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Value of Direct Decompression of Lumbosacral Roots in Sacral Fractures with Neurologic Deficit: Is It Mandatory?

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Background: The value of direct decompression of neural structures to treat lumbosacral plexus injury associated with sacral fractures is still debatable. Direct decompression allows decompression of nerve roots by sacral laminectomy and removal of bone fragments in the spinal canal. In contrast, indirect decompression may offer similar neurological outcomes if good fracture reduction and correction of sacral kyphosis are achieved. In this comparative retrospective study, we analyzed differences between direct and indirect neurological decompression in terms of neurological recovery, complications, and functional outcome.

Methods: This study included 33 cases with spinopelvic dissociation with variable degrees of lumbosacral plexus injury. All cases were managed by spinopelvic fixation. Eighteen patients (group 1) had direct decompression of lumbosacral nerve roots while 15 patients (group 2) had indirect decompression.

Results: Initial sacral kyphosis, quality of fracture reduction, and postoperative residual kyphosis were the main factors that significantly affected functional and neurological outcome in both groups. The final neurological improvement was similar in both groups. No significant difference was observed between both groups in the residual Gibbons' score recorded in the last visit (p = 0.206). The final Majeed score also showed no significant difference between the two groups (p = 0.869).

Conclusions: Indirect decompression of sacral fractures showed similar final functional outcome and neurological recovery compared to direct decompression. Restoration of lumbosacropelvic stability and anatomic reduction seem to be the cornerstone for better functional outcome and neurological recovery rather than direct decompression of neural elements.

Keywords: *Spinopelvic fixarion, Sacrum, Cauda equina, Pelvic fracture*

Lumbosacral plexus injury associated with spinopelvic dissociation is considered a challenging problem that, if not properly treated, might lead to progressive disabilities. The lumbar and lumbosacral plexuses are both vulnerable to injury with pelvic fractures.[1] Some studies have identified the pathogenic mechanisms of lesions to the lumbosacral plexus resulting from pelvic fractures, including radicular stretching or root avulsion.[2,3] Several studies on management of vertically unstable pelvic fractures and spinopelvic dissociation are available in the literature. However, the reports on management of associated lumbosacral plexus injuries are scarce. Is it necessary to have direct neurological decompression or will just indirect decompression suffice? The final neurological recovery following open decompression was noted to have almost comparable results even to nonoperative treatment.[4]

To date, it is clear that there is no solid consensus among pelvic surgeons on the effect of direct neurological decompression in such cases. Our aim was to compare the efficacy of direct versus indirect decompression of lumbosacral plexus during spinopelvic fixation for treatment

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of spinopelvic dissociation and the analysis of different factors that can influence the final outcome in both procedures.

METHODS

This retrospective study was conducted after approval of the ethical committee of Elbank Elahly Hospital, Cairo, Egypt (No. 19-2022/14). The patients received an explanation of the procedures and possible risks of the surgery and gave written informed consent. All the patients in this study have given their informed consent for the article to be published.

The study inclusion criteria were comminuted sacral fractures associated with sensorimotor neurologic deficit, with or without bladder and/or bowel dysfunction, in patients older than 16 years old and treated by spinopelvic fixation either with direct or indirect neural decompression. Cases treated by using iliosacral screws were excluded from the study to standardize the procedure in all cases. The 16 years of age limit was chosen to exclude pediatric pelvic fractures, which usually have other management considerations. Neglected old fractures, nonunited sacral fractures, and revision surgeries were also not enrolled. Another 6 cases were also excluded due to inadequate follow-up data.

From January 2013 until December 2020, 33 cases with lumbosacral plexus injury associated with spinopelvic dissociation were managed and followed up in our trauma center. All patients received the standard emergency management according to Advanced Trauma Life Support guidelines in accident and emergency department and then referred to orthopedic department for definitive treatment. Once generally stabilized, all cases were managed definitively by spinopelvic fixation through a midline posterior approach, with either direct (group 1) or indirect decompression (group 2), and followed up for an average of 12 months (range, 9–18 months). Group 1 included 18 patients, while group 2 included 15 patients.

Patients who failed to participate in a detailed preoperative neurological assessment due to associated brain or spine injuries were not included in our study since their postoperative neurological status could not be accurately attributed to either the index trauma or iatrogenic injury. Patients who were not able to urinate spontaneously due to pain associated with the pelvic fracture were considered having normal urinary control so long as their perianal sensation and anal tone were adequate.

Preoperative Evaluation

Neurological deficit was diagnosed on admission according to American Spinal Injury Association (ASIA) score and Medical Research Council (MRC) grading scale and then categorized according to Gibbons' classification (Fig. 1A).[5] Tibialis anterior and extensor hallucis longus muscles were examined to assess L4 and L5 roots, respectively. Ankle plantar flexors were used to examine S1 root. The injury was considered incomplete when muscle power examination was recorded 2–4 on MRC scale or in case of isolated sensory affection on a dermatomal distribution.

