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## Sacral fractures with neurological injury: is early decompression beneficial?

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**Abstract** During a 6-year period, 177 patients with a displaced sacral fracture were treated at our level-one trauma centre. At the initial presentation, 13 patients demonstrated a neurological deficit as a result of their sacral fracture. Six patients underwent surgical decompression, and seven patients were managed without surgical decompression. All patients were re-assessed at an average follow-up of 27.1 (range 12–84) months using the modified SOFCOT Index and the SF-36. Patients undergoing surgical decompression had a significantly better neurological improvement as measured by the modified SOFCOT Index ( $p=0.014$ ). Moreover, patients undergoing surgical decompression had a significantly better physical function than the patients that were managed without surgical decompression, as measured by the SF-36 ( $p=0.044$ ). We therefore believe that patients undergoing surgical decompression achieve better neurological improvement and better functional results.

**Résumé** Pendant une période de six années, 177 malades avec une fracture déplacée du sacrum ont été traités à notre centre de trauma (niveau un). À la présentation initiale, 13 malades avaient un déficit neurologique suite à leur fracture sacrée. Six malades ont subi une décompression chirurgicale, et sept malades ont été traités sans décompression. Tous les malades étaient revus avec un délai moyen de 27,1 mois (12 à 84) en utilisant l'index SOFCOT modifié et le SF-36. Les malades qui avaient eu une décompression chirurgicale avaient une amélioration neurologique notablement meilleure selon l'index SOFCOT modifié ( $p=0.014$ ) et une meilleure fonction quotidienne, comme mesuré par le SF-36 ( $p=0.044$ ).

Nous croyons par conséquent que les malades qui subissent une décompression chirurgicale ont de meilleurs résultats.

### Introduction

The purpose of this study was to determine the functional and neurological outcome of sacral fractures associated with severe neurological injuries. Our hypothesis was that early surgical decompression would increase the degree of functional and neurological recovery as compared to a group of patients managed non-operatively.

### Materials and methods

The charts and X-rays of all patients admitted with a sacral fracture to our level-one trauma centre within a 6-year period were carefully reviewed. Patients were excluded from this study if they had an associated acetabular fracture or a spine fracture with paralysis. Thus, 177 consecutive patients were identified. Thirteen patients had a neurological deficit comprised of one or more of the following: lower-extremity radicular pain, sensory disturbance, a lower-extremity motor strength of three over five or less according to the classification of the Medical Research Council [16], or bowel/bladder dysfunction.

#### Patient data

The demographic and clinical data were documented for each patient (Table 1). There were eight male and five female patients with an average age of 25 (15–53) years. Twelve patients were involved in a motor vehicle accident, whereas one patient sustained a fall from a height. All patients also had additional injuries, and the average Injury Severity Score (ISS) was 22.3 (8–48) [1].

#### Classifications

All sacral fractures were identified by plain radiographs (anteroposterior, inlet, and outlet views) and computed tomography scans. Pelvic injuries were classified according to the Tile classification [18]; sacral fractures were classified using the Denis et al. [3]

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**Table 1** Demographic and clinical data. DC decompression, Ex external, IS iliosacral, ORIF open reduction and internal fixation

