SERIES IN INTENSIVE CARE MEDICINE: TRAUMATIC ACUTE SPINAL CORD INJURY

Update on traumatic acute spinal cord injury. Part 2

M. Mourelo Fariña a, S. Salvador de la Barrera b, A. Montoto Marqués b,c, M.E. Ferreiro Velasco b, R. Galeiras Vázquez a,a

a Unidad de Cuidados Intensivos, Complexo Hospitalario Universitario de A Coruña, A Coruña, Spain
b Unidad de Lesiones Medulares, Complexo Hospitalario Universitario de A Coruña, A Coruña, Spain
C Departamento de Medicina, Universidad de A Coruña, A Coruña, Spain

Received 30 July 2016; accepted 31 October 2016

Keywords
Spinal cord injuries/surgery; Spinal cord injury/pain; Tracheostomy; Prolonged mechanical ventilation

Abstract The aim of treatment in acute traumatic spinal cord injury is to preserve residual neurologic function, avoid secondary injury, and restore spinal alignment and stability. In this second part of the review, we describe the management of spinal cord injury focusing on issues related to short-term respiratory management, where the preservation of diaphragmatic function is a priority, with prediction of the duration of mechanical ventilation and the need for tracheostomy. Surgical assessment of spinal injuries based on updated criteria is discussed, taking into account that although the type of intervention depends on the surgical team, nowadays treatment should afford early spinal decompression and stabilization. Within a comprehensive strategy in spinal cord injury, it is essential to identify and properly treat patient anxiety and pain associated to spinal cord injury, as well as to prevent and ensure the early diagnosis of complications secondary to spinal cord injury (thromboembolic disease, gastrointestinal and urinary disorders, pressure ulcers).

© 2016 Elsevier España, S.L.U. and SEMICYUC. All rights reserved.

PALABRAS CLAVE
Lesión medular/cirugía; Lesión medular/dolor; Traqueostomía; Ventilación mecánica prolongada

Actualización en lesión medular aguda postraumática. Parte 2

Resumen El objetivo en el tratamiento de la lesión medular aguda traumática es preservar la función neurológica residual, evitar el daño secundario, y restaurar la alineación y la estabilidad de la columna. En esta segunda parte proporcionaremos un enfoque en el tratamiento de la lesión medular en cuestiones relativas al manejo respiratorio a corto plazo, donde es prioritaria la preservación de la función diafragmática, así como la posibilidad de predecir la duración de la ventilación mecánica y la necesidad de traqueostomía. Abordaremos la valoración quirúrgica de las lesiones de columna en función de unos criterios de tratamiento actualizados, teniendo


* Corresponding author.
E-mail address: ritagaleiras@hotmail.es (R. Galeiras Vázquez).

2173-5727/© 2016 Elsevier España, S.L.U. and SEMICYUC. All rights reserved.
Respiratory support. Prolonged mechanical ventilation

The need for respiratory support in the acute phase of a spinal cord injury has a variable incidence. The two most important markers used to predict the need for intubation are the level at which the injury occurs and the score shown on the ASIA impairment motor score.

Spinal cord injuries (SCI) at cervical or thoracic levels affect the spinal nerves innervating the respiratory muscles. The diaphragm, the main muscle involved in breathing, is innervated from the third, fourth, and fifth cervical spinal segments. Injuries above C5 level cause paralysis of the diaphragm, the intercostal and abdominal muscles and without the appropriate respiratory support they are incompatible with life and they require intubation in almost 100 per cent of the cases. In incomplete upper cervical injuries (C2–C4) or lower injuries (C5–T5) spontaneous ventilation may be feasible. However, the respiratory function is substantially compromised and ventilation failure can be due to fatigue.1

Respiratory dysfunction in patients with acute SCIs is associated with three factors: muscle strength, secretion retention, and anatomic dysfunction. The first 24h after the occurrence of the SCI predispose to the development of complications (atelectasis, pneumonia, thromboembolism, and pulmonary oedema) that are the main cause of morbimortality. In respiratory failure, the associated traumatic injuries and the patient’s basal situation (age, comorbidity, and genetic predisposition)2,3 can also play a significant role.