A Gibbons' classification	
Fracture grade	Criteria
Grade 1	Normal
Grade 2	Sensory deficit
Grade 3	Motor deficit
Grade 4	Bowel and bladder dysfunction
B Roy-Camile classification	
Fracture	Criteria
Type 1	Only flexion deformity (kyphosis angulation) on fracture site
Type 2	Flexion deformity and translation of fracture
Type 3	Complete anterior translation of lumbar spine and upper part of sacrum
Type 4	Impaction of upper segment of sacrum due to the axial load
C Denis classification	
Fracture	Criteria
Type 1	Fracture in sacral, lateral to the sacral foramens
Type 2	Fracture through the sacral foramens, transforaminal fracture
Type 3	Fracture medial to the foramens and through the canal

Fig. 1. (A) Gibbons' classification. (B) Roy-Camile classification. (C) Denis classification.

A needle prick sensitivity test was performed for dermatomal sensitivity assessment. Tendon reflexes were routinely tested: patellar tendon jerk for L4 root and Achilles reflex for S1 root.

Competency of anal sphincters by digital rectal examination and perianal sensation were evaluated and recorded in all cases. The findings were documented in ASIA chart including sensory, motor, and reflexes to facilitate the postoperative monitoring of neurological improvement. Preoperative electromyogram and nerve conduction studies were not carried out in all patients. All fractures were evaluated by plain X-ray (anteroposterior, inlet, and outlet views of the pelvis) and fine cuts three-dimensional computed tomography (CT) and were classified accordingly by Roy-Camille (Fig. 1B)[3] and Denis classifications (Fig. 1C).[6]

Preoperative sacral kyphosis angle was carefully measured to determine its reflection on the final outcome (Fig. 2). Timing of spinopelvic fixation surgery was planned as an urgent procedure to avoid any unnecessary delay, especially in patients with incomplete neurological deficit. All patients received perioperative venous thromboembolism prophylaxis.

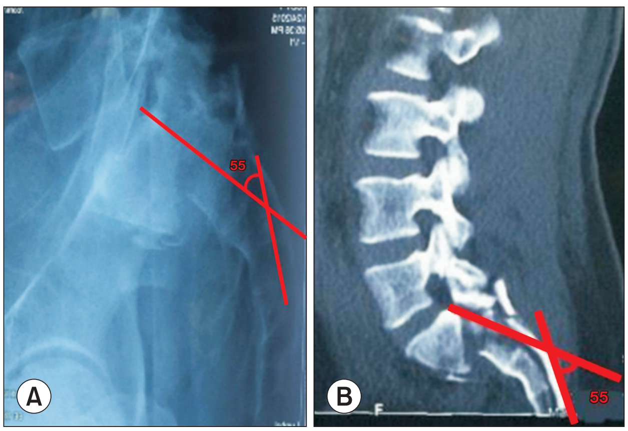

Fig. 2. Preoperative measurement of initial sacral kyphosis angle in lateral view X-ray (A) and sagittal computed tomography (B).

Surgical Technique

Surgical management was done in a single stage under general anesthesia. Firstly, anterior pelvic ring injury was usually addressed by symphyseal plate or infix spinal system in supine position. Afterwards, posterior ring fracture was subsequently managed through posterior midline approach from L3 to S4 levels while the patient was in prone position on a radiolucent table. The skin of the lower back was scrubbed and draped in the ordinary manner including both lower limbs to allow traction and fracture reduction. Soft tissue and paravertebral muscles were dissected subperiosteally so as to obtain an access to L4 and L5 pedicles bilaterally. Through the same approach, an access above the erector spinae muscle fascia was obtained to expose the posterior superior iliac spine (PSIS) on both sides for iliac screw insertion.

The choice between direct and indirect decompression was almost always debatable. It was usually decided by each surgical team based on surgeon's preference, clinical judgment, degree of sacral canal compromise, and intraoperative fluoroscopic evaluation of fracture reducibility. However, there were no strict guidelines favoring one procedure over the other.