Patient	Age	Gender	Associated injuries	Zone	Tile	DC	Pelvis fixation	Time to DC	Intra-operative findings
1	49	F	Proximal tibia fixation	3	C-2	None	Ex fixation	-	
2	22	M	1. De-gloving wound above sacrum 2. Distal femur fixation 3. Spleen rupture	2	B-1	None	IS screw fixation ORIF pubic symphysis	-	
3	53	M	1. Closed head injury 2. Haemothorax 3. Retroperitoneal bleeding 4. Forearm fixation	2	C-2	None	IS screw fixation ORIF pubic symphysis	-	
4	29	F	1. Perinephric haematoma 2. L5 transverse process fixation	3	B-2	None	IS screw fixation	-	
5	22	M	1. Multiple facial fractures 2. Liver and spleen laceration 3. Knee dislocation 4. Proximal tibia fixation	2	C-2	None	Posterior tension plate fixation of sacrum ORIF pubic symphysis	-	
6	30	M	1. Transverse process fixation L5	3	B-2	None	None	-	
7	19	F	1. Closed head injury 2. Nasal fixation 3. Bladder tear 4. Femur fixation 5. Multiple skin lesions	2	C-2	None	ORIF pubic symphysis	-	
8	15	M	1. Ulna fixation 2. Ankle fixation	3	B-2	Yes	None	15 days	Bony compression of S1 and S2 by retro-pulsed fragments Two small dural tears Multiple free nerve fragments of S2 root No transection of neural structures Bony compression of S1 nerve root No transection of neural structures Bony compression of S1 nerve root No transection of neural structures Bony retropulsion with compression of nerve roots L5 and S1 Kinking of S1 root Edematous swelling of S1 root No transection of neural structures Retropulsed bony fragments with compression of S1 root No transection of neural structures
9	17	F	1. Smallbowel-wall haematoma	2	C-1	Yes	IS screw fixation	7 days	
10	18	M	1. Bladder rupture 2. Clavicle fixation 3. Femur fixation 4. Multiple skin lesions	2	C-2	Yes	IS screw fixation Plate fixation posterior pelvis Screw fixation pubic rami Spinal fusion L5-S1	5 days	
11	17	M	1. Urethral tear 2. Tibia fixation	3	C-1	Yes	None	1 days	

Table 1 (continued)

Patient	Age	Gender	Associated injuries	Zone	Tile	DC	Pelvis fixation	Time to DC	Intra-operative findings
12	17	M	1. Rib fracture 2. Retroperitoneal haematoma 3. L5 spinous process fixation	2	B-2	Yes	None	1 days	Retropulsed fragments with compression of nerve roots Transsected S3 nerve root, Dural tear
13	16	F	1. Colonic and mesentery tears 2. Bladder haematoma 3. L4/L5 transverse process fracture	2	C-1	Yes	Ex fixation Posterior plate fixation sacrum	8 days	Bony fragments adjacent to L5 and S1 Bony compression of the sacral foramina S1-S3 Edematous swelling of S1 nerve root Severely compressed S2 No transection of neural structures

classification system: Zone I injuries (alar zone) include fractures through the ala without any damage to either the foramina or the central canal. Zone II injuries (foraminal zone) include fractures involving one or several foramina. They may go through the ala as well but do not impinge on the central canal. Zone III injuries (central zone) include fractures involving the central canal including transverse fractures that may involve several zones. Eight patients had a zone II and five a zone III injury. Of patients with a zone III injury, two had a transverse fracture and three had a vertical fracture.

#### Treatment

All patients were managed and evaluated by an orthopaedic trauma surgeon in consultation with an orthopaedic spine surgeon. Seven patients were managed without surgical decompression, whereas surgical decompression was performed in six patients. The time to surgical decompression varied between 1 and 15 days. The decision to perform surgical decompression was made according to the preference of the consulting spine surgeon. Surgical decompression was accomplished via sacral laminectomy. In all patients undergoing surgical decompression, a bony decompression was performed including the removal of fracture fragments and exposure of the sacral nerve roots within the neural canal (Fig. 1). Sacral fractures that were severely displaced or grossly unstable were managed with internal fixation. Therefore, five patients who were managed without surgical decompression required internal fixation of the sacrum.

