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SERIES IN INTENSIVE CARE MEDICINE: TRAUMATIC ACUTE SPINAL CORD INJURY

Update on traumatic acute spinal cord injury. Part 2☆

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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).

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

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en cuenta que, aunque el tipo de intervención depende del equipo quirúrgico, en el momento actual el tratamiento implica descompresión y estabilización precoz. En el tratamiento integral del paciente con lesión medular es fundamental identificar y tratar adecuadamente el dolor asociado a la lesión medular, así como la ansiedad, al igual que prevenir y diagnosticar precozmente complicaciones secundarias a la afectación que la lesión medular ocasiona en todos los sistemas del organismo (enfermedad tromboembólica, alteraciones gastrointestinales, afectación del sistema urinario, úlceras por presión).

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 24 h 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 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_2O, 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 traumatisms. 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_2O affects the prognosis.[7] When it comes to PEEP, the theory was using 0 cmH_2O 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 atelectrauma with the adequate plateau-pressure (PEEP $\geq$ 5 cmH_2O and plateau-pressures < 30 cmH_2O)[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 $\geq$ 16.[9–11] 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 $-20\,cmH_2O$). Also, we will need to assess the diaphragmatic function using, if possible, ultrasounds. 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 benefitial 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.[11,15] The contributing factors are an impaired level of consciousness at admission (GCS < 9), Injury Severity Score $\geq$ 16, and associated thoracic injuries.[16]

In these patients, the tracheostomy should be performed during the first seven days because this would be extremely benefitial 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 immobiliation 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 occipitoatloaxoid region is a different story given its complexity, the different possible options available, and the experience of the surgical team. Martín-Ferrer[22] published a very useful review with the results he obtained.

Approaching the occipitoatloaxoid 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, Allen et al.,[24] Harris, and White and Punjabi, the Subaxial Injury Classification[25] and Cervical Spine Injury Severity Score[25] 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.

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

Tomada de Vaccaro et al.[25]

the severity score of clinical manifestations, an option of definitive treatment is recommended[21,26] (Table 1). There has also been controversy on how to approach and stabilize cervical fractures and subluxations. The benefits associated with the aforementioned approach are that there is not as much tissue damage or bleeding, that it is easy to access the injured intervertebral disc complex, and that it is possible to decompress the spinal canal,[27] and reliably perform intersomatic fixation in circumscribed injuries to one or two vertebral segments.[28] The posterior approach allows us to release fragments from neural arches, and gives us the possibility of reducing any posterior articular apophysis, and safely stabilize pedicle screws.[27] However, it usually associates a higher risk of complications of the surgical wound and, in case of protrusion or herniated disc, decompression would be required through the anterior approach prior to the reduction. Depending on the experience of the surgical team is, the actual results can be similar.

In the study of thoracolumbar spinal injuries, classifications based on instability criteria according to the three-column concept developed by Denis and McAfee[29] were used. Thus, the most widely used classification is that of Magerl et al.,[30] with further reviews for its clinical application. Aebi[29] describes this classification by distinguishing three types of injuries based on the structures affected and the mechanism of production. Its treatment and management has evolved and changed with the passing of time. Until the decade of the 1990s, the main focus of interest was the techniques of posterior stabilization. The last two decades have seen the birth of techniques of anterior and combined approaches.[31,32] One review of 733 patients conducted by a German multicentre group[33] 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 percentage 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.[34]

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.[35] This would endorse the theory that decompressive surgery after one traumatic SCI attenuates the mechanisms of secondary injuries and improves neurological outcomes.[35]

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.[36]

In a recent systematic review, El Tecle 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 eary surgeries increase mortality and neurological impairment.[36] All clinical trials were retrospective, except for the Surgical Timing in Acute Spinal Cord Injury Study[37] 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 pain[41,42] (Table 2). Nocioceptive 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]

Table 2 Classification of pain associated with spinal cord injuries *(International Spinal Cord Injury Pain)*.

