CASE REPORT

Should post-traumatic thoracolumbar Frankel A paraplegia be operated as an emergency? Report of three cases and review of the literature

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Summary
Spinal cord injury is an important contributing factor to morbidity. The thoracolumbar junction is a highly vulnerable axial region due to the biomechanical stresses and the risk of conus medullaris injuries in some cases. In the event of an incomplete neurological injury and if the patient’s condition is stable, emergency surgical treatment should be considered. Yet, no clear consensus has emerged regarding the treatment modalities of complete injuries but surgical management is advocated to maximize neurological recovery and reduce the risk of decubitus ulcer formation. We report on the cases of three patients with L1 Frankel A paraplegia resulting from injury to the conus medullaris, treated within the first 6 hours from injury and demonstrating a very satisfactory neurological recovery since independent walking could be resumed at 2.5 years follow-up. Persistent urinary sphincter dysfunctions were observed in two of these patients. Early surgical management appears as an important predictive factor for neurological recovery in conus medullaris injuries. We believe that delayed surgical management in patients with complete paraplegia could be an inappropriate treatment option, which should be further studied.

Introduction
Spine trauma is a very common injury, which is associated with spinal cord injury (SCI) in 15 to 30% of the cases [1]. About 30 to 50,000 people in France are currently living with SCI sequelae with an average of 1000–2000 new cases a year. Spinal cord injury remains an important cause of morbidity and mortality with major societal impact since it mainly occurs in young patients. Most traumatic SCI occur in men with a male-to-female ratio of 3/1. People aged 16–25 and over 50 are more likely to sustain spinal cord injuries [2]. The most common causes of SCI are motor vehicle accidents in 40 to 45%, falls in 15 to 30% and sports-related injuries in 15 to 25%. The location of spinal cord injuries is related to the vulnerability of each spinal segment, the cervico-dorsal and thoracolumbar junctions being more vulnerable.

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to injury. 15% of all spinal injuries occur in the thoracolumbar junction (T12-L1) [3]. It is well-admitted that early surgical management performed within the first 6 hours from trauma, of a spinal fracture associated with incomplete neurological deficit sustained through spinal cord concussion, compression or contusion may lead to recovery of sensory-motor function as well as improvement of urinary sphincter deficits. However, there is much debate about the best treatment strategy for complete deficits. We report on three consecutive cases of young patients having sustained a spinal cord trauma at the level of the thoracolumbar junction with initial complete Frankel A paraplegia [4] and favorable controlled recovery at more than 2 years follow-up. The aim of that work was to analyze the treatment modalities, which contributed to neurological recovery.

Case n°1

A 35-year old patient sustained a fall from a 12 meters scaffolding at his workplace in August 2008 with an impact to his back and occiput. The patient was conscious on his arrival at the emergency department. On admission he had a Frankel A flaccid paraplegia at L1 level with priapism. Full-body CT scan revealed a fracture dislocation at L1-L2 graded C1.1 according to Magerl et al. [5] (Fig. 1) associated with fractures of the spinous process from L1 to L4, low lumbar fractures of L4 and L5; a tear drop cervical fracture at C4 with skull base fracture and cerebral contusion; at the level of the trunk, fractures of the 9th and 11th left ribs with slight pneumothorax, minor fractures of the inferior pole of the spleen, left kidney and liver. The patient was hemodynamically stable and conducted emergently to the operating room within 5 hours after injury for spinal decompression and fusion. He was also administered intravenous 30 mg/kg intravenous bolus of methylprednisolone sodium succinate followed by 48 hours of maintenance infusion at 5.4 mg/kg per hour using an electrical syringe pump. Surgery consisted in laminectomy from T12 to L2, which evidenced a dural breach through which were seen torn radicles on the left side of the conus medullaris. Intradural exploration helped evacuate a small intra-parenchymal haematoma from the conus medullaris. The dural breach was then sutured followed by fusion from T10 to L5 using pedicular screws and sub-laminar hooks at the lower extremity of the construct (Fig. 2). Anterior arthrodesis of the Tear Drop fracture at C4-C5 was performed at this stage. The patient was extubated after 72 hours. Neurological examination revealed a Frankel C paraplegia. Fifteen days later, an anterior bone grafting at L1-L2 was performed in the management of bone defect of the anterior column. The patient was transferred to a functional rehabilitation facility after 2 weeks. After 1 month of functional rehabilitation, the neurological status had improved to Frankel D. Self-urinary catheterization was still necessary associated with persistent faecal incontinence. The patient was able to walk independently. Nine months after trauma, the walking perimeter was evaluated to 2 km with support of a walking stick. The patient was autonomous for washing and dressing but still required self-urinary catheterization and demonstrated faecal incontinence. Due to a muscular discomfort, the patient asked for the removal of the instrumentation at 18 months post-trauma (Fig. 3). At 2-year and 7-month follow-up, the patient’s clinical status was stationary.

