Seat Belt Path of Pregnant Occupants Visualised through Upright Open MRI

Vivian W. J. Chung, Jade Levine, Danielle Rowlands, Jason Forman, Michelle Oyen,
Desirée Reichhardt, Jason Hallman, Ananna Ahmed, Jason Burrows, Peter A. Cripton

I. INTRODUCTION

It has been estimated that as many as 92,500 pregnant occupants are injured each year in motor vehicle collisions (MVCs) in the US alone [1], putting them at an increased risk of adverse gestational complications such as placental abruption and fetal death [2]. For pregnant women, MVC is a leading cause of injury, trauma-related mortality, and traumatic fetal loss [3-4]. To predict injury outcomes of pregnant occupants in an MVC, several efforts have been made to develop predictive tools to study pregnant occupant interactions with vehicle safety restraint systems. These developments include the MAMA-2B Anthropomorphic Test Devices (ATDs) [5] and computational human body models (HBMs) [6-7]. However, due to a scarcity of anatomical data available on pregnant occupants, many of these models are based on data collected through manual digitisation of volunteers' bodies and/or images acquired from a single individual using traditional MRI, CT or ultrasound. With traditional MRI/CT, volunteers cannot be imaged in realistic automotive postures due to the limited scanner bore size. Yet, it is understood that the uterus is a highly pliable structure [8] that may change shape with posture.

In this study, we aim to enhance our understanding of the internal anatomy of pregnant occupants in realistic automotive postures by capturing MRI images of volunteers in an automotive seat replica, which is made possible through Upright Open MRI technology. Of interest were each volunteer's preferred driving posture and a reclined posture, which has become increasingly relevant with automated driving vehicles [9]. With the acquired images, we will characterise key anatomical information and the seat belt path. This information will be important for advancing future developments in injury prediction models (i.e. ATDs and HBMs).

II. METHODS

Six pregnant volunteers were recruited for nine sets of scans, with three scan sets per gestational age of interest: 24, 30, and 36 weeks. Three volunteers participated twice by returning at a later gestational age.

Volunteer scanning: an MRI-safe automotive seat replica (Fig. 1) and seat belt system were developed for this study. To ensure that the MRI setup reflected each volunteer's in-car configuration, volunteers first sat in the driver's seat of an equivalent vehicle, adjusting the seat to their driving preference. With the seat belt fastened, we measured seat and seat belt configurations, which were then replicated in the MRI. A similar process was followed for the reclined posture, but with the seatback angle fixed to 50° from vertical.

MRI analysis: the belt position, the anterior superior iliac spines (ASIS), and the posterior superior iliac spines (PSIS) were identified using *3D Slicer* software. Pelvis angles were calculated using ASIS and PSIS locations.

III. INITIAL FINDINGS

For the preferred driving posture, the pregnant volunteers on average selected a seatback angle of 17° from vertical and a seat-base angle of 15° from horizontal, with standard deviations of 2.9° and 1.5°, respectively. When the seatback was further reclined to 50° from vertical, the change in pelvis angle expressed as a percentage of the change in seatback angle ranged from 31% to 72% (Table I). This information is relevant in the context of automotive safety since a more posterior pelvic tilt could adversely affect how well the seat belt engages with the pelvis during an MVC [10]. In addition, the distance from the lower edge of the seat belt to each of the left/right ASIS in the driving posture was also quantified by taking measurements along a sagittal plane intersecting each of the ASIS.

V. Chung (e-mail: vivian.chung@ubc.ca) and D. Rowlands are Research Engineers, J. Levine is a MASc student, and P. Cripton is a Professor in the School of Biomedical Engineering at the University of British Columbia (UBC). J. Forman is an Associate Professor at the Center for Applied Biomechanics at the University of Virginia. M. Oyen is an Associate Professor in Biomedical Engineering at Wayne State University. A. Ahmed is a Senior Research Scientist and J. Hallman is a Senior Manager at Toyota Collaborative Safety Research Center. D. Reichhardt is a Nurse Practitioner and Clinical Instructor and J. Burrows is a Clinical Associate Professor in Maternal Fetal Medicine at UBC.

