Persistent Impairment After Surgically Treated Lateral Compression Pelvic Injury

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Abstract

Background Recently, fixation of lateral compression (LC) pelvic fractures has been advocated to improve patient comfort and to allow earlier mobilization without loss of reduction, thus minimizing adverse systemic effects. However, the degree of acceptable deformity and persistence of disability are unclear.

Questions/purposes We determined if (1) injury pattern; (2) demographics; (3) final posterior displacement; (4) L5/S1 involvement; (5) associated injuries; and (6) time influence outcome measurements, sexual dysfunction, and pain.

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Methods We retrospectively reviewed 119 patients with unstable LC injuries treated surgically between 2000 and 2010. There were 52 males and 67 females; mean age was 39 years with a mean body mass index of 27 kg/m². All patients underwent clinical examination and radiographic imaging for instability and accompanying injuries. We obtained Short Musculoskeletal Function Assessment (SMFA). The minimum followup was 12 months (mean, 33 months; range, 12–100 months).

Results SMFA subscores were not affected by injury pattern and demographics. Posterior reduction was less than 5 mm with persistent displacement in 99 of 119 (83%). Displacement of 5 to 10 mm did not affect any SMFA subscore at any time interval. Patients with additional lower extremity injuries had worse SMFA scores. Function improved with time. A visual analog scale pain score of 4 or more at 6 months predicted pain and overall SMFA score at last followup.

Conclusions Unstable LC pelvic ring injuries result in persistent disability based on validated outcome measurements. Near anatomical reduction can be achieved and maintained. While our findings need to be confirmed in studies with high rates of followup, patients with unstable LC pelvic injuries should be counseled concerning the possibility of some degree of persistent disability.

Level of Evidence Level IV, therapeutic study. See Guidelines for Authors for a complete description of levels of evidence.

Introduction

Lateral compressive forces cause the greatest number of pelvic ring disruptions [39, 50]. These injuries are often related to high-energy trauma and lateral compression fractures [3] are often caused by motor vehicle accidents

[20]. Pure lateral compression fractures account for more than 57% of the pelvic fractures [56]. Lateral impact to the innominate bone occurs either directly or through the proximal femur and iliac crest; simultaneously, the pelvis on the side of impact rotates toward the midline [58].

Although in the past, most pelvic injuries were managed nonoperatively [33, 51], advances in fixation techniques and a clearer understanding of biomechanics led to more operative approaches [24, 38]. Over the past decade or two, fixation of lateral compression (LC) fractures has been advocated to improve patient comfort and to allow earlier mobilization without loss of reduction, thus minimizing the adverse systemic effects of bed rest [20, 44]. Lefaivre et al. [24] found that even LC I fractures according to Young and Burgess showed potential instability and complete sacral fractures in 48%. Biomechanically, pelvic stability especially depends on the integrity of the posterior structures [51, 56]. Approximately 45% of all pelvic ring disruptions include fractures of the sacrum [32]. Posterior displacement of greater than or equal to 1 cm is a common indication for reduction and fixation [3, 26, 37, 44, 48, 53]. Additional fixation of unstable injury patterns of the anterior pelvic ring should be performed [11].

Many factors have been associated with worse functional outcome, including open fracture, sacroiliac joint disruption [8], urologic injury [16], neurologic injury [46], open reduction and internal fixation, residual posterior displacement [8, 14, 29], and psychological problems. Previous studies focused on unstable pelvic fractures but did not distinguish between Tile B and C fractures [14, 17, 29, 46]. A systematic review of the literature demonstrated better reduction quality, less pain, and improved undisturbed walking capacity for posterior pelvic ring fixation compared with nonoperative intervention [38]. With regard to LC pelvic fractures, the degree of acceptable deformity [1] and persistence of disability are unclear.

Therefore, we determined if (1) injury pattern; (2) demographics; (3) final posterior displacement; (4) L5/S1 involvement; (5) associated injuries; and (6) time influence function, sexual dysfunction, and pain of operatively treated LC pelvic ring injuries.

