Early intradural microsurgery improves neurological recovery of acute spinal cord injury: A study of 87 cases

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This research article is available in Journal of Neurorestoratology: https://tsinghuauniversitypress.researchcommons.org/journal-of-neurorestoratology/vol6/iss1/2
Early intradural microsurgery improves neurological recovery of acute spinal cord injury: A study of 87 cases

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ARTICLE INFO

Received: 12 October 2018
Revised: 04 December 2018
Accepted: 24 December 2018

Objective: To introduce a novel intradural microsurgery method for acute spinal cord injury, while evaluating the safety and effect.

Methods: 87 patients with complete spinal cord injury were enrolled and treated with the novel intradural microsurgery within 48 h, in addition to traditional surgical interventions (internal fixation, laminectomy).

Results: Complications including massive hemorrhage, infection and impairment aggravation did not occur during and after surgery. There were 16 cases of B grade, 13 cases of C grade, 6 cases of D grade based on the ASIA impairment scale 3 months after surgery, and average 18.51 increase in motor score, 16.64 increase in light touch score, 17.12 increase in pin prick score were achieved.

Conclusions: Early intradural microsurgery is safe, causing no neurological function lost and no major adverse event, and it is associated with neurologic improvement in patients with severe spinal cord injury.

1 Introduction

Spinal cord injury (SCI) is a disastrous clinical condition that usually leads to permanent neurologic impairment which is associated with severe physical, psychological, socioeconomic burdens on patients and their families. Since it typically affects young adults, mostly males, for whom SCI commonly means spending rest of their vigorous lives in the wheelchair. However the incidence of SCI has gradually increased with the expansion of human activities [1]. According to a latest systematic review and meta-analysis study, the incidence of SCI worldwide is approximately 105 cases per million population, or about 768,000 new patients each year, while 48.8% of these patients require surgery [2]. Thus, any therapeutic intervention aimed towards reducing the spinal cord damage and improving clinical outcome is of paramount importance.

Fortunately clinical neurorestorative therapies have already been able to help patients with complete chronic SCI partially restore their neurological function and improve quality of life [3].

Nowadays, an increasing number of clinical evidences have indicated that early surgical intervention may result in better neurologic outcomes on some of the patients [4–8]. However as far as decompression surgery is concerned, conventional surgical operations mainly focus on an immediate means of relieving physical pressure (laminectomy) as well as further protection against subsequent injuries related to instability (spinal internal fixation), while doing little to prevent progressive spinal cord damage. Utilizing microsurgical techniques as dealing with spinal cord tumors, we performed intradural microsurgery on acute spinal cord injured patients and preliminarily evaluated its safety and the clinical effects.

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2 Patients and methods

2.1 Patient population

A total of 87 patients (69 male and 18 female) aged 19–56 years with acute traumatic spinal cord injuries (no more than 48 hours) were enrolled. Among these patients, 52 were cervical injuries (C4–C7), 35 were thoracic injuries (T1–T12). All subjects were admitted in the Clinical Center for Spinal Cord Injury of the Chinese People's Liberation Army (PLA) between January, 2016 and December, 2017, who were informed in detail about the surgical procedures, giving written informed consent before surgical intervention. All procedures were approved by the Science and Research Committee of Kunming General Hospital of PLA.

All included patients were neurologically examined on admission according to standards established by the American Spinal Injury Association (ASIA) to confirm that their ASIA Impairment Scale were Grade A (ASIA A), which implicated that the patients had no perianal sensation and no voluntary contraction of the anal sphincter. X-ray, CT, and/or MRI were employed to determine the injury site and degree of spine and spinal cord damage.

2.2 Surgical intervention

Posterior pedicle screw fixation was first implemented to restore stability of the injured vertebrae. Then bilateral laminectomy was performed to expose the spinal cord at the site of injury. A vertebral canal exploration was applied to remove any hematoma or bone fragments. Then a longitudinal posterior midline incision of the dura was made according to spinal cord lesion dimensions assessed by preoperative MRI as well as onsite intraoperative observations. We examined the gross appearance of the cord and the status of the cerebrospinal fluid (CSF) flow of each patient to determine further procedures, under a surgical microscope, to remove spinal arachnoid adhesions to restore pulsations of the injured spinal cord. If the softening of the cord tissue was found at the injury site, a lateral longitudinal incision of the spinal cord at the posterolateral sulcus was performed to remove necrotic spinal tissues within the injured cord and to reduce intraspinal pressure. We summarized major intraoperative observations and associated surgical interventions that were implemented (Table 1). After intraspinal and/or subdural surgical procedures, the dura was sutured close. The connective tissue and skin were closed in layers.

