Clinical Note

Treatment of ‘Suicidal Jumper Fractures’ with Lumbopelvic Fixation: A Report of Nine Cases

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Abstract: To discuss the characteristics of Suicidal Jumper Fractures (SJF) and evaluate clinical outcomes treated with lumbopelvic fixation. From August 2007 to August 2012, nine consecutive cases with SJF were included into the study. The clinical data of these cases including fracture classifications, associated injuries and the degrees of neurological impairment were analyzed and assessed preoperatively. All cases were followed-up continuously after an average of 42 ± 4.54 months (range: 34-90 months). All fractures healed after 5 ± 1.53 months (range: 3-11 months). None of these cases had fracture re-displacement and fixation failure. Based on the Majeed scoring system, the postoperative prognosis of these patients were excellent in four cases, good in three cases, fair in one case, and poor in one case. There was a significant improvement in neurological deficiency in all postoperative patients, and their average Gibbons scores changed from 3.12 ± 0.23 preoperatively to 1.54 ± 0.45 postoperatively; and the difference was statistically significant (t=3.22, P<0.05). Lumbopelvic fixation has a significant advantage in the treatment of this series of fractures, and can help obtain a satisfactory clinical outcome. Intraoperative nerve decompression is necessary if indications exist and the improvement of neurological impairment is optimistic.

Key words: Surgical management, Lumbopelvic fixation, Suicidal Jumper Fracture, Clinical prognosis

Introduction

Suicidal Jumper Fractures (SJF) refer to a series of complicated sacral fractures that consists of a transverse fracture line, which shears the sacral canal and bilateral intraforaminal longitudinal fracture lines; resulting in spinopelvic dissociation\textsuperscript{1-3}. The fractures result from high-energy injuries, of which the most common mechanism is suicidal falling; and this is always associated with neurological impairment\textsuperscript{4}. This type of fracture is classified into two subtypes: U-shaped and H-shaped fracture. Both subtypes have similar pathological characteristics of injury.

SJF are rare, and its occurrence rate is 3%-6\textsuperscript{\%}\textsuperscript{5,6}. The sacrum is the mechanical nucleus of the axial skeleton, and serves as the base of the spinal column, as well as the keystone of the pelvic ring\textsuperscript{6}. SJF results in traumatic spinopelvic dissociation and complete instability of the posterior pelvic ring, which can leave over unaccepted severe complications such as the inability of standing and walking due to nonunion or malunion of fracture, progressive nerve injury and cauda equin syndrome; and lastly, lumbo-sacral pain, if the surgical procedure is not undertaken. In recent years, internal fixation has shown marked advantages including the reconstruction of the stable load axis from the spine to the pelvic ring. This allows patients to bear the weight early and protects the local neuroanatomy from additional injury, which may be caused by progressive fracture deformity; improving the life quality of patients\textsuperscript{5,6,7}.

There is no standard paradigm to formulate the selection of the type of internal fixation treatment for SJF. Iliosacral screws, the transiliac rod and the transsacral plate have been reported. At present, more and more surgeons advocate lumbopelvic fixation, which was designed and applied by Käch and Trentz\textsuperscript{6}, and improved by other surgeons. This fixation can afford more reasonable biomechanical models, more fixed strength, and better neurological deficiency improvement\textsuperscript{5-8}.

This study focuses on the injury characteristics of SJF, the prognosis of SJF treated with lumbopelvic fixation, the advantages of this implant, and its related issues.

Materials and Methods

Inclusion criteria: 1. SJF treated with lumbopelvic fixation; 2. Accurate evaluation the prognosis of patient, the reduction quality of fracture and neural healing; 3. Continuous follow up more than 30 months and the data was integral.

Exclusion criteria: 1. Open sacral fracture; 2. Associated severe internal medical disease or other contadications which can not allow the operation. 3. Loss of follow-up in 30 postoperative months.