Step 1	Step 2	Step 3
Nocioceptive pain	Musculoskeletal Visceral Other	Examples: Associated to spams Constipation Decubitus ulcer
Neuropathic pain	Pain associated with SCI At SCI level Below the SCI Other neuropathic pain	Syringomyelia Cauda equine syndrome Post-thoracotomy pain Carpal tunnel syndrome
Other type of pain Unknown causes		

Adapted and translated from Finnerup,[41] 2013.

Acute pain coming from injured osteoarticular structures may be considered nocioceptive 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–that 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 lancinanting 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.[44,45] 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 infralesional neuropathic pain is of late appearance though it may appear at any time during the first year of SCI.[40]

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.

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

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.[47]

According to the recommendations by the International Association for the Study of Pain and associated reviews, pregabalin[48] stands as the first-line therapy, being the only known drug for the management of neuropathic pain of SCIs,[40] associated to tramadol,[49] tricyclic antidepressants, and serotonin reuptake inhibitors, duloxetine[50] as a long term strategy, and opioids[51] 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 propofol[52] 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,[45] 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 thromboprophilaxis 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 heparines 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 heparines[58,61,63,64] 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.[63] 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

quadriplejia.[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.[66–68] SCIs, especially the cervical SCI, associate a high risk of stress ulcer occurrence.[69] An early management with nutritional support and prophylaxis with H_2 blockers or proton pump inhibitors (PPI) for four weeks[63,68] is recommended. Its prolonged use may increase the risk of intestinal infection due to *Clostridium difficile*. Cholelithiasis is more common in patients with SCIs than in the general population[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.[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.[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 (uretheral 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.[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 48 h 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.[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 4–6 h) 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 aroud 400 ml and vesicle distension is avoided.[74] The patient needs to be hemodynamically stable, have an adequate fluidification 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.[75] The more serious the SCI is (quadriplegy, 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.[63,76] Serum levels that are low in proteins, and malnutrition are associated with higher mortality rates.[77]

The recommendation is to start feeding during the first 72 h, 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 (<72 h) compared to patients with late initiation of feeding (>120 h).[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.[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.[80]

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[63] is recommended.