The need for respiratory support occurs more commonly four days after the lesion of muscle fatigue so if conservative management is required, a close monitoring of respiratory function will be required too. What we will have to do is monitor the levels of $\text{pCO}_2$ (capnography/arterial blood gas) and perform one spirometry, while measuring the vital capacity (excellent correlation with pulmonary function test) and the maximum respiratory pressure (estimating the strength of respiratory musculature). These are the indicators of respiratory failure: vital capacity $< 15$ ml/kg, maximum respiratory pressure $< -20$ cmH$_2$O, and increased levels of carbonic dioxide.1,4 Recent studies show that, on the MRI, the mere presence of injury or swelling at C3 level predicts the occurrence of respiratory failure.5

Patients with injuries above T5 level, serious associated injuries or patients requiring respiratory monitorization should be admitted in intensive care units in order to minimize damage secondary to hypoxia. We should remember that if the patient needs respiratory support, then the intubation will have to be planned, since urgent intubations in situations of respiratory failure increase the risk of neurological damage.3

When it comes to applying ventilation to these patients, the special characteristics of SCI should be observed. Even though it has been reported that patients have "healthy" lungs, up to 60 per cent show associated thoracic traumasms. In these cases, we will need to implement a strategy of protective ventilation.

Preserving the diaphragmatic function needs to be a primary goal since it is a key goal in respiratory function. The ventilator-induced diaphragmatic dysfunction occurs early with the diaphragmatic inactivity in any of the modalities of controlled ventilation. In order to avoid it, the goal with these patients should be keeping the total support provided by the ventilator in order to avoid fatigue, thus allowing the patient’s initiation of most of the cycles (certain level of diaphragmatic contraction) and the adjustment of breathing time (while avoiding autotrigger, and auto-PEEP).6

The practices of setting breathing patterns like the tidal volume and the PEEP have evolved during the last years. The practice of ventilating with high tidal volumes has been abandoned after different studies showed that ventilating with volumes of 10–15 ml/kg, and volumes of 10 ml/kg makes no difference at all. It has been confirmed that keeping plateau-pressures $< 30$ cmH$_2$O affects the prognosis.7 When it comes to PEEP, the theory was using 0 cmH$_2$O to avoid air entrapment in patients with impaired breathing out muscles. If we have in mind that breathing out is a passive phenomenon the aforementioned argument simply does not stand. Also, the use of PEEP increases residual functional capacity and avoids the cyclic alveolar collapse, while avoiding the pulmonary lesion associated with mechanical ventilation (MV). This is why PEEP zero is not recommended, at least in the acute phase, instead PEEP levels capable of minimizing the atelectrma with the adequate plateau-pressure (PEEP $\geq 5$ cmH$_2$O and plateau-pressures $< 30$ cmH$_2$O)8 are recommended.

Prolonged mechanical ventilation

When it comes to defining the concept of prolonged MV there is a great variability in the actual medical literature. In general, when the patient is ventilated for over 21 days during, at least, 6 h/day we usually talk about prolonged MV. The possibility of predicting the duration of MV facilitates
implementing weaning strategies where tracheostomy plays a significant role.

It is well known that the location and degree of the injury affects both the initiation of VM and how successful the weaning process will be. Among the highest risk factors we have injuries above C5 and ASIA A. Recently it has been confirmed that both a motor index < 10, and the presence of respiratory complications are important predictors. Also the duration of MV is a factor: age (≥45 years old), concomitant pulmonary conditions, history of smoking, low level of consciousness (GCS < 9), comorbidity and Injury Severity Score ≥ 16. In patients with acute MV hospitalized in the ICU, acute renal failure is associated with longer durations of MV.12

In the MV weaning process we will need to take into account the breathing physiopathology of MV, at what level the injury occurs, and the degree of respiratory function when initiating MV. The respiratory function is usually assessed through arterial blood gas/capnography and spirometry. One of the most important indicators is effective cough (flow > 2.71 s, or maximum breathing pressure −20 cmH2O). Also, we will need to assess the diaphragmatic function using, if possible, ultrasound. Before initiating the weaning process, the patient’s vital signs need to be stabilized.13

