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The timing of surgical decompression for spinal cord injury

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Abstract

Research into the pathophysiological mechanisms of spinal cord injury (SCI) has resulted in a classification scheme of primary and secondary injury. Primary injury refers to the destructive nature of the initial impact and the subsequent shearing, penetrating, and compressive forces that injure the delicate neural tissue. Secondary injury refers to a complex array of pathophysiologial processes – including ischemia, inflammation, excitotoxicity, and oxidative cell damage – that contribute to the ultimate loss of neural tissue. While our understanding of secondary mechanisms improves with continued research, novel treatments for SCI are currently being developed with a foundation rooted in halting deleterious secondary mechanisms. In this article, we will review the current evidence for surgical decompression as a treatment for SCI. Emerging evidence and a growing consensus among surgeons are in support of early surgical intervention to help minimize the secondary damage caused by compression of the spinal cord after trauma.

Introduction and context

Pathophysiology

Secondary spinal cord injury (SCI) refers to the mechanisms (such as ischemia, vasospasm, delayed axonal loss, apoptosis, ion-mediated cell damage, excitotoxicity, neuroinflammation, mitochondrial dysfunction, and oxidative cell damage) that occur in the minutes to weeks to years following the initial injury. For a complete understanding of these secondary mechanisms, one should refer to a recent review by Rossignol *et al.* [1]. Of particular importance to this overview is the notion that persistent compression and instability are key contributors to secondary injury and exacerbate ischemia. The timing of arresting these secondary mechanisms has been established in many preclinical studies. For example, the Weaver group [2] demonstrated that by halting leukocyte infiltration after traumatic SCI one could achieve improved neurological outcomes and tissue sparing while maintaining the ability to mount a delayed immune response. Surgical decompression offers a means of relieving physical pressure and allows for the possibility of mitigating secondary damage.

Definition of timing

A group of highly specialized spinal surgeons was surveyed to determine the timing of early surgery, and a range from 8 to 72 hours was considered appropriate [3]. They also concluded that additional clinical research is needed to properly address this important question.

On the basis of the biology of secondary mechanisms in SCI, the Spine Trauma Study Group operationally defined early intervention as occurring within 24 hours and included in its definition the important caveat of avoiding hypotension and hypoxia as each contributes to a cascade of secondary cellular mechanisms which results in progressive tissue damage. This group recognizes that there is unlikely to be a specific threshold at which surgical decompression provides clinical benefit but rather a continuous relationship and the details of this continuous relationship are certainly multifactorial and still unknown.

Preclinical animal models

A number of investigations, dating back to the 1970s, have been used successfully both to elucidate the

secondary mechanisms of SCI and to mount evidence that early surgical decompression affords better neurological outcome. For example, Dimar *et al*. [4] used a rat model with a range of timed extradural compression of up to 72 hours and demonstrated that animals with shorter compression times fared better neurologically. With this historical context, we aim to highlight the most recent studies and demonstrate that the duration of spinal cord compression correlates with the neurological outcome.

Clinical literature

The historical clinical literature is more difficult to interpret than preclinical studies. The main reason for this rests in recent improvements in pre-hospital care, critical care transport, and improved in-hospital intensive care and surgical procedures. Outcome measures can be broadly classified into neurological improvement and medical complications/length of stay (LOS) in-hospital.

Vaccaro *et al*. [5] examined the role of early surgery in acute cervical SCI in two groups of patients (early surgery [<72 hours] and late surgery [>5 days]) for change in ASIA (American Spinal Injury Association) grade or motor score as well as intensive care unit (ICU) and rehabilitation LOSs. The authors found no difference between groups in terms of neurological recovery but cautioned that because of referral patterns and an average 'early' time of 1.8 days, many patients may not have benefited from what was thought to be early surgery. Vale *et al*. [6] studied the outcome of acute SCI patients who received both aggressive medical management (the prominent focus being on volume resuscitation and maintenance of blood pressure) and early surgical decompression. The authors demonstrated that aggressive hemodynamic modulation serves to maximize spinal cord blood flow and perfusion after traumatic injury. They hypothesize that the ideal management of acute SCI is a combination of pharmacological therapy, early surgery, or fracture reduction, plus aggressive volume resuscitation and blood pressure elevation to maximize spinal cord perfusion. Some authors have reported neurological improvement after SCI with delayed surgery [7-9].

Recent advances

Preclinical animal models

In the last decade, about 10 preclinical animal studies have addressed the question of prolonged compression of the spinal cord and its effect on outcome. In 2003, Carlson *et al*. [10] studied spinal cord compression in a dog model with a piston acting to apply force to the spinal cord. They compared outcomes when removing the piston at 30 minutes versus 3 hours and found that the latter group both performed worse neurologically and showed greater lesion volumes. The authors, in agreement with previous investigators, hypothesized that prolonged exposure to secondary injury mechanisms accounts for worse neurological outcome and found that with the removal of the stimulus for these secondary mechanisms came better neurological outcomes.

