■ ANNOTATION

Which treatment provides the best neurological outcomes in acute spinal cord injury?

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Initial treatment of traumatic spinal cord injury remains as controversial in 2023 as it was in the early 19th century, when Sir Astley Cooper and Sir Charles Bell debated the merits or otherwise of surgery to relieve cord compression. There has been a lack of high-class evidence for early surgery, despite which expeditious intervention has become the surgical norm. This evidence deficit has been progressively addressed in the last decade and more modern statistical methods have been used to clarify some of the issues, which is demonstrated by the results of the SCI-POEM trial. However, there has never been a properly conducted trial of surgery versus active conservative care. As a result, it is still not known whether early surgery or active physiological management of the unstable injured spinal cord offers the better chance for recovery. Surgeons who care for patients with traumatic spinal cord injuries in the acute setting should be aware of the arguments on all sides of the debate, a summary of which this annotation presents.

Cite this article: ***Bone Joint J*** **2023;105-B(4):347–355.**

"Progress, far from consisting in change, depends on retentiveness... Those who cannot remember the past are condemned to repeat (the mistakes of) it."

- George Santayana, *The Life of Reason; Reason in Common Sense*[1]

Introduction

Controversy has existed about how best to treat traumatic spinal cord injuries (tSCIs) since antiquity. Laminectomy had been favoured by some surgeons since the 16th century, but Burrell,[2] in the mid-19th century, was the first to suggest that decompression of the spinal cord should be carried out routinely soon after traumatic spinal cord injury to preserve neural function. Opinion about the timing of surgery in acute tSCI has been polarized ever since. Currently, the prevailing surgical opinion is that early decompression of the spinal cord carries benefits in some groups of patients even though the evidence for this is weak.[3-6] In 2020, Wilson et al,[7] recognizing the lack of robust data in this area, looked forward to the results of the prospective observational European study of acute surgical decompression after traumatic spinal cord injury (SCI-POEM). The results of that study are now published in this edition of *The Bone & Joint Journal*.[8]

Outcomes of the SCI-POEM trial were analyzed based on the timing of surgery. An early surgical decompression group (< 12 hours from the time of injury) was compared to a late decompression group, in which surgery occurred after 12 hours and before 14 days from injury. The trial was a meticulously constructed, prospective study, conducted in 17 specialist spinal centres in Europe, and reported the outcomes of 294 patients, 159 of whom were allocated to the early surgery group and 135 to the late group. The primary objective outcome measure was the American Spinal Injury Association (ASIA) neurological examination: the primary endpoint was the Lower Extremity Motor Score. Both were assessed at baseline and at 12 months after treatment.

The results of the study, after careful statistical analysis that fully considered baseline imbalances, the heterogeneity within the patient cohort, the ceiling effects of the outcome measures used, and the effect of loss to follow-up on surgical success rates, showed that early surgical decompression following acute tSCI did not result in statistically significant or clinically meaningful

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doi:10.1302/0301-620X.105B4.BJJ-2023-0111 $2.00

Bone Joint J 2023;105-B(4):347–355.

neurological improvement a year after the injury when compared to delayed surgery.

This study reinforces the well-established requirement for appropriate acute medical management in patients with tSCI, but it does not support a need for very early surgical decompression. It emphasizes that advanced, adjusted statistical analysis in studies of this heterogeneous patient population is needed to understand the outcome of treatment. Unadjusted statistical treatments can overestimate the effect of an intervention such as early surgery. As a result, the authors suggest that the study prompts reconsideration of current international clinical practice guidelines about the timing of surgery in acute tSCI.

The prevalent surgical thinking in many SCI centres is derived from a series of studies published over the last decade that have formed the basis for international clinical practice guidelines.[4-6] In 2012, Fehlings et al[9] reported on the outcomes of the Surgical Timing in Acute Spinal Cord Injury Study (STASCIS) trial, the results of which were described as showing that surgery in patients with cervical tSCI before 24 hours from the time of injury was safe and associated with improved neurological outcomes at six months. However, problems with the methodology of the study were identified which caused controversy and a robust rebuttal, with the original authors citing further data from a study published by a group in Ontario, Canada, which they considered supportive of early decompression in tSCI.[10–13]

A year later, two systematic reviews and meta-analyses of preclinical and clinical studies compared the outcomes of early and delayed decompression of the acutely compressed spinal cord.[14,15] In both the reviews of animal experiments and human trials, lack of methodological rigour and significant publication bias were identified. Although the second study included reports that early surgery improved outcomes, the data were not sufficiently robust because of the different sources of heterogeneity in the patient population.

Since 2013, a number of reports have examined the outcomes of various surgical regimes for a range of indications in tSCI. There have been arguments that early decompression is better than delayed surgery:[16-19] others have suggested that it makes little difference to the neurological outcome.[20,21] Some have advocated a delay in operating on patients with acute traumatic cervical central cord syndrome on the basis that early surgery is associated with an increase in mortality,[22] while exactly the opposite view – that there is no increase in mortality – has also been advanced.[23]

When there is such a divergence of opinions it is difficult for non-specialists to judge what the correct course of clinical action should be when they are faced with patients with a tSCI who present to a non-specialist unit. Should urgent referral and transfer be prioritized or not, particularly in cases of polytrauma where there might be non-spinal priorities to deal with? Such decision-making is often complicated by logistical difficulties that are inherent in arranging urgent transfer to specialist units. These have, in many parts of the world, been made worse since the onset of the COVID-19 pandemic.[24-26]

However, what is missing from these arguments is a comparison of surgery with non-surgical treatment and the availability of strong evidence for particular forms of treatment. In this annotation, we present summaries of the arguments for and against surgery to decompress the spinal cord after a tSCI and a synthesis of the newer statistical approaches to that evidence. We address the debate from the side of the noninterventionist, collate the arguments for surgery, and present evidential arguments for advanced statistical analysis to try to cut through the difficulties that are inherent in understanding how treatment of this very diverse and complex condition can be optimized. We hope this information will allow readers to judge for themselves whether the currently available evidence is sufficient to allow logical decision-making in their daily clinical practice, or whether the situation remains one of equipoise.

The case against early decompression of the spinal cord in traumatic spinal cord injury

Prior to the 16th century, all treatment of tSCI was nonoperative. In the late 16th century, Ambroise Paré was the first to recommend laminectomy if the spinal cord was compressed.[27] In the early 19th century, a fierce debate raged between Sir Astley Cooper and Sir Charles Bell about the relative merits of conservative and surgical treatment for patients with a tSCI.[28–30] Cooper was a strong proponent of laminectomy, an opinion formed from his extensive clinical experience, which Bell vehemently opposed on the basis of his scientific study of the anatomy and physiology of tSCI. There was no resolution to the controversy prior to the deaths of both men, but Bell's view came to be widely accepted for the following 150 years.