2.3 Neurological evaluation

For each patient the ASIA motor, pinprick, and touch scores, as well as the ASIA Impairment Scale and the neurological level were evaluated according to standardized ASIA examinations [9] and recorded accurately before surgical treatment, 15 days and 3 months after surgery.

2.4 Statistical analysis

ASIA scores were expressed as means ± S.E.M. Differences between different time groups were determined with one-way ANOVA by SAS software (8.2). A value of \( P < 0.05 \) was considered to denote statistical significance.

Table 1 Intraoperative findings and corresponding surgical procedures.

<table>
<thead>
<tr>
<th>Intraoperative Findings</th>
<th>Surgical Procedures</th>
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<tbody>
<tr>
<td>(a) The spinal arachnoid was intact. The spinal cord appeared pale, swollen, lack of pulsation, but no softening.</td>
<td>Opened the spinal arachnoid by a longitudinal incision. Explored and removed adhesion of the spinal arachnoid to restore the pulsation of the cord and CSF flow.</td>
</tr>
<tr>
<td>(b) The spinal arachnoid was intact. The spinal cord appeared pale, swollen, lack of pulsation, and softening region of the spinal cord was found.</td>
<td>Opened the spinal arachnoid by a longitudinal incision. Explored and removed adhesion of the spinal arachnoid to restore the pulsation of the cord and CSF flow. Moreover, a 0.3–0.5 cm longitudinal incision was made over the tissue softening region to remove intraspinal softening necrotic tissue. The lesion cavity was rinsed with physiological saline gently.</td>
</tr>
<tr>
<td>(c) The spinal arachnoid was lacerated. The spinal cord tissue was severely damaged partly liquefied.</td>
<td>Explored the injury site. Open the dura longitudinally to allow the gush out of degenerated tissue. Washed the region gently with physiological saline.</td>
</tr>
</tbody>
</table>
3 Results

In this study, all the 87 patients were classified ASIA A at the time of admission to the clinical center with various degrees of vertebral column damage (fracture or/and dislocation, Fig. 1), showing no evidence of peri-anal sensation or voluntary anal sphincter contraction.

The surgical procedures were carried out within 48 hours after injury. During surgery different extent of the CSF flow blockade was found in every case. The contused spinal cord usually appeared edematous. Patches of surface pial hemorrhage could often be seen. At the center of the contusion site, pial blood vessels were sparse and the spinal cord was typically pale. In more severely injured spinal cords, gentle probing usually revealed a liquefied or softened region below the surface, covered by a thin layer of tissue (Fig. 2). In such cases, we incised the spinal cord to allow the underlying necrotic tissue to exit, and washed the opening with a gentle stream of saline.

At 15 days and 3 months after surgery, all the patients were carefully tested for motor and sensory scores, ASIA Impairment Scale. No subject lost motor or sensory function after surgery compared to preoperative levels. By 15 days after surgery, 59 patients (68%) remained ASIA A, 13 (15%) had become ASIA B, 11 (12%) had become ASIA C, and 4 (5%) had become ASIA D. While by 3 months after surgery, 52 patients (60%) remained ASIA A, 16 (18%) had become ASIA B, 13 (15%) had become ASIA C, and 6 (7%) had become ASIA D. None of the patients had recovered normal neurological function up till then. Table 2 lists the distribution of patients in each ASIA grade.

Mean motor and sensory scores clearly improved after surgery. We did repeated measures ANOVA to evaluate the effects of time (15 d, 3 m). As shown in Table 3, mean motor and sensory scores increased

Fig. 1 Imaging examinations before surgery.

Fig. 2 Morphology of injured spinal cord during surgery: (A) The spinal cord was hyperemic and swelling; (B) the necrotic tissue poured out during surgery.
after surgery. Repeated measure ANOVA revealed highly significant effects of different time on spinal cord function ($F = 3.86$, $P = 0.0065$). These results suggest that decompression surgery significantly affected neurological function recovery.

Throughout the study period, no subjects lost neurological function as a result of the surgery. No major adverse event occurred. Remarkably, no subjects developed urinary tract infections requiring antibiotic therapies, decubiti, thrombophlebitis, or other common complications of acute spinal cord injury.