At present, the weaning process focuses on the progressive withdrawal of the ventilator using a T-tube or pressure support techniques. When compared between the two, it is evident that the T-tube reduces the time of MV since it achieves a progressive increase of muscle strength. Regardless of the modality of weaning process that we use, the withdrawal of MV in tetraplegic patients is a slow process. The weaning process is considered successful when the patient is fine after spending 48 h without any assisted ventilation. In these patients, the most beneficial technique is BPAP because it avoids the cyclic alveolar collapse following minimum PEEP. We need studies endorsing its use in patients with spinal cord injuries, though at present it can be a possibility to take into consideration in carefully selected patients.14

The role of tracheostomy

Tracheostomy is a common proceeding in patients with traumatic, acute spinal cord injuries. It is part of an effective therapy of patients in whom the implementation of prolonged MV is expected since it facilitates the weaning process. The main risk factors for needing one tracheostomy are: the cervical spinal level at admission and motor index < 10.15 The contributing factors are an impaired level of consciousness at admission (GCS < 9), Injury Severity Score ≥ 16, and associated thoracic injuries.16

In these patients, the tracheostomy should be performed during the first seven days because this would be extremely beneficial when it comes to managing breathing and reducing complications.17 If a patient requires anterior spinal cervical fixation, the best moment to perform the tracheostomy will have to be determined.18

Until recently, surgical tracheostomy was an elective proceeding in these patients while the cutaneous tracheostomy was counterindicated. At present, it has already been confirmed that the percutaneous tracheostomy is a safe technique to be performed in the ICUs in patients with spinal cord injuries without neck extension. There are different techniques of percutaneous tracheostomies (Ciaglia, Griggs, Fantoni, Frova, balloon-tracheostomy), and even though studies comparing these different techniques when it comes to safety and effectiveness in patients with SCI are needed to establish what the ideal method would be, the most widely accepted technique today is the single dilator one (Ciaglia Blue Rhino). The percutaneous dilation technique is faster, it minimizes the occurrence of injuries in the adjacent structures of the neck and associates fewer late stromal infections. This is an important advantage in patients in whom spine fixation through anterior approach is required.19,20

Surgical assessment

Traumatic lesions of the spine with neurological compromise usually translate into vertebral fractures or luxations that, while taking into account damage to the neural structures, should be considered and treated as unstable in order to avoid more serious neurological damage. The adequate immobilization techniques should be observed in order to guarantee osseous alignment and absolute bed rest until implementing the eventual treatment that will include the corresponding criteria depending on the affected region of the spine.

Management criteria have not always been uniform given the lack of universally accepted classifications. Several factors influence these criteria, like the level of fracture, its morphology, the alignment of the affected segments, the neurological affectation, and the expected stability.21 Approaching the occipitoatlaxoid region is a different story given its complexity, the different possible options available, and the experience of the surgical team. Martin-Ferrer22 published a very useful review with the results he obtained.

Approaching the occipitoatlaxoid region should be a job for an experienced team given its surgical technical complexity, and the existing different management criteria for every type of injury based on whether it affects the atlas, the axis, and interrelations, together with the occipital joint. Its description exceeds the goal of this chapter, and is the reason why the existing reviews of this condition should be taken into consideration.22,23

At the subaxial spine level, several classifications based on the biomechanics of the injuries have been developed and then submitted for ongoing review. From the mechanistic classifications, published before the boom of the digital modalities of actual images, by Holdsworth, Alien et al.,24 Harris, and White and Punjabi, the Subaxial Injury Classification25 and Cervical Spine Injury Severity Score26 systems provide a reliable guideline for the assessment of fracture instability and, consequently, give the corresponding treatment. The Subaxial Injury Classification holds an important correlation with the clinical manifestations; it identifies three major characteristics that should be taken into consideration: the morphology of the injury, the state of the disc–ligamentous complex, and the presence, or not, of neurological clinical manifestations. Based on
Table 1  Subaxial injury classification.