During the early 20th century, conservative treatment held sway, but there were differences in opinion about the best way to manage tSCI. Forceful reduction of fractures using a variety of postures and positions with relatively short recumbency was advocated by many. However, others advocated acceptance of the spinal deformity, allowing the spine to heal as it would, with prolonged recumbency (three to six months or more).[30-32]

Irrespective of the method chosen, most patients before World War II died early from complications including pressure sores, pyelonephritis, hydronephrosis/pyonephrosis, urinary calculi, contractures of paralyzed muscles, osteoporosis, and septicaemia. The rate and severity of these complications were greatly increased by certain treatments such as the use of plaster beds as described by Nissen,[33] which resulted in this method of management being strongly condemned by the leaders in the field at that time.[30,33–36]

During World War II, Dr W. W. Guttmann, an experienced and aggressive neurosurgeon, was appointed to Stoke Mandeville Hospital (Aylesbury, UK) to look after injured veterans with tSCI.[27] He established a multidisciplinary team that developed the Active Physiological Conservative Management (APCM) system to manage multisystem impairment and malfunction in the absence of sensation, which was particularly important in the transitional period between the resolution of neurogenic shock and full return of the reflexes. He showed that with APCM from the very first few hours or days, and prior to the patient developing respiratory complications, no patient required ventilation or intensive care monitoring unless they had associated life-threatening injuries, a previous history of chronic respiratory disease, or a cord injury above C4. He also showed that almost all the complications of tSCI could be prevented, or diagnosed and treated early, to minimize their effects, some of which could potentially cause further non-mechanical damage to the injured cord leading to neurological deterioration and delay in, or absence of, recovery. In the first 12 weeks of treatment, postural reduction, bony healing, and the return of neurogenic and spinal reflex activity were facilitated by APCM. At the same time, patients underwent active medical-modulated management of the various malfunctioning systems of the body throughout the transitional phase of return to adequate and stable autonomic and spinal reflex activity. They were provided with psychological and peer support, and education in the condition was started. In time, the period of recumbency was reduced to an average of four to six weeks. The actual length of time depended on the density of the cord damage, and was further modified as more experience was gained in safe monitoring and an increasing understanding of the influence of the effects of a degree of sparing of the long tracts.

Guttmann observed that by preventing hypotension, hypoxia, hypertension, hypothermia, sepsis, and electrolyte imbalance, some patients made a degree of spontaneous neurological recovery.[37] He was dissatisfied with the outcomes of laminectomy, which he observed were poorer than those of active conservative management of the injured spine and the medical effects of cord damage, and he abandoned the procedure. The possible mechanisms of deterioration of neural function following laminectomy were not actually described until years later,[38-40] but they were in accordance with the careful observations Guttmann had made.

In the mid-1960s, through repeated thorough neurological examination of patients based on the MRC recommendations, Frankel et al[41] observed that spontaneous motor recovery correlated well with clinically detectable sparing of sensory and sensorimotor tracts adjacent to and/or below the level of cord injury. They confirmed this observation in a retrospective study of 612 patients admitted within 15 days of injury. All had been treated at Stoke Mandeville Hospital according to the principles of APCM. They classified the neurology of these patients into five groups based on the clinical detection of long tract-sparing and the ability to move the limbs on admission and on discharge. This has since been known as the Frankel classification.[41] About 6% of the patients without any clinical sensorimotor sparing below the cord level of injury recovered useful motor function, allowing them to move their lower limbs, stand, or walk. By comparison, over 70% of patients with long tract sensory sparing only, i.e. without motor sparing, recovered useful motor function. This motor recovery occurred irrespective of the radiological appearances of the injury, without any intervention and despite failure to realign the spine by closed reduction. Building on Frankel's work, Folman and El Masri[42] showed that normal pin-prick sensory sparing was a better predictor of motor recovery than posterior column sensation (vibration sense and proprioception) and impaired spinothalamic sparing (pain and temperature appreciation). They also confirmed the discrepancy between radiological and neurological outcomes. The prognostic value of pin-prick sensory sparing was subsequently confirmed by other groups.[43–45] The anatomical level and physiological extent of the injury, inclusivity of all neurological presentations from the time of the injury, reliability, stability, reproducibility, and consistent prognostic value of the neuro-functional outcomes of the Frankel classification, even soon after injury, evidenced over more than five decades, means that to this day, the Frankel classification remains the most practical, useful, and meaningful method of classifying patients neurologically at all stages after a tSCI.

From the 1950s onward, most patients were treated holistically from the early days of injury in centres dedicated to the complex management of this very small group of patients.[46-50] Following the introduction of CT and MRI in the 1970s and 1980s, the radiological assessment of patients was enhanced. At the same time, the safety of anaesthetics was improved and a wider range of spinal instrumentation became available. As a result, an attempt to improve neurological outcomes further by surgery was understandably pursued. Unfortunately, with little evidence of the superiority or equality of outcomes, attention and resources were directed at the injured spine frequently at the expense of the medical and non-medical effects of cord damage. Thus, the treatment of biomechanical instability was prioritized over the management of physiological instability of the spinal cord and its systemic medical, non-medical, and possible neurological effects. Coincidentally, a revival of the hypothesis of the secondary injury to the spinal cord derived from animal models was increasingly being quoted as a reason to offer surgery early.[51-54]

Despite the differences between animal models and humans, despite the absence of vascular pathology, bony injury, and biomechanical instability in the animal models of cord injury, and despite the lack of evidence of equality or superiority of early or late decompression over conservative management, surgical stabilization and decompression of the injured human spinal cord has almost become routine since the turn of the century.

Within a few years of the adoption of the widespread use of the new imaging methods, the first reports were published suggesting that traumatic spinal canal encroachment did not reliably correlate with the degree of neurological impairment, prevent neurological recovery, or result in neurological deterioration.[55-63] The same conclusions were reached on reviewing the outcome of conservative treatment of a cohort of 50 consecutive patients, with between 10% and 90% canal encroachment in Frankel C, D, and E groups. Patients in the Frankel C and D groups recovered the ability to walk and none of the patients deteriorated neurologically or otherwise.[64] Significantly, a potential detrimental effect of surgical decompression was reported in 2009 by Kwon et al,[65] who found an increase in CSF pressure after surgical decompression in all 21 patients in whom the CSF pressure was measured.[65]

Early decompression, within 12 hours of injury, started to become aggressively and increasingly advocated after the publication of the STASCIS study in 2012, despite the lack of evidence of its value in improving outcomes and despite the possibility of causing further damage to the injured cord.[9]

Clinically, it is extremely difficult, if not impossible, for clinicians accurately to document motor power numerically in patients who have suddenly become paralyzed and who may be confused, anxious, in pain, are under the effects of significant levels of analgesia and sedation, and are often disorientated and requiring resuscitation. Motor power is almost always likely to be recorded as improved in most patients once their general condition has stabilized. This is usually within the first two to three weeks after injury, and it continues to improve for the first two to three years from injury and, in some patients, for even longer.