Case n°2

A 25-year old patient sustained a motorbike accident in September 2008. On admission to the emergency department, he reported a flaccid paraplegia at L1 associated with anal sphincter atony. He was graded Frankel A. Assessment revealed a type B2.3 fracture at L1 according to Magerl et al. [5] with bulky intracanal fragments (Fig. 4) associated with fracture of the right sacral ala, a right sub-trochanteric fracture and pulmonary contusion. Surgery was emergently performed within 5 hours after trauma. It consisted in
laminectomy from T12 to L1, which allowed decompression of the dural sac associated with fusion at T10-L2 using pedicular screws, and sub-laminar hooks (Fig. 5). At that stage, femoral nail osteosynthesis was also performed. The patient was intraoperatively administered intravenous 2.5 g bolus of methylprednisolone sodium succinate followed by 48 hours of maintenance infusion at 5.4 mg/kg per hour. At the 5th postoperative day, the patient reported no functional mobility but had preservation of light touch in the lower extremities. He was graded Frankel B. On the 20th postoperative day, voluntary contraction of anterior tibialis and quadriceps muscles of the two lower limbs was reported but the patient still suffered from atony of the anal sphincter. His neurological status was thus graded Frankel C. An anterior graft was performed secondarily. The patient was then transferred to a functional rehabilitation facility for neurological recovery until January 2009. He could resume walking activities with support of two crutches and was graded Frankel D. However, self-urinary catheterization was still necessary due to persistent sphincter deficiency. At 9-month follow-up, the patient was in stable condition and kept walking with support of two crutches. At 1 year, he was able to walk with support of one crutch over a distance of 500 meters and with two crutches for approximately 1 km. Anal sphincter atony was total. An electrocardiogram was then performed and revealed a central neurogenic atrophy from L2 to S2 in the right lower limb, a denervation at S1-S2 in the left lower limb as well as complete pelvic floor denervation. At 2.5-year follow-up, the patient was able to walk with support of two crutches and still required self-urinary catheterization.

Figure 3 Case n°1: clinical aspect of the patient after removal of instrumentation at 1.5 year post-trauma.

Figure 4 Case n°2: sagittal and axial CT scans of a L1 Magerl B2.3 fracture.

Figure 5 Case n°2: A/P and lateral radiographs of T10-L2 osteosynthesis-arthrodesis with T12-L1 laminectomy (note the absence of a rib at T12).

Figure 6 Case n°2: clinical aspect of the patient after removal of instrumentation at 1.5 year post-trauma.
Case n° 3

