**Review Article**

# Prehospital management of spinal cord injuries

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## ABSTRACT

Prehospital management of spinal cord injury is of critical importance since 25% of spinal cord injury damage may occur or be aggravated after the initial event. Prehospital management includes examination of the patient, spinal immobilisation, careful airway management (intubation, if indicated, using manual in-line stabilisation), and cardiovascular support. Studies have not demonstrated convincingly that methylprednisolone or other pharmacological agents really have clinically significant and important benefits for patients suffering from spinal cord injury. Published statements also do not support the therapeutic use of methylprednisolone in patients suffering from spinal cord injury in the prehospital setting any more, although it is the only treatment that has demostrated to improve the motor function if it is used wthin the first 8 hours after the injury. Moreover, at this stage, it is not known whether pharmacological intervention has beneficial effects or not. Therefore, networks for clinical studies in spinal cord injury patients should be established, as a basic requirement for further improvement in outcome in such patients.

**Key Words:** *Spinal cord injury. Emergency treatment. Fluid therapy. Drug therapy.*

## RESUMEN

### Manejo prehospitalario de la lesión medular

El manejo prehospitalario de la lesión medular (LM) tiene una importancia crítica ya que el 25% del daño puede producirse o agravarse después de la lesión inicial. Su manejo incluye exploración, inmovilización espinal, manejo cuidadoso de la vía aérea (intubación, si indicado, usando estabilización manual de columna cervical), y soporte cardiovascular. Los estudios no han demostrado convincentemente que la metilprednisolona u otros fármacos realmente aporten ventajas clínicamente significativas e importantes para los pacientes que sufren LM. Los estudios publicados tampoco apoyan el empleo terapéutico de metilprednisolona en pacientes que sufren una LM en la fase prehospitalaria, aunque es el único tratamiento que ha demostrado mejorar la función motora si se emplea dentro de las primeras 8 horas tras la lesión. Además, en esta etapa, no se sabe si alguna intervención farmacológica tiene efectos beneficiosos o no. Por lo tanto, deben realizarse ensayos clínicos en pacientes con LM, para intentar mejorar el resultado en dichos pacientes.

**Palabras clave:** *Lesión medular. Tratamiento de emergencia. Fluidoterapia. Tratamiento con fármacos.*

## INTRODUCTION

This article provides a practical perspective of prehospital management of spinal cord injury (SCI). We shall deal with the epidemiology, examination, patient immobilisation, airway management, cardiovascular support and pharmacological treatment.

The real incidence of SCI varies according to the region and methodology applied. It can generally be set at 9-53 SCI per million inhabitants and year. Approximately 20% die before arrival to hospital[1]. In Spain the incidence is estimated to be 12-20 per million inhabitants and year. The incidence of traumatic pathology in Spain is closer to 12 cases per million inhabitants and year. The estimated prevalence of patients presenting with SCI in our country is 350 persons per million inhabitants, with a rising and progressive evolution over time due to the increased life expectancy as a result of specialized treatment[2].

It predominantly affects males, at a rate of 4:1 to females. These are young patients, with a mean age of 35 years. The main cause for SCI is trauma (81.5%), of which the most frequent is traffic accident in 52.4% – followed by fortuitous accidents (22.8%), accidents at work (13.6%), sports accidents (5.3%), suicide attempts (2.3%) and others (3.6%). The degree of the injury

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varies according to the author, with paraplegia at 60% (45-75%) and quadriplegia at 40% (35-53).

Once the process is stabilized, less than 30% manage to the come independent, with the remaining 70% needing assistive devices or wheelchairs, 22% depending on the care of another, and only 13% of patients return to work[3].

## INITIAL PREHOSPITAL MANAGEMENT OF SCI

A suspected SCI requires specific treatment at a prehospital level, making it important to know the symptoms associated with SCI: lower back pain (40%), cranial injury (35%), alterations in consciousness (30%), cervical pain (15%), neurological deficit (only 15%), chest pain (10%), and pain sensitivity in the spine (5%)[4].