Patients and Methods

Between June 2000 and June 2010, we treated 1635 patients with pelvic ring injuries. Nonoperative treatment was performed in 796 patients, whereas 839 were treated with surgery under one of the Current Procedural Terminology codes 27216, 27217, and 27218. Of these 839 operatively treated patients, 280 (33%) had outcome data. Based on mechanism and confirmed by imaging studies, 136 of these 280 patients had LC fractures. The indications

for surgery were: (1) mechanical instability with examination under anesthesia; (2) posterior pelvic ring displacement > 1 cm; (3) marked pelvic ring deformity with leg length discrepancy; and (4) associated ligamentous injury of the sacroiliac joint or fracture dislocation (crescent fracture). The contraindications for surgery were: (1) life-threatening comorbidities; and (2) impaction injury with < 5 mm posterior displacement. We included patients ≥ 16 years at the time of injury with obtained outcome surveys. We excluded 12 patients for followup less than 1 year and insufficient medical or radiographic data. Additional five patients were excluded because of age (one), initial nonoperative treatment (two), and external fixation for posterior treatment (two). This left 119 patients with a mean age of 39 years (range, 16–86 years). There were 52 of 119 (44%) males and 67 of 119 (56%) females with a body mass index (BMI) of 27 kg/m² (range, 18–46 kg/m²). The minimum followup was 12 months (mean, 33 months; range, 12–100 months).

Each patient had three views of the injured pelvis. These were an AP view with the patient supine (Fig. 1A), a pelvic inlet view, and an outlet view [57]. Each patient had a CT scan (Fig. 1B) with reconstruction of the pelvis that provided information on both extent of the injury and the magnitude of the posterior displacement. Furthermore, the CT defined injury to the L5 transverse process and/or L5-S1 joint injury extension. The diagnosis of LC injury was based on reported mechanism, clinical examination [36], and radiographic criteria [2]. All patients underwent stress stability examination of the pelvis under anesthesia (EUA) and fluoroscopy to confirm instability. Although the EUA is controversial and subjective, fluoroscopic inlet view imaging of the translation and deformity of the anterior and posterior ring created by symmetrical LC force generated by an experienced pelvic surgeon can aid in operative versus nonoperative decision-making of minimally displaced complete fractures or fracture-dislocations of the posterior pelvic ring. Of the 119 LC pelvic ring injuries, 99 fractures (83%) were classified as B2 fractures and 20 fractures (17%) were classified as B3 according to Tile and AO/OTA classification. Different posterior injury patterns were observed (Table 1). Using the Isler classification [19], 24 of 119 (20%) involved the L5-S1 facet and the sacrum and were therefore further subdivided into 13 Type 1, four Type 2, and seven Type 3.

We recorded injury mechanism and potential contributing factors (Table 2). One hundred twelve of the 119 patients (94%) sustained high-energy trauma. Forty-eight of the 119 patients (40%) had an Injury Severity Score (ISS) greater than 15 and therefore were classified as polytrauma. Ten of the 119 patients (8.4%) had local soft tissue degloving (Morel-Lavellée lesion [41]). Associated injuries were predominantly related to the trunk and lower

Fig. 1A–E An example of a typical injury pattern and treatment. (A) Preoperative injury radiograph. (B) Preoperative axial CT demonstrating the instability with complete sacral fracture pattern. (C–D) Postoperative inlet and outlet views demonstrating post reconstruction and stabilization of the pelvis initial insertion of a

percutaneous right sacroiliac (SI) partially threaded screw to compress and stabilize the SI joint, temporary femoral distractor to disimpact the LC, sacral stabilization of the left sacral fracture with a fully threaded left SI screw, and final percutaneous retrograde ramus screw. (E) Postoperative CT illustrating the sacral reduction and screw fixation.

extremities (Table 3). Anterior pelvic ring injuries occurred in different patterns in 115 of 119 (97%) (Table 4).