A 23-year old patient sustained a car crash accident in August 2008. She was the passenger of the car and was not wearing her seat belt. She sustained a right lateral impact and was ejected from the vehicle. On her arrival at the emergency department, she was conscious and complained of pain in the thoracolumbar junction. A Frankel A flaccid paraplegia at L1 was detected. Full-body CT scan revealed a fracture dislocation at T12-L1 graded C2.1 according to Magerl et al. [5] (Fig. 6). Surgery was emergently performed within 3 hours after trauma. A laminectomy was carried out at T12-L1 thus allowing suture of the dura mater defect and fusion from T9 to L3 using pedicular screws and sub-laminar hooks (Fig. 7). She was intraoperatively administered 30 mg/kg bolus of methylprednisolone sodium succinate followed by a maintenance infusion of 5.4 mg/kg for 48 hours. When the patient woke up 3 hours after surgery, she was able to move her inferior limbs with good sensory function and was graded Frankel C. The neurological assessment demonstrated progressive improvement in motor and sensory function of the lower limbs and was graded Frankel D after a few days. An anterior graft at T12-L1 was performed 3 weeks after the initial surgery. The patient was then transferred to a rehabilitation facility. After 2-month follow-up, the patient could walk independently but demonstrated persistent triceps surae motor deficit on her right side, which was, graded 4/5. There was no evidence of urinary sphincter deficiency. The neurological status was graded Frankel D. Social reintegration was progressive and 2 years after trauma, the osteosynthesis instrumentation was removed in order to free the non-grafted L2-L3 mobile segment (Fig. 8). At 2-year and 7-month follow-up, the patient had returned to a normal way of life and could resume her professional activity as a waitress. Her neurological status was graded Frankel E.

Discussion

More than half of traumatic SCI involves the cervical spine due to the high mobility and major instability of this segment. Cervical spine injuries can be sustained through different mechanisms such as flexion-extension, vertical compression (axial loading), extension-rotation and combined movements. Injuries to the thoracic segment account for 20 to 30% of all spinal cord injuries despite good spinal stabilization by the thorax. The thoracolumbar junction is a fulcrum between the inflexible thoracic region and the stronger and mobile lumbar levels. This makes it

Figure 6 Case n° 3: sagittal and axial CT scans of T12-L1 Magerl C2.1 fracture.

Figure 7 Case n° 3: A/P and lateral radiographs of T9-L3 osteosynthesis-arthrodesis with T1 laminectomy.
more vulnerable to injury due to the major stresses exerted in this transitional area with 15% of all spinal injuries occurring in this region. It is the second most common site of unstable spinal injury. The lumbo-sacral segment of the spine is less commonly involved but may be subjected to unstable injuries. Moreover, in 25% of the cases, patients with spine fractures have concomitant spine injury [6,7].

Fractures of the thoracolumbar junction may cause injury to the conus medullaris in the presence of regional kyphotic deformity and shortening of the posterior wall thus inducing two types of spinal cord injuries. Primary injury is the damage incurred during the initial insult and induced by compression forces at the origin of neural and vascular structure disruption. Four stages were described:

- spinal cord concussion which fully recovers within a few hours;
- spinal cord compression, responsible for persistent ischemia of the spinal cord;
- spinal cord contusion which leads to axonal degeneration associated with microhemorrhages;
- spinal cord transection.

Injury to the spinal cord triggers a complex cascade of enzymatic events at the origin of secondary lesions. These responses evolve in three successive phases: inflammation, healing and neuronal regeneration. Hypoperfusion resulting from the inflammatory and edematous phase, extends to the gray matter and adjacent white matter within a few hours. The local consequences include blood-brain barrier disruption and loss of auto-regulation, while the general consequences are systemic hemodynamic troubles contributing to the secondary aggravation of spinal cord-related disorders. At the cellular level, neuronal damage is characterized by the ischemia-reperfusion phenomenon with generation of elevated levels of inflammatory and hemostatic mediators, excitatory amino acids and free radicals.

Three fundamental notions result from these phenomena: the "ischemic penumbra" refers to the area of peri-necrotic tissue, which may evolve to apoptotic cell death or may recover. The "secondary aggravating factors" (hypotension, hypoxia, spinal cord edema...) which promote the extent of the lesions and "therapeutic window" defining the period of time during which the treatment will provides safe effective therapy and limit the extent of injury [1,8]. Then comes the healing process through which reactive astrocytes promote neuronal regeneration.

Clinical symptoms of complete conus medullaris injury include flaccid paraplegia immediately associated with priapism or loss of anal sphincter tone. It is first induced by the bone fragments, which are commonly retropulsed into the spinal canal in burst fractures. Moreover, post-traumatic kyphotic deformity (or torsion-dislocation deformity) leads to major spinal canal obstruction during trauma. There is no systematic radiographic evidence of the displacements occurring during trauma. Spinal canal occlusion prior to disruption of the posterior vertebral arch associated with kyphotic tension placed on the spinal cord is thought to be responsible for the lesion. This disrupting displacement is reflected through spontaneous kyphosis observed during initial assessment rather than through final occlusion. Treatment is based on three major principles, which are early spinal reduction, decompression and stabilization. Therefore, any trauma center should be able to provide appropriate emergency treatment at any hour of the day or night.