#### Patient evaluation

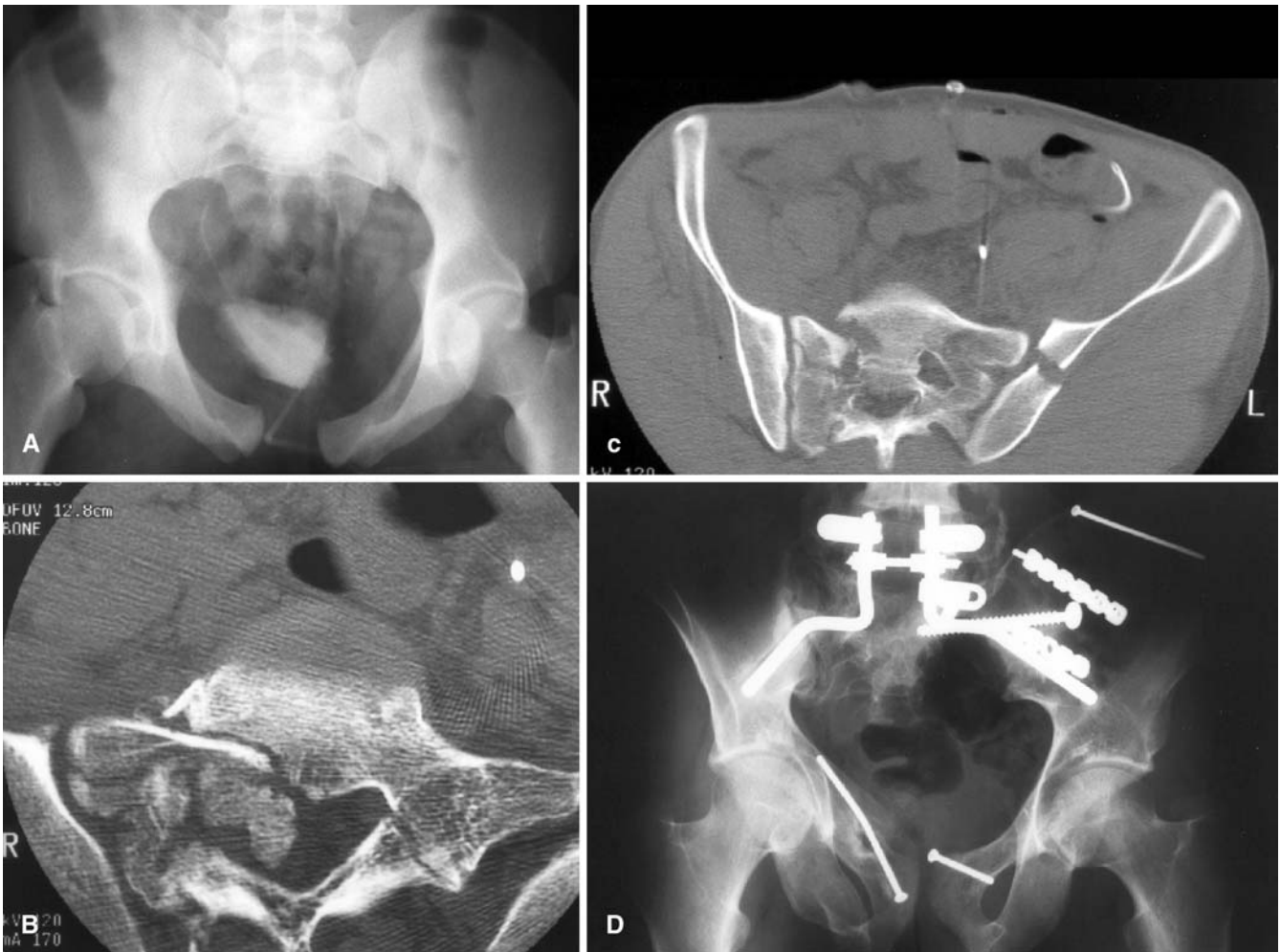
The minimum follow-up period was 12 months post-injury. Pre-operative and post-operative neurological dysfunction was graded using the modified SOFCOT Index, a validated score for outcome assessment following lumbar and sacral spinal surgery [9]. Loss of muscle strength was evaluated according to the classification of the Medical Research Council [16] and assessed manually. Bowel function was recorded by the presence of a sphincter tone; the bladder function was determined by a voiding cystometrogram. At follow-up, the SF-36 was recorded for each patient [19]. In addition, radiographic follow-up studies were obtained on a monthly basis until osseous fracture union was achieved.

#### Statistical analysis

The results of patients undergoing surgical decompression were compared to the results of patients who were managed without surgical decompression. The variables radicular pain, loss of sensation, motor function and bowel/bladder function were quantified using values from the modified SOFCOT Index. Neurological improvement was calculated by pre-operative and post-operative values. Sum scales of the SF-36 were compared in both groups. Variables that were normally distributed were compared using the *t* test. Variables that were not normally distributed were compared using the Kruskal-Wallis test. Statistical analysis was done using SPSS for Windows (SPSS 11.0, Chicago, IL, USA). A *p* value of <0.05 was considered to be significant.

