The Role of the Pia Mater in Controlling Brain and Spinal Cord Intraparenchymal Pressure

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Introduction

Several multicenter randomized control trials have shown that decompression with durotomy/duroplasty significantly decreases intracranial pressure (ICP), improving mortality. Currently, decompressive craniectomy combined with augmentative duraplasty is widely performed and is recommended by most authors. However, there is a paucity of evidence regarding the effectiveness of decompression of the spinal cord by meningoplasty.

Methods

The supratentorial brain and spinal cord were carefully removed from four fresh cadavers. The dura and arachnoid mater investments were removed. ICP monitors were placed bilaterally in the frontal and parietal lobes, as well as the cervical and thoracic spinal cord. The specimens were then submerged in a hypotonic solution and intraparenchymal pressures were monitored over 5 days. After 5 days, a complete dorsal midline piotomy was made on the spinal cord and the final pressures were recorded.

Results

Both the brains and spinal cords showed marked swelling. Brain and spinal cord both increased in weight. IPP significantly increased in both brain and spinal cord. The IPP increase within the spinal cord was substantially greater (averages: all four lobes = 4.0 mm Hg; cervical = 73.7 mm Hg; thoracic = 49.3 mm Hg). After piotomy, cervical and thoracic spinal cord IPP decreased immediately (avg. post-piotomy IPP = 9.7 and 10.3, respectively).

Conclusions

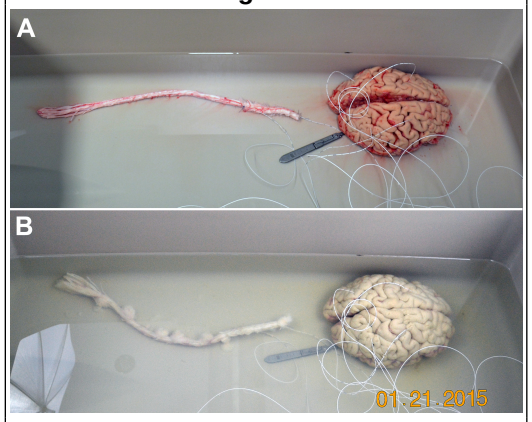
The simulated edema model has differential effects on brain and spinal cord IPP. Brain IPP increased only slightly, consistent with the model that increased intracranial pressure is primarily due to constraints imposed by the cranium and dura mater. In contrast, spinal cord IPP increased substantially. Piotomy immediately and dramatically reduced spinal cord IPP. These data are consistent with the hypothesis that intramedullary pressure is primarily due to constraints imposed by the pia mater. Conversely, we hypothesize that the brain sulci permit the pia-invested brain to better accommodate edema without significant increases in IPP.

Learning Objectives

By the conclusion of this session, participants should be able to 1) Discuss a novel method for modeling neural edema. 2) Describe the contribution of the pia mater to spinal cord intraparenchymal pressure. 3) Understand how piotomy can ameliorate IPP in this model.

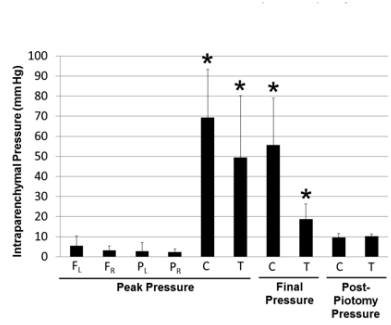
Movie

Figure 1



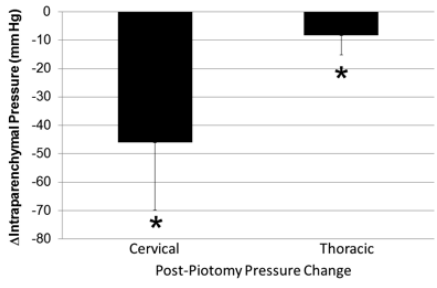
An example of one representative preparation at baseline (A) and after (B) 5 days of submersion in a hypotonic solution. Note the sulcal effacement as well as the generalized swelling of the brain. Focal herniations are seen in the spinal cord.

Figure 2



Peak IPP, Final IPP after 5 days, Post-piotomy IPP. Key: left frontal (FL), right frontal (FR), left parietal (PL), right parietal (PR) lobes. Cervical (C) and thoracic (T) spinal cord. Bars: mean + standard deviation. * indicates statistical significance compared with FL, FR, PL, and PR peak IPP.

Figure 3



IPP in cervical and thoracic spinal cord following piotomy. Bars indicate mean + standard deviation (mm Hg). * indicates statistical significance compared with final IPP after 5 days.