Assessment of Anterior Spinal Artery Blood Flow Following Spinal Cord Injury

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Abstract

Introduction: The incidence of spinal cord injury (SCI) in the US is approximately 12,000 individuals annually, due to various forms of trauma and disease. (1) Previous studies show that increased force on or prolonged compression of the spinal cord results in progressive ischemia, as indicated by a reduction in spinal cord perfusion (2). Diminished flow over a prolonged period of time can cause necrosis and permanent damage if perfusion falls below the critical level, or vascular threshold (3).

Methods: We constructed a 3D finite element model (FEM) of the cervical spinal cord using COMSOL Multiphysics 4.0a to examine the role of compressive mechanical loading of the spinal cord on ischemia, which could arise from acute compression, distraction, or vasospasms. The FEM included the spinal cord, dura mater, and spinal vasculature and was built using the Fluid-Structure Interaction module provided by the COMSOL software. We assessed the effects of different loading scenarios on the blood flow in the anterior spinal artery and correlating arterial branches, as shown in figure 1.

Results: After running the model with various applied loads, it was found that the magnitude and direction of forces on the spinal cord model, including anterior, posterior, and axial loading, had various effects on blood flow. Maximal reduction in perfusion was shown in the posterior loading, while maximal reduction in flow of the anterior spinal artery (ASA) was observed in the anterior loading, as shown in Figure 2. Axial loading affected vessels within proximity of the loading site. Changes in the mechanical properties of the arterial walls had no significant effect on the force-induced changes in blood flow rate.

Conclusion: Anterior loading results in a notable reduction in ASA flow, which is understood through the significant physical deformation of the artery caused by this mode of compression. We speculate that such a disruption in the configuration of the vessel could compromise the auto-regulation mechanism of the arteries and induce maladaptive remodeling. Although it minimally affected the ASA, posterior loading reduced perfusion within the spinal cord, making it a more time-sensitive injury.

Reference

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Figures used in the abstract

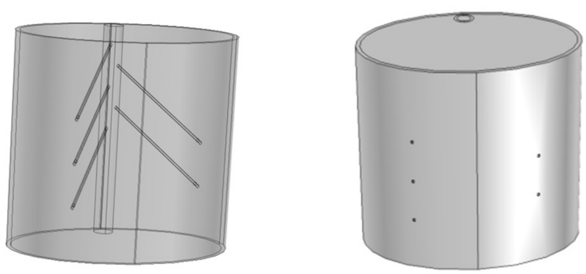

Figure 1: Cervical spine model with (from deep to superficial) anterior spinal artery, spinal cord, and dura mater. The five arterial branches were allowed to leave the dura mater for analysis and simulate blood flow out of the spinal cord.

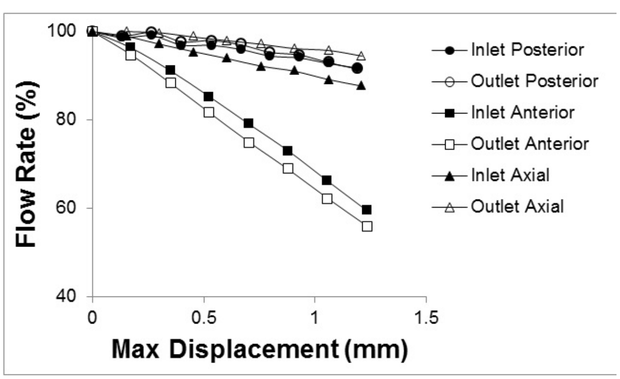

Figure 2: Comparison of percent flow in the ASA as a result of anterior, posterior, and axial compression of the spinal cord.