In group 1, direct neurological decompression and laminectomy were done before definitive reduction and fixation. Sacral fracture was exposed carefully by a spine surgeon (Fig. 3A). Laminectomy from L5 down to S4 was

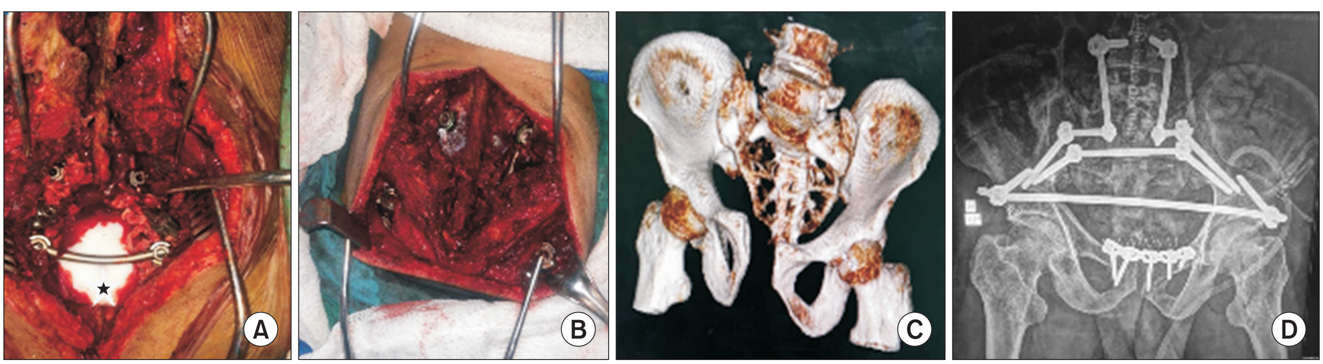

Fig. 3. (A) After direct decompression, asterisk points to gel foam covering the laminectomy. (B) Indirect decompression, showing lesser soft-tissue dissection. (C) Preoperative three-dimensional computed tomography of a case in group 2 showing spinopelvic dissociation. (D) Immediate postoperative picture showing anatomical reduction and fixation of a case in group 2 (Note: anterior infix system was added because the screws of symphyseal plate were loose).

performed with preservation of L4–5 and L5–S1 facet joints to preserve lumbosacral junction stability and to negate the need of lumbosacral fusion. Bony fragments inside the sacral canal and neural foramina were excised as much as possible. Foraminal decompression starting from L4 down to S4 nerve root was also done to decompress all the roots of lumbosacral plexus especially on the affected side with observation and assessment of the integrity of all roots of lumbosacral plexus for postoperative documentation. Any discovered dural tears either from the trauma or iatrogenic tears were repaired by non-absorbable suture or muscle patch based on its size, location, and whether the tear was repairable or not. After finishing decompression, fracture reduction and fixation were routinely performed in the same way as in group 2 as described below. Final check of the decompression after completion of fracture reduction and fixation was performed by a blunt hook to assess free mobility of all roots.

In group 2 (Fig. 3B-D), indirect decompression was achieved through fracture reduction by longitudinal traction of both lower limbs without exploring the neural elements. During fracture reduction in both groups, major efforts were usually focused on reducing the sacral kyphosis as a main indicator of achieving good reduction. Longitudinal traction while both hips in extended position was usually beneficial to correct sacral kyphosis and reduce sacral shortening. Two 4.5-mm cortical screws were placed in the PSIS bilaterally to be used as fixation points for the large pelvic reduction clamp to reduce vertical displacement of the injured hemipelvis and to maintain the reduction obtained primarily by longitudinal traction (Fig. 4A). Once the reduction was satisfactorily checked under fluoroscopy, two 7-mm polyaxial screws with an appropriate length (usually 60–80 mm) were placed into the PSIS bilaterally just below the level of the previously placed cortical screws. The direction of screws should usually aim at the anterior inferior iliac spine. The bone bed of the iliac polyaxial screws was nibbled by a rongeur before final tightening to reduce the screw head prominence in order to reduce postoperative wound complications.

A contoured 6-mm titanium rod was placed transversely to connect the polyaxial screws' heads. The two cortical screws were then removed and another two 7-mm polyaxial screws were put in their tapped tracks. Two molded titanium rods were passed through tracks made in the paraspinal muscle fascia. These two rods were used to connect the iliac screws to pedicular screws inserted in L4 or L5 bilaterally to complete the construct assembly (Fig. 4B). The wound was closed tightly with two layers of fascial suturing, subcuticular skin sutures, and suction drain (Fig. 4C). Non-suction subcutaneous drain was used in case of associated dural tears repaired by muscle patch.

Postoperative Care

Patients were instructed about the wound care and advised to avoid prolonged supine position in order to decrease wound complications related to screws prominence. Wounds were followed up weekly until complete healing. Non-weight-bearing protocol continued for 2 weeks, then gradual partial to full weight-bearing started as tolerated based on the status of associated injuries. Radiographs including lumbosacral and pelvic views were taken immediately postoperatively and monthly in the first 3 months to assess union and fulfill Matta radiological scoring for quality of fracture reduction. Follow-up assessment included wound status, neurological status, range of motion of the affected limb, and progression of union. Functional assessment was evaluated in every visit by Majeed[7] and neurological improvement was assessed by Gibbons' criteria.