All procedures were performed as open or closed reduction and internal fixation of the posterior ring injury on a radiolucent table by three trauma fellowship-trained orthopaedic surgeons (CBJ, JRR, TJE). Approaches to the pelvis were based on the particular pattern of the injury,

location of the fracture, associated injuries, and soft tissue involvement [14]. All patients had initial postoperative pelvic radiographs (AP, inlet, outlet) and CT (Fig. 1C–E) imaging to confirm postreduction displacement and implant position. Initial temporary stabilization with an external fixator was performed in 20 of 119 patients (17%). Definitive posterior stabilization was performed in 112 of

Table 1. Posterior injury patterns represented a wide variety

Posterior injury pattern	Number	Percent
Denis Zone 1	30	25.2
Denis Zone 2	25	21.0
Iliosacral fracture-dislocation	17	14.3
Iliosacral disruption	11	9.2
Fracture of the iliac ala	11	9.2
Bilateral injuries	25	21.0
Fracture of L5 transverse process	32	26.9

Table 2. High-energy trauma was the predominant injury cause

Mechanism	Number	Percent
Low-energy fall	3	2.5
High-energy fall	11	9.2
Sports	1	0.8
Pedestrian	7	5.9
Motorcycle accident/bike	12	10.1
Motor vehicle accident	75	63.0
All-terrain vehicle	2	1.7
Crush	5	4.2
Unknown	3	2.5

Table 3. Lateral compression fractures were often related to associated injuries (multiple possible)

Associated injuries	Number	Percent
Urologic injury	15	12.6
Spine injury	23	19.3
L5/S1 involvement	32	26.9
Associated lower extremity injuries	33	27.7
Degloving injury	10	8.4

Table 4. Different patterns of anterior pelvic ring injuries were recorded

Accompanying pelvic ring injuries	Number	Percent
Ramus fracture	104	87.4
Symphyseal disruption	20	16.8
Acetabular fracture	19	16.0
Anterior ring fracture plus acetabular fracture	14	11.8

119 (94%). Anterior pelvic internal fixation was performed in 101 of 119 patients (85%). The initially applied external fixator was maintained to treat the anterior instability in seven of 119 patients (6%) (Fig. 2).

Morel-Lavallee degloving injuries had excisional débridements, closure over suction drainage, and continued

Fig. 2 Patients were treated with posterior and anterior fixation implants based on their injury pattern. ORIF = open reduction and internal fixation; Ex fix = external fixation.

antibiotics until drains were removed. Postoperatively, patients had antibiotics and deep vein thrombosis prophylaxis. Patients were mobilized based on the constellation of pelvic and accompanying injury pattern. In general, non-weightbearing was continued for 3 months corresponding to the ipsilateral posterior pelvic injury. On beginning weightbearing, formal therapy was instituted working on ROM, strengthening, and conditioning.

Patients were evaluated at regular intervals of 2 weeks, 6 weeks, 12 weeks, 6 months, 1 year, and 2 years. Reports of pain with visual analog scale, erectile dysfunction, urinary dysfunction, and sexual problems were recorded. Radiographs consisting of AP, inlet, and outlet views of the pelvis were obtained at each interval. Functional outcome questionnaires were performed at 6 months, 1 year, and 2 years. The Short Musculoskeletal Function Assessment (SMFA) was chosen as a well-established, validated, and reproducible measure of health status with normative data [18, 47]. The SMFA consists of 46 questions representing six general health attributes: daily activity, emotional status, arm/hand function, mobility, dysfunction index, and bother index. The dysfunction index assesses the patient's perception of their functional performance, whereas the bother index assesses how much patients are bothered by problems in daily activity. The SMFA scores of 0 to 100 were compared with normative data [18]. A separate analysis was performed on Question 22 concerning sexual dysfunction and Question 46 concerning pain with a potential range of score of least (1) to worst (5). Patients' work status was determined preinjury and at final followup.

The first author (MFH), who was not involved in surgical treatment or patient care, evaluated reduction quality on the initial postoperative radiographs, initial postoperative CT, and final radiographs. Displacement can occur in three dimensions. Therefore, the greatest displacement comparing the posterior iliac crest and cephalad rim of the sacrum compared with the contralateral side on all three radiographs as well as anterior cortex displacement on CT was measured. We recorded loss of fixation and reduction based on the initial and final radiographs. Loss of fixation was defined as signs of screw loosening in combination with 3 mm additional displacement or 5 mm additional displacement without signs of implant failure.