## Results

All patients were evaluated at an average of 27 (12–84) months following injury. Results of patients undergoing surgical decompression (DC) were compared to results of patients managed without a surgical decompression (NONDC). At the time of the initial presentation, the



**Fig. 1A–D** Patient #10: Pre-operative radiograph of the pelvis showing anterior and posterior displacement of the pelvis (A). Preoperative computed tomography scan showing the right S1 foramen bony encroachment (B) and the left-posterior crescent

fracture (C). Posto-perative radiograph of the pelvis following sacral decompression with spinal fusion of L5-S1 (Galveston Technique) and pelvic ring fixation (D)

ISS ( $p=0.94$ , Kruskal-Wallis test) and the modified SOFCOT Index ( $p=0.16$ ,  $t$  test) did not significantly differ between these two groups (Table 2).

#### Radicular pain

Two of three patients with DC and severe radicular pain improved completely and one had residual intermittent pain at 33 months follow-up. In patients with NONDC, one of three patients with moderate-to-severe radicular pain improved completely, and two had residual mild pain at 14 and 20 months follow-up. Regarding the improvement of radicular pain, there was no significant difference identified between the groups ( $p=0.60$ , Kruskal-Wallis test).

#### Motor function

Four out of seven patients with NONDC and three out of six with DC were recorded to have had some residual weakness in the lower extremity. The only patient who showed no improved motor function was patient #3 (NONDC). The patient had a motor strength of zero at initial presentation. Using the values for motor strength of the modified SOFCOT Index, the post-operative improvement of motor function was significantly higher in patients with DC ( $p=0.048$ , Kruskal-Wallis test).

#### Loss of sensation

Four out of six patients with DC and four out of seven with NONDC had improved sensory function. The difference was, however, not significant ( $p=0.62$ , Kruskal-Wallis test).

**Table 2** Pre-operative and post-operative neurological examination and SOFCOT Index. *EHL* extensor hallucis longus, *AT* anterior tibialis, *PT* posterior tibialis

Patient	Initial exam					
	Radicular pain	Motor	Sensory	Bowel/bladder	SOFCOT	
1	None	EHL=3/5 AT=3/5 PT=2/5	Normal	Partial	13	
2	None	EHL=3/5 AT=3/5 PT=5/5	Mild loss (S1-S4)	Intact	15	
3	Severe L5-S1	EHL=0/5 AT=0/5 PT=0/5	Moderate loss (L5-S1)	Intact	6	
4	Moderate S1	EHL=3/5 AT=3/5 PT=4/5	Normal	Intact	14	
5	None	EHL=0/5 AT=0/5 PT=0/5	Moderate loss S1	Complete dysfunction	6	
6	Mild S1	EHL=5/5 AT=5/5 PT=5/5	Normal	Normal	18	
7	Moderate S1	EHL=4/5 AT=4/5 PT=5/5	Mild loss S1	Normal	13	
8 <sup>a</sup>	None	EHL=3/5 AT=3/5 PT=3/5	Mild loss S1-S4	Complete loss	9	
9 <sup>a</sup>	Severe L5-S1	EHL=3/5 AT=3/5 PT=4/5	Mild loss L5+S1	Normal	9	
10 <sup>a</sup>	Severe S1	EHL=3/5 AT=2/5 PT=4/5	Mild loss S1	Normal	9	
11 <sup>a</sup>	None	EHL=3/5 AT=0/5 PT=0/5	Mild loss L5-S4	Partial dysfunction	10	
12 <sup>a</sup>	None	EHL=3/5 AT=2/5 PT=4/5	Mild loss perianal	Complete dysfunction	9	
13 <sup>a</sup>	Severe S1-S3	EHL=0/5 AT=0/5 PT=0/5	Mild loss S1-S5	Complete dysfunction	1	
Patient	Follow-up exam					Follow-up (months)
	Radicular pain	Motor	Sensory	Bowel/bladder	SOFCOT	
1	None	EHL=5/5 AT=5/5 PT=4/5	Mild loss L5	Normal	17	39