<table>
<thead>
<tr>
<th>Subaxial Injury classification</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Morphology</strong></td>
<td></td>
</tr>
<tr>
<td>No abnormality</td>
<td>0</td>
</tr>
<tr>
<td>Compression</td>
<td>1</td>
</tr>
<tr>
<td>Burst</td>
<td>+1 = 2</td>
</tr>
<tr>
<td>Distraction (hyperextension, facet perch)</td>
<td>3</td>
</tr>
<tr>
<td>Rotation/translation (facet dislocation, tear-drop or flexion-compression injury)</td>
<td>4</td>
</tr>
<tr>
<td><strong>Disc-ligamentous complex</strong></td>
<td></td>
</tr>
<tr>
<td>Intact</td>
<td>0</td>
</tr>
<tr>
<td>Indeterminate (isolated interspinous widening, MR signal change only)</td>
<td>1</td>
</tr>
<tr>
<td>Disruption (widening of disc space, facet perch or dislocation)</td>
<td>2</td>
</tr>
<tr>
<td><strong>Neurological state</strong></td>
<td></td>
</tr>
<tr>
<td>Intact</td>
<td>0</td>
</tr>
<tr>
<td>Radicular injury</td>
<td>1</td>
</tr>
<tr>
<td>Complete spinal cord injury</td>
<td>2</td>
</tr>
<tr>
<td>Incomplete spinal cord injury</td>
<td>3</td>
</tr>
<tr>
<td>Image of spinal cord compression</td>
<td>+1 = 1</td>
</tr>
<tr>
<td>with neurological deficit</td>
<td></td>
</tr>
</tbody>
</table>

Tomada de Vaccaro et al.  

Conducted by a German multicentre group describes the results and complications of the different techniques available, with correlation results of major deformities using the anterior approach, but without any differences in neurological progression, and a 15% of overall perioperative complications. However, the compression of the canal per se is not a criterion for surgical management, as it has already been discussed in several reviews.

In sum, in the surgical assessment of spinal injuries there are several factors that come together and should be handled with updated criteria; also, the type of intervention to be implemented will depend on the experience of the surgical team. In general, the correct surgical management includes a combination of spinal decompression, correction of the deformity, and reduction and fusion of the fracture in order to be able to provide vertebral stability in the long run.

**When should the surgical management be approached?**

The actual surgical management of traumatic SCIs includes decompression and stabilization. However, there is no consensus on when is the best time to approach surgical management. While some advocate for early surgical decompressions in order to minimize the compression time of the spinal cord, what is the best time to perform decompression, at least in a prospective and randomized way, has not been established yet.

Evidence from experimental studies indicates that prolonged spinal cord compressions after suffering from one traumatic SCI exacerbate the secondary injury and are inversely proportional to neurological recovery. This would endorse the theory that decompressive surgery after one traumatic SCI attenuates the mechanisms of secondary injuries and improves neurological outcomes.

The arguments in favour of early decompressions include less secondary injuries, shorter hospital stays and shorter ICU stays, and fewer medical complications, and comorbidities. The arguments against early decompressions include the risk of neurological impairment, and complications associated with emergent surgical interventions.

In a recent systematic review, El Tecake et al. analyzed the medical literature in an effort to determine the optimal moment to approach surgical management. Both in experimental and clinical trials, researchers found a large variability in the definition of early decompression when compared to late decompression (1 min and 8 h in experimental trials, and less than 24 and 72 h in clinical trials). Data from experimental trials favour early decompressions, yet from a clinical standpoint there is little evidence showing feasibility and safety in early decompressions. Also, there is no conclusive evidence of better results in any of the two groups. The results from the clinical trials were variable. Thus, some trials confirmed recoveries in patients who underwent early decompressions (these trials defined early decompression as those decompressions performed in <24 h), while others confirmed that early surgeries increase mortality and neurological impairment. All clinical trials were retrospective, except for the Surgical Timing in Acute Spinal Cord Injury Study in 2012, and Jug et al.’s study
in 2015. In this last study, the neurological results of 22 patients with traumatic cervical SCIs who underwent early decompressions and instrumented spinal fusions before 8 h were better than the neurological results of 20 patients who underwent surgery after 8 and before 24 h.38 The Surgical Timing in Acute Spinal Cord Injury Study is a new prospective, multicentre, cohort clinical trial conducted in 6 centres of the United States in patients with cervical SCIs with ages between 16 and 80 years old, GCS > 13, initial ASIA classification A–D, cervical spine compression confirmed through MRI or myelo-CT scan, neurological level of the injury between the C2 and T1, and being capable of giving their informed consent. Patients with cognitive impairment, penetrating cervical injuries, prior neurological conditions, vital injuries preventing early decompressions, who arrived at the hospital >24 h and those who underwent surgery >7 days after the SCI were precluded from the study. Out of 470 patients, 313 met the study criteria; among them, 182 were operated in less than 24 h and constituted the early surgery cohort, while 131 were operated after 24 h and constituted the late surgery cohort. Both groups were followed prospectively six months after the injury. The outcomes measurements were changes in the ASIA classification, in the rate of complications and in mortality. The conclusion was that early decompressions (<24 h) in cervical, traumatic SCIs can be performed safely and are associated with better neurological results (19.8 per cent of patients who underwent early surgeries showed a 2 point score improvement in the ASIA classification versus 8.8 per cent of those who underwent late surgeries).37