Descriptive statistics were used to describe the demographics, determine range and variance of SMFA indices, sexual dysfunction, and pain. The injury pattern, final posterior displacement, L5/S1 involvement, and associated injuries were also described. We used t-tests to determine differences in SMFA subscores and pain when comparing groups of injury patterns, age, BMI, gender, posterior displacement, L5-S1 involvement, polytrauma, and lower extremity (LE), urologic, and neurologic injuries. A repeated measures analysis of variance with post hoc tests, Bonferroni if equal variances were present and Tamhane's T2 if variances were not equal, was used to determine differences in SMFA subscores and pain over the 6-, 12-, and 24-month time intervals. Significant variables were entered stepwise in a multiple regression model to determine the influence on SMFA subscores. Data were analyzed using PASW[®] 18 (IBM, Armonk, NY, USA).

Results

We found no difference in SMFA subscores and sexual dysfunction at the final followup for patients with isolated sacral fractures compared with the group of patients that had iliosacral joint disruptions, iliac wing fractures, or bilateral lesions. No differences were noted between Zone 1 and Zone 2 sacral fractures. Those with Zone 1 sacral fractures experienced more pain (Table 5).

We found no differences in SMFA subscores for patients 60 years old or older compared with patients younger than 60 years old. Patients < 60 years old experienced more pain ($p = 0.009$) than older patients at 6 months. No differences in SMFA subscores, sexual dysfunction, or pain were found for patients with BMI less than 30 kg/m² compared with patients with BMI greater than 30 kg/m². No differences in SMFA scores, sexual dysfunction, or pain were noted comparing males with females (Table 5).

The posterior reduction quality was less than 5 mm displacement in 99 of 119 (83%) and 5 to 10 mm displacement in 20 of 119 (17%). The grade of reduction did not cause a difference in any SMFA subscore or pain. At 6 months, patients with 5 to 10 mm posterior displacement had more difficulty with sexual intercourse than patients with < 5 mm remaining displacement, but no differences were noted at any other time interval (Table 5).

We found no differences in SMFA subscores or sexual dysfunction regardless of the underlying fracture in those with L5-S1 injuries compared with those without L5-S1 injuries (Table 5). At final followup, pain was greater ($t = 2.368$; $p = 0.021$) among those who did not have L5-S1 involvement. Three of the 119 patients (2.5%) reported sitting imbalance or pain. Thirteen of the 119 patients (11%) had gait impairment. Eighty patients (70%) returned to work with an additional seven (6%) returning to a different job as a result of the injury; 20 (17%) were not able to return to any kind of work.

We observed no differences in SMFA subscores or sexual dysfunction in polytraumatized patients compared with patients with isolated pelvic injuries (Table 5). Polytraumatized patients reported less pain ($t = 1.992$, $p = 0.050$) at 6 months.

Patients with associated lower extremity injuries had worse SMFA subscores, sexual dysfunction, and pain (Table 6). Persistent urologic and neurologic dysfunction was noted in nine of 119 (8%) patients and in 15 of 119 (12%) patients (Table 7), respectively, but the only difference was sexual dysfunction with a urologic complication and mobility and pain with a neurologic injury (Table 5).

Improvement in all SMFA subscores except arm/hand occurred at the 2-year interval compared with the 6-month interval (Fig. 3). Compared with normative data, patients with LC pelvic injuries had worse daily activity, emotional, mobility, dysfunction, and bother outcome measurements at all time intervals. Compared with normative data and known orthopaedic conditions, patients with LC pelvic ring injuries had worse bother and dysfunction indices than an acute upper extremity injury, an upper extremity repetitive motion disorder or osteoarthritis, or a LE repetitive motion disorder but better than a LE acute fracture or chronic osteoarthritis (Fig. 4).