If pain at a specific point is suggestive of SCI, special care must be taken as the SCI may be located in a different segment of the spinal cord. In 20% of cervical injuries, 60% of chest injuries and 10% of lumbar SCI's the pain was located elsewhere[4].

The objective of prehospital management of the spinal cord patient is the mitigation of neurological deficit and prevention of any additional damage of neurological function.

Action at the scene of the accident includes a quick primary appraisal of the patient with restoration of the vital functions (A,B,C,D: airway, breathing, circulation and neurological evaluation), a careful secondary evaluation and finally the definitive measures including transport and admission at A&E or a trauma centre. I would also add that that upon arrival at the scene of the accident it is important to "read" the situation in order to observe the mechanism of the injury and therefore detect a possible SCI.

Prehospital management, in general, and that of airway and ventilation in particular, should include the immobilization of the spine in suspected cases in order to minimize SCI secondary to poor patient mobilization. Fluid therapy for shock and pharmacological treatment complete the prehospital treatment of the SCI syndrome.

### Primary evaluation and restoration of vital functions

During the initial examination, the ABCD must be appraised, controlled and restored in accordance with the medical care guidelines in the event of multiple injuries[5].

Secondary examination is an exhaustive evaluation from head to toe. This examination must focus on the patients with possible SCI if they report pain in the neck or the back, pain in the spine upon touch, signs of muscular weakness, paralysis, paresthesia, signs of incontinence, priapism, increase in skin temperature or erythema.

The conclusions of the prehospital evaluation must be included in the clinical history in full detail.

### Patient immobilization

It is estimated that up to 25% of SCIs can be aggravated after the injury, either during transport or in the course of initial treatment[6,7]. It must be pointed out that the data are more than 20 years old and there have been no recent studies. Careful mobilization and the use of appropriate rescue techniques are crucial for all patients with SCI or in accidents involving injuries which could potentially lead to a spinal injury. The immobilization of the spine en bloc is essential and must be carried out in a systematic way. The patient must be placed in supine position on a hard surface and in neutral position, aligning the head-neck-trunk-limb axis, applying slight axial traction at the neck, also keeping it in neutral position and avoiding any movement thereof. Meanwhile, another person shall place the neck brace removing any clothing or hair which might prevent a correct fit. It is important to carry out a careful inspection and palpation of the cervical area before immobilization in order to detect any injury and appraise external jugular veins, carotid pulse, trachea and laryngeal cartilage.

The patient must be immobilized at the site of the accident and during transport by means of a rigid neck brace, and laid upon a rigid back board with straps[6-8]. A vacuum mattress (vacmat) with a neck brace is a frequently used and effective immobilization system[7]. The vacuum mattress is a structure filled with insulating material which is pumped up to create a vacuum and turn it into a rigid support with the required shape, as it can mould and adapt to all body curvatures. Other advantages include the ease with which the patient can be placed on his/her side in the event of vomiting and a good cushioning against vehicle vibrations thanks to its insulating filling. Nevertheless, despite its rigidity, it is prone to bend and must therefore be placed on a more rigid support underneath (a board or a folding stretcher) or on the ambulance stretcher.

Immobilization devices are generally effective in limiting the movement of the cervical spine. They are, however, associated with a significant degree of morbidity (discomfort, painful pressure, decubitus ulcer and breathing difficulty)[7,8]. Immobilization devices must, therefore, be removed once spinal cord injury has been excluded with certainty at the hospital following the performance of diagnostic tests.

Immobilization systems such as Kendrick's extrication device combined with a neck brace are useful in providing an almost complete immobilization from the head to the torso. The fitting of such devices does take some time and must, therefore, only be fitted in the event of non life-threatening injuries and if the patient's vital signs are stable. Furthermore, these devices are unsuitable in the event of a rapid release being required (for instance, a car on fire with a patient trapped inside)[9]. In this case, the patient should be evacuated using manual stabilization.