In sum, even though there is not enough evidence to endorse that early decompression interventions lead to better neurological results after the occurrence of traumatic SCIs, it seems proven that they are feasible and clinically safe. Considering that in traumatic SCIs, the priority is to maximize both the possibilities and degree of recovery,39 in today’s practice we should recommend the early surgical management (decompression and instrumented fusion) based on the feasibility and availability of the expert surgical teams of each hospital.

### Pain and anxiety

The patient with acute SCI has pain killing and sedation needs during the time he/she is being managed in the ICU or the trauma centre that are common to other polytraumatized patients, but with special considerations in the progression and management of his/her condition.

The pain of patients with acute SCIs has several origins and characteristics, and based on these, different progression and prognosis. According to the series, its incidence is highly variable ranging between 26 and 96 per cent.40

In its most recent review, the International Association for the Study of Pain proposes three main types of pain associated with SCIs: nociceptive pain, neuropathic pain, and a third group that includes other remaining types of pain41,42 (Table 2). Nociceptive pain is usually described as a dull, constant, continuous pain that grows worse with movement, improves with rest, and is localized in areas of preserved sensitivity. Neuropathic pain depends on whether it is located “above” (at present, this is not considered a typical type of pain associated with SCI), “at” or “below” the level of the neurological injury. It is often described as a burning sensation, pressure, itch or electric current, and can be associated with allodynia or hyperalgesia and located in areas of impaired sensitivity.43

Acute pain coming from injured osteoarticular structures may be considered nociceptive pain according to the classification designed by the International Association for the Study of Pain, and shows characteristics that are common to other traumatized patients; as such it becomes more intense with move and varies on the vectors of strengths applied on the fracture focus.

The injured neural structures are source of the so-called neuropathic pain. In its physiology, anatomical changes are implied in nerve structures, inflammatory processes, neuronal hyperexcitability—activates the transfer in pain pathways, and sympathetic activation.44 This type of pain can be classified under two categories: at the same injury level, or below the injury. In the former one, the changes located in the neurons of the posterior horn of the spinal cord generate impulses that are transmitted towards the pain pathways. Similarly, the injury or root compression may also generate lancinating pain of radicular or metameric distribution. It is in the acute phase when this pain becomes more common—at injury level, it maintains over time and becomes chronic, being characteristic its appearance during the first few weeks.45,46 This is why its diagnosis is important both for the early stabilization of the fracture and assessment of the need for radicular decompression.

Finally, the infrasional neuropathic pain is of late appearance though it may appear at any time during the first year of SCI.48

Thus, in the strategy of managing pain in the acute phase of one SCI, we should assess the type of pain the patient has during its progression from the very moment of hospital admission.