This study was conducted in accordance with the declaration of Helsinki and approved by the Ethics Committee of The Second Hospital of Tianjin Medical University (NO. KY2021K006). From August 2007 to August 2012, nine consecutive cases were selected and included into this study from 13 SJF. Among the excluded patients, two were open sacral fractures, one had serious pressure sore preoperatively and could not accept surgical management of fracture, and one patient lost follow-up postoperative 12 months. The medical records of the nine patients were retrospectively reviewed. According to the morphology, U-shaped fractures were in four cases and H-shaped fractures were in five cases. According to the Roy-Camille classification, six cases were...
type II and three cases were type III. The following injury data were collected: gender, age, mechanism of injury, Injury Severity Score (ISS) score, associated injuries, and neurological impairment score graded based on the Gibbons classification (Table 1). All patients had the pelvic anterior ring injuries, which pubic rami fractures in 7 cases and pubic symphysis dissociation in 2 cases. and associated injuries and the detailed data were listed in Table 1.

All patients followed Advanced Trauma Life Support (ATLS) protocol during the acute phase of treatment. Resuscitation and urgent operation such as laparotomy and thoracic drainage were performed in emergencies, and patients were transferred to the intensive care unit (ICU) to accept further treatment based on the Damage Control Orthopaedics (DCO) principles, until their physiological conditions were allowed to accept the definitive operation. The standard preoperative plan included the physical examination of neurological deficiency, an imaging examination to assess the lateral displacement, inclination angular and rotational deformity degree of sacral fracture. Every patient accepted three dimensional (3D) CT regularly with GE gem energy spectrum CT which the slice thickness and interval were both 5mm while the pitch was 1.375. Then the data were collected and transfer to AW4.6 wok station to reconstruct the sacrum with the slice of 0.625 mm in order to evaluate the degree of sacral canal and foram en compression in the patients who had neural injured symptoms, MRN (magnetic resonance neurography) of lumbosacral plexus was necessary to judge the damage level of nerve and locate the focal area which was need to decompression intraoperatively.

Operative techniques

The patient was placed in the prone position on the operation bed, which can assure free fluoroscopy after general anesthesia.

The median incision was from the L3 spinous process to the S3’s. The bilateral erector spinae were dissociated and exposed the laminae, transverse processes, articular processes of L4 and L5, and the laminae of the sacrum.

The pedicle screws were inserted through the bilateral pedicles of L4 or L4 and L5. The amount of screws depended on the degree of fracture displacement, and the complexity of reduction was prejudged preoperatively. Then, the deep fascia was dissociated and incised to expose the bilateral posterior superior iliac spines (PSIS). One or two pairs of Schantz screws were inserted 10cm deep in the direction from PSIS to the anterior inferior iliac spines and between the medial and lateral lamina of iliac wing. The bone around the Schantz screw ends was partly removed to avoid the prominence of internal fixation. The lateral modal connectors and pre-contoured rods were placed, and the pedicle and Schantz screws were connected.

Nerve decompression should be performed before the reduction of fracture. In our study, six cases with a score >2 points based on the Gibbons classification, who had traumatic spinal canal stenosis or sacral nerve compression induced by displaced fragments of the fracture with preoperative imaging examination, accepted sacral laminectomy and neurolysis. The compressed fragments were removed, and the sacral nerves were dissected and completely loosened.

The reduction of vertical displacement was obtained through the distraction of the device. Rotational deformity and horizontal displacement were corrected with reduction clamps and extra Schanz screws, which were temporarily inserted to the upper sacrum to manipulate the fracture element as a joystick. Intraoperative AP and lateral fluoroscopy are important to evaluate the quality of the reduction. As soon as the satisfied reduction was obtained, all connectors were screwed up; and the transversely connected instruments were fixed to form a stable triangular fixation.

Lumbosacral spondylodesis was perfumed in three patients who had injuries of the lumbosacral conjunction, in order to prevent joint instability postoperatively.

Irrigation and vacuum drainage instruments were applied, and the wound was closed. The operations of pelvic anterior ring injuries were performed simultaneously after the procedure of lumbopelvic fixation. Open reduction were perfomed and the injury were fixed with reconstruction locking plate.