Most recently, Rabinowitz *et al*. [11] conducted a randomized prospective study in dogs in which early surgical decompression (6 hours) combined with or without methylprednisolone was compared with methylprednisolone alone in an attempt to reproduce the treatments currently available to humans. Decompressive surgery was carried out 6 hours following the initial insult. The animals were followed clinically and electrophysiologically for 2 weeks and then sacrificed and examined histologically. The authors demonstrated that surgical decompression with or without methylprednisolone administration offers greater neurological improvement than with the use of methylprednisolone alone.

Clinical literature

Several clinical studies within the last decade have grappled with the question of the ideal timing of surgical decompression following SCI. As mentioned above, one of the challenges has been to maintain a balance between advances in medical care and conducting appropriate research studies to reflect these improvements. One innovative way to incorporate these discrepancies is through the use of structured systematic reviews of published literature along with expert opinion gathered through a modified Delphi process. Briefly, this involves formulating specific questions that are important to patient outcomes. A systematic literature search is conducted and all participants are presented the results. Each expert then votes while taking into account the context of the original literature and the methodological quality of the study and its conclusions. This has recently been conducted with regard to timing of surgery in SCI. We elaborate on this below.

Outcome: neurological improvement

In the most recent clinical trial conducted, Papadopoulos *et al*. [12] evaluated 91 patients with complete SCI, with a stringent inclusion criteria of patients with clinically and radiographically confirmed acute traumatic spinal cord and vertebral column injury (excluding central cord syndrome secondary to cervical spondylosis). The authors demonstrated that early surgery (within 9.6 hours of injury) led to improvement in 39 of 66 patients versus 6 of 25 in the control (no surgery) group. Patients

in the early surgery group had shorter ICU and shorter overall LOSs. Moreover, some patients with complete SCI improved following surgery. The Vaccaro and Papadopoulos groups have not only different criteria for the early versus late surgery groups but also different inclusion and exclusion criteria, and this explains the differences in their results.

As alluded to above, Furlan *et al.* [13] published the results of a systematic review in combination with a modified Delphi process to gain expert opinion. When the panel of experts was specifically asked about the effect of early surgical decompression on neurological outcome, the conclusions were as follows: all studies conducted to address this question are level-4 evidence with the exception of one level-2b study, early surgery proved to be safe provided that the patient was hemodynamically stable and did not suffer from extensive polytrauma that may compromise cardiopulmonary function, and early surgery has the potential to offer improved neurological function based on preclinical studies and preliminary data from the recent STASCIS (Surgical Treatment for Acute Spinal Cord Injury) trial [14].

Outcome: medical complications and length of stay

Recent studies have focused on outcome measures other than neurological improvement, each of which has an effect on patient well-being following SCI. Some authors report that early surgery results in reduced LOS, fewer secondary complications, early mobilization, and transfer to rehabilitation and should be considered in all SCI patients. Croce *et al.* [15] reported lower rates of pneumonia and deep vein thrombosis in persons receiving surgery within 24 hours. Chipman *et al.* [16] reported a lower frequency of all complications in patients with an injury severity score (ISS) of greater than 15 (indicating a higher degree of traumatic injury) and receiving surgery within 72 hours of injury (although the same group reports equal medical complications in persons with low ISS [i.e., less than 15] regardless of the time of decompression). McKinley *et al.* [17] report higher rates of pneumonia in the late surgery group but equal rates of other complications (deep vein thrombosis, pulmonary embolism, and ulcers).

Implications for clinical practice

The most recent evidence demonstrates that no standard of care regarding the timing of surgical decompression after acute SCI has been established. Animal models suggest that early decompression directly correlates with improved neurological outcome. There are no class I clinical trials to guide management decisions. Several class II and class III studies have been carried out; they demonstrate the following:

- Early surgery is safe.
- Early surgery (decompression/reconstruction) should be strongly considered in patients without life-threatening polytrauma and without major medical co-morbidities.
- High-quality imaging (computerized tomography or magnetic resonance imaging) enhances the safety and logistics of early intervention.
- Urgent surgical decompression should be carried out in patients with deteriorating neurology.
- It is essential that intra-operative hypotension be avoided to minimize the peri-operative risks with early intervention – we start a dopamine infusion prior to induction of anesthesia.

Abbreviations

ICU, intensive care unit; ISS, injury severity score; LOS, length of stay; SCI, spinal cord injury.

Competing interests

The authors declare that they have no competing interests.

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