Nociceptive pain should be responsive to the usual protocols: paracetamol, opioids and anti-inflammatory drugs.46

| Table 2 Classification of pain associated with spinal cord injuries (International Spinal Cord Injury Pain). |
|---|---|---|
| **Step 1** | **Step 2** | **Step 3** |
| **Nociceptive pain** | **Musculoskeletal** | **Examples:** |
| | **Visceral** | **Associated to spasms** |
| | **Other** | **Constipation** |
| **Neuropathic pain** | **Pain associated with SCI** | **Decubitus ulcer** |
| | **At SCI level** | **Syringomyelia** |
| | **Below the SCI** | **Cauda equine syndrome** |
| | **Other neuropathic pain** | **Post-thoracotomy pain** |
| **Other type of pain** | **Carpal tunnel syndrome** |
| **Unknown causes** | | |

Adapted and translated from Finnerup,41 2013.
Even though there are few references on its initiation in the acute phase, in the pharmacological armamentarium for the management of neuropathic pain we find anticonvulsants, tricyclic antidepressants, sodium channel blockers, and opioids, among others.46,47

According to the recommendations by the International Association for the Study of Pain and associated reviews, pregabalin stands as the first-line therapy, being the only known drug for the management of neuropathic pain of SCIs,48 associated to tramadol,49 tricyclic antidepressants, and serotonin reuptake inhibitors, duloxetine as a long term strategy, and opioids50 as major analgesia in the acute phase, with a recommendation of trying to limit the time of administration.

Thus, in our routine clinical practice there is usually a correlation among paracetamol, opioids-morphine-and gabapentin,52 while nowadays pregabalin is preferred, that requires high doses (>300 mg/day) after several weeks of therapy.

Anxiety in the polytraumatized patient is a known factor that may require sedation in order to guarantee the patient’s wellbeing and security while enabling routine neurological evaluations. The situation of patients with AML translates into a crisis where pain, sensory privation, confusion, anxiety and rejection overlap,53 making psychological support, communication with the patient, and management of acute symptoms necessary. For early sedation, the administration of opioids is recommended, together with benzodiazepines-midazolam, lorazepam, and the induction of anaesthesia with propofol54 in order to guarantee powerful anaesthesia. In patients who do not need intubation it is advisable to reduce the level of anxiety by implementing a strategy of cooperative sedation with propofol, midazolam, and fentanyl. However, in patients who need prolonged MV, deep sedation will be necessary during the first few days, with the use of medications with short half lives in case they need routine neurological evaluations. Dexmedetomidine should not be used in cervical and thoracic SCIs due to its sympathetic-lytic effects.

The prevalence of pain, anxiety, and depression in the acute phase of SCIs is high. Pain can amount to 77 per cent, and there can be confluence with depression in 22–35 per cent of the case.54 The high prevalence of pain interferes with the initial treatment of rehabilitation, and up to 47 per cent of patients report pain in various locations,55 that in 30–42 per cent of patients is categorized as moderate-severe pain. However, the intensity of pain is not a determining factor per se in the concurrence of depression in the progression of spinal cord injuries (SCI).

The evaluation and management of chronic pain in SCI patients is one of the key aspects in the comprehensive approach of these patients, since it is going to have a significant impact on the patient’s future quality of life.55

**Secondary prevention**

After SCIs, respiratory and cardiac functions need special attention. However, all systems of the human organism are affected, and this is why both the prevention and early diagnosis of any associated complications are part of the comprehensive management of these patients.

**Venous thromboembolic disease**

Patients with acute SCIs have a higher risk of suffering from venous thromboembolic disease than other patients with severe trauma.56 This is due to the simultaneous presence of venous stasis, transient states of hypercoagulability, and intimal lesions. Using screening tests, the silent deep venous thrombosis could be detected in up to 62 per cent of all patients.57 The generalized use of thromboprophylaxis is believed to be behind the reduction of deaths due to pulmonary thromboembolisms (8.5 per cent from 1983 to 1985, and 3.3 per cent in 2014).58

The venous thromboembolic disease is more common in patients with paraplegia, complete lesions ASIA A, concomitant fractures of lower limbs, acute phases of the injury (more common during the first 3 months), without prophylaxis or delayed onset, prior thromboembolism, and thrombophilia.56,58