Considering that most of the studies that advocate early decompression are from multiple centres, it is not possible from the published data to know whether the medical, non-spinal effects of cord damage, which can affect the neurological outcome, were managed uniformly well to ensure adequate containment of the physiological instability of the injured cord and confirm that the published outcomes are related solely to the decompression.

The outcomes of the STASCIS study rely on the ASIA method of documentation and the ASIA Impairment Scale (AIS). The ASIA documentation has been updated and revised several times, including in 2019,[66] which undermines its use for adequate comparison within and between groups of patients. The published manuscripts in support of decompression (both early and late) do not always specify which version has been used to assess the presentation, outcomes, and determination of the value of their results when comparing early and late decompression. In addition, with the ASIA method of documentation, there are difficulties in interpreting the neuroanatomical and neurofunctional status of the patient and their classification on admission and at follow-up. The definition of complete AIS A and B depends on the presence or absence of sensory function in the S4/S5 dermatomes. Therefore, an AIS A patient can have sensory sparing above S4/S5 with the potential to walk and/or improve their ability to cough depending on the level of lesion. These patients will be labelled as complete on presentation. Those who advocate any local or systemic intervention, including decompression, can claim that improvement was due to the intervention. Similarly, an AIS B patient who does not have sensory sparing in S4/5 will be labelled as complete if they have sensory sparing above this level. Again, those who advocate any local or systemic intervention including decompression can claim that improvement was due to the intervention. To date there has been no correlation found between the sparing of S4/S5 and the return of normal bladder or sphincter control.

Criticism has been levelled at the Frankel classification by some professionals working in the field, citing a lack of its ability to acurately transmit key neuroanatomical and functional neurological information between clinicians that informs management and provides prognostic information. This might be the result of a lack of familiarity with the development of the classification. However, the same criticism can be levelled at the various classifications that have attempted to replace the Frankel classification.

Sadly, there has never been a serious comparison of the outcomes of APCM and any local or systemic intervention that claims to improve such outcomes. Such a comparison would be possible if the measurement of the clinical parameters that are relevant to tSCI were recorded by independent clinicians not involved in clinical decision-making or provision of care. These include: timing of the initial neurological assessment carried out following the injury and before the intervention; the time interval between neurological assessments; the method of management of the various physiologically impaired and malfunctioning systems as the result of cord damage; a record of the complications of treatment; a record of the total period of neurological assessment prior to the evaluation of the neurological and other relevant outcomes. Given the evidence of spontaneous neurological recovery with APCM, a comparison with surgical intervention would require the latter to demonstrate superiority, not just equivalence. This could then be considered as the 'added value' of surgery.[67] Fehlings et al,[9] and all subsequent authors with the same message, seem to have relied on one interpretation only for the difference of outcomes between early and late decompression, without comparison to APCM and nonintervention, hence the false impression that the outcomes of early decompression compared to late decompression are statistically significantly more favourable. There is no evidence to show that there has been added value.

The great majority of patients who present with sensory sparing only, or with sensory and motor sparing below the cord lesion and the zone of partial preservation (up to three adjacent distal segments), spontaneously recover significant motor power of functional value in standing and walking with APCM and without surgical intervention. Considering the large number of patients with long tract sparing who need to be studied in order to show statistical equality or added value of an intervention, it would be reasonable to suggest that comparison between surgical decompression, or any intervention, and APCM should be studied in patients who present without any sensory or motor sparing below the level of the lesion and the zone of partial preservation. Only a small percentage recover motor function spontaneously: if there is a beneficial effect of surgery it would become evident quite quickly. This would facilitate, if not ensure, meaningful clinical and statistical interpretation of studies examining the outcomes of treatment of tSCI. A minor modification of the Frankel classification would also ensure meaningful comparative studies would be possible between the outcomes of local or systemic interventions in patients with incomplete injuries, in whom spontaneous neurological recovery commonly occurs with APCM.

Based on the unevidenced assertion that early decompression after tSCI is essential or strongly advisable to achieve better neurological outcomes than late decompression or APCM, clinicians are likely to be at risk of being wrongly accused of negligence and penalized if they fail to carry it out. This is likely to lead to defensive rather than evidence-based management. Courts tend to rely on the prevalent opinion of clinicians who assert that opinion irrespective of the quality of the evidential basis, irrespective of the details of the clinician's involvement in the short- and long-term comprehensive treatment and follow-up of this small group of patients with significantly complex problems, and irrespective of their background training and experience. Therefore, extreme caution by the medical profession is necessary to avoid adopting fashionable methods of unproven treatment causing an unnecessary waste of resources, limiting advances in the field of spinal injuries, and adding stress to clinicians who do not follow recommendations that are not based on adequate evidence.

The case for early decompression of the spinal cord in tSCI

Early decompression for tSCI has a clear and sound rationale. These conditions have severe and devastating long-term sequelae for patients and their families and become a long-term burden on the healthcare infrastructure. Improvements in motor and sensory function may significantly enhance a patient's quality of life and reduce the costs of care. Hence, early neuroprotection is key to optimize outcomes and mitigate secondary injury mechanisms by reducing ischaemia, haemorrhage, oxidative stress, and excitatory neurotransmitter release. Of all currently available treatment options, surgical decompression is the one intervention that can dramatically alter the trajectory of a patient's recovery. Surgery relieves pressure within the spinal cord and can partially restore the microvascular blood flow. Reducing local ischaemia and compression of the neuroglial cell membrane can further encourage recovery.

The adage "time is spine" is an appropriate notion for tSCI discussions. There is a strong rationale for early decompression surgery to mitigate secondary injury. At the forefront, preclinical data in animals supports the efficacy of decompression surgery. Batchelor et al[14] reported a meta-analysis of preclinical studies with 79 experiments on 873 animals, showing that early decompression improved neurobehavioral outcome by 35.1%: the effect size is closely related to duration of compression and compressive pressure. As compressive pressure and duration increase, the rate of development of severe paraplegia increases, thereby suggesting the urgency of decompressive surgery.