Upon arrival of the team to the hospital the patient must be transferred to the stretcher in the A&E department. Ideally the hospital should have available equipment that is interchangeable with that used in the ambulance, thus avoiding the hurried removal of the patient in order to allow the mobile unit to resume its operating capacity as soon as possible. In the event that this is not possible (which is the norm), the transfer must be carried out preferably using a folding stretcher, as the use of the board alone results in the patient having to be turned once again.

## Oxygenation and airway management

Airway management is the same in most victims of multiple injuries given that the situations in which there is a possibility of SCI are frequent and numerous, especially with patients with consciousness alterations and trauma above the clavicle.

However, and despite seeming obvious, it is worth remembering at this point that the permeability of the airway in an essential priority, and that perfect immobilization and scrupulous management is useless if the patient should die or suffer serious encephalopathy due to severe hypoxia secondary to a delayed or unsuitable management thereof. It is therefore necessary to take a prudent approach, based on common sense and the physician's experience, when determining in which situations certain risks for the patient must be undertaken.

In the event of complete injury above the $C_3$ level, respiratory arrest and death ensue unless immediate ventilation support is administered and[8], if possible, urgent intubation. An injury of the upper cervical segment ($C_3$-$C_5$) produces acute respiratory insufficiency and hypoxia caused by hypoventilation, aspiration or due to paralysis of the diaphragmatic function[10]. When the SCI does not affect the diaphragm but paralyses the intercostal and abdominal muscles, this can lead to inadequate coughing, paradoxical movement of the lateral rib margin, an important decrease in vital capacity and loss of active expiration. Other problems in the management of the airway in patients suffering a SCI can occur if associated with facial or thoracic injury, such as pneumothorax or aspiration of the haemorrhage[10].

Orotracheal intubation (OTI) carried out in patients with an unstable spine can produce severe SCI and death[11]. In order to preserve the integrity of the spine and spinal cord, and prevent the worsening of neurological function, the patient must be carefully intubated, with a careful risk/benefit appraisal of each patient.

Quadriplegic patients with adequate ventilation at the expense of high energy consumption must be intubated and connected to the respirator as a prophylactic measure[12].

A rapid intubation sequence used by a perfectly trained prehospital A& E team is a safe system to ensure a correct management of the airway[13]. OTI in patients who have suffered a SCI must be performed using rapid sequence induction to reduce coughing and spontaneous movement.

The use of succinylcholine in patients who have suffered an SCI can caused bradycardia and cardiac arrest due to hyperpotasaemia, but its use is almost certainly safe during the first 48 hours after SCI[12].

Eighty percent of SCI occur below $C_3$. Most of the cervical movement during OTI with direct laryngoscopy in subjects with no cervical abnormality and in cadavers occurs at the atlantoccipital joint[14] and the atloaxoid joint[15], with movement in the segments below the axis being less frequent.

Cadaver studies indicate that manual in-line stabilization considerably reduces anteroposterior movement during OTI versus the use of the rigid neck brace. Moreover, it is harder to open the mouth with a neck brace and cervical mobility is restricted, which complicates the intubation process with possible adverse effects in the airway, difficult intubation and aspiration[15].

Immediately after arriving at the scene of the accident and always prior to intubation, the patient must be given oxygen, after having ensured cervical immobilization. Intubation of the trachea (or any other method to protect the airway) and controlled ventilation are recommended if saturation (Sat=2) is lower than 90% (despite oxygen therapy), if respiratory frequency is low, or if the Glasgow coma scale score (GCS) is less than 9. Intubation must be carried out after rapid sequence induction[13]. When intubation is urgent, the neck brace must be opened and manual stabilization of the cervical spine (MSCS) must be performed in order to ensure mechanical stability of the spinal cord[18]. MSCS involves a second person immobilizing the cervical spine in a neutral position, placing a hand on either side of patient's head to prevent any neck motion. After intubation the neck brace should be fitted once again. MCSC reduces cervical spine motion during intubation but does not completely prevent movement[16].