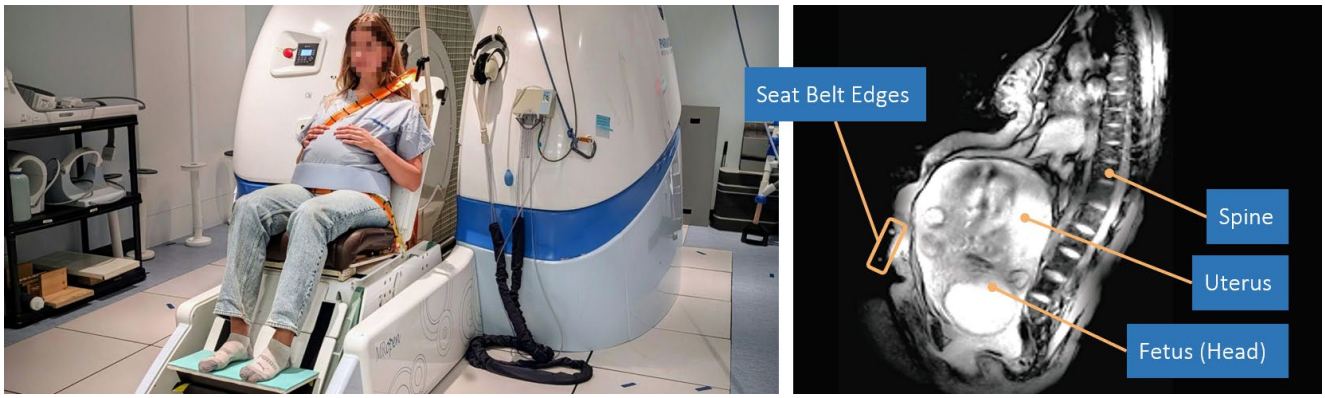

Fig. 1. *Left:* a volunteer inside the Open MRI, positioned on the automotive seat replica. *Right:* a sagittal MRI slice of a pregnant volunteer, capturing the seat belt, fetus, uterus, and maternal spine.

TABLE I
CHANGES IN PELVIS ANGLE AND LAP-BELT-TO-ASIS DISTANCE BETWEEN DRIVING (UPRIGHT) POSTURE AND RECLINED POSTURE

Volunteer [a]	Change in seatback angle [°]	Change in pelvis angle		Lower belt edge to ASIS distance [b]	
		[°]	% of change in seatback angle	In driving posture [mm]	Change with reclined posture [mm]
A24	34	13	39%	93	5
A30	36	11	31%	N/A	N/A
B30	29	19	66%	98	-23
B36	29	17	60%	118	-29
C24	32	N/A [c]	N/A	N/A	N/A
C36	37	17	46%	146	-51
D30	35	25	72%	112	-44
E36	35	19	53%	110	-16
F24	33	15	46%	84	-11
Mean	*33*	*17*	*52%*	*108*	*-24*
Std. Dev.	*2.9*	*4.3*	*14%*	*20*	*19*

[a] Each letter denotes a unique individual, with the number denoting gestational week at the time of the MRI scan.
[b] Distances reported are an average of the left and right lap-belt-to-ASIS distance.
[c] N/A: Not available due to obscured measurement or motion during MRI scans.

IV. DISCUSSION

Our initial findings reported here focus on two measurements that have been linked with the quality of lap-belt engagement with the pelvis: the pelvis angle and the ASIS-to-belt distance. Compared with our group's previous study applying a similar methodology to a non-pregnant cohort [11], we can observe that the pregnant volunteers selected similar seatback angles for the driving posture as the females from the non-pregnant cohort (mean of 17° and 15°, respectively). However, the mean change in pelvis angle as a result of changing the seatback angle was less in our pregnant cohort (52%) compared to the previously reported value for non-pregnant females (62%), with the results quite variable, as indicated by the large standard deviations (14° and 15°, respectively). The distance between the ASIS and lap belt showed a pronounced difference between the non-pregnant (44–96 mm) and pregnant data (84–146 mm). While an increase in abdominal volume during pregnancy is expected, quantifying this is an important step towards understanding the extent of soft-tissue involvement during automotive collisions.

V. REFERENCES

[1] Sirin, H., *et al.*, *Matern Child Health J*, 2007.
[2] Amezcua-Prieto, C., *et al.*, *BMJ* Open, 2020.
[3] Weiss, H., *Accid Anal Prev*, 2001.
[4] Petrone, P., *et al.*, *Eur J Trauma Emerg Surg*, 2019.
[5] Rupp, J., *et al.*, *Stapp Car Crash J*, 2001.
[6] Auriault, F., *et al.*, *J Biomech*, 2014.
[7] Izumiyama, T., *et al.*, *Int J Environ Res Public Health*, 2024.
[8] Louwagie, E., *et al.*, *PLoS One*, 2021.
[9] McMurry, T., *et al.*, *Traffic Inj Prev*, 2018.
[10] Nishida, N., *et al.*, *PLoS One*, 2021.
[11] Forman, J., *et al.*, *J Biomech Eng*, 2024.

ERRATUM

Seat Belt Path of Pregnant Occupants Visualised through Upright Open MRI

Vivian W. J. Chung, Jade Levine, Danielle Rowlands, Jason Forman, Michelle Oyen,
Desirée Reichhardt, Jason Hallman, Ananna Ahmed, Jason Burrows, Peter A. Cripton

Following publication of the manuscript, the authors were alerted to an item that required correction and is amended below.

In DISCUSSION, where the original manuscript reads:
However, the mean change in pelvis angle as a result of changing the seatback angle was less in our pregnant cohort (52%) compared to the previously reported value for non-pregnant females (62%), with the results quite variable, as indicated by the large standard deviations (14° and 15°, respectively).

We here correct the statement as:
However, the mean change in pelvis angle as a result of changing the seatback angle was less in our pregnant cohort (52%) compared to the previously reported value for non-pregnant females (62%), with the results quite variable, as indicated by the large standard deviations (14% and 15%, respectively).