The Doppler ultrasound scan, the impedance plethysmography, and phlebography are the recommended diagnostic methods.59,60 Clinical diagnosis is not very reliable; 65 per cent of deep venous thrombosis may not show any evident clinical signs.61 Similarly, determining the D-dimer amount in the acute phase of SCIs is not useful and is not recommended; it may be useful for screening during the rehabilitation phase since its negative predictive value is high.62 The phlebography has been considered the best diagnostic test, but it is an invasive method not without complications. The Doppler ultrasound scan can be performed at the patient’s bedside, is less invasive, and more cost-effective than the phlebography, and this is why it is the recommended method to diagnose deep venous thrombosis in patients with SCIs. When the Doppler ultrasound scan is negative and clinical suspicion is high, the phlebography should be performed, prophylaxis is mandatory and, if it is not counterindicated, should be initiated during the first 72 h after the occurrence of the SCI.58,60,63

The use of low molecular weight heparins is recommended during the 8th–12th weeks.58-60,63 Also, moving the lower limbs, using mechanical methods like sequential compression devices or elastic stockings, and low molecular weight heparins58,61,63,64 may help. However, placing filters in the inferior vena cava (IVC) is not recommended as a routine prophylactic regimen.58,59

**Gastrointestinal alterations**

Gastrointestinal tract dysfunctions are a common consequence of SCIs. Both the gastroparesis and paralytic ileus occurring during the first 24–48 h are due to a lack of sympathetic and parasympathetic activity during the spinal shock phase, and usually resolve within 2–3 days. Gastrointestinal tract dysfunctions make their debut with abdominal distension that may worsen the respiratory function in patients with high cervical or thoracic SCIs. Management is based on keeping the patient in absolute diet, and placing one open nasogastric catheter until the return of bowel function.55

The use of metoclopramide, neostigmine, or erythromycin can be effective too.

Dysphagia with its corresponding risk of aspiration is present in up to 16–41 per cent of patients with
quadriplegia.\textsuperscript{65} Also, other risks factors are the presence of tracheostomy, cervical orthosis, anterior cervical surgery, and concomitant TBI (traumatic brain injury), among others. An assessment of the swallowing function should be performed before starting any oral feeding.

The acute abdomen process, though rare, is hard to detect in patients with SCIs. Signs like pain, stiffness, or abdominal defense are usually absent, mainly in high SCIs. Haemorrhages and intestinal perforation, cholecystitis, and pancreatitis are common causes.\textsuperscript{66-68} SCIs, especially the cervical SCI, associate a high risk of stress ulcer occurrence.\textsuperscript{69} An early management with nutritional support and prophylaxis with $\text{H}_2$ blockers or proton pump inhibitors (PPI) for four weeks\textsuperscript{63,65} is recommended. Its prolonged use may increase the risk of intestinal infection due to \textit{Clostridium difficile}. Cholelithiasis is more common in patients with SCIs than in the general population\textsuperscript{70}; it is suggested that sympathetic innervation leads to impaired vesicle motility, that in turn leads to bile stasis and to the formation of stones. Pancreatitis may be misdiagnosed in patients with acute SCIs. In a study conducted by Pirolla et al., of 78 patients with acute SCIs, pancreatitis was diagnosed in 11.5 per cent of the patients, and an increased level of pancreatic enzymes in 37.1 per cent of the patients that, in more than two thirds, was accompanied by an adynamic ileus.\textsuperscript{67} Cholecystitis and pancreatitis should be included as part of the differential diagnosis of acute abdomen in patients with spinal cord injuries.

The upper mesenteric artery syndrome is less common, but a characteristic trait of SCIs. It is manifested by recurrent abdominal distension, pain, and vomits after eating.\textsuperscript{71}

As soon as the patient starts being fed through enteral feeding, one programme should be established in order to achieve periodic bowel movements. This is usually accomplished through a combination of oral and rectal laxatives.

The urinary system

During the period that comes right after the occurrence of one SCI, the reflex activity of the urinary tract is lost. There is urinary retention even in incomplete patients. Oliguria, possibly as a result of the formation of the third space, is common in the early phase. The placing of one transurethral catheter from the beginning avoids the overdistension of the vesicle and the monitoring of diuresis. If the transurethral catheter is counterindicated (urethral trauma) one suprapubic catheter should be placed.