Alternative devices for airway management such as the laryngeal mask, the *Combitube,* can exert greater pressure on the cervical vertebrae than conventional intubation techniques and should only be used when normal intubation is not possible[17]. An accepted standard for hospital patients suffering a SCI is intubation via endoscopic methods but this technique is hardly ever available in prehospital care.

### Cardiovascular support

Hypovolemic and neurogenic shock can be present with SCI. Neurogenic shock can occur in SCI above D5 when the injury has caused a sympathectomy below the level of the injury. Neurogenic shock is associated with hypotension secondary to arterial and venous vasodilation, hypotension secondary to loss of splanchnic vascular sympathetic innvervation and bradycardia secondary to interruption of the sympathetic innvervation. Therefore, neurogenic shock is often associated with a systolic arterial pressure (SAP) below 90 mm Hg and severe bradycardia below 60 per minute.

Hypovolemic shock is often associated with SAP lower than 90 mm of Hg and tachycardia. It is possible to differentiate between neurogenic shock and hypovolemic shock but often both occur simultaneously in prehospital appraisal.

In SCI the main objective is to restore circulation to the nervous tissue. During neurogenic shock management, the patient should therefore be placed in the Trendelenburg position and given IV atropine and catecholamines, if indicated. For restoration of circulation to the nervous tissue in the event of hypovolemic shock, the patient must be placed in the Trendelenburg position and given intravenous fluids. Fluid administration must be done carefully as it can result in pulmonary oedema. At least two large IV lines must be placed. Average blood pressure (ABP) should be at least 90 mm Hg; hypotension episodes must be prevented and resolved as soon as possible. Use of fluids plays an essential role in the prehospital management of SCI associated with hypovolemia.

• Crystalloids and colloids. The use of crystalloids or colloids in prehospital care is still a matter open to debate. Compared with crystalloids, colloids have the same osmolarity but different oncotic pressure. It depends on the type used, but colloids can cause anaphylaxis and disturbances in blood clotting. Colloids should therefore not be used in a situation with SCI.

• Hypertonic-hyperosmotic solutions. There is a relatively new concept of "small-volume resuscitation". Hypertonic-hyperosmotic solutions are used and make up the initial treatment of severe hypovolemic and trauma-associated shock[19]. No clinical trials on small volume resuscitation have been carried out in patients with SCI. However, there are some data available in patients with multiple trauma and severe brain injury. In a randomized, double-blind, clinical trial, 166 trauma patients with a SAP lower than or equal to 100 mm Hg were divided into two groups. One was given an initial dose of Ringer lactate solution, whereas the other group was treated with 250 ml of 7.5% sodium chloride/dextran 70. In the multiple injury patient group (among them some with several brain injury), the patients treated with sodium chloride/dextran showed a higher survival rate upon arrival to the hospital. In the subgroup which only had severe brain injury, the survival differences did not reach statistical significance[20].

Available data do not clarify whether there are clinical advantages in the use of hypertonic or hypertonic-hyperosmotic solutions in patients with cranioencephalic injury (CEI). From a scientific perspective, we do not know whether hypertonic-hyperosmolar solutions provide any clinical advantages in the management of patients with CEI or SCI.

Consequently, in cases in which there is hypotension or multiple trauma combined with SCI, the use of hypertonic-hyperosmolar or hypertonic solutions might be justified, is not harmful and may be possibly be indicated. But we still lack clinical trials in SCI patients.

• Glucose. Prehospital care should not include glucose as a perfusion, as it leads to at least two problems. Firstly, its behaviour as "free" water leads to oedema. Secondly, the patient is at risk of hyperglycaemia with an increase in the rate of anaerobic glycolysis, which increases lactate and reduces pH.

IV administration of glucose is only justified in cases of acute hyperglycaemia.

## PHARMACOLOGICAL TREATMENT OF PATIENTS WITH SCI

Some experimental studies have suggested that treatment with methylprednisolone (MP) could be beneficial in SCI[21]. Possible positive effects of MP inlcude stabilization of the cellular membrane, the inhibition of lipidic peroxidation and a reduction in the free radical release, increase in blood flow and reduction of oedema and inflammation.