Instrumentation Removal

In our protocol, posterior instrumentation removal was planned on average 12 months after the index surgery since primary spinopelvic fusion was not performed. In patients who had anterior infix for anterior ring stabilization, removal of the infix was routinely performed 3–6 months after the index surgery. All patients consented to

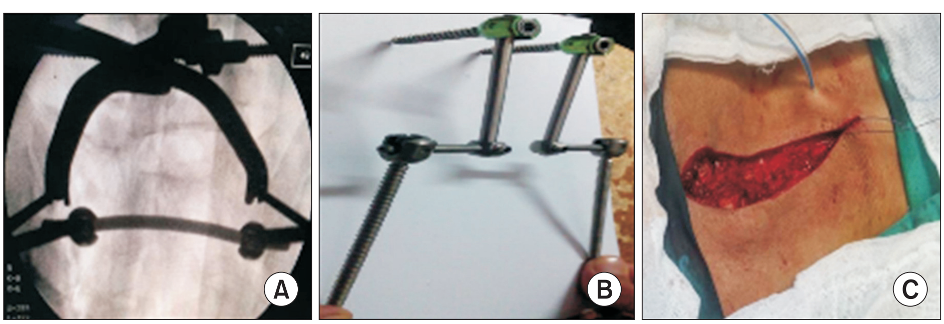

Fig. 4. (A) The use of a pelvic reduction clamp in reduction of posterior ring fracture. (B) A model of implant assembly in preoperative planning. (C) One of the cases showing wound status after indirect decompression with good fascial coverage over the hardware.

the removal surgery from the beginning. The implant removal surgery was done after complete fracture union was confirmed clinically and radiologically by plain X-ray or CT.

Statistical Analysis

IBM SPSS statistics ver. 26.0 (IBM Corp., Armonk, NY, USA) was used for data analysis. Data were expressed as median and percentiles for quantitative nonparametric measures, in addition to both number and percentage for categorized data. Interquartile range (IQR) is the 25–75 percentile range. The following tests were done: (1) comparison between two independent groups for nonparametric data using Wilcoxon Rank Sum test and (2) chi-square test to study the association between two variables or compare the two independent groups with regard to the categorized data. The probability of error at 0.05 was considered significant, while at 0.01 and 0.001 was highly significant.

RESULTS

Perioperative Data

The data illustrated in Table 1 showed the perioperative and demographic records of both groups. The median age in both groups was 30 years (IQR: group 1, 25–38; group 2, 27–33). Group 1 included 6 women (33.3%) and 12 men (66.7%), while group 2 included 3 women (20%) and

Table 1. Analysis of Significance of Different Factors by Wilcoxon Rank-Sum Test

Variable	Group*	Median (IQR)	Z	*p*-value	Significance
Age (yr)	1	30 (25–38)	–0.327	0.744	NS
	2	30 (27–33)			
Delay to surgery (day)	1	2 (1–3)	–1.023	0.307	NS
	2	2 (2–3)			
Operative time (min)	1	180 (160–180)	–3.891	0	HS
	2	120 (120–140)			
Majeed score	1	80 (76–88)	–0.165	0.869	NS
	2	78 (77–85)			
Residual Gibbons' score	1	1 (1–2)	–1.264	0.206	NS
	2	2 (1–2)			
Follow-up period (mo)	1	12 (9–12)	–1.398	0.162	NS
	2	12 (12–18)			
Fracture union (mo)	1	9 (8–10)	–1.332	0.183	NS
	2	8 (8–8)			
Implant removal (mo)	1	12 (6–12)	–1.707	0.088	NS
	2	12 (12–12)			
Roy-Camille type	1	2.5 (2–3)	–0.573	0.567	NS
	2	3 (2–3)			
Initial sacral fracture kyphosis angle (°)	1	32.5 (0–45)	–0.277	0.782	NS
	2	30 (0–55)			
Residual sacral fracture kyphosis angle (°)	1	9 (0–20)	–0.111	0.912	NS
	2	15 (0–15)			

IQR: interquartile range, NS: not significant, HS: highly significant.
*Group 1: n = 18, Group 2: n = 15.

12 men (80%). Falling from a height was the mechanism of injury in 12 patients (66.7%) in group 1 and 9 patients (60%) in group 2, while road traffic accident was the mechanism of injury in 6 patients (33.3%) in group 1 and 6 patients (40%) in group 2. The neurological injury was incomplete in 6 out of 18 patients (33%) in group 1 and 3 out of 15 patients (20%) in group 2.

