two sides on the CX-5 and Forester was 18 and 21 cm, respectively. It should be noted that beyond specific small overlap countermeasures, structural asymmetry exists in many vehicles with transverse engine and transmission configurations. In addition, steering assemblies, braking components, etc. all are typically placed on the driver side, while the right front passenger is not exposed to them.

Dummy Injury Measures and Kinematics

In both vehicles with and without symmetric structural countermeasures, there were some indications of the need for improvements to restraint systems. Compared with driver occupants, there are fewer challenges associated with airbag protection for passengers because the passenger frontal airbag is typically larger than the driver airbag and located in the dash instead of the steering wheel, which often moves out of position when the instrument panel intrudes. High levels of instrument panel intrusion on the passenger side were typically associated with leg injury measures exceeding a Good boundary of 80% of the IARV, while the comparable driver-side results with low structural intrusions indicated low risk of leg injury, within the Good boundary. All other aspects of the passenger injury measures and kinematics were similar to those of the near-side driver dummies.

In all right-side tests regardless of symmetry, the far-side driver injury measures indicated a low risk of injury, due to the lack of structural intrusion into the far-side occupant compartment space. Most far-side driver dummies had stable interaction with the frontal airbag, and there were no hard head contacts. The exception was the Encore test, in which the driver dummy shoulder belt partially slipped off and allowed the head to partially slide off the airbag toward the center stack. In all other vehicle pairs, the chest compressions for the far-side driver were greater than for the near-side driver, though none indicated values greater than 70% of the IARV.

For the far-side driver, the seat belt likely plays a larger role in restraining the dummy and, therefore, there is greater chest loading compared with the near-side driver. Observations from left-side tests indicate the driver dummy's lateral motion is partially controlled by the curtain airbag, requiring less loading by the belt. While the far-side driver faces lower injury risks compared with the near-side passenger, observations about restraint system performance hint that there are still potential risks that cannot be ignored. These observations also align with the real-world far-side driver injury mechanisms identified by Brumbelow and Zuby [9]. Additionally, the driver seat is always occupied in real-world crashes, and this new evaluation provides an opportunity to monitor and improve performance of the driver-side restraint system in these types of crashes. No conclusions about observed injury risks for right front passenger dummies in driver-side small overlap crashes can be made, as no tests have been conducted in that configuration. Further research is needed to fully evaluate the real-world relevance of far-side occupant injuries for both drivers and right front passengers in small overlap crashes.

V. CONCLUSIONS

IIHS has been rating vehicles for small overlap protection on the basis of left-side tests since 2012. These ratings have encouraged manufacturers to make structural changes to vehicles in order to earn higher ratings. No such incentive exists to make improvements to the right side. Early on, IIHS encouraged implementing left-side-only countermeasures in the short-term if it meant more models would be outfitted with countermeasures, but it was always assumed that future designs would provide comparable levels of protection on both sides of the vehicle. Consumers are unlikely to accept that vehicles provide different levels of protection on the left and right sides of vehicles.

The range of performance in right-side small overlap tests among vehicles with Good left-side small overlap ratings suggest automakers have not yet consistently applied design changes to both sides of the vehicle. These tests also highlight the need to evaluate vehicle protection for far-side drivers. While far-side driver dummies indicate reduced risks compared with their near-side counterparts that experienced higher structural intrusions, observations of inadequate restraint system performance suggest a potential need to evaluate risks for far-side drivers in this crash mode.

IIHS will continue to monitor differences in small overlap driver- and passenger-side performance and may begin issuing passenger-side small overlap ratings as early as 2018.

VI. REFERENCES

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VII. APPENDICES

Appendix A

TABLE A-1
FAR-SIDE INTRUSION

	2015 Honda CR-V	2014 Honda CR-V	2015 Toyota RAV4	2013 Toyota RAV4
Lower hinge pillar (cm)	1	1	0	1
Footrest (cm)	2	1	0	1
Left toepan (cm)	2	1	1	1
Brake pedal (cm)	2	1	0	0
Rocker panel (lateral) (cm)	0	0	0	0
Steering column (longitudinal) (cm)	0	0	0	0
Upper hinge pillar (cm)	1	1	0	0
Upper dash (cm)	1	1	0	1
Left instrument panel (cm)	1	1	0	0