Postoperative treatment

The antibiotic was transfused at 48 hours postoperatively, in addition to the regular application performed preoperatively and intraoperatively. The drainage instrument was removed at 48-72 hours postoperatively, according to the amount of drainage fluid. Low-molecular heparin was applied regularly as thromboprophylaxis during the admission period. Rehabilitation was planned and performed by a physical therapist as soon as the physical and wound condition allowed.

Follow-up and clinical outcome evaluation

Follow ups were undertaken regularly. The schedule of follow ups was four weeks, eight weeks and every three months postoperatively.

Table 1. Information of patients

| No. | Gender | Age | Mechanism | Morphological classification | Roy-Camille classification | Gibbons score | Associated injury | ISS score |
|-----|--------|-----|-----------|-----------------------------|---------------------------|--------------|------------------|----------|
| 1   | M      | 35  | Falling   | U                           | II                        | 3            | Scapular fracture, L1 fracture, multi-rib fractures, traumatic wet lung | 34       |
| 2   | M      | 50  | Falling   | H                           | IV                        | 4            | Urethra disruption, distal radius fracture | 50       |
| 3   | F      | 40  | Falling   | U                           | II                        | 2            | Tibial and fibular fractures | 25       |
| 4   | M      | 39  | Falling   | H                           | II                        | 4            | Bilateral acetabular fracture | 25       |
| 5   | M      | 30  | Falling   | H                           | III                       | 2            | T12 fracture, distal radius fracture | 34       |
| 6   | M      | 43  | Falling   | H                           | III                       | 2            | Spleen rupture, DVT, horrible tride | 66       |
| 7   | M      | 23  | Falling   | H                           | III                       | 3            | Bilateral calcaneal fractures | 29       |
| 8   | M      | 20  | Falling   | U                           | IV                        | 3            | Morel-Lavelle lesion, acetabularfracture, calcaneal fracture | 50       |
| 9   | F      | 40  | Traffic accident | H                     | III                       | 3            | Morel-Lavelle lesion, hemothorax | 22       |
Physical examinations were applied to evaluate the degree of neurological impairment and daily-life ability improvement, and the imaging exams (3D CT reconstruction) were performed to judge the degree of fracture healing. The sacral fracture healing were defined as both vertical fracture lines were disappeared or surrounded by continuous callus at no less than consecutive four slices which the thickness was 0.625 mm.

Results

All operations of SJF were undertaken by same group of surgeons for 5-24 days (range: 12 ± 3.42 days) after primary injuries. The average time of the procedure was 225 ± 32.71 minutes (range: 130-450 minutes) and the average amount of intraoperative bleeding was 730 ± 43.53 ml (range: 400-3,000 ml). None of the patients had severe complications or died intra- or post-operatively.

All patients were followed up consecutively, and the average period of follow up was 42 ± 4.54 months (range: 34-90 months). All fractures were healed, and the average time of healing was 5 ± 1.53 months (3-11 months). None of the cases had fracture re-displacement or fixation failure.

In Roy-Camille type II fractures, preoperative PI changed from 78.2 ± 5.42 degrees to 54.2 ± 3.57 degrees postoperatively.

According to the Majeed evaluation system, four cases was excellent (Fig. 1), three cases was good, one case was fair, and one case was poor because of the fracture was old and difficult to reduce.

There were significant improvements in neurologic impairment in all postoperative patients Even three patients who did not undergo the nerve decompression had significant changes of feeling parathesia. The other six cases all had improvements of neurological deficiency at different degrees postoperatively. In our study, one patient keep the partial dysfunction of the bladder, one patient had not restored the unilateral plantar flexion of the ankle completely, and the feeling of abnormality lasted in three patients. At the last follow up, the average Gibbons score changed from 3.12 ± 0.23 preoperatively to 1.54 ± 0.45 postoperatively.