In group 1, preoperative Gibbons' score was 3 in 15 patients (83.3%) and 4 in 3 patients (16.7%). In group 2, preoperative Gibbons' score was 3 in 12 patients (80%) and 4 in 3 patients (20%) with insignificant difference between both groups. The median Roy-Camille type was 2.5 (IQR, 2–3) in group 1 and 3 (IQR, 2–3) in group 2. The median preoperative sacral kyphosis was 32.5° (IQR, 0°–45°) in group 1 and 30° (IQR, 0°–55°) in group 2, while the median residual postoperative kyphosis following reduction was 9° (IQR, 0°–20°) in group 1 and 15° (range, 0°–15°) in group 2.

No displacement in the reduction at the final follow-up was reported in any of our cases in both groups when compared to the immediate postoperative radiographs. Group 1 had a significantly higher rate of deep wound infections: 6 patients (33.3%) in group 1 compared to 0 patient in group 2. Those cases were managed by serial debridement, wound cultures, vacuum-assisted closure (VAC) therapy, and antibiotic regimen. The antibiotics were based on culture results and continued until quantitative C-reactive protein became normal (average, 4–12 weeks). Moreover, those patients were advised to avoid prolonged supine position in bed. Instrumentation was retained in all these cases and the wounds healed properly without the need of early implant removal in any case.

Three cases in group 1 had dural tears (2 iatrogenic and 1 traumatic) and were managed by 6–0 (Prolene or Vicryl) sutures in 2 cases. Muscle patch was used in 1 case that had a large lacerated side tear that could not be sutured. This case developed postoperative pseudo-meningocele 6 weeks after surgery and was managed by debridement, lumbar cerebrospinal fluid (CSF) drain, and another muscle patch. Four cases (22.2%) in group 1 complained of implant prominence, which was annoying especially after prolonged sitting.

Group 2 did not encounter deep wound infections or dural tears since the spinal canal was basically not violated; however, implant prominence was recorded in 3 patients (20%). In both groups, the median timing of surgical intervention following hospital admission was 48 hours (IQR, 24–72 hours) except in 3 patients whose general condition and associated injuries did not permit early intervention.

Soft-tissue injury in the form of Morel-Lavallee lesions was encountered in 5 patients (2 in group 1 and 3 in group 2) and was managed during surgery by debridement and VAC therapy. Unilateral L5–S1 facet injury was recorded in 5 cases (3 in group 1 and 2 in group 2). No primary fusion surgery was performed in any of these cases. Our protocol was to avoid primary fusions in trauma patients and to plan for removal of implant after complete fracture union to allow restoration of lumbosacral movement.

The final Majeed pelvic score in the last follow-up visit showed insignificant difference between the two groups ($p = 0.869$). The median Majeed score was 80 (IQR, 76–88) in group 1 and 78 (IQR, 77–85) in group 2. It was excellent (> 84%) in 6 cases (33.3%) in group 1 and 6 cases (40%) in group 2. The remaining cases in both groups had good score (70%–84%). The worst outcome was recorded in 6 patients (3 in each group). It was noticed that patient dissatisfaction in both groups was basically related to one or more of the following factors: incomplete recovery of neurological deficit with residual motor weakness and/or bladder incontinence, prominent painful implants, and partial or total erectile dysfunction in men. In both groups, Majeed score was significantly better in these cases: younger age (< 34 years), women, Tile C2 fractures, Roy-Camille type 1 and 2 fractures, 1 or 2 final postoperative Gibbons' score, < 35° preoperative sacral kyphosis angle, and < 15° residual sacral kyphosis angle.

Wound-related problems including wound dehiscence, deep infections, implant prominence, dural tears, and Morel-Lavallee lesions had insignificant effect on the final functional outcome in both groups. Preoperative Gibbons' score and presence of unilateral L5–S1 facet injury did not have significant effect on the final outcome as well. The median operative time was significantly higher in group 1 (180 minutes; IQR, 160–220) than in group 2 (120 minutes; IQR, 120–140 minutes). Table 2 illustrates the difference between major variables in both groups.

In the preoperative CT report, 6 cases (33.3%) in group 1 were recorded to have bone fragments in the spinal canal compared to 6 cases (40%) in group 2. This factor significantly affected the final outcome in group 1: all the 3 cases who did not accomplish full neurological recovery were among this group although they had direct neurological decompression. On the contrary, this variable did not have any significance in the outcome in group 2 because all the cases that had bone fragments near the neural elements achieved full neurological recovery while the 3 cases that failed to gain full neurological recovery did not have bone fragments in the spinal canal.