TABLE A-2A

NEAR-SIDE INTRUSION

	2015 Honda CR-V		2015 Toyota RAV4		2016 Hyundai Tucson		2015 Subaru Forester		2015 Buick Encore	
	Driver	Passenger	Driver	Passenger	Driver	Passenger	Driver	Passenger	Driver	Passenger
Lower hinge pillar (cm)	3	15	9	40	5	19	9	29	14	11
Footrest (cm)	5	13	6	40	7	15	10	24	9	11
Left toepan (cm)	3	8	2	23	6	11	6	17	8	7
Brake pedal/center toepan (cm)	4	3	3	22	6	9	6	11	9	1
Rocker panel (lateral) (cm)	2	4	2	17	2	12	0	4	2	4
Steering wheel/center of dash (cm)	2	6	1	8	2	6	0	10	4	6
Upper hinge pillar (cm)	4	14	4	26	4	11	5	26	14	12
Upper dash (cm)	4	10	5	23	5	3	4	13	12	6
Left instrument panel (cm)	4	8	5	21	4	8	2	21	12	10

TABLE A-2B

NEAR-SIDE INTRUSION

	2014 Nissan Rogue		2015 Mazda CX-5		2014 Honda CR-V		2014 Toyota RAV4	
	Driver	Passenger	Driver	Passenger	Driver	Passenger	Driver	Passenger
Lower hinge pillar (cm)	10	36	7	25	26	20	31	39
Footrest (cm)	3	16	7	17	15	17	20	25
Left toepan (cm)	2	13	5	6	13	5	4	13
Brake pedal/center toepan (cm)	3	7	8	3	10	3	7	9
Rocker panel (lateral) (cm)	2	2	1	4	14	9	12	16
Steering wheel/center of dash (cm)	3	12	0	8	11	5	4	9
Upper hinge pillar	9	20	8	20	31	19	21	25
Upper dash	8	9	7	9	26	12	17	25
Left instrument panel	9	24	8	13	26	10	17	19

Appendix B

TABLE B-1A
INJURY MEASURES

		2015 Honda CR-V			2015 Toyota RAV4			2013 Toyota RAV4		
Measure (units)	IARV	Near-side Driver CEN1444	Passenger CN15001	Far-side Driver CN15001	Near-side Driver CEN1451	Passenger CN15002	Far-side Driver CN15002	Near-side Driver CEN1319	Passenger CN15003	Far-side Driver CN15003
HIC	700	137	116	99	163	102	33	283	58	42
BrIC	1	1	1	0	1	1	0	1	0	0
Neck A-P shear force (kN)	-3	-1	0	0	-1	0	0	-1	0	-1
Nij	1	0.30	0.16	0.20	0.26	0.23	0.15	0.27	0.18	0.17
Neck axial compression (kN)	4	0	0	0	0	0	0	0	0	0
Neck axial tension (kN)	3	1	1	1	1	1	1	2	1	1
Chest acceleration (3 ms clip) (g)	60	33	27	23	42	26	17	27	26	16
Chest compression (mm)	50	22	20	26	22	21	24	18	16	22
Sternum deflection rate (m/s)	8	-1	-1	-1	-1	-1	-1	-1	-1	-1
Viscous criteria (m/s)	1	0	0	0	0	0	0	0	0	0
Left KTH injury		0	0	0	0	0	0	0	0	0
Left femur force (kN)	9	0	1	0	2	1	2	3	1	1
Left knee displacement (mm)	15	0	2	1	0	2	2	5	1	1
Left upper tibia index	1	1	0	0	0	1	0	1	0	0
Left lower tibia index	1	0	0	0	0	1	0	1	1	0
Left tibia axial force (kN)	8	2	1	0	4	1	1	5	1	1
Left foot acceleration (g)	150	56	49	23	62	71	32	67	96	41
Right KTH injury		0	7	0	0	0	0	0	1	0
Right femur force (kN)	9	0	-6	0	-1	-2	-1	-1	-3	-1
Right knee displacement (mm)	15	0	3	0	1	4	3	1	4	1
Right upper tibia index	1	1	1	0	0	0	0	0	0	0
Right lower tibia index	1	1	0	0	0	1	0	0	1	0
Right tibia axial force (kN)	8	-1	-1	-1	-2	-1	-1	-2	-1	-1
Right foot acceleration (g)	150	61	46	41	47	118	50	125	103	56