Anecdotally, there is little controversy among spinal surgeons on when a patient with tSCI and spinal column instability needs surgery. This is highlighted by an international survey of 971 spinal surgeons.[68] A case presentation of a 45-year-old male with bilateral C6/7 locked facet dislocation and tSCI was provided to study participants, and 85.3% and 96.3% of surgeons elected to operate within 24 hours for complete SCI and incomplete SCI, respectively. Interestingly, if probed further, 46.2% and 72.9% of the surgeons would operate even earlier within four to six hours for complete and incomplete SCI, respectively.

The landmark study that has provided the strongest evidence for early decompression surgery for tSCI is the STASCIS trial.[9] This prospective cohort trial was carried out in six North American centres with 313 patients and compared the outcomes of surgery less than and more than 24 hours after tSCI. The results suggest that it is safe to operate on patients early after injury, and that early decompression improves neurological recovery. If surgery is carried out less than 24 hours from the tSCI, the odds ratio (OR) for at least two-grade improvement in ASIA grades at six-month follow-up is 2.83. This improvement is specific to the more severe grades of tSCI (ASIA A or B) as there is a ceiling effect for ASIA D which dilutes the OR (1.38) for a one-grade improvement in ASIA grades.

Herein lies the problem of understanding the outcomes of previous studies on tSCI which may have resulted in controversy. The aforementioned ceiling effect of less severe injuries, which may represent in some part the central cord syndrome population, reduces the statistical significance of previous studies by being included under the umbrella of tSCI. The benefit is less clear for early (< 24 hours) surgery in central cord syndrome. Yet, the literature still tends to support early decompression in these incomplete injuries. Many animal models use low-velocity injury mechanisms, such as contusion rather than transection, to illustrate the advantages of early decompression on neurological recovery.[69-71] These models are more representative of central cord syndrome than of a tSCI due to fracture or dislocation. A systematic review of central cord injuries without spinal column instability suggests that surgery within 24 hours of injury leads to a 6.31 ASIA total motor score improvement and a 7.79 ASIA total score improvement in the functional independence measure at one-year follow-up.[72] The authors concluded that early decompression is recommended in profound neurological deficits such as ASIA C, and in patients with persistent compression from developmental spinal canal stenosis. Patients presenting with ASIA D can be observed at first and be reassessed for surgery at a later stage if there is a lack of dramatic neurological recovery without early surgery. In the STASCIS trial, there was similarly no significant difference in neurological improvement in the ASIA D group. The previously referenced international survey of surgeons also reported responses to this scenario.[68] For a 65-year-old male with hyperextension traumatic cervical central cord syndrome, there was more controversy and a wide variation in responses. Most surgeons would still offer surgery within 12 to 24 hours, but there were many who instead elected to operate between 24 to 72 hours later, and some five to six weeks later.

Central cord syndrome remains a more debatable topic than severe tSCI with instability. The primary injury to the spinal cord is smaller than with a fracture or dislocation, but there may be a greater role for early decompression to prevent secondary injury from an oedematous compressed spinal cord. However, there are more concerns about early intervention and more proponents of delayed surgery for central cord syndrome. Samuel et al[22] showed in a database of 1,060 patients that delaying surgery decreased the odds of inpatient mortality, with a 19% decrease in the odds of dying with each 24-hour surgical delay. Fundamentally, there is a considerable difference in the profile of patients who sustain a severe tSCI and those with a central cord syndrome. Although the STASCIS trial showed no overall difference in postoperative complications between early and late groups in terms of cardiopulmonary sequelae, infection, neurological deterioration, and pulmonary embolism, it is unclear if their profile is the same as that of patients with central cord syndrome. These patients are often elderly with more significant underlying medical conditions that preclude safe early surgery. In the elderly, emergency surgery in general may result in greater morbidity and mortality (OR 1.39 for death and OR 1.31 for major complications).[73] Elective surgery may reduce the morbidity and mortality rates by a half compared to emergency/urgent operations.[74] This is often why there is increasing motivation to operate on 'silent' cervical spinal canal stenosis pre-emptively before a SCI occurs to avoid the dangers of operating early on an elderly patient with a SCI.[75]

In view of the discussions about the lack of neurological recovery in relatively mild tSCI and concerns about emergency surgery in an elderly patient with multiple comorbidities, it can be concluded that not every patient needs or should have emergency surgery. However, if feasible and safe, early surgery should be considered to maximize desirable outcomes. This is also the recommendation set out by the AOSpine knowledge forum on SCI.[4] Although the strength of recommendation is still weak, it will likely be strengthened by further large-scale studies such as a recent publication based on four prospective data cohorts (n = 1,548), which looked at early and late surgery for acute tSCI and outcomes at one year after injury.[76] Surgical decompression within 24 hours of injury was associated with improved sensorimotor recovery. There was a four-point increase in total motor scores reported, a 4.2-point increase in light touch scores, and a 3.9-point increase in pin-prick scores for early decompression (< 24 hours) when compared to late decompression (> 24 hours). There was also a steep decline in change of motor score at 24 to 36 hours after injury and this change reached a plateau 36 hours after injury. Thus, the first 24 to 36 hours after injury is the crucial time in which to achieve optimal neurological recovery from surgical decompression. A clear dose-response effect was observed within the first 24 hours after SCI and the highest improvements in ASIA score occurred within this window. Not only should surgery be undertaken within 24 hours of injury but it should be done as soon as possible. This study also proposed that the 24-hour time window is not absolute and that the benefits from early surgical decompression may persist up to 36 hours after SCI. This is particularly important for patients with multiple injuries and medical comorbidities in whom early surgery may lead to increased complications. Other traumatic injuries such as brain injuries, pelvic fractures, or visceral haemorrhage will take precedence to save life. Furthermore, medical conditions such as poorly controlled diabetes mellitus, chronic obstructive pulmonary disease, and acute lung infections may need to be optimized before surgery can be safely carried out. Application of clinical judgement to which cases benefit most must therefore be done on an individual basis. However, if medical problems are optimized, surgery should be offered as soon as possible. Consideration for ultra-early surgical decompression has been proposed, such as less than eight hours or 12 hours after SCI.[16–18] However, these studies are limited by their small sample sizes and should be validated with larger prospective cohorts.

As a final note, it is also important to guarantee that the surgery undertaken is executed properly. An MRI study of 184 tSCI patients (119 ASIA A and 65 ASIA B) showed that only 66% of 184 tSCI patients had an adequate decompression on postoperative MRI scans.[77] Rates of decompression were only 46.8% for anterior cervical discectomy and fusion (ACDF), and 46.8% and 58.6% for anterior cervical corpectomy and fusion (ACCF). With a laminectomy, the decompression rate increased to 72% for ACDF and 73% for ACCF. As such, only laminectomy was associated with successful decompression (OR 4.85). Hence, in addition to all the above principles supporting early surgery, the operation should also succeed in achieving spinal cord decompression to optimize patient recovery.