Conflicts of interests

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

References

1. Roth EJ, Nussbaum SB, Berkowitz M, Primack S, Oken J, Powley S, et al. Pulmonary function testing in spinal cord injury: correlation with vital capacity. Paraplegia. 1995;33:454–7.
2. Claxton AR, Wong DT, Chung F, Fehlings MG. Predictors of hospital mortality and mechanical ventilation in patients with cervical spinal cord injury. Can J Anaesth. 1998;45:144–9.
3. Velmahos GC, Toutouzas K, Chan L, Tillou A, Rhee P, Murray J, et al. Intubation after cervical spinal cord injury: to be done selectively or routinely? Am Surg. 2003;69:891–4.
4. Biering-Sørensen F, Krassioukov A, Alexander MS, Donovan W, Karlsson AK, Mueller G, et al. International spinal cord injury pulmonary function basic data set. Spinal Cord. 2012;50:418–21.
5. Huang YH, Ou CY. Magnetic resonance imaging predictors for respiratory failure after cervical spinal cord injury. Clin Neurol Neurosurg. 2014;126:30–4.
6. Jaber S, Petrof BJ, Jung B, Chanques G, Berthet JP, Rabuel C, et al. Rapidly progressive diaphragmatic weakness and injury during mechanical ventilation in humans. Am J Respir Crit Care Med. 2011;183:364–71.
7. Fenton JJ, Warner ML, Lammertse D, Charlifue S, Martinez L, Dannels-McClure A, et al. A comparison of high vs standard tidal volumes in ventilator weaning for individuals with sub-acute spinal cord injuries: a site-specific randomized clinical trial. Spinal Cord. 2016;54:234–8.
8. Salman D, Finney SJ, Griffiths MJ. Strategies to reduce ventilator-associated lung injury (VALI). Burns. 2013;39:200–11.
9. Como JJ, Sutton ER, McCunn M, Dutton RP, Johnson SB, Aarabi B, et al. Characterizing the need for mechanical ventilation following cervical spinal cord injury with neurologic deficit. J Trauma. 2005;59:912–6, discussion 916.
10. McMichan JC, Michel L, Westbrook PR. Pulmonary dysfunction following traumatic quadriplegia. Recognition, prevention, and treatment. JAMA. 1980;243:528–31.
11. Menaker J, Kufera JA, Glaser J, Stein DM, Scalea TM. Admission ASIA motor score predicting the need for tracheostomy after cervical spinal cord injury. J Trauma Acute Care Surg. 2013;75:629–34.
12. Yu WK, Ko HK, Ho LI, Wang JH, Kou YR. Synergistic impact of acute kidney injury and high level of cervical spinal cord injury on the weaning outcome of patients with acute traumatic cervical spinal cord injury. Injury. 2015;46:1317–23.
13. Chiodo AE, Scelza W, Forchheimer M. Predictors of ventilator weaning in individuals with high cervical spinal cord injury. J Spinal Cord Med. 2008;31:72–7.
14. Galeiras Vázquez R, Rascado Sedes P, Mourelo Fariña M, Montoto Marqués A, Ferreiro Velasco ME. Respiratory management in the patient with spinal cord injury. Biomed Res Int. 2013;2013:168757.
15. Branco BC, Plurad D, Green DJ, Inaba K, Lam L, Cestero R, et al. Incidence and clinical predictors for tracheostomy after cervical spinal cord injury: a National Trauma Databank review. J Trauma. 2011;70:111–5.
16. Jones TS, Burlew CC, Johnson JL, Jones E, Kornblith LZ, Biffl WL, et al. Predictors of the necessity for early tracheostomy in patients with acute cervical spinal cord injury: a 15-year experience. Am J Surg. 2015;209:363–8.
17. Leelapattana P, Fleming JC, Gurr KR, Bailey SI, Parry N, Bailey CS. Predicting the need for tracheostomy in patients with cervical spinal cord injury. J Trauma Acute Care Surg. 2012;73:880–4.
18. Binder H, Lang N, Tiefenboeck TM, Bukaty A, Hajdu S, Sarahrudi K. Tracheostomy following anterior cervical spine fusion in trauma patients. Int Orthop. 2016;40:1157–62.
19. Sustić A, Krstulović B, Eskinja N, Zelić M, Ledić D, Turina D. Surgical tracheostomy versus percutaneous dilational tracheostomy in patients with anterior cervical spine fixation: preliminary report. Spine (Phila Pa 1976). 2002;27:1942–5, discussion 1945.
20. Putensen C, Theuerkauf N, Guenther U, Vargas M, Pelosi P. Percutaneous and surgical tracheostomy in critically ill adult patients: a meta-analysis. Crit Care. 2014;18:544.
21. Patel AA, Hurlbert RJ, Bono CM, Bessey JT, Yang N, Vaccaro AR. Classification and surgical decision making in acute subaxial cervical spine trauma. Spine (Phila Pa 1976). 2010;35 21 Suppl.:S228–34.
22. Martín-Ferrer S. [High cervical spine injuries: classification, therapeutic indications, and surgical approaches: 286 consecutive cases] Spanish. Neurocirugia (Astur). 2006;17:391–419.
23. Ryken TC, Hadley MN, Aarabi B, Dhall SS, Gelb DE, Hurlbert RJ, et al. Management of acute combination fractures of the atlas and axis in adults. Neurosurgery. 2013;72 Suppl. 2:151–8.
24. Allen BL Jr, Ferguson RL, Lehmann TR, O'Brien RP. A mechanistic classification of closed, indirect fractures and dislocations of the lower cervical spine. Spine (Phila Pa 1976). 1982;7:1–27.
25. Vaccaro AR, Hulbert RJ, Patel AA, Fisher C, Dvorak M, Lehman RA Jr, et al. The subaxial cervical spine injury classification system: a novel approach to recognize the importance of morphology, neurology, and integrity of the disco-ligamentous complex. Spine (Phila Pa 1976). 2007;32:2365–74.
26. Dvorak MF, Fisher CG, Fehlings MG, Rampersaud YR, Oner FC, Aarabi B, et al. The surgical approach to subaxial cervical spine injuries: an evidence-based algorithm based on the SLIC classification system. Spine (Phila Pa 1976). 2007;32:2620–9.
27. Gelb DE, Aarabi B, Dhall SS, Hurlbert RJ, Rozzelle CJ, Ryken TC, et al. Treatment of subaxial cervical spinal injuries. Neurosurgery. 2013;72 Suppl. 2:187–94.
28. Woodworth RS, Molinari WJ, Brandenstein D, Gruhn W, Molinari RW. Anterior cervical discectomy and fusion with structural allograft and plates for the treatment of unstable posterior cervical spine injuries. J Neurosurg Spine. 2009;10:93–101.
29. Aebi M. Classification of thoracolumbar fractures and dislocations. Eur Spine J. 2010;19 Suppl 1:S2–7.
30. Magerl F, Aebi M, Gertzbein SD, Harms J, Nazarian S. A comprehensive classification of thoracic and lumbar injuries. Eur Spine J. 1994;3:184–201.