TABLE B-1B

INJURY MEASURES

		2014 Honda CR-V			2016 Hyundai Tucson			2015 Subaru Forester		
		Near-side		Far-side	Near-side		Far-side	Near-side		Far-side
		Driver	Passenger	Driver	Driver	Passenger	Driver	Driver	Passenger	Driver
Measure (units)	IARV	CEN1223	CN15004	CN15004	CEN1522	CN15005	CN15005	CEN1303	CN15006	CN15006
HIC	700	102	34	31	399	321	61	127	77	44
BrIC	1	1	0	0	1	1	1	1	0	0
Neck A-P shear force (kN)	-3	-1	-1	0	1	0	0	0	-1	-1
Nij	1	0.36	0.19	0.15	0.36	0.19	0.15	0.36	0.19	0.15
Neck axial compression (kN)	4	0	0	0	0	0	0	0	0	0
Neck axial tension (kN)	3	1	1	1	1	1	1	0	1	1
Chest acceleration (3 ms clip) (g)	60	32	23	15	42	51	25	32	35	19
Chest compression (mm)	50	13	16	19	23	27	33	26	25	28
Sternum deflection rate (m/s)	8	-1	-1	-1	-1	-2	-1	-1	-2	-1
Viscous criteria (m/s)	1	0	0	0	0	0	0	0	0	0
Left KTH injury		4	0	0	0	0	0	0	0	0
Left femur force (kN)	9	5	1	0	2	0	0	2	2	1
Left knee displacement (mm)	15	8	1	0	9	2	0	4	2	3
Left upper tibia index	1	1	0	0	1	0	0	0	1	0
Left lower tibia index	1	1	0	0	0	0	0	0	0	0
Left tibia axial force (kN)	8	6	2	1	2	1	0	2	2	1
Left foot acceleration (g)	150	79	28	24	55	69	47	50	129	55
Right KTH injury		0	11	0	0	0	0	0	1	0
Right femur force (kN)	9	-1	-7	0	0	-1	0	-1	-4	-1
Right knee displacement (mm)	15	3	4	0	0	3	1	1	10	2
Right upper tibia index	1	1	1	0	0	1	0	0	1	0
Right lower tibia index	1	0	1	0	1	1	0	0	1	0
Right tibia axial force (kN)	8	-2	-4	-1	-1	-2	-1	-2	-2	-1
Right foot acceleration (g)	150	66	108	32	83	52	38	47	73	35

TABLE B-1C

INJURY MEASURES

		2015 Buick Encore			2014 Nissan Rogue			2015 Mazda CX-5		
		Near-side		Far-side	Near-side		Far-side	Near-side		Far-side
		Driver	Passenger	Driver	Driver	Passenger	Driver	Driver	Passenger	Driver
Measure (units)	IARV	CEN1502	CN15007	CN15007	CEN1407	CN15008	CN15008	CEN1345	CN15009	CN15009
HIC	700	107	110	105	185	68	53	181	120	62
BrIC	1	1	1	1	1	1	0	1	0	1
Neck A-P shear force (kN)	-3	0	0	1	-1	-1	-1	0	0	0
Nij	1	0.23	0.17	0.26	0.29	0.24	0.19	0.26	0.25	0.18
Neck axial compression (kN)	4	0	0	0	0	0	0	0	0	0
Neck axial tension (kN)	3	1	1	1	1	1	1	1	1	1
Chest acceleration (3 ms clip) (g)	60	34	25	19	30	20	18	36	38	22
Chest compression (mm)	50	25	25	22	27	17	33	24	19	27
Sternum deflection rate (m/s)	8	-1	-1	-1	-1	-2	-2	-1	-1	-1
Viscous criteria (m/s)	1	0	0	0	0	0	0	0	0	0
Left KTH injury		1	0	0	0	0	0	0	0	0
Left femur force (kN)	9	4	1	0	2	3	0	1	2	0
Left knee displacement (mm)	15	7	4	0	2	5	0	3	6	1
Left upper tibia index	1	1	1	0	0	0	0	0	0	0
Left lower tibia index	1	0	0	0	0	0	0	0	0	0
Left tibia axial force (kN)	8	2	2	0	1	1	0	1	2	0
Left foot acceleration (g)	150	56	46	35	28	45	44	52	34	47
Right KTH injury		0	1	0	0	2	0	0	1	0
Right femur force (kN)	9	0	-4	-1	0	-4	0	0	-3	0
Right knee displacement (mm)	15	2	5	4	0	5	1	0	3	1
Right upper tibia index	1	0	1	0	0	1	0	0	0	0
Right lower tibia index	1	0	0	0	0	1	0	0	1	0
Right tibia axial force (kN)	8	-1	-2	0	-1	-1	0	-2	-2	-1
Right foot acceleration (g)	150	49	50	49	26	48	33	58	57	27