Statistical analysis used to improve the evidence base

As described in previous reports, traumatic spinal cord injury includes a wide variety of pathological conditions: an oversimplified discussion of early surgical decompression may harm clinician decision-making.[78-80] Therefore, identifying subgroups for whom early surgical decompression is effective and the optimal time for surgery are undoubtedly two important issues.[7] In addition to these discussions, the primary outcome used and the timing of the assessment of neurological recovery should be kept in mind when interpreting study results. These factors may contribute to the conflicting conclusions of reports on early surgical decompression for tSCI.

Although the inclusion of patients with injuries of the cervical and thoracolumbar spine is likely to weaken the conclusions, this paper is the first comprehensive report on the results of the SCI-POEM study.[8] We look forward to future subgroup analyses and comparisons with the results of recent tSCI studies at the thoracolumbar spine level.[81,82]

The Optimal Treatment for Spinal Cord Injury associated with Cervical Canal Stenosis (OSCIS) trial is a prospective randomized clinical trial consisting only of patients with an AIS grade C injury and no fracture.[21] By contrast, the SCI-POEM study includes a broad tSCI population. Therefore, although this study may provide a particular perspective, the results may be blurred for controversial conditions (e.g. incomplete SCI without instability and persistent cord compression). To help unravel the controversial conditions behind a treatment strategy for tSCI, a report summarizing the opinions of surgeons using the Delphi method is available.[78] The results show that spinal instability, cord compression on imaging, and neurological status were the most clinically important factors, and that the surgeon's judgement (need for surgery or early surgery within 24 hours) differed greatly depending on these factors. Based on these findings, a simplified classification system was proposed. However, the paper did not specify the criteria for determining the presence or absence of spinal instability and cord compression. Nonetheless, it is hoped that future studies will be conducted to examine the appropriateness of treatment for each condition according to this classification. In contrast to the above experience-based report, an interesting recent study by Badhiwala et al,[83] used a 'bottom-up', data-driven approach to group the trajectory of motor recovery. This study used group-based trajectory modelling to dissociate unique temporal profiles of motor recovery from injury to long-term (> six months) follow-up, and used four datasets, including data from the STASCIS study. There were 801 patients of AIS grades B to D with time course data on upper limb functional recovery from an incomplete cervical SCI who could be classified into four distinct trajectory groups: poor outcome, moderate recovery, good recovery, and excellent outcome. Younger age, less severe AIS grade (i.e. C or D vs B), lower neurological level (i.e. mid, or lower, rather than upper cervical spine), and early decompressive surgery were closely correlated with more favourable recovery profiles. This report is the first to describe a data-driven classification in incomplete SCI, although imaging and laboratory findings were not included.

The STASCIS report published in 2012 by Fehlings et al[9] is a key paper in this area, showing the benefits of early surgery for tSCI within 24 hours in a straightforward manner and with at least a two-level improvement in AIS grade at six months after injury.[9] However, it is reasonable to assume that the effects of early surgery were overestimated due to the imbalance in paralysis between the early and late groups and the ceiling effect in the assessment of neurological recovery.[10,11] However, this fact does not mean that early surgery is invalid, as the authors argued for the power of the STASCIS report.[12] Many reports, including the STASCIS study, have used 24 hours as the time threshold. However, the SCI-POEM study arbitrarily set a threshold of 12 hours, motivated mainly by feasibility considerations and pathophysiological rationale. The most impactful report to date, which analyzes time to surgery as a continuous variable, is a pooled analysis by Badhiwala et al[76] of four prospective cohorts, which indicated that the effects of early surgery had diminished 24 to 36 hours after injury. The SCI-POEM study group plans to analyze the effect of time to surgery as a continuous variable with different thresholds. We would like to see how this relates to the pooled analysis report[76] and the aforementioned data-driven classification.[83]

Central spinal cord syndrome (CCS) is a concept that lacks a strict definition and is part of incomplete SCI. It includes at least three subtypes: cervical incomplete SCI from high-impact mechanisms resulting in spinal fracture and instability; incomplete cervical SCI seen after a low-energy mechanism trauma resulting in hyperextension injury on a background of degenerative cervical spondylosis and canal narrowing without fracture; and cervical incomplete SCI due to acute cervical disc herniation.[78] Bulloch et al[79] advocated reconsidering the diagnosis of CCS using the concept of acute traumatic myelopathy. This is limited to patients with acute SCIs (ASIA grades A to D) who have congenital and/or degenerative stenosis with spinal cord compression and a structurally stable cervical spine. This condition is a cervical SCI due to low-energy trauma, which increases with ageing of the population.[84] This concept is practical because it allows us to target a controversial patient population which is otherwise difficult to identify. Furthermore, it is consistent with the classification proposed by Hachem et al[78] based on the presence or absence of instability, the presence or absence of compression on imaging, and the severity of paralysis.[78]

Randomized controlled trials (RCTs) targeting each of the conditions mentioned above may provide more robust evidence to determine a treatment strategy for tSCI. In reality, as seen in the OSCIS study, it was not easy to achieve a sufficient sample size due to ethical barriers even with multicentre studies.[21] The Conservative or Surgical treatment for Incomplete Cord lesion (COSMIC) trial, which was planned to compare early decompressive surgery (< 24 hours) and conservative treatment, was discontinued due to an insufficient number of patients meeting the inclusion criteria.[85] However, the advanced statistical analysis used in the SCI-POEM study provided robust results to mitigate the infeasibility of RCTs in this domain. It is notable that, even with a threshold of 12 hours, adjustment for clinically important factors can lead to a substantial loss of the advantage of early surgical decompression. The group-based trajectory analysis by Badhiwala et al[83] also used advanced statistical analysis to develop a classification system that may predict the anticipated temporal profile of recovery. We believe that rigorous statistical analysis will continue to be indispensable in the future for building evidence for the management of tSCI, and we look forward to developing new evidence incorporating imaging, and serum and spinal fluid biomarkers.

Conclusion

It is clear from the three presentations in this article that there are strongly held views about the appropriate treatment of acute SCI which are at considerable variance. The evidence base has been deficient on all sides until recently, which compounds the divide between groups of researchers and clinicians, not necessarily to the benefit of patients. That lack is now being addressed by multiple groups, including the authors of the SCI-POEM study report.[8] Resolving the issue of which treatments are most effective for each sub-group of patients with acute SCI will be the most important task for researchers in the years to come.