31. Oner FC, Wood KB, Smith JS, Shaffrey CI. Therapeutic decision making in thoracolumbar spine trauma. Spine (Phila Pa 1976). 2010;35 21 Suppl.:S235–44.
32. Verlaan JJ, Diekerhof CH, Buskens E, van der Tweel I, Verbout AJ, Dhert WJ, et al. Surgical treatment of traumatic fractures of the thoracic and lumbar spine: a systematic review of the literature on techniques, complications, and outcome. Spine (Phila Pa 1976). 2004;29:803–14.
33. Reinhold M, Knop C, Beisse R, Audige L, Kandziora F, Pizanis A, et al. Operative treatment of 733 patients with acute thoracolumbar spinal injuries: Comprehensive results from the second, prospective, Internet-based multicenter study of the Spine Study Group of the German Association of Trauma Surgery. Eur Spine J. 2010;19:1657–76.
34. Charles YP, Steib JP. Management of thoracolumbar spine fractures with neurologic disorder. Orthop Traumatol Surg Res. 2015;101 1 Suppl.:S31–40.
35. Dimar JR, Glassman SD, Raque GH, Zhang YP, Shields CB. The influence of spinal canal narrowing and timing of decompression on neurologic recovery after spinal cord contusion in a rat model. Spine (Phila Pa 1976). 1999;24:1623–33.
36. El Tecle NE, Dahdaleh NS, Hitchon PW. Timing of surgery in spinal cord injury. Spine (Phila Pa 1976). 2016;41:E995–1004.
37. Fehlings MG, Vaccaro A, Wilson JR, Singh A, Cadotte D.W., Harrop JS, 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:e32037.
38. Jug M, Kejžar N, Vesel M, Al Mawed S, Dobravec M, Herman S, 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;32:1385–92.
39. Ropper AE, Neal MT, Theodore N. Acute management of traumatic cervical spinal cord injury. Pract Neurol. 2015;15:266–72.
40. Saulino M. Spinal cord injury pain. Phys Med Rehabil Clin N Am. 2014;25:397–410.
41. Finnerup NB. Pain in patients with spinal cord injury. Pain. 2013;154 Suppl. 1:S71–6.
42. Bryce TN, Biering-Sørensen F, Finnerup NB, Cardenas DD, Defrin R, Ivan E, et al. International Spinal Cord Injury Pain (ISCIP) Classification: Part 2. Initial validation using vignettes. Spinal Cord. 2012;50:404–12.
43. Attal N, Cruccu G, Baron R, Haanpää M, Hansson P, Jensen TS, et al. EFNS guidelines on the pharmacological treatment of neuropathic pain: 2010 revision. Eur J Neurol. 2010;17:1113–88.
44. Finnerup NB, Jensen TS. Spinal cord injury pain – mechanisms and treatment. Eur J Neurol. 2004;11:73–82.
45. Zanca JM, Dijkers MP, Hammond FM, Horn SD. Pain and its impact on inpatient rehabilitation for acute traumatic spinal cord injury: analysis of observational data collected in the SCIRehab study. Arch Phys Med Rehabil. 2013;94 4 Suppl:S137–44.
46. Zeiler FA, AlSubaie F, Zeiler K, Bernard F, Skrobik Y. Analgesia in neurocritical care: an international survey and practice audit. Crit Care Med. 2016;44:973–80.
47. Baastrup C, Finnerup NB. Pharmacological management of neuropathic pain following spinal cord injury. CNS Drugs. 2008;22:455–75.
48. Cardenas DD, Nieshoff EC, Suda K, Goto S, Sanin L, Kaneko T, et al. A randomized trial of pregabalin in patients with neuropathic pain due to spinal cord injury. Neurology. 2013;80:533–9.
49. Norrbrink C, Lundeberg T. Tramadol in neuropathic pain after spinal cord injury: a randomized, double-blind, placebo-controlled trial. Clin J Pain. 2009;25:177–84.
50. Vranken JH, Hollmann MW, van der Vegt MH, Kruis MR, Heesen M, Vos K, et al. Duloxetine in patients with central neuropathic pain caused by spinal cord injury or stroke: a randomized, double-blind, placebo-controlled trial. Pain. 2011;152:267–73.