Table 2. Difference between Groups in Main Variables

Variable	Group 1	Group 2	Total	Pearson chi-square test (*p*-value)
Neurologic recovery				0.061 (0.805)
No	3 (16.7)	3 (20.0)	6 (18.2)	
Yes	15 (83.3)	12 (80.0)	27 (81.8)	
Total	18 (100.0)	15 (100.0)	33 (100.0)	
Deep wound infection				6.111 (0.013)
No	12 (66.7)	15 (100.0)	27 (81.8)	
Yes	6 (33.3)	0	6 (18.2)	
Total	18 (100.0)	15 (100.0)	33 (100.0)	
Matta X-ray score				8.871 (0.012)
Excellent	11 (61.1)	6 (40.0)	17 (51.5)	
Fair	7 (38.9)	3 (20.0)	10 (30.3)	
Good	0	6 (40.0)	6 (18.2)	
Total	18 (100.0)	15 (100.0)	33 (100.0)	
Bone fragments in spinal canal				0.157 (0.692)
No	12 (66.7)	9 (60.0)	21 (63.6)	
Yes	6 (33.3)	6 (40.0)	12 (36.4)	
Total	18 (100.0)	15 (100.0)	33 (100.0)	

Values are presented as number (%).

Table 3. Correlation between Neurologic Recovery and Other Variables among All Cases by Wilcoxon Rank-Sum Test

Variable	Neurologic recovery*	Median (IQR)	Z	*p*-value	Significance
Delay to surgery (day)	No	2 (1–3)			
	Yes	2 (2–3)	–0.44	0.66	NS
Surgery duration (min)	No	170 (120–220)			
	Yes	140 (120–180)	–0.655	0.512	NS
Majeed score	No	71 (70–72)			
	Yes	82 (78–88)	–3.839	0.0	HS
Roy Camille type	No	3 (3–3)			
	Yes	2 (2–3)	–1.33	0.183	NS
Initial fracture kyphosis angle (°)	No	52.5 (30–60)			
	Yes	30 (0–45)	–2.049	0.04	S
Residual fracture kyphosis angle (°)	No	20 (13.25–20)			
	Yes	5 (0–15)	–2.122	0.034	S

IQR: interquartile range, NS: not significant, HS: highly significant, S: significant.
*Case with no neurologic recovery: 6, Case that gained neurologic recovery: 27.

Neurological Recovery

Full neurological recovery was recorded if the last-visit Gibbons' score was 1. In a few cases (2 patients among the whole series), isolated mild patchy dermatomal sensory deficits that were detected by meticulous neurological examination and did not affect patient's satisfaction were also considered a complete recovery. Full neurological recovery was achieved in 15 patients (83.3%) in group 1 and 12 patients (80%) in group 2 with insignificant difference between the groups. Table 3 illustrates the correlation between neurologic recovery and other variables in both groups.

Regarding the 3 cases (16.7%) in group 1 who did not gain full neurological recovery, they were documented to have incomplete neurological injury on admission. The initial Gibbons' score for them was 3. All of the 3 cases were men with a mean age of 49 years. They all had a fall from height injury (> 6 m), Roy-Camille type 3, and Denis III sacral fractures. They were all operated within 24 hours after admission with an average operative time of 200 minutes (range, 180–220 minutes). All of them did not have dural tears or postoperative wound complications. The quality of reduction in postoperative X-rays was fair according to Matta radiological score. All of them had preoperative sacral kyphosis > 50° and postoperative residual kyphosis > 19°. They all had bone fragments inside the spinal canal in preoperative CT and had direct decompression of spinal canal and neural foramina by a spine

Table 4. The Effect of Main Variables on Neurologic Recovery in Both Groups Together

Variable	Neurologic recovery		Total	Pearson chi-square test (*p*-value)
	No	Yes		
Sex				2.750 (0.097)
Female	0	9 (33.3)	9 (27.3)	
Male	6 (100.0)	18 (66.7)	24 (72.7)	
Total	6 (100.0)	27 (100.0)	33 (100.0)	
Mode of trauma				4.190 (0.041)
Falling from a height	6 (100.0)	15 (55.6)	21 (63.6)	
Road traffic accident	0	12 (44.4)	12 (36.4)	
Total	6 (100.0)	27 (100.0)	33 (100.0)	
Preoperative neurologic deficit				1.910 (0.167)
Complete	3 (50.0)	21 (77.8)	24 (72.7)	
Incomplete	3 (50.0)	6 (22.2)	9 (27.3)	
Total	6 (100.0)	27 (100.0)	33 (100.0)	
Initial Gibbon's score				1.630 (0.202)
Grade 3	6 (100.0)	21 (77.8)	27 (81.8)	
Grade 4	0	6 (22.2)	6 (18.2)	
Total	6 (100.0)	27 (100.0)	33 (100.0)	
Matta score				16.867 (0.000)
Excellent	0	17 (63.0)	17 (51.5)	
Good	0	6 (22.2)	6 (18.2)	
Fair	6 (100.0)	4 (14.8)	10 (30.3)	
Total	6 (100.0)	27 (100.0)	33 (100.0)	

Values are presented as number (%).

surgeon.

