INTRODUCTION

Blast-induced traumatic brain injury (bTBI) has received increasing attention in recent years. Numerous theories are currently being evaluated by various research groups to indentify the causes of TBI. One issue that has remained controversial is the initiation of cavitation in the brain due to the incident shock waves and the resulting negative pressure. In this study we focus on regions of tension that may, particularly in cerebrospinal fluid (CSF), cause cavitation. Cavitation from negative pressure at the contrecoup site in the brain has been hypothesized as early as 1948 [1]. However whether or not cavitation occurs, few studies have studied brain tissue damage caused by cavitation especially for mild bTBI. The objective of this research is to develop a system to introduce and control cavitation around a live brain tissue slice to detect damage due to the shock waves caused by the collapse of bubbles.

METHODS

To introduce cavitation, the slices were submerged in a fluid-filled (water or artificial CSF, aCSF) plastic chamber with a 2 mm height with a sealed piston at one end. The chamber was placed in a polymeric split Hopkinson pressure bar system, see Figure 1, which was designed to pull the fluid chamber away from the fixed piston. The striker bar was launched at 15 psi from the gas gun, and upon impact with the incident bar. The wave velocity in the bar was 2230 m/s, and the duration of stress wave was ~565 μs. This stress wave loading was imparted to aluminum U-shape feet which impacted the back holder of the test chamber. The piston was held in place using a clamp which was fixed to the test platform. In this way, fluid in the chamber was placed under a tensile load which caused negative pressure and cavitation.

Cavitation was captured using a high-speed imaging system (Vision Research, Wayne, NJ) that was triggered from the acoustic signal generated by the gas gun. The camera was set at approximately 100,000 frames per second. Total test duration was relatively short (~5 min). A high frequency pressure transducer (ICP 113B24, 2000 Hz sampling rate over 5 μs, PCB Piezotronics Inc., Depew, NY) embedded at the top of the test specimen holder was used to measure fluid pressure.

In addition to these tests, live rat brain tissue slices will be used to test this system. Protocols and procedures for this study have been approved by the University of Florida Institutional Animal Care and Use Committee. Fluoro-Jade C and DAPI staining will also be used to detect neuronal tissue damage. Brain tissue slices stained with FJC (green fluorescence) and DAPI (blue) will be imaged with a fluorescent microscope within dentate gyrus (DG), CA1, and CA3 regions of the hippocampus which have a high density of neurons. Degenerating neurons (with FJC images) and total cells (with DAPI images) within select fields of view will be counted via a custom MATLAB subroutine. Histological methodologies have been completed for the case of no cavitation see Figure 2.
RESULTS AND DISCUSSION

Within the developed tension system, gas bubbles formed at different locations. Bubbles suddenly appeared, grew and underwent collapse within a time span of approximately 1.8 ms, see Figure 3. Negative pressure was recorded by the pressure sensor. With a 15 psi air gun setting, the pressure in the test chamber reached approximately -12 psi. Negative pressure may be controlled by varying air gun pressure. Since pressure directly affects bubble size, further control of bubble size may also be achieved. Control of bubble location may also be achieved by seeding bubbles at specific sites.

CONCLUSION

This new PSHPB tension test system has the ability to introduce cavitation in a fluid-filled chamber by providing a negative pressure. Controlled pressure testing will provide more control over bubble size and position. In ongoing studies, neural injury due to cavitation will be studied by introducing rat brain tissue slices to this system. Histological methodologies have been completed for the case of no cavitation within hippocampal regions.

REFERENCES


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