Some clinical trials have considered naloxone or tirilazad but have failed to show any effectiveness. The clinical use of MP has been studied in the United States in three national studies on acute spinal injury *(National Acute Spinal Cord Injury Studies or NASCIS).*

## NASCIS 1

The first NASCIS clinical trial was a multicentre, randomized, double-blind study including 330 patients[22,23]. These patients were given a bolus IV of 100 mg of MP per day during 10 days or a bolus IV of 1,000 mg of MP per day for 10 days. The results showed no difference with regard to neurological recovery after 6 weeks, 6 months and 1 year following administration of MP. However, the incidence of infection was considerably higher in the group receiving the higher dosage of MP compared with the group which received 100 mg. of MP (9.3% v. 2.6%, relative risk 3.6 ; P=0.01)[22].

The main problem with NASCIS 1 is that the results are not compared with a placebo group. The results are therefore inconclusive and we still do not know whether MP is useful in treating SCI. The only thing that remains clear is that high doses of MP are not useful and can actually be harmful.

## NASCIS 2

NASCIS 2 was carried out in the 80's[24,25]. It was a multicentre, randomized, double-blind and placebo-controlled study including 487 patients. The efficacy and safety of MP was evaluated (initial IV bolus of 30 mg/kg + perfusion of 5.4 mg/Kg/h during 23 h, n=162) and naloxone (initial IV bolus 5.4 mg/kg + perfusion of 4 mg/kg/h during 23 h, n=154) within the first 12 hours following SCI versus placebo. Neurological function was evaluated upon arrival at A&E with a motor function neurological scale with a score of 0 to 70 and a sensitivity scale (pin-prick/light touch) with a range of 29 to 87. The study evaluated the changes with regard to these scales.

In terms of the pin-prick/light touch sensitivity scale, the patients in the group treated with MP did not show a significant increase compared with the placebo group after 6 weeks. However, after 6 months, the data truly suggested a small but significant increase in the pin-prick/light touch sensitive function (p=0.012)[24]. The question remains whether an improvement of 10.0 versus 6.6 on a scale of 29 to 87 is a relevant clinical improvement[26]. Evaluation results did not yield any positive effect in the MP group or in the naloxone group compared with placebo. The analysis of the subgroup of patients which were treated within 8 hours of the SCVI showed a small but significant improvement in motor and sensitive functions both within 6 weeks and after 6 months[24]. Follow-up after one year showed a small but significant improvement in the motor function of patients treated with MP (12.0 v.17.2, p=0.0325).

After NASCIS 2, the treatment with MP within the first 8 hours after SCI became standard therapy in acute SCI in the United States and many other parts of the world, despite various criticisms published on the study[26,27]. The main criticism of the subgroup analysis was that it lacked demographic data. It seems that the study had important limitations and faulty data. Moreover, the patients treated with MP showed clinically important side effects (for instance, infection: MP 7.1% vs. 3.3% with naloxone vs. 3.6% in placebo group; p=0.21). It is clear that this study cannot be considered as a basis for general recommendation of the use of MP in SCI patients[27].

## NASCIS 3

The NASCIS 3 study was carried out in the 90's. It was a clinical, multicentre, randomized, double-blind study carried out in 499 patients with SCI[28,29]. This study evaluated the efficacy and safety of MP (initial IV bolus 30 mg/kg + perfusion of 5.4 mg/kg/h for 24 hours, n=166); another group given MP (initial IV bolus 30 mg/kg/ + perfusion of 5.4 mg/Kg/h during 48 hours, n=167); and another group which was given tirilazad combined with MP (initial IV bolus MP 30 mg + one IV bolus of 2.5mg/kg of tirilazad + bolus of tirilazad IV 2.5mg/kg every 6 h during 48 h, n=166).

Patients treated with MP during 48 hours showed an improvement in motor function after 6 weeks which was a small but significant difference compared to the patients treated with MP during 24 h (8.8 v. 12.4, p=0.04; based on a motor function scale from 0 to 70).