In contrast, the 3 cases (20%) in group 2 that did not achieve neurological recovery were documented to have complete neurological injury on admission. Moreover, all of them were men with a mean age of 39 years and preoperative Gibbons' score of 3. They also had a fall from height injury (> 6 m), Roy-Camille type 3, and Denis III fractures. They were all operated within 72 hours after admission and the average surgery duration was 140 minutes (range, 120–160 minutes). The quality of reduction on postoperative X-rays for those 3 patients was fair according to Matta score and there were no recorded dural tears or postoperative wound complications. Additionally, preoperative sacral kyphosis was ≥ 30° and residual sacral kyphosis was > 12°. None of the 3 cases had bone fragments in the spinal canal in their preoperative CT. Table 4 shows the effect of main variables on the neurological recovery in both groups.

DISCUSSION

Spinopelvic dissociation is frequently associated with neurological injury ranging from sensory, motor foot drop to complete Cauda equina syndrome.[8] The injuries that may cause neurological deficit result from compression, traction, and root avulsions.[9] Compression may occur as a result of fracture hematoma that compresses the lumbosacral trunk.[9,10] Root avulsion is less common and usually seen with more severe pelvic and sacral fractures.[11-13] sacroiliac fracture and/or dislocation associated with an L5 transverse process fracture may also result in an L5 nerve root tractioninjury.[14]

Interestingly, the final neurological recovery achieved after direct decompression was reported to be almost comparable to nonoperative treatment in some studies.[4] In fact, neurological improvement is expected in up to 83% of patients regardless of operative or conservative management.[4,8,15,16] It could be due to the hypothesis claiming that the severity of the primary neurological insult and the success of fracture reduction are the principal determinants of the neurological improvement.

The adoption of the indirect decompression technique was similar among some studies describing the management of thoracolumbar burst fractures by indirect decompression and fixation without laminectomy.[17-22] They showed that there was no difference in the final neurological recovery following direct or indirect decompression because the neurological damage occurred mainly at the moment of the primary injury and not due to secondary injury by the retained bone fragments in the spinal canal. Furthermore, there was a spontaneous remodeling potential of the spinal canal that cleared all the bone fragments with time.[23] Despite the obvious management differences between thoracolumbar fractures and sacral fractures, the same idea probably can be used to explain the results in our study.

In sacral fractures with neurological injury, some studies mentioned that nonoperative management resulted in a neurological improvement similar to the results obtained with surgical management. However, the residual long-term complaints with conservative treatment were very frequent compared to operative management.[15] We speculate that the complaints with conservative management of sacral fractures are more likely related to the fracture malunion and lumbopelvic instability rather than the failure to recover the neurological injury. This instability is frequently attributed to the imperfect fracture reduction and excessive residual sacral kyphosis. Hence, this can explain the better functional outcomes and patient satisfaction obtained with surgical management even though the rate of neurological recovery was almost the same in operative and conservative management.

In our current practice, spinopelvic dissociation with neurological injury is almost always treated surgically in order to allow early weight-bearing and rehabilitation. However, the surgeon must evaluate on a case by case basis to decide direct or indirect decompression. Some surgeons often try to obtain indirect decompression by good fracture reduction to correct sacral kyphosis at the beginning of the surgery. If that could not be achieved, they would proceed to direct decompression as a trial to improve the outcome.

In his series, Ayoub[24] reported an overall 96.5% of partial or complete neurological recovery after direct or indirect decompression. In his algorithm, direct decompression was done for patients who had bone fragments in the spinal canal whether their neurologic deficit was complete or incomplete. However, the patients who were treated by indirect decompression showed a significantly better final functional outcome. In our series, full neurological recovery was achieved in 15 patients (83.3%) in the direct decompression group and 12 patients (80%) in the indirect decompression group with no significant difference in the final functional outcome between both groups.

In our study, the poor outcome in neurological improvement was reported in 3 cases (16.7%) in the direct decompression group and 3 cases (20%) in the indirect decompression group. It was evident that those 6 cases had severely displaced sacral fractures with initial sacral kyphosis ≥ 30°. They also had poor fracture reduction according to Matta radiological score with postoperative sacral kyphosis > 12°. This is similar to another study,[15] which mentioned that 80% of the cases with initial Gibbons types III and IV injuries were related to initial kyphosis angles more than 40° (range, 43°–60°). Based on the results in our series, we also suggest that the residual postoperative sacral kyphosis and the quality of fracture reduction had greater impact on the neurological recovery than direct decompression.

