Mechanical Response and Brain Injury of Swine Subject to Free-Field Blast

Ke Feng, Xin Jin, Srinivasu Kallakuri, Liying Zhang, Chaoyang Chen, John Cavanaugh, Albert I. King

Bioengineering Center, Wayne State University, Detroit, MI 48201, USA

Introduction

The mechanisms by which primary blast overpressure produce mild to moderate traumatic brain injury is still unclear. The assessment of the severity of injury following primary blast is still a great challenge clinically. The aim of this study is to explore and quantify relationships between mechanical response and brain injury on live anesthetized swine exposed to open-field blast. The goal of the study is to understand the mechanisms of primary blast-induced injury and to determine the relationship between intracranial pressure in the brain and its effect on axonal damage and cellular injury.

Experimental setup

Open air blast test setup

❑ Explosive

o 8 lb of C4 (equivalent to 5.19 kg of TNT)

❑ Distance to specimen

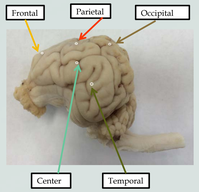
o Low level blast: 4.7m

o Medium level blast: 3.6m

o High level blast: 3.1m

❑ Distance to the ground

o 1.2 m



Swine specimen

❑ Adult Male Yucatan pig

o Weight: 50-60 kg

❑ Intracranial pressure (ICP) measurement

o Kulite pressure sensor

o Location: Frontal, Parietal , Left Temporal, Right Temporal, Occipital and Center lobe.

❑Linear acceleration (LA) and angular velocity (AS) measurement

o 3 linear accelerometers and 3 angular rate sensors were mounted in a block and placed on the occipital bone

❑ Test arrangement

o Instrumented pig paired with non-instrumented pig

o Each instrumented pig was blasted at 3 different levels (low, medium and high) at 3 directions (front, side and back)

o Data Acquisition system: DEWETRON system

Design and methodology

❑ Instrumented swine tests

o All the intracranial pressure sensors were calibrated with pencil pressure in air in a shock tube.

o Error in peak pressure was less than 10%.

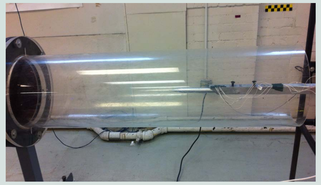
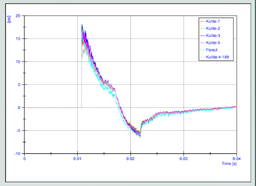


Photo of the calibration setup. Five Kulite sensors were placed next to a calibrated pencil pressure transducer in side-on direction. Blast pressure was produced in a shock tube.



Readings from Pencil and 5 Kullite pressure sensors in a single calibration.

o In the open air test, we initiated the testing with frontal blasts, followed by rear blasts and side blasts. The nominal incident pressure (IP) were 150 (Low Level), 300 (Medium Level) and 400 (High Level) kPa for the instrumented swine.

o We utilized the pressure from the Mach stem to avoid ground reflections.

❑ Non-instrumented swine tests

o Tests were on swine only in front direction at nominal 300 kPa IP.

o Sham group of 6 swine

o Perform serum biomarker studies at 6 hr, 24 hr, 48 hr and 72 hr

o Sacrifice animals at 72 hr and perform histological studies.

o Inflammatory response :glial fibrillary acidic protein (GFAP) and microglial (Iba1)

o Cellular injury: caspase 3 immunocytochemistry, FluoroJade B, TUNEL and H&E staining

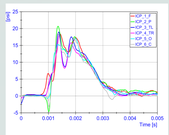
o Hemorrhage: Prussian blue

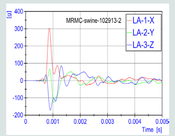
o Temporal changes: Biomarkers (S100B, NSE, MBP, NF-H, SBDP, IL-6, and HSP-70)

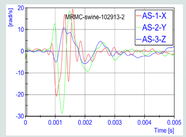
Results

o A total number 19 blasts were performed on 3 instrumented pigs. A summary of the tests is provided below.

	Low IP	Medium IP	High IP
Front	2	4	4
Rear	2	2	2
Side	1	1	1







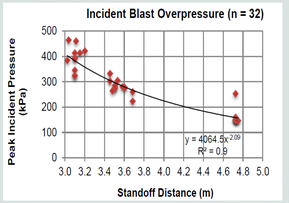
The three figures above showed the typical intracranial pressure readings, linear acceleration and angular velocity, respectively, in low IP exposures.

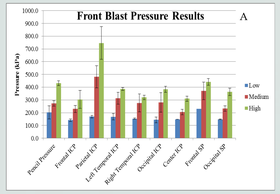
❑ Biomechanical data

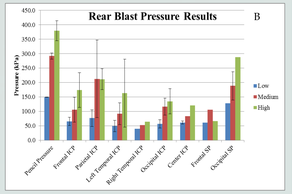
o Figure on the right shows the distribution of peak IP at swine in relation to standoff distance.

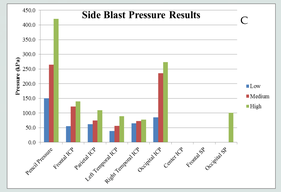
o With higher, ICP readings at different regions of the brain increased (see Figures A, B, C, D and E).

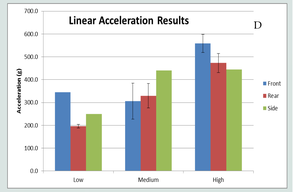
o In front blast, among all the regions of the brain, ICP readings at parietal region had the highest values at medium and high level of blasts (see Figure A). ICP readings at central regions were much lower than parietal regions. SP readings at frontal region were higher than at occipital region.

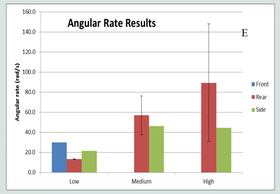










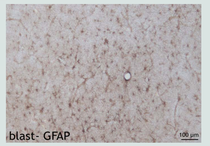


o In rear blasts, all the ICP readings at different regions increased with increasing IP.ICP readings at parietal region had the highest values among all the ICPs. Surface pressure (SP) readings at occipital region were higher than SP readings at frontal area (see Figure B).

o In side blasts, we only acquired one set of data, but all the ICP readings also increased with increasing IP pressure (see Figure C).

o Resultant linear acceleration results are shown in Figure D. Resultant angular rate results are shown in Figure E.

❑ Brain injury- Histology results



o A total number of 5 non-instrumented tests were performed at Medium Level IP.

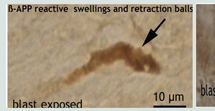
o Stains and ELISA are not completed. The finished stains are frontal lobes.

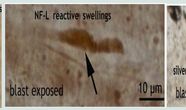
o It appears that GFAP reactivity is more prominent in blast group than in sham group. Quantification technique to identify group differences in GFAP reactivity are underway.

o A higher number of β-APP reactive profiles were found in brain sections from blast group than in sham expressed.

o NF-L immunostaining revealed a preponderance of swollen axons and axons with vacuolations in blast exposed brain sections.

o Silver staining showed signs of degenerating axons in both the groups.





Conclusions

Overall, in front, rear and side blast exposures, ICP in various brain regions increased with increasing IP. The peak ICP values were by and large lower than the peak IPs. We are investigating possible causes of this phenomenon, since it was expected that ICPs would be greater than IPs. In the non-instrumented swine exposed to Medium Level IP histological evidence of increased GFAP activity and axonal injury was present. Further quantification of biomarker and histology outcomes is underway.

Acknowledgements

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