> *"For it must be acknowledged, that what are professionally called facts, are for the most part only those notions, which a man insensibly adopts in the course of his practice, and which takes colour from his education and previous studies. It is this, which makes the facts of one age differ from the facts of another age; and the opinions of men differently educated to vary on what they are inconsistent enough to call matters of fact."*.
>
> Sir Charles Bell, 1824[29]

Take home message

- There is a lack of high-class evidence for early surgery in the treatment of traumatic spinal cord injury; despite this, expeditious intervention has become the norm.
- This evidence deficit has been addressed in the last decade and some issues have been clarified, although there has never been a properly conducted trial of surgery versus active conservative care.
- As a result, it is still not known whether early surgery or active physiological management of the unstable injured spinal cord offers the better chance for recovery.

Supplementary material

Case reports and videos of two patients who sustained traumatic spinal cord injuries treated with active physiological management showing useful recovery of function without surgery, and irrespective of the biomechanical instability of the original injury.

References:

1. **Santayana G**. *The Life of Reason, Reason in Common Sense*. Vol 284. New York, New York, USA: Charles Scribner's, 1905.
2. **Burrell HL**. I. Fracture of the spine: a summary of all the cases (244) which were treated at the Boston City Hospital from 1864 to 1905. *Ann Surg*. 1905;42(4):481–506.
3. **Dvorak MF**, **Noonan VK**, **Fallah N**, **et al**. The influence of time from injury to surgery on motor recovery and length of hospital stay in acute traumatic spinal cord injury: an observational Canadian cohort study. *J Neurotrauma*. 2015;32(9):645–654.
4. **Fehlings MG**, **Tetreault LA**, **Wilson JR**, **et al**. A clinical practice guideline for the management of patients with acute spinal cord injury and central cord syndrome: recommendations on the timing (≤24 hours versus >24 hours) of decompressive surgery. *Global Spine J*. 2017;7(3 Suppl):195S–202S.
5. **Parthiban J**, **Zileli M**, **Sharif SY**. Outcomes of spinal cord injury: WFNS Spine Committee recommendations. *Neurospine*. 2020;17(4):809–819.
6. **Ramakonar H**, **Fehlings MG**. "Time is Spine": new evidence supports decompression within 24 h for acute spinal cord injury. *Spinal Cord*. 2021;59(8):933–934.