Three cases had complications, postoperatively. One patient had wound superficial infection, which healed with debridment and irrigation. One patient had posterior prominence of internal fixation and complained pain. The fixation was removed one year postoperatively as soon as the fracture healed and the symptom disappeared. One patient who had Morel-Lavallee lesion and healed preoperatively recurred after three months postoperatively. Bursa resection and vacuum suction were performed, and the hematoma did not recur.
Injury characteristics

SJF have special pathological and imaging characteristics, which include:

1) The diagnosis of SJF is often missed or delayed due to the difficulty in imaging the upper sacrum on the anterior-posterior pelvic radiograph with the inclination of the sacrum and the overlying bowling gas. Physiological examination and some specific imaging sign such as paradoxical inlet view and stepladder sign are important indexes of suspicion, and multi-planar CT is necessary for diagnosis.

2) Injury energies are high, and the most common mechanism is suicidal falling from a high place. Injury energy loads through spine-sacrum axis further shear the sacrum or lumbosacral region in the status of excessive flexion or extension, resulting in fractures of the weak parts of the sacrum. One transverse and two longitudinal fractures resect the sacrum and lead to spinopelvic dissociation. The fractures are completely unstable, and sagittal or horizontal displacement, as well as angular and rotational deformity, occurs frequently.

3) We prefer to classify SJF into type IV, according to the Hannover classification; which is most compatible for the morphology of this series of fractures. U-shaped and H-shaped fractures are the described classifications and are not standard. SJF can be typed according to the Dennis classification based on the different positions of the longitudinal fracture lines, or classified according to the Roy-Camille classification based on the displacement directions of the superior sacral fragments.

4) The fracture lines of SJF simultaneously involve the sacral canal and bilateral sacral foramen, and this easily results to neurological deficiency that ranges from incomplete monoradiculopathies to complete cauda equine syndrome. König et al. reported that the incidence rate of nerve injury in U-shaped fractures was 94.3%. In our study, all patients had neurological deficiencies, in which the degrees were different. In some SJF cases, the L5 nerve can be injured as a result of vertical shear displacement of the posterior pelvic ring, and the far-out syndrome may occur.

5) SJF almost have associated injuries, and the scores of ISS are high. DCO protocol should be undertaken throughout the whole treatment period if the injury is severe (ISS>17). Soft tissue injuries of the pelvis and peripheral region must be given particular attention. If a Morel-Lavalle lesion exists, it must be cured before a definitive operation, in order to avoid severe infections and skin necrosis.

Discussion

SJF are completely unstable, results in traumatic lumbarpelvic dissociation, and almost associates with nerve injury. Therefore, surgical management is necessary. The purpose of the operation is pelvic ring reconstruction, lumbarpelvic stability restoration, fracture displacement prevention, or correction to improve neurological deficiency. More and more surgeons have advocated this option; and in their study, internal fixation has shown marked benefits over conservative treatment.

Many studies have proven the advantage of lumbarpelvic fixation over other fixations such as iliosacral screws, posterior plating and sacral rods, and have shown excellent clinical outcomes.

We concluded the advantages of lumbarpelvic fixation as follows:

1) In most SJF, the fixation can provide indirect reduction and fixation of fractures simultaneously, on order to facilitate the procedure of reduction, avoid excessive exposure, and prevent additional bleeding and extra operation time caused by direct reduction.

2) The procedure of reduction with lumbarpelvic fixation is the reversed simulation of the injury mechanism and fracture displacement, which is more accordant with biomechanical principles.

3) The fixation formulates a three-dimensional interlocking structure to obtain more fixed strength in the region of the lumbar-lumbosacral conjunction-bilateral iliac wings. Biomechanical analysis has confirmed that lumbarpelvic instrumentation is among the most stable methods of posterior pelvic fixation, and the superior mechanical stability of such structure has been proven by many authors. Otherwise, lumbarpelvic fixation unloads the area of injury by mimicking the normal load transfer from the acetabulum across the sacroiliac joints to the lumbar spine, in order to avoid the shear force on injured area of the sacrum.

This can prevent progressive nerve injury and re-displacement of the fracture, which can create a stable circumstance to help fracture union. Kanezaki et al. reported 19 cases using lumbarpelvic fixation, in which every patient was mobilized immediately and allowed to weight bear and ambulate. A total of 17 patients with more than 12 months of follow-up achieved satisfactory bone union without loss of reduction.