All the 3 cases in the direct decompression group that failed to achieve full neurological recovery had loose bone fragments inside the spinal canal that were detected in preoperative CT and were excised during direct decompression. Nevertheless, the Gibbons' score of those 3 cases did not improve at the final follow-up. In contrast, none of the 3 cases in the indirect decompression group who did not achieve neurological improvement had bone fragments in the spinal canal. Hence, the common factors in both groups likely linked to failure of neurological improvement were mainly the initial and postoperative sacral kyphosis angle and the quality of reduction rather than the type of decompression itself. The often-held belief that the removal of loose bone fragments inside the spinal canal is a key step for neurological recovery[16,24] is probably not consistent with the satisfactory outcomes obtained with both indirect decompression in our study and conservative management in other studies.[4,8,15,16] In our study, the 6 patients in the indirect decompression group who had loose bone fragments in the spinal canal entirely achieved full neurological recovery.

Several studies showed that the timing of surgical intervention was important to gain neurological recovery, especially if it was done within 24–72 hours after injury.[16,24-26] In our study, 30 patients had surgery within 24–72 hours, while only 3 patients in the indirect decompression group underwent surgery 96 hours after admission because they had associated thoracic and brain injuries that delayed their surgical interference. Those 3 patients did not have disturbed conscious levels on admission, so they were included in our study. The factor of timing of surgical intervention needs further analysis to determine its actual effect on neurological recovery.

In one study, indirect decompression showed better functional outcome compared to direct decompression.[24] In contrast, in our study, the final Majeed score showed no significant difference between the two groups. The poor outcome was usually related to incomplete neurological recovery in Roy-Camille 3 and Denis III fractures and that was consistent with other studies in literature.[3,27]

Primary posterolateral fusion of the associated injury of L5–S1 facet was proposed in one study.[24] In our practice, avoiding primary L5–S1 fusion in spinopelvic dissociation was adopted. It was because our objective was to restore the normal lumbosacral and sacroiliac movement after removal of instrumentation. Unnecessary lumbosacral fusion is believed to have adverse effects on the biomechanics of the hip and sacroiliac joints and may affect the long-term functional outcome.

Despite the benefits and robustness of spinopelvic fixation construct, the associated wound-related problems are recorded to be high in most studies.[16,28,29] This risk seems to be even higher with direct decompression due to longer operative time, more soft-tissue dissection and possible CSF leakage if dural tears are encountered. In our study, the direct decompression group had a higher rate of deep wound infections ($p = 0.013$): 6 patients (33.3%) compared to no patient in the indirect decompression group. Nevertheless, deep wound infections and Morel-Lavallee lesions did not have significant effect on the final Majeed score in both groups, which was similar to other studies.[24,30,31]

Implant prominence was documented in 4 cases (22.2%) in the direct decompression group and 3 cases (20%) in the indirect decompression group. This was the commonest complication in all studies dealing with spinopelvic fixation[16,32-34] and more frequent in thin patients due to the lack of soft-tissue coverage over the instrumentation. Another comparative study[34] suggested percutaneous spinopelvic fixation to reduce the high rate of wound-related complications. While comparing open and percutaneous fixation, they noticed that one of the patients who had bilateral L4 motor weakness achieved full recovery after having only indirect decompression while another patient with bladder incontinence did not improve at all although sacral laminectomy and open decompression were performed.

The strength of the current study lies in comparing two homogenous groups of patients. All patients had neurological deficit due to posterior pelvic ring injury and all were treated with the same fixation method (spinopelvic fixation) whether with direct or indirect decompression. Other studies in literature included case reports,[35] nonoperative management of such injuries,[4] management of similar injuries with main emphasis on electrodiagnosis,[14] management of these injuries by iliosacral screws,[36] general evaluation of spinopelvic fixation for sacral fractures,[34,37,38] isolated assessment of direct decompression surgery,[16,39] and general assessment of open decompression without addressing the difference between direct and indirect decompression.[24]

However, this study obviously has the common limitations of the retrospective nature, and perhaps a randomized controlled prospective study with a larger sample size and various demographics would add more understanding of the current results. Timing of the surgical intervention needs to be researched to determine its influence on the final neurological recovery. The spinopelvic fixation provides a viable option for treatment of spinopelvic dissociations with lumbosacral neurological injury. Restoration of lumbosacropelvic stability and anatomical reduction seem to be the cornerstone for better functional outcome and neurological recovery. Indirect decompression with anatomical reduction achieved similar final functional outcome and neurological recovery comparable to direct decompression even in the presence of bone fragments inside the sacral canal. In addition, indirect decompression seems to have a lesser operative time and consequently, a lesser rate of wound-related complications.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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