7. **Wilson JR**, **Witiw CD**, **Badhiwala J**, **Kwon BK**, **Fehlings MG**, **Harrop JS**. Early surgery for traumatic spinal cord injury: where are we now? *Global Spine J*. 2020;10(1 Suppl):84S–91S.
8. **Hosman AJF**, **Barbagallo G**, **the SCI-POEM Study Group**, **van Middendorp JJ**. Neurological recovery after early versus delayed surgical decompression for acute, traumatic spinal cord injury: a Prospective, Observational, European Multicentre (SCI-POEM) cohort study. *Bone Joint J*. 2023;105-B(4):400–411.
9. **Fehlings MG**, **Vaccaro A**, **Wilson JR**, **et al**. Early versus delayed decompression for traumatic cervical spinal cord injury: results of the Surgical Timing in Acute Spinal Cord Injury Study (STASCIS). *PLOS One*. 2012;7(2):e32037.
10. **van Middendorp JJ**. Letter to the editor regarding: "Early versus delayed decompression for traumatic cervical spinal cord injury: results of the Surgical Timing in Acute Spinal Cord Injury Study (STASCIS)." *Spine J*. 2012;12(6):540.
11. **O'Toole JE**. Timing of surgery after cervical spinal cord injury. *World Neurosurg*. 2014;82(1–2):e389–90.
12. **Fehlings MG**, **Vaccaro A**, **Wilson JR**, **et al**. Response to the van Middendorp Letter to the Editor of The Spine Journal. *Spine J*. 2012;12:541.
13. **Wilson JR**, **Singh A**, **Craven C**, **et al**. Early versus late surgery for traumatic spinal cord injury: the results of a prospective Canadian cohort study. *Spinal Cord*. 2012;50(11):840–843.
14. **Batchelor PE**, **Wills TE**, **Skeers P**, **et al**. Meta-analysis of pre-clinical studies of early decompression in acute spinal cord injury: A battle of time and pressure. *PLoS ONE*. 2013;8(8):e72659.
15. **van Middendorp JJ**, **Hosman AJF**, **Doi SAR**. The effects of the timing of spinal surgery after traumatic spinal cord injury: A systematic review and meta-analysis. *J Neurotrauma*. 2013;30(21):1781–1794.
16. **Jug M**, **Kejžar N**, **Vesel M**, **et al**. Neurological recovery after traumatic cervical spinal cord injury is superior if surgical decompression and instrumented fusion are performed within 8 hours versus 8 to 24 hours after injury: a single center experience. *J Neurotrauma*. 2015;32(18):1385–1392.
17. **Grassner L**, **Wutte C**, **Klein B**, **et al**. Early decompression (< 8 h) after traumatic cervical spinal cord injury improves functional outcome as assessed by spinal cord independence measure after one year. *J Neurotrauma*. 2016;33(18):1658–1666.
18. **Burke JF**, **Yue JK**, **Ngwenya LB**, **et al**. Ultra-early (<12 hours) surgery correlates with higher rate of American Spinal Injury Association Impairment Scale conversion after cervical spinal cord injury. *Neurosurgery*. 2019;85(2):199–203.
19. **Badhiwala JH**. Early vs late surgical decompression for central cord syndrome: a pooled analysis of individual patient data. *JAMA Surg*. 2022;157(11):1024–1032.
20. **Aarabi B**, **Akhtar-Danesh N**, **Chryssikos T**, **et al**. Efficacy of ultra-early (< 12 h), early (12-24 h), and late (>24-138.5 h) surgery with magnetic resonance imaging-confirmed decompression in American Spinal Injury Association Impairment Scale grades A, B, and C cervical spinal cord injury. *J Neurotrauma*. 2020;37(3):448–457.
21. **Chikuda H**, **Koyama Y**, **Matsubayashi Y**, **et al**. The OSCIS investigators. Effect of early vs delayed surgical treatment on motor recovery in incomplete cervical spinal cord injury with pre-existing cervical stenosis: a randomized clinical trial. *JAMA Netw Open*. 2021;4:11.
22. **Samuel AM**, **Grant RA**, **Bohl DD**, **et al**. Delayed surgery after acute traumatic central cord syndrome is associated with reduced mortality. *Spine (Phila Pa 1976*). 2015;40(5):349–356.
23. **Godzik J**, **Dalton J**, **Hemphill C**, **et al**. Early surgical intervention among patients with acute central cord syndrome is not associated with higher mortality and morbidity. *J Spine Surg*. 2019;5(4):466–474.
24. **Maas AIR**, **Peul W**, **Thomé C**. Surgical decompression in acute spinal cord injury: earlier is better. *Lancet Neurol*. 2021;20(2):84–86.
25. **Battistuzzo CR**, **Armstrong A**, **Clark J**, **et al**. Early decompression following cervical spinal cord injury: examining the process of care from accident scene to surgery. *J Neurotrauma*. 2016;33(12):1161–1169.
26. **Ahuja CS**, **Badhiwala JH**, **Fehlings MG**. "Time is spine": the importance of early intervention for traumatic spinal cord injury. *Spinal Cord*. 2020;58(9):1037–1039.
27. **Silver JR**. *The development of the modern ideas of treatment of spinal injuries* [MD Thesis 2001]. ProQuest LLC, 2015; U642623.
28. **Cooper AP**, **Cline H**. Of wounds of the scalp. *Lancet*. 1824;1:393–398.
29. **Bell C**. *Observations on Injuries of the Spine and of the Thigh Bone in Two Lectures. With nine plates*. London, UK: Thomas Tegg, 1824: 4–73.
30. **Guttmann L**. *Spinal cord injuries: comprehensive management and research*. Oxford, UK: Blackwell, 1976.
31. **Davis AG**. Fractures of the spine. *Am J Surg*. 1932;11(2):325–335.
32. **Bohler L**. *The Treatment of Fractures*. Bristol, UK: Wright & Son, 1935.
33. **Nissen KI**. The treatment of spinal injuries with nervous involvement. *Proceedings of the Royal Society of Medicine*. 1942;35(11):707–710.
34. **Guttmann L**. New hope for spinal cord sufferers. *Med Times*. 1945;73:318–326.
35. **Guttmann L**. Nursing problems in the rehabilitation of spinal injuries. *Nurs Times*. 1946;42:798 passim.
36. **Watson-Jones R**. *Fractures and Joint Injuries*. Fourth edition. Baltimore, Maryland, USA: Williams & Wilkins, 1955.
37. **El Masry WS**. Physiological instability of the injured spinal cord: editorial. *Paraplegia*. 1993;31:273–275.
38. **Morgan TH**, **Wharton GW**, **Austin GN**. The results of laminectomy in patients with incomplete spinal cord injuries. *Paraplegia*. 1971;9(1):14–23.
39. **Bohlman H**. Acute fractures and dislocations of the cervical spine. *J Bone Joint Surg Am*. 1979;61-A(8):1119–1142.
40. **Bohlman HH**, **Freehafer A**, **Dejak J**. The results of treatment of acute injuries of the upper thoracic spine with paralysis. *J Bone Joint Surg Am*. 1985;67-A(3):360–369.
41. **Frankel HL**, **Hancock DO**, **Hyslop G**, **et al**. The value of postural reduction in the initial management of closed injuries of the spine with paraplegia and tetraplegia. I. *Paraplegia*. 1969;7(3):179–192.
42. **Folman Y**, **el Masri W**. Spinal cord injury: prognostic indicators. *Injury*. 1989;20(2):92–93.
43. **Crozier KS**, **Graziani V**, **Ditunno JF**, **Herbison GJ**. Spinal cord injury: prognosis for ambulation based on sensory examination in patients who are initially motor complete. *Arch Phys Med Rehabil*. 1991;72(2):119–121.
44. **Katoh S**, **el Masry WS**. Motor recovery of patients presenting with motor paralysis and sensory sparing following cervical spinal cord injuries. *Paraplegia*. 1995;33(9):506–509.
45. **Poynton AR**, **O'Farrell DA**, **Shannon F**, **Murray P**, **McManus F**, **Walsh MG**. Sparing of sensation to pin prick predicts recovery of a motor segment after injury to the spinal cord. *J Bone Joint Surg Br*. 1997;79-B(6):952–954.
46. **Bedbrook G**. Recovery of spinal cord function. *Paraplegia*. 1980;18(5):315–323.
47. **Bedbrook GM**, **Sakae T**. A review of cervical spine injuries with neurological dysfunction. *Paraplegia*. 1982;20(6):321–333.
48. **Tator CH**, **Duncan EG**, **Edmonds VE**, **Lapczak LI**, **Andrews DF**. Comparison of surgical and conservative management in 208 patients with acute spinal cord injury. *Can J Neurol Sci*. 1987;14(1):60–69.
49. **Fidler MW**. Remodelling of the spinal canal after burst fracture. A prospective study of two cases. *J Bone Joint Surg Br*. 1988;70-B(5):730–732.
50. **Jaffray D**. Recent developments in the management of injuries of the cervical spine. In: Vinken PJ, Bruyn GW, Klawans HL, Frankel HL, eds. *Handbook of Clinical Neurology; Rev Series*. 1992.
51. **Dolan EJ**, **Tator CH**, **Endrenyi L**. The value of decompression for acute experimental spinal cord compression injury. *J Neurosurg*. 1980;53(6):749–755.
52. **Collins WF**. A review and update of experiment and clinical studies of spinal cord injury. *Paraplegia*. 1983;21(4):204–219.
53. **Ducker TB**, **Bellegarrigue R**, **Salcman M**, **Walleck C**. Timing of operative care in cervical spinal cord injury. *Spine (Phila Pa 1976*). 1984;9(5):525–531.
54. **Guha A**, **Tator CH**, **Endrenyi L**, **Piper I**. Decompression of the spinal cord improves recovery after acute experimental spinal cord compression injury. *Paraplegia*. 1987;25(4):324–339.
55. **El Masri(y) WS**, **Meerkotter DV**. Early decompression of the spinal cord following injury: arguments for and against. In: Illis LS, ed. *Spinal Cord Dysfunction Vol II: Intervention and Treatment*. Oxford, UK: Oxford University Press, 1992: 7–27.
56. **Katoh S**, **el Masry WS**. Neurological recovery after conservative treatment of cervical cord injuries. *J Bone Joint Surg Br*. 1994;76-B(2):225–228.
57. **El Masri(y) WS**, **Katoh S**, **Khan A**. Reflections on the neurological significance of bony canal encroachment following traumatic injury of the spine in patients with frankel C D and E presentation. *J Neurotrauma*. 1995;10 suppl:70.
58. **Katoh S**, **el Masry WS**, **Jaffray D**, **et al**. Neurologic outcome in conservatively treated patients with incomplete closed traumatic cervical spinal cord injuries. *Spine (Phila Pa 1976*). 1996;21(20):2345–2351.
59. **Limb D**, **Shaw DL**, **Dickson RA**. Neurological injury in thoracolumbar burst fractures. *J Bone Joint Surg Br*. 1995;77-B(5):774–777.
60. **Rosenberg N**, **Lenger R**, **Weisz I**, **Stein H**. Neurological deficit in a consecutive series of vertebral fracture patients with bony fragments within spinal canal. *Spinal Cord*. 1997;35(2):92–95.
61. **Boerger TO**, **Limb D**, **Dickson RA**. Does "canal clearance" affect neurological outcome after thoracolumbar burst fractures? *J Bone Joint Surg Br*. 2000;82-B(5):629–635.
62. **Mohanty SP**, **Venkatram N**. Does neurological recovery in thoracolumbar and lumbar burst fractures depend on the extent of canal compromise? *Spinal Cord*. 2002;40(6):295–299.