4) Many studies have focused on pelvic incidence (PI), which is a reduction guide to assess the reduction quality of sacral fractures associated with spinopelvic dissociation. They concluded that PI was a valuable radiographic parameter that can be used to assess the adequacy of the sagittal planar reduction of displacement and angular deformity in patients with spinopelvic dissociation. In our study, PI of the six Roy-Camille type II fractures had significant improvements and changed to

Lumbarpelvic fixation

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normal range postoperatively. This indicates a high bone healing rate and low complication occurrence rates\(^\text{29}\). Furthermore, we can conclude that the lumbopelvic fixation can guarantee a higher quality of reduction and have the possibility of better prognosis.

5) Unlike other instrumentation, lumbopelvic fixation does not utilize or occult the sacrum to fix. This provides a wider exposure intraoperatively, which is in favor of performing nerve decompression; allowing it to loosen more efficiently and completely.

**Sacral nerves decompression**

In our study, all SJF patients were associated with sacral neurological impairment. The occurrence rate of nerve injury in U-shaped fractures in literature is 69%; and 22% of these injuries are permanent\(^\text{3, 4}\). Lindahl and Hirvensalo\(^\text{26}\) documented permanent neurological injury as a strong poor prognostic factor. Therefore, the effort to recover the function of the damaged nerve is vital for treatment. Some reports have shown that there is no difference between conservative treatment and the operation on treating nerve injury of traumatic spinopelvic dissociation\(^\text{33}\). Nevertheless, most surgeons advocate that early surgical inference can obtain better improvement of neurological impairment\(^\text{27, 28}\).

Liuzza et al.\(^\text{34}\) concluded that the chance of neurological improvement is very low when there are bilateral tangential or avulsions of nerve roots. However, the sacral roots subjected to compression, contusion, or traction caused by displacement and angulation of the sacral fracture fragments has a theoretical chance of recovery. Surgical management should be undertaken when the symptom and sign of nerve injury are significant (Gibbons III and IV), the free bone fragments are proven to compress nerves, and the sacral canal or sacral foramen have significant deformation and stenosis.

Decompression of neural elements is preferably undertaken early, within the first 24-72 hours, in order to minimize the chance of further injury\(^\text{29}\). Decompression of the sacral nerve roots after fracture healing is more difficult due to epineural fibrosis and increased scarring of the sacral canal and foramen. Decompression should be performed either indirectly with fracture reduction or directly with laminectomy or focal foraminotomy. Complete or partial sacral laminectomy should be performed when occlusion of the central canal is determined on CT scan. The nerve roots should be traced to its anterior foraminal exit and any occupied free bone fragments must be removed. Sacral nerve root decompression should be performed before reduction even in the absence of neurological abnormality, if the CT scan indicates the presence of intraforaminal bone fragments, which may injure the nerve roots during fracture reduction. At the same time, the correction of translation and angulation can enhance the decompression of the tented sacral roots\(^\text{1, 14}\).

**Complications of lumbopelvic fixation**

The posterior prominence of iliac screws related to lumbopelvic fixation is a frequent complication that induce local pain and occasionally even decubitus ulceration and infection\(^\text{15}\). Screws that are not initially prominent at the time of surgery may become more prominent secondarily to weight loss due to nutritional deficiency. Partial bony resection at the starting point and countersinking screws can intraoperatively decrease the problem effectively\(^\text{30}\). Breakage of the rod occurs occasionally. The reason of this complication is that the surgeon fails to notice the lumbosacral conjunction injury, and does not perform fusion of the joint, which results in the instability and excessive motion of the injured area; and this eventually leads to the fatigue failure of fixation. Other complications reported include infection and skin necrosis of the wound, inferior lumbar pain and screw loosening; which are infrequent.

In conclusion, SJF are complicated fractures and have specific injury characteristics. The lumbopelvic fixation has been proven to be effective in treating this series of fractures and has an irreplaceable advantage.

**Competing Interest**

The authors declare that they have no competing interests.

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