**4 Discussion**

Acute spinal cord injury resulting from traumatic disturbance of the spinal cord elements is associated with tremendous societal and individual consequences. It has been widely accepted that acute SCI consists of the initial traumatic event, known as primary injury, followed by a prolonged and progressive cascade of secondary injury. Since the primary injury is inevitable and is best addressed through prevention, the identification of secondary injury as an important contributor to final neurological disability is a milestone and foundation for many principles underlying the medical and surgical management of SCI. Within seconds after the primary injury, the initial spinal cord trauma sets off a signaling cascade that drives a number of deleterious downstream events collectively known as secondary injury. Neuroinflammation, free radical formation, and lipid peroxidation lead to gradual expansion of the initial lesion in a rostrocaudal direction from the injury epicenter [10, 11]. The role of neuro-protection and therapeutic intervention lies in the preventing and mitigating such secondary injuries.

Besides realigning the spinal column and restoring spinal stability, surgery is now considered to have played an important role in decompressing the spinal cord and facilitating neural restoration [4, 12, 13]. However, in most cases the “decompressive surgery” referred to laminectomy and other operations relieving physical pressure outside the injured spinal cord, without operating on the spinal cord directly [8, 14–16].

According to the pathophysiologic process of secondary injury, spinal cord edema and secondary changes develop within hours of injury, peaking around day 3 to 6 post-injury, and then the injured spinal cord is gradually replaced by a central hemorrhagic necrosis. Theoretically, some of these secondary events might be ameliorated with appropriate surgical intervention on the injured spinal cord directly, exactly as neurosurgeons have always been dealing with cerebral contusion: opening the dura mater and clearing hemorrhagic necrosis.

In 1911, Allen described central hemorrhagic necrosis in contused dog spinal cords, reported that intramedullary decompression of the spinal cord improves neurological recovery, and proposed the theory of secondary injury in the spinal cord [17]. Afterwards, Perkins reported that 6 acute SCI patients achieved significant neurological improvement by
bony decompression of the spinal canal associated with durotomy, suggesting that dural decompression may be of some use in preventing a “compartment syndrome” of the spinal cord [18]. In this study, we utilized microsurgical techniques to perform intradural decompression on 87 acute spinal cord injured patients to determine whether such intramedullary debridement would be beneficial in acute human spinal cord injury. Our results indicated that the microsurgery to remove arachnoid adhesions and intramedullary decompression of the spinal cord is remarkably safe. No patient lost neurological function as a result of the surgery and no major adverse event occurred. Moreover, 35 of 87 (40%) patients converted from ASIA A to B, C, or D by 3 months. It was a remarkable progress comparing with that of 3%–14% spontaneous conversion rates from ASIA A to B, C, or D in other studies [19, 20], as well as that of 28% overall conversion rates after conventional osseous decompression surgery [21]. Meanwhile, mean motor and sensory scores of the patients increased significantly after surgery, and then remained increasing slightly over time.

As for the timing of surgical decompression, the Spinal Trauma Study Group identified the first 24 hours as the most promising time window during which decompression may afford neuroprotection [8, 22]. Furthermore, studies from Central Europe indicated that surgical decompression within the first 8 hours might be even more beneficial. Neurologic recovery was superior if surgical intervention occurred within the first 8 hours versus 8–24 hours [23, 24]. However, it makes sense to relieve the pressure or compression on the spinal cord as soon as possible in order to develop potential neuroprotective effects on spared neural tissue, exactly as treatment paradigms for osteofascial compartment syndrome. According to long-time clinical experience of our center, traumatic SCI is a neurologic emergency, which needs to be treated with similar paradigms as dealing with traumatic brain injury (TBI). In our opinion, surgical decompression should be applied as soon as possible when medically feasible. However, in the real world setting, quite a lot of factors often pose barriers to performing surgery in a timely fashion, which include pre-hospital transportation, diagnostic evaluation, medical stabilization, preoperative preparation and so on. That is the very reason why we performed decompressive microsurgery within 48 hours in this study, and we are working on shortening the time gap between emergency department and operation room in our daily clinical practice at present.

Although early surgical decompression for traumatic spinal cord injury appears promising, it is still far from a cure. The ultimate goal of surgery would be saving spared spinal cord tissue (neuroprotection) and providing preconditions for more neuroregenerative treatment strategies. So we would combine other neurorestoratological applications with early intradural microsurgery to treat severe spinal cord injured patients for better clinical and neurological outcomes in future studies.

5 Conclusion

Our study suggests that early intradural microsurgery is safe, causing no neurological function lost and no major adverse event, and it is associated with neurologic improvement in patients with severe spinal cord injury.

Disclosure

The authors report no conflicts of interest in this work.

References