63. **Osman AE**, **El Masry(i)WS**. Clinical perspectives on spinal injuries. In: Cassar-Pullicino V, Imhof H, eds. *Spinal Trauma: An Imaging Approach*. Vol 1. 2006: 1–14.
64. **El Masri(y) W**, **Barnes M**. 24.13.2 Spinal cord injury and its management. In: Firth J, Conlon C, Cox T, eds. *Oxford Textbook of Medicine*. Sixth edition. Oxford, UK: Oxford University Press.
65. **Kwon BK**, **Curt A**, **Belanger LM**, **et al**. Intrathecal pressure monitoring and cerebrospinal fluid drainage in acute spinal cord injury: a prospective randomized trial. *J Neurosurg Spine*. 2009;10(3):181–193.
66. **Kirshblum S**, **Snider B**, **Rupp R**. Read MS for the International Standards Committee of ASIA and ISCOS. Updates of the international standards for neurologic classification of spinal cord injury: 2015 and 2019. *Phys Med Rehabil Clin N Am*. 2020;31(3):319–333.
67. **El Masri WS**. Spontaneous neurological recovery of patients with acute traumatic spinal cord injuries (ATSCI) without intervention the injured cord. *Int J Orthopedics Rehabil*. 2021;8:19–29.
68. **Fehlings MG**, **Rabin D**, **Sears W**, **Cadotte DW**, **Aarabi B**. Current practice in the timing of surgical intervention in spinal cord injury. *Spine (Phila Pa 1976*). 2010;35(21 Suppl):S166–73.
69. **Kwon BK**, **Oxland TR**, **Tetzlaff W**. Animal models used in spinal cord regeneration research. *Spine (Phila Pa 1976*). 2002;27(14):1504–1510.
70. **Sharif-Alhoseini M**, **Khormali M**, **Rezaei M**, **et al**. Animal models of spinal cord injury: a systematic review. *Spinal Cord*. 2017;55(8):714–721.
71. **Zhang N**, **Fang M**, **Chen H**, **Gou F**, **Ding M**. Evaluation of spinal cord injury animal models. *Neural Regen Res*. 2014;9(22):2008–2012.
72. **Lenehan B**, **Fisher CG**, **Vaccaro A**, **Fehlings M**, **Aarabi B**, **Dvorak MF**. The urgency of surgical decompression in acute central cord injuries with spondylosis and without instability. *Spine (Phila Pa 1976*). 2010;35(21 Suppl):S180–6.
73. **Havens JM**, **Peetz AB**, **Do WS**, **et al**. The excess morbidity and mortality of emergency general surgery. *J Trauma Acute Care Surg*. 2015;78(2):306–311.
74. **Mullen MG**, **Michaels AD**, **Mehaffey JH**, **et al**. Risk associated with complications and mortality after urgent surgery vs elective and emergency surgery: implications for defining "quality" and reporting outcomes for urgent surgery. *JAMA Surg*. 2017;152(8):768–774.
75. **Shigematsu H**, **Cheung JPY**, **Mak K-C**, **Bruzzone M**, **Luk KDK**. Cervical spinal canal stenosis first presenting after spinal cord injury due to minor trauma: An insight into the value of preventive decompression. *J Orthop Sci*. 2017;22(1):22–26.
76. **Badhiwala JH**, **Wilson JR**, **Witiw CD**, **et al**. The influence of timing of surgical decompression for acute spinal cord injury: a pooled analysis of individual patient data. *Lancet Neurol*. 2021;20(2):117–126.
77. **Aarabi B**, **Olexa J**, **Chryssikos T**, **et al**. Extent of spinal cord decompression in motor complete (American Spinal Injury Association Impairment Scale Grades A and B) traumatic spinal cord injury patients: post-operative magnetic resonance imaging analysis of standard operative approaches. *J Neurotrauma*. 2019;36(6):862–876.
78. **Hachem LD**, **Zhu M**, **Aarabi B**, **et al**. A practical classification system for acute cervical spinal cord injury based on a three-phased modified Delphi process from the AOSpine Spinal Cord Injury Knowledge Forum. *Global Spine J*. 2022;21925682221114800.
79. **Bulloch LR**, **Spector L**, **Patel A**. Acute traumatic myelopathy: rethinking central cord syndrome. *J Am Acad Orthop Surg*. 2022;30(23):1099–1107.
80. **Pedro KM**, **Fehlings MG**. Time is spine: What's over the horizon. *J Clin Orthop Trauma*. 2022;35:102043.
81. **Balas M**, **Guttman MP**, **Badhiwala JH**, **et al**. Earlier surgery reduces complications in acute traumatic thoracolumbar spinal cord injury: analysis of a multi-center cohort of 4108 patients. *J Neurotrauma*. 2022;39(3–4):277–284.
82. **Haghnegahdar A**, **Behjat R**, **Saadat S**, **et al**. A randomized controlled trial of early versus late surgical decompression for thoracic and thoracolumbar spinal cord injury in 73 patients. *Neurotrauma Rep*. 2020;1(1):78–87.
83. **Badhiwala JH**, **Wilson JR**, **Kulkarni AV**, **et al**. A novel method to classify cervical incomplete spinal cord injury based on potential for recovery: a group-based trajectory analysis. *J Neurotrauma*. 2022;39(23–24):1654–1664.
84. **Engel-Haber E**, **Botticello A**, **Snider B**, **Kirshblum S**. Incomplete spinal cord syndromes: current incidence and quantifiable criteria for classification. *J Neurotrauma*. 2022;39(23–24):1687–1696.
85. **Bartels RHMA**, **Hosman AJF**, **van de Meent H**, **et al**. Design of COSMIC: a randomized, multi-centre controlled trial comparing conservative or early surgical management of incomplete cervical cord syndrome without spinal instability. *BMC Musculoskelet Disord*. 2013;14:52.

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Funding statement:

The authors received no financial or material support for the research, authorship, and/or publication of this article.

This article was primary edited by A. C. Ross.