The analysis of the patient subgroup treated within 3-8 hours after a SCI showed an increase of 10 points in motor function in favour of patients treated with MP for 48 hours.

The main criticisms of the NASCIS 3 trial were published[26,27]. The first problem was that the treatment groups appeared to be out of balance. The number of patients beginning with a normal motor function in the MP treatment group for 24 h. compared to that for 48 h. were considerably different (25% v. 14%; 0=0.007). The main results of the study should, therefore, be interpreted with caution. Moreover, after administration of MP for 48 h., patients reported an increase in side effects (for example, severe pneumonia: MP 24 h 2.6% v. tirilazad 0.6% v. MP 48 h 5.8%; p= 0.02)[26].

From a scientific perspective, even after NASCIS 3, the treatment of MP in patients with SCI remains questionable.

What should be done with steroid therapy in prehospital management of SCI?

Based on the above data, MP was not considered by some in the treatment of patients with SCI[30,31]. Moreover, at a consensus conference, following a review of all the literature from 1966 to 2001, the American Association of Neurological Surgeons[32], concluded that: "Treatment with MP during the first

24 to 48 hours as a treatment option in patients with acute spinal cord injury should be used with awareness that the evidence suggests that harmful side effects are more evident than any clinical benefit". In addition, in 2004 the National Association of EMS Physicians (NAEMSP)[33] published that the evidence on the use of high dosage steroids must not be considered as standard treatment, and routine use of steroids in European emergency medical systems is not recommended.

However, a Cochrane review published by the Cochrane Library Plus in 2006 states that, after having analysed the NASCIS trials and another two (the Otani trial of 1994 and the Petitjean trial of 1998), treatment with MP should commence within eight hours of occurrence of the injury, an initial bolus of 30 mg/kg IV for 15 minutes and, after 45 minutes, a continuous infusion of 5.4 mg/kg/h for 24 hours. An additional improvement in motor function was shown to occur if the treatment was prolonged to 48 hours. The authors conclude that MP improves neurological recovery but has little probability of recovering normal function unless the initial deficit is very small.

## TRANSPORT AND TYPE OF ORTHOPAEDIC SURGERY CENTRE

The type of vehicle depends on the patient and available means. Transport by land or by helicopter can both be used. Haemodynamic stability of the patient must be taken into account when deciding which centre to take the patient. Stable patients must be taken to a neurosurgical centre. It is often worth considering travelling a further distance to a specialized centre. Unstable patients should be taken to the nearest orthopedic surgery centre to achieve haemodynamic stability, even if it is not a neurosurgical centre. Transport to a high level centre in the event of SCI must be done once haemodynamic stability has been achieved.

There is a belief that initial transfer to a specialized centre in SCI leads to a reduction in the time spent in the ICU, a reduction in the total time spent in hospital and reduction in the incidence of pressure ulcers. Nevertheless, an analysis of the Cochrane database states that "scientific evidence does not allow conclusions to be drawn on the advantages and disadvantages of immediate transfer to a medical centre specializing in SCI. More and better designed studies must be carried out."

## CONCLUSIONS

Prehospital management of SCI is undoubtedly very important, as 25% of the damage can be caused or aggravated after the initial injury during such management. Prehospital management of acute SCI includes the examination of the patient, en bloc immobilization of the spine, oxygenation and careful management of the airway as well as cardiovascular support. Emergency treatment to reduce to the risk of secondary SCI includes intubation of the trachea, if indicated (with manual stabilization of cervical spine) and maintenance of the ABP above 90 mm Hg.

From a scientific perspective it is not yet clear whether specific additional therapy is useful. Early treatment with MP has not been convincingly proven to have important clinical benefits for patients with SCI and, despite the widespread use of MP, many questions remain unanswered with regard to this treatment[36].

The American Association of Neurological Surgeons and the NAEMSP do not support the routine use of MP in the treatment of patients with SCI[32,33].

However, a Cochrane review translated in 2006 recommends the use of MP, although it acknowledges that this is only beneficial if the initial deficit is small and so long as it is used within the first eight hours of the injury[34].

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