The 1-year sexual difficulty and 2-year pain predicted final bother, dysfunction, and mobility outcome measurements. The 6-month visual analog scale score of 4.0 or greater determined final pain score and final emotional measurement ($F = 25.983$, $p < 0.001$, $R^2 = 0.565$, $F = 23.965$, $p < 0.001$, $R^2 = 0.480$, respectively). The 6-month and 2-year pain and difficulty sexual activity determined final daily activity ($F = 57.518$, $R^2 = 0.878$, $p < 0.001$).

Table 5. Twenty-four-month Short Musculoskeletal Function Assessment, sexual dysfunction, and pain comparison

Comparison by groups	Daily activity	Emotional	Arm/Hand	Mobility	Dysfunction	Bother	Sexual dysfunction	Pain
Sacral fracture Zones 1 and 2	24.7 ± 24.6	30.1 ± 23.4	7.7 ± 14.9	24.6 ± 22.1	21.7 ± 17.8	23.1 ± 20.5	2.2 ± 1.6	2.7 ± 1.4
Other posterior ring injury patterns	23.4 ± 25.0	35.5 ± 25.3	6.1 ± 9.4	27.4 ± 21.6	22.3 ± 19.3	25.8 ± 25.7	2.1 ± 1.4	2.8 ± 1.3
t result; significance	t = -0.226; 0.822	t = -0.923; 0.359	t = -0.581; 0.563	t = 0.549; 0.585	t = 0.143; 0.886	t = 0.492; 0.624	t = 0.412; 0.682	t = -2.212; 0.833
Sacral fracture Zone 1	26.9 ± 21.1	33.9 ± 21.0	8.8 ± 14.0	30.4 ± 19.0	24.7 ± 14.5	27.9 ± 18.6	2.4 ± 1.7	3.3 ± 1.3
Sacral fracture Zone 2	22.7 ± 27.8	26.8 ± 26.4	6.8 ± 16.1	19.4 ± 24.0	18.9 ± 20.3	19.0 ± 21.6	1.9 ± 1.4	2.1 ± 1.3
t result; significance	t = 0.491; 0.626	t = 0.862; 0.395	t = -0.396; 0.695	t = 1.460; 0.154	t = 0.945; 0.352	t = 1.249; 0.221	t = 0.822; 0.418	t = 2.728; 0.011
Age < 60 years	21.9 ± 23.3	34.3 ± 25.3	5.1 ± 9.0	24.4 ± 21.4	20.7 ± 18.1	24.2 ± 24.2	2.1 ± 1.4	2.8 ± 1.4
	(0-88)	(0-89)	(0-41)	(0-72)	(0-71)	(0-100)	(1-5)	(1-5)
Age ≥ 60 years	33.0 ± 28.6	25.1 ± 19.0	16.2 ± 20.0	31.7 ± 22.6	27.4 ± 19.5	24.0 ± 17.1	2.3 ± 1.6	2.5 ± 1.3
	(0-95)	(0-59)	(0-66)	(0-81)	(0-67)	(0-52)	(1-5)	(1-5)
t result; significance	t = -1.491; 0.140	t = 1.238; 0.220	t = -1.953; 0.073	t = -1.111; 0.270	t = -1.208; 0.231	t = 0.036; 0.971	t = -0.465; 0.441	t = 0.551; 0.583
BMI < 30 kg/m ²	21.9 ± 23.3	34.3 ± 25.3	5.1 ± 9.0	24.4 ± 21.4	20.7 ± 18.1	24.2 ± 24.2	2.1 ± 1.4	2.8 ± 1.4
BMI ≥ 30 kg/m ²	33.0 ± 28.6	25.1 ± 19.0	16.2 ± 20.0	31.7 ± 22.6	27.4 ± 19.5	24.0 ± 17.1	2.3 ± 1.6	2.4 ± 1.4
t result; significance	t = 0.688; 0.503	t = -0.786; 0.435	t = 1.000; 0.335	t = 0.731; 0.467	t = 0.532; 0.603	t = -0.121; 0.904	t = 0.260; 0.795	t = -0.980; 0.331
Male	25.6 ± 24.9	32.6 ± 29.8	6.2 ± 10.8	26.0 ± 22.6	22.9 ± 19.9	27.3 ± 28.1	2.3 ± 1.5	2.8 ± 1.4
Female	23.0 ± 24.8	33.3 ± 21.1	7.3 ± 13.2	26.1 ± 21.5	21.4 ± 17.8	22.9 ± 20.1	2.0 ± 1.4	2.7 ± 1.3
t result; significance	t = 0.440; 0.661	t = -1.108; 0.914	t = -0.371; 0.712	t = -0.014; 0.989	t = 0.328; 0.744	t = -0.715; 0.478	t = 0.793; 0.431	t = 0.297; 0.767
Reduction quality 0-4 mm	26.7 ± 24.7	36.1 ± 25.6	7.0 ± 11.2	27.9 ± 20.9	23.8 ± 18.7	27.7 ± 24.7	1.9 ± 1.3	2.5 ± 1.1
Reduction quality 5-10 mm	19.1 ± 27.8	28.4 ± 22.9	8.2 ± 19.4	27.5 ± 28.3	20.7 ± 20.6	19.7 ± 18.4	2.3 ± 1.5	3.0 ± 1.4
t result; significance	t = -0.909; 0.367	t = -0.933; 0.355	t = 0.284; 0.777	t = -0.055; 0.956	t = -0.503; 0.617	t = -1.013; 0.315	t = -0.748; 0.457	t = -1.137; 0.260
With L5/S1 involvement	18.7 ± 21.1	25.4 ± 21.0	5.4 ± 14.0	23.2 ± 19.0	18.3 ± 14.5	17.5 ± 18.6	1.7 ± 1.7	2.2 ± 1.3
Without L5/S1 involvement	26.5 ± 27.8	36.3 ± 26.4	7.8 ± 16.1	27.6 ± 24.0	23.8 ± 20.3	27.5 ± 21.6	2.3 ± 1.4	3.0 ± 1.3
t result; significance	t = 1.237; 0.220	t = 1.736; 0.087	t = 0.747; 0.457	t = 0.784; 0.436	t = 1.150; 0.254	t = 1.691; 0.095	t = 1.675; 0.100	t = 2.368; 0.021
Isolated trauma	24.6 ± 25.0	34.5 ± 25.3	7.6 ± 12.1	25.9 ± 21.7	22.2 ± 19.2	24.7 ± 23.2	2.0 ± 1.3	2.9 ± 1.1
Polytrauma	23.8 ± 24.9	32.1 ± 19.0	6.3 ± 12.9	27.8 ± 22.7	22.6 ± 18.1	25.7 ± 24.3	2.2 ± 1.6	2.8 ± 1.3
t result; significance	t = 1.129; 0.898	t = 0.385; 0.701	t = 0.428; 0.670	t = -0.346; 0.730	t = -0.088; 0.930	t = -0.173; 0.864	t = -0.736; 0.465	t = 0.282; 0.779

