

# THE EFFECT OF SHOULDER TRANSLATION AND FOREARM PRONATION ON UPPER EXTREMITY LOADING DURING SIDE AIR BAG DEPLOYMENT

Stefan M. Duma, Brian M. Boggess, Edwin M. Sieveka, and Jeff R. Crandall  
Automobile Safety Laboratory, University of Virginia, Charlottesville, Virginia  
Email: [duma@virginia.edu](mailto:duma@virginia.edu)

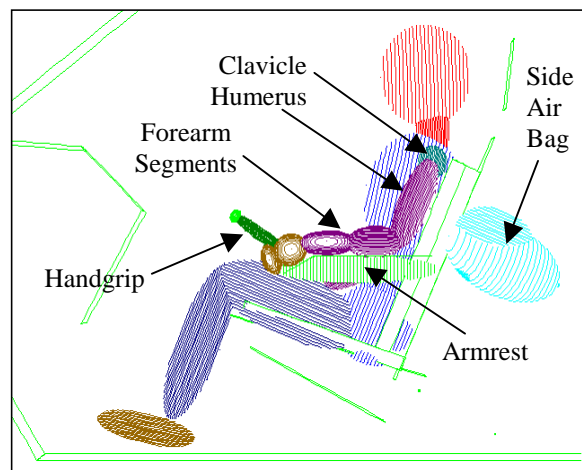
## INTRODUCTION

Although side air bags have been installed in only a limited number of vehicles to date, experimental studies with cadaveric subjects have elucidated the risk of upper extremity injury from side air bag deployment. Duma et al. (1998) found chondral and osteochondral fractures in the elbow joint in seven of the twelve upper extremities that had been loaded by a deploying side air bag. In similar tests by Jaffredo et al. (1998) and Kallieris et al. (1997), fractures of the trapezium and humerus were observed. In order to evaluate the injury potential of side air bags, automobile manufacturers utilize test dummies that currently do not include biofidelic shoulder and forearm kinematics. The purpose of this study was to investigate the effect of shoulder translation and forearm pronation on upper extremity loading during side air bag deployment.

## METHODOLOGY

Simulations were conducted using the CVS/ATB multi-body modeling software. The air bag was represented as a multi-body system of ellipsoidal surfaces and validated against a production air bag system. Time-dependent functions were incorporated to control both the force of the simulated deployment of the bag from behind the seat, as well as the stiffness of each ellipsoid. Additional surfaces and ellipsoids were used to simulate the armrest and handgrip (Figure 1). All simulations were performed in a static test environment that was similar to the cadaveric experimental studies.

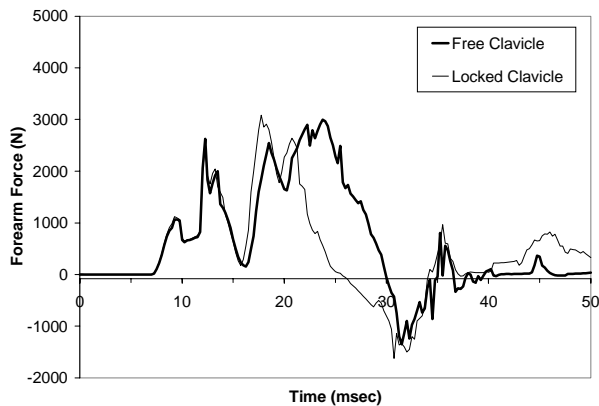
The occupant mass and geometric properties were based on a 5<sup>th</sup> percentile female occupant in order to represent a higher risk segment of the adult population. The upper extremity was modeled using a total of 9 ellipsoids, including one each for the humerus and clavicle which allowed shoulder translation. To allow for pronation and supination of the forearm, the forearm was divided into two segments of equal length with longitudinal rotation the only degree of freedom allowed at the midpoint. To simulate the hand engaged in the handgrip, ellipsoids were added to model the wrist, fingers, and thumb. Joint segment dimensions, masses, moments of inertia, and moment versus angle joint properties were included in the model for the 5<sup>th</sup> percentile female. While the loads and moments at each joint were recorded, the forearm axial force (FZ) was presented as the overall indicator of load severity.



**Figure 1:** The side air bag, occupant, armrest, and handgrip as modeled in CVS/ATB simulation software.

## RESULTS

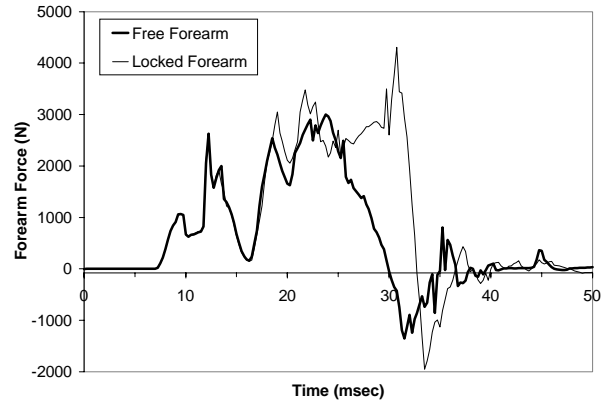
Simulated air bag deployments were performed with the shoulder allowed to translate, labeled free clavicle, and with a rigid shoulder that was allowed only to rotate, labeled locked clavicle. The simulations revealed discrepancies in the forearm axial load (Figure 2). Although the inertial loads at the beginning of impact were the same, the momentum transfer was much greater in the free clavicle case. This discrepancy was due to a completely different interaction with the handgrip between the two cases. The shoulder translation allowed the forearm to translate further and interact more extensively with the handgrip compared to the locked clavicle case.



**Figure 2:** Forearm axial load (FZ) for a locked and free clavicle during side air bag loading with the forearm pronation permitted in both simulations.

Additional simulations were performed with forearm pronation allowed, labeled free forearm, and with forearm pronation prevented, labeled locked forearm. In contrast to the shoulder translation results, the inclusion of forearm pronation resulted in a lower peak force and momentum transfer compared to the locked forearm (Figure 3). Again, a different interaction

pattern was observed with the door handgrip.



**Figure 3:** Forearm axial load (FZ) for a locked and free forearm during side air bag loading with the clavicle free in both simulations

## DISCUSSION

The simulations suggest that preventing shoulder translation or forearm pronation will result in non-biofidelic interaction patterns. Given that there is no consistent interaction pattern between the simulations with the free and locked joints, it is impossible to develop a technique that could be used to scale the dummy response. It is suggested that in order to accurately predict the upper extremity loading, the shoulder translation and forearm pronation must be incorporated into the dummy design.

## REFERENCES

- Duma, S., Crandall, J., Hurwitz, S., Pilkey, W., (1998), Stapp International Car Crash Conference.
- Jaffredo, A., Potier, P., Robin, S., Le Coz, J., Lassau, J., (1998) International Research Council on the Biomechanics of Impact.
- Kallieris, D., Rizzetti, A., Mattern, R., Jost, S., Priemer, P., Unger, M., (1997) Stapp International Car Crash Conference.