**Table 2** (continued)

Patient	Follow-up exam					Follow-up (months)
	Radicular pain	Motor	Sensory	Bowel/bladder	SOFCOT	
2	None	EHL=5/5 AT=5/5 PT=5/5	Normal	Normal	20	32
3	Mild L5	EHL=0/5 AT=0/5 PT=0/5	Mild loss L5-S1	Normal	11	20
4	None	EHL=5/5 AT=5/5 PT=5/5	Normal	Normal	20	12
5	None	EHL=1/5 AT=1/5 PT=5/5	Mild loss S1	Normal	13	12
6	None	EHL=5/5 AT=5/5 PT=5/5	Normal	Normal	20	12
7	Mild S1	EHL=4/5 AT=5/5 PT=5/5	Normal	Normal	16	14
8 <sup>a</sup>	None	EHL=4/5 AT=5/5 PT=4/5	Normal	Partial dysfunction	15	84
9 <sup>a</sup>	Mild S1	EHL=5/5 AT=5/5 PT=5/5	Normal	Normal	18	33
10 <sup>a</sup>	None	EHL=5/5 AT=5/5 PT=5/5	Normal	Normal	20	15
11 <sup>a</sup>	None	EHL=4/5 AT=4/5 PT=4/5	Normal	Normal	18	21
12 <sup>a</sup>	None	EHL=5/5 AT=5/5 PT=5/5	Mild loss perianal	Normal	19	12
13 <sup>a</sup>	None	EHL=5/5 AT=5/5 PT=4/5	Mild loss S1	Normal	17	45

<sup>a</sup>Patients undergoing surgical decompression

### Bowel/bladder dysfunction

At the initial presentation, six patients (two NONDC/four DC) demonstrated bowel or bladder dysfunction. They subsided in all but one patient with DC. This patient sustained a transverse zone III fracture associated with bowel and bladder disturbance. A delayed surgical decompression was performed at 15 days after the injury. Eighty-four months post-injury, symptoms of a neurogenic bladder persisted, whereas anal sphincter tone was documented as normal, and no clinical symptoms of anal incontinence were present. No difference regarding the improvement of bowel and bladder dysfunction was found

between patients with DC and NONDC, as determined by the values from the modified SOFCOT Index ( $p=0.21$ , Kruskal-Wallis test).

### SOFCOT Index

Values of the modified SOFCOT Index increased in all patients in this study. In patients with DC, the average total score increased from 7.8 points initially to 17.8 at follow-up. In patients with NONDC, the average total score increased from 12.1 points initially to 16.7 at follow-up. Regarding total score of the modified SOFCOT Index,

post-operative gain was significantly higher for patients undergoing surgical decompression (10 points in DC versus 4.6 in NONDC,  $p=0.014$ , Kruskal-Wallis test).

### SF-36

The physical function scale of the SF-36 showed significantly higher values in patients with DC ( $p=0.044$ ). In five other categories, values trended higher in DC without reaching statistical significance ( $p>0.05$ ). Only one category (emotional role) trended towards higher values in NONDC ( $p>0.05$ ). Values for the general health scales were comparable in both groups.

### Complications

All patients went on to radiographic union of the sacral fracture. In two patients (patients #1 and #8), a urinary tract infection was recorded. In both patients, symptoms resolved with antibiotic treatment. In one patient (patient #12), a line sepsis was recorded. Symptoms subsided with antibiotic treatment.

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## Discussion

Between 15 and 40% of sacral fractures are associated with a significant neurological injury [3, 6, 7, 12]. Incidence of neurological injuries depends on fracture type and location. Denis et al. described a classification system that was predictive of neurological injury [3]: Zone I injuries involve the sacral ala, zone II the sacral foramen, and zone III the sacral canal. Zone III injuries also include fractures that involve several zones such as transverse fractures. Several large series have demonstrated that higher-zone injuries are associated with a higher incidence of neurological deficits [3, 6, 7].