51. McNicol ED, Midbari A, Eisenberg E. Opioids for neuropathic pain. Cochrane Database Syst Rev. 2013;8. CD006146.
52. Barr J, Fraser GL, Puntillo K, Ely EW, Gélinas C, Dasta JF, et al. Clinical practice guidelines for the management of pain, agitation, and delirium in adult patients in the intensive care unit. Crit Care Med. 2013;41:263–306.
53. North NT. The psychological effects of spinal cord injury: a review. Spinal Cord. 1999;37:671–9.
54. Cuff L, Fann JR, Bombardier CH, Graves DE, Kalpakjian CZ. Depression, pain intensity, and interference in acute spinal cord injury. Top Spinal Cord Inj Rehabil. 2014;20:32–9.
55. Widerström-Noga E, Biering-Sørensen F, Bryce TN, Cardenas DD, Finnerup NB, Jensen MP, et al. The International Spinal Cord Injury Pain Extended Data Set (Version 1.0). Spinal Cord. 2016;54:1036–46.
56. Godat LN, Kobayashi L, Chang DC, Coimbra R. Can we ever stop worrying about venous thromboembolism after trauma? J Trauma Acute Care Surg. 2015;78:475–80, discussion 480-1.
57. Matsumoto S, Suda K, Iimoto S, Yasui K, Komatsu M, Ushiku C, et al. Prospective study of deep vein thrombosis in patients with spinal cord injury not receiving anticoagulant therapy. Spinal Cord. 2015;53:306–9.
58. Consortium for Spinal Cord Medicine [web host]. Clinical prevention of venous thromboembolism in individuals with spinal cord injury: Clinical practice guideline for health care providers. Washington: Paralyzed Veterans of America; 2016. p. 1–43 [consulted Sep 2016]. Available in: http://www.pva.org/atf/cf/%7BCA2A0FFB-6859-4BC1-BC96-6B57F57F0391%7D/CPG_thrombo_fnl.pdf
59. Dhall SS, Hadley MN, Aarabi B, Gelb DE, Hurlbert RJ, Rozzelle CJ, et al. Deep venous thrombosis and thromboembolism in patients with cervical spinal cord injuries. Neurosurgery. 2013;72 Suppl 2:244–54.
60. Ploumis A, Ponnappan RK, Maltenfort MG, Patel RX, Bessey JT, Albert TJ, et al. Thromboprophylaxis in patients with acute spinal injuries: an evidence-based analysis. J Bone Joint Surg Am. 2009;91:2568–76.
61. Aito S, Pieri A, D'Andrea M, Marcelli F, Cominelli E. Primary prevention of deep venous thrombosis and pulmonary embolism in acute spinal cord injured patients. Spinal Cord. 2002;40:300–3.
62. Akman MN, Cetin N, Bayramoglu M, Isiklar I, Kilinc S. Value of the D-dimer test in diagnosing deep vein thrombosis in rehabilitation inpatients. Arch Phys Med Rehabil. 2004;85:1091–4.
63. Consortium for Spinal Cord Medicine[sede web]. Early acute management in adults with spinal cord injury: A clinical practice guideline for healthcare professionals. Washington: Paralyzed Veterans of America; 2008. p. 403–479 [consulted Sep 2016]. Available in: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2582434/pdf/i1079-0268-31-4-408.pdf
64. Kakkos SK, Caprini JA, Geroulakos G, Nicolaides AN, Stansby GP, Reddy DJ. Combined intermittent pneumatic leg compression and pharmacological prophylaxis for prevention of venous thromboembolism in high-risk patients. Cochrane Database Syst Rev. 2008;4:CD005258.
65. Shem K, Castillo K, Wong S, Chang J. Dysphagia in individuals with tetraplegia: incidence and risk factors. J Spinal Cord Med. 2011;34:85–92.
66. Sarıfakıoğlu B, Afşar SI, YalbuzdağF Ş., Ustaömer K, Ayaş Ş. Acute abdominal emergencies and spinal cord injury; our experiences: a retrospective clinical study. Spinal Cord. 2014;52:697–700.
67. Pirolla EH, de Barros Filho TE, Godoy-Santos AL, Fregni F. Association of acute pancreatitis or high level of serum pancreatic enzymes in patients with acute spinal cord injury: a prospective study. Spinal Cord. 2014;52:817–20.