There can be an immediate or early presence of priapism right after the occurrence of the SCI, which is indicative of complete SCI. It is characterized by being of high flow (non-ischaemic) and resolves within a few hours without any specific treatments; it rarely requires urological consultation.\textsuperscript{72}

Based on our own experience, the rhabdomyolysis (CPK > 500 IU/L) that occurs in 51.5 per cent of the patients with acute SCI requires ICU admission during the first 48h after the occurrence of the injury. Even though prognosis looks good and does not have a direct influence on mortality or the average hospital stay, it is a variable that should be taken into consideration when trying to establish the most adequate therapy.\textsuperscript{73}

The vesicle re-education programme should also be initiated during the acute phase, though it is not as urgent as the bowel programme. Vesicle emptying using intermittent catheterization (initially every 4–6h) is associated with fewer complications than the permanent catheter. It requires the adjustment of fluids in order to be able to maintain diuresis < 100 ml/h, so that the volume of catheters is kept around 400 ml and vesicle distension is avoided.\textsuperscript{74} The patient needs to be hemodynamically stable, have an adequate fluidization of respiratory secretions and, in general, not require any IV fluids.

Nutrition

After the occurrence of one SCI there is a quick loss of nitrogen with negative nitrogen balance associated with flaccid paralysis and muscle atrophy due to denervation below the injury.\textsuperscript{75} The more serious the SCI is (quadriplegic, upper body paraplegia, and ASIA A injuries), the more severe the loss is, that will go on for another 2–4 weeks yet despite nutritional support. Energetic expenditure (EE) at rest is lower than the estimates and trying to correct the loss of nitrogen by increasing the caloric intake can lead to overfeeding. The indirect calorimetry is the most reliable method to measure the EE and assess the caloric needs of patients with SCI.\textsuperscript{63,76} Serum levels that are low in proteins, and malnutrition are associated with higher mortality rates.\textsuperscript{77}

The recommendation is to start feeding during the first 72h, yet a pilot study (Dvorak et al., 2004) did not find any differences in the nutritional state, in the incidence of infection, in the time of MV, or in the average stay of patients with early initiation of feeding (<72h) compared to patients with late initiation of feeding (>120h).\textsuperscript{78}

There are no studies conducted in humans on how the numbers of glucose influence the prognosis of patients with acute SCIs. Its influence on other neurocritical populations is part of an ongoing debate. In one systematic review, Kramer et al. conclude that the strict control of glycemia does not seem to influence mortality in neurocritical patients; even levels in very low ranges were associated with worse neurological prognosis, and this is the reason why intermediate levels are the most suitable of all.\textsuperscript{79}

Pressure ulcers

Pressure ulcers may be prevented and prevention strategies should start at hospital admission and extend during the hospital stay. They occur in areas of bony prominences as a result of the pressure exerted by support structures. The factors contributing to its occurrence during the first few days are loss of sensitivity, immobility, TBI, spinal immobilization devices such as Crutchfield skull traction tongs, and boards; also casts, and splints in cases of injuries accompanied by limbs affectation. Any areas of bony prominences are at risk, especially the occiput, shoulder blades, sacrum and coccyx, ankles and heels; also chin, ears, and clavicles in patients who wear neck braces.

The patient should not wear any spinal immobilization devices upon arrival at the hospital emergency room. On some occasions, the board will be maintained during long periods of time, until the completion of radiological scans,
with the corresponding risk of developing subdermal injuries that could become evident from the very first hour of maintained pressure.\textsuperscript{30}

The presence of spinal cord injuries leads to bed immobilization and bed rest, and use of Crutchfield skull traction tongs or neck braces until definitive surgical management. Piling pillows to liberate areas at risk (heels, sacrum, shoulder blades) and changing the patient’s position every 2–3 h are essential preventive measures. Also, if special beds are available to allow changes of position without moving the patient they will surely facilitate the task and barely move the patient’s spine. With each repositioning, the patient’s skin should be examined for the early detection of injury progression. Similarly, the daily inspection and cleaning of the areas of pin insertion (cranial traction, halo) and skin underneath the neck braces should be observed. Also the periodic assessment of nutritional state\textsuperscript{65} is recommended.

Conflicts of interests

We the authors declare that while conducting this paper there were no conflicts of interests linked whatsoever.

References