Currently, the treatment of sacral fractures with an associated neurological injury remains controversial. While some authors advocate routine decompression for all sacral fractures associated with a neurological deficit [3, 4, 8, 13, 15], other authors did not encourage surgical decompression for these patients because intra-operative findings have shown torn, stretched, contused, or lacerated nerve roots [5, 6, 11, 14]. However, reports in the literature of functional and neurological recovery following sacral fractures associated with neurological injuries are limited to small series [2, 3, 5, 6, 8, 10, 13, 17, 18]. Denis et al. reported a series of five patients [3], all of whom experienced neurological improvement following surgical decompression. They also reported one case in which a delayed surgical decompression was performed. This case resulted in an unfavourable outcome. Therefore, Denis et al. encouraged early surgical decompression of these injuries [3]. Schmidek et al. reported improvement in bowel and bladder dysfunction in 11 patients with transverse sacral fractures undergoing surgical decompression

[15]. Kim et al. described a series of six patients [8], five of whom underwent sacral laminectomy with all but one showing improvement. In contrast to studies in which operative treatment was employed, Sabiston and Wing recommended non-operative treatment for these injuries [14]. Their conclusion was based on a series of 35 sacral fractures treated non-operatively. Their series, however, included only one patient with a complete cauda equina syndrome and this patient experienced no significant neurological improvement. Phelan et al. also encouraged non-surgical treatment for sacral fractures associated with neurological injuries [11]. They treated four patients non-operatively and reported spontaneous neurological recovery in all patients. Nork et al. treated nine patients with percutaneous iliosacral screw fixation without surgical decompression. These authors achieved neurological improvement in seven patients and emphasised the importance of surgical fixation for neurological recovery [10]. However, they noted that the role of surgical decompression has been poorly defined and requires further investigation [10].

To our knowledge, our study is unique in its attempt to compare outcomes between decompressed versus non-decompressed patients using quantifiable outcome measurements such as the modified SOFCOT Index and the SF-36. All patients included in this series had some neurological improvement, both clinically and as measured by the modified SOFCOT Index. Results support the principle of early surgical decompression of sacral fractures associated with a severe neurological injury. Despite the relatively small number of patients, significantly better neurological improvement, as measured by the modified SOFCOT Index ( $p=0.048$ ), was obtained in DC. Although the initial SOFCOT Index was lower in DC than in NONDC (7.1 versus 12.1), post-operative score in DC was higher than in NONDC (17.8 versus 16.7). Recovery of motor function following surgical decompression appears to be beneficial, as demonstrated by a significantly higher improvement in muscle strength. Moreover, those patients decompressed within 5 days of injury tended to improve their neurological function better than those managed with delayed surgical decompression. However, this series is too small to demonstrate a significant correlation between timing of surgery and eventual outcome. In addition, SF-36 scores were higher in DC. Physical function scale of the SF-36 was significantly higher in DC ( $p=0.044$ ). In most other categories of the SF-36, values in DC trended higher. Thus, the majority of sacral fractures associated with a neurological deficit appear to benefit from surgical decompression.

Our study has both strengths and limitations. Its strength lies in the detailed documentation and quantification of pre-operative and post-operative neurological deficit. In addition to neurological outcome, our study attempts to quantify functional and subjective outcome using the SF-36, a widely accepted outcome measurement. Its limitations include the relatively small number of patients, retrospective design, lack of randomisation, and thus

potential selection bias. Therefore, our study cannot provide comprehensive information on the impact of various demographic and clinical factors that may influence neurological recovery.

Although conclusions that can be drawn from our study are limited, we believe our data suggest that the majority of sacral fractures with neurologic deficit benefit from early surgical decompression. An adequate bony decompression can be achieved by a posterior sacral laminectomy. This allows for removal of retropulsed bony fragments, nerve-root decompression and surgical exposure of the sacral nerve roots. In summary, our current treatment protocol utilises a surgical decompression in patients with a motor strength of less than 3/5, unrelenting radicular pain, or bowel/bladder dysfunction.

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