68. Kuric J, Lucas CE, Ledgerwood AM, Kiraly A, Salciccioli GG, Sugawa C. Nutritional support: a prophylaxis against stress bleeding after spinal cord injury. Paraplegia. 1989;27:140–5.
69. Simons RK, Hoyt DB, Winchell RJ, Holbrook T, Eastman AB. A risk analysis of stress ulceration after trauma. J Trauma. 1995;39:289–93, discussion 293–4.
70. Xia CS, Han YQ, Yang XY, Hong GX. Spinal cord injury and cholelithiasis. Hepatobiliary Pancreat Dis Int. 2004;3:595–8.
71. Ohry A, Zeilig G, Shemesh Y. Acute intermittent arteriomesenteric occlusion of the duodenum after use of Harrington's spinal instrumentation: case report. Paraplegia. 1988;26:350–4.
72. Todd NV. Priapism in acute spinal cord injury. Spinal Cord. 2011;49:1033–5.
73. Galeiras R, Mourelo M, Pértega S, Lista A, Ferreiro E, Salvador S, et al. Rhabdomyolysis and acute kidney injury in patients with traumatic spinal cord injury. Indian J Crit Care Med. 2016;20:504–12.
74. Consortium for Spinal Cord Medicine. Bladder management for adults with spinal cord injury: a clinical practice guideline for health-care providers. J Spinal Cord Med. 2006;29:527–73.
75. Rodriguez DJ, Benzel EC, Clevenger FW. The metabolic response to spinal cord injury. Spinal Cord. 1997;35:599–604.
76. Thibault-Halman G, Casha S, Singer S, Christie S. Acute management of nutritional demands after spinal cord injury. J Neurotrauma. 2011;28:1497–507.
77. Chen X, Liu Z, Sun T, Ren J, Wang X. Relationship between nutritional status and mortality during the first 2 weeks following treatment for cervical spinal cord injury. J Spinal Cord Med. 2014;37:72–8.
78. Dvorak MF, Noonan VK, Bélanger L, Bruun B, Wing PC, Boyd MC, et al. Early versus late enteral feeding in patients with acute cervical spinal cord injury: a pilot study. Spine (Phila Pa 1976). 2004;29:E175–80.
79. Kramer AH, Roberts DJ, Zygun DA. Optimal glycemic control in neurocritical care patients: a systematic review and meta-analysis. Crit Care. 2012;16:R203.
80. Gefen A. How much time does it take to get a pressure ulcer? Integrated evidence from human, animal, and in vitro studies. Ostomy Wound Manage. 2008;54:26–8, 30–5.