Surgical management of spinal trauma associated with incomplete SCI performed within 6 hours post-injury has been shown to improve neurologic outcomes, whatever the severity of the lesion. However, there is much debate about the best treatment strategy for complete neurological deficits. According to many authors, early surgery performed within 24 hours, 12 hours or even 8 hours shows no benefits [9–16]. According to McKinley et al. [17] early surgery does not improve neurologic outcome but is associated with shorter hospital stay and fewer complications. In contrast, Cengiz et al. [18], Papadopoulos et al. [19] and Rabinowitz et al. [20] admit that early surgery performed within 8 hours in patients with complete injury may enhance neurologic recovery. However, in the majority of these studies, “early” surgery is defined as being within 24 hours or even 72 hours after SCI, which is far beyond the well-admitted 6-hour timing for improved neurologic outcome [21]. A study was conducted to review the current opinion of 971 spine surgeons regarding the optimal timing of surgery after spinal cord injury and demonstrated that in most cases, early surgical management would be performed in neurologically incomplete injuries rather than in complete ones [10].

As illustrated in the three cases of our study, early decompression within 6 hours after trauma in patients with complete SCI improves neurologic outcome similarly as in those with incomplete SCI, despite uncertain prognosis. Urgent surgical decompression associated with fracture reduction and stabilization resulted in complete or partial functional recovery of the conus medullaris. As described by Dendrinos et al. [20], neurologic recovery is also dependent on restoration of the sagittal alignment of the spine.
through instrumentation. Restoration of anatomical lordosis has been shown to reduce the intracranial bone fragments through ligamentotaxis and decrease the amount of compression exerted at the spinal cord. Despite high-dose corticosteroid administration in our patients according to the NACIS III protocol [21], we remain convinced that timely surgery after spinal trauma is the most consistent predictor of enhanced neurologic recovery. Surgery should be performed within the shortest possible time if the patient condition and associated trauma injuries are favourable. It is a race against time, which requires appropriate expertise from all health care providers (firemen, emergency physicians, nurses, anaesthetists, surgeons) for optimal recovery. Despite the interest of emergency magnetic resonance imaging (MRI) in proper visualization of spinal cord injuries, such imaging modality could delay treatment in paraplegic patients and would only modify the indication for surgery in case of spinal cord transection. Therefore, we recommend MRI within the first postoperative days.

The thoracolumbar junction appears to be the most suitable spinal segment for early surgical treatment since trauma is located at the lower end of the spinal cord or horse’s tail [22—24]. Damages to the cervical segment with associated cerebral lesions as well as fractures of the upper thoracic spine associated with lesions of intra-thoracic organs are life-threatening conditions. Early spinal cord decompression and stabilization at these levels has thus generated considerable controversy since these segments are associated with poorer neurologic outcome.

Finally, two additional factors may influence spinal cord recovery. The first one is hemodynamic stability, which acts directly on spinal cord perfusion. In our observations, the mean arterial pressure remained stable within normal values during each surgical intervention. Moreover, the young age of our three patients is a well-known predictor of recovery. According to Van Middendorp et al. [25] the patient’s age is an early predictive factor for walking recovery in spinal cord injuries.

Conclusion

Spinal fractures involving the thoracolumbar junction are common due to the biomechanical stresses and may be associated with neurologic deficit in 15 to 30% of the cases. Surgical management of spinal fractures is advocated within 6 hours after trauma in patients with incomplete neurologic deficit. Moreover, in view of the outcome of the three consecutive Frankel A patients included in our study, early decompressive surgery based on an identical treatment modality should be considered as part of the therapeutic management of patients with complete SCI to ensure a possible neurologic recovery and reduce morbidity. Further prospective studies based on a larger cohort of patient should be conducted to confirm this hypothesis.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

References