

**A COMPUTATIONAL MODEL OF THE PREGNANT OCCUPANT:  
 LOCAL UTERINE COMPRESSION EFFECTS THE RISK OF FETAL INJURY**

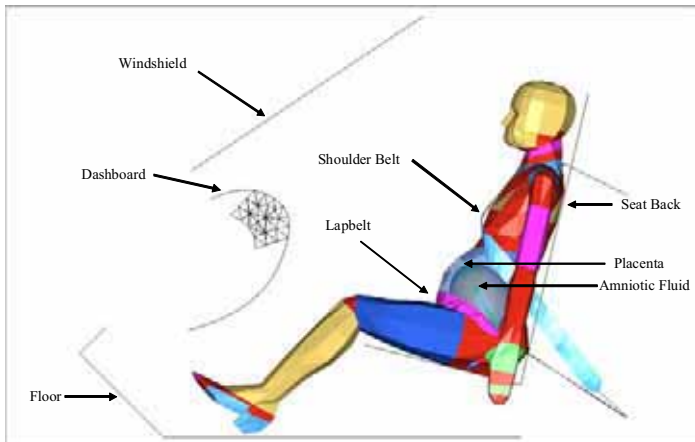
Stefan M. Duma, David M. Moorcroft, Joel D. Stitzel, Greg G. Duma  
 Virginia Tech – Wake Forest, Center for Injury Biomechanics; Email: [Duma@vt.edu](mailto:Duma@vt.edu); Web: [www.CIB.vt.edu](http://www.CIB.vt.edu)

**INTRODUCTION**

Automobile crashes are the largest single cause of death for pregnant females and the leading cause of traumatic fetal injury mortality in the United States (US) (Weiss, 2002). Unfortunately, fetal injury in motor vehicle crashes is difficult to predict due to the fact that real world crash data is limited and cadaver studies are not feasible. The purpose of this study was to develop a computational model of the pregnant occupant, and to identify the best correlation between uterine compression and risk of fetal injury as predicted by the strain at the uterine-placental interface.

**METHODOLOGY**

A finite element and multi-body model of the 30 week pregnant small female was created using the MADYMO software package (Figure 1). The finite element abdomen consists of the uterus, placenta, and amniotic fluid that are supported by two pairs of ligaments and surrounded by fat. These structures were imported into a multi-body model of the small female in order to examine overall crash kinematics.



**Figure 1:** Simulation configuration of pregnant occupant in passenger position with three-point belt.

Four techniques were used to validate the pregnant model. First, a global biofidelity response was evaluated by using a seatbelt to compress dynamically the pregnant abdomen (Moorcroft, 2003). Second, a similar validation procedure was performed with a rigid bar and these results were also consistent with previous data. The third technique involved validating the model against real-world crashes in order to investigate the model’s ability to predict injury. The fourth method compared the physiological failure strain from placental tissue tests to the model failure strain.

Next, a total of 15 computer simulations were performed on the right-front passenger seat. The test matrix consisted of simulations with five different lap belt locations with each evaluated at three velocities (13 kph, 35 kph, 55 kph). Abdominal measurements were taken at five locations, named AB1, AB2, AB3, AB4 and TH1 ranging from the upper pelvis

to the lower thorax. Linear regression analysis was used to correlate the peak uterine compression values to the peak strain at the uterine-placental interface (UPI) and subsequent risk of fetal injury.

**RESULTS**

Using fatal crashes from pregnant occupants (Klinich et al., 199b), the model showed strong correlation ( $R^2 = 0.85$ ) between peak strain at the uterine-placental interface (UPI) as measured in the model compared to risk of fetal demise as reported in the real-world crashes over a range of impact velocities and restraint conditions. Tissue tests suggest approximately a 60% failure strain for UPI tissues which is in agreement with the model’s prediction of 75 % risk of fetal loss at a 60% strain in the UPI. In summary, the global, injury, and tissue level validation techniques all indicate the model is good at predicting injurious events for the pregnant occupant.

The peak uterine strain increased with crash speed and lap belt height except for the top belt location. However, overall compression, which is the peak compression value for all locations, was constant over the range of lap belt locations for a given speed; 20% for 13 kph, 35% - 40% for 35 kph, and 50% for 55 kph. The best correlation was between AB 4 and peak UPI strain for all three impact velocities (Table 1).

**Table 1:** Correlation coefficient values for each uterine compression measurement versus peak UPI strain.

Measurement Location	13 kph	35 kph	55 kph	All speeds
AB 1	0.48	0.62	0.69	0.53
AB 2	0.50	0.69	0.77	0.65
AB 3	0.24	0.45	0.72	0.05
AB 4	0.92	0.97	0.92	0.93
TH 1	0.20	0.14	0.33	0.26

**CONCLUSION**

The AB 4 (upper abdomen) measurement location correlated the best because the strain is measured in the uterus at the placental location, which is at approximately the same height as the AB4 measurement location. Therefore, it is suggested as best practice to measure abdominal loading at the uppermost uterine location in an attempt to predict injury to the UPI and risk of fetal demise. It is important to note that all simulations indicate that it is safest for the pregnant occupant to ride in the passenger seat while wearing a three-point belt and utilizing the frontal airbag when possible.

**REFERENCES**

Klinich KD, et al. UMTRI-99-29. 1999.  
 Moorcroft DM, et al. **American Journal of Obstetrics and Gynecology**: 189 (2), pp. 540-544, 2003.  
 Weiss HB, et al. **Injury Prevention**: 8(3), pp. 207-214, 2002.