Table 5. continued

Comparison by groups	Daily activity	Emotional	Arm/Hand	Mobility	Dysfunction	Bother	Sexual dysfunction	Pain
Neurologic injury	44.1 ± 34.6	54.2 ± 33.8	10.2 ± 13.1	46.5 ± 23.4	39.3 ± 24.6	47.9 ± 36.8	3.0 ± 1.5	3.8 ± 1.3
No neurologic injury	20.9 ± 22.5	28.2 ± 21.5	6.5 ± 12.6	22.4 ± 20.3	18.9 ± 16.6	19.7 ± 17.9	2.0 ± 1.4	2.5 ± 1.3
t result; significance	t = -1.844; 0.103	t = -2.123; 0.067	t = -0.766; 0.466	t = -3.111; 0.003	t = -2.287; 0.052	t = -2.137; 0.068	t = -1.657; 0.102	t = -2.485; 0.016
Urologic injury	13.3 ± 34.6	19.1 ± 33.8	1.0 ± 13.1	15.7 ± 23.4	12.3 ± 24.6	12.5 ± 36.8	1.0 ± 1.5	2.6 ± 1.3
No urologic injury	21.3 ± 22.5	28.6 ± 21.5	6.8 ± 12.6	22.7 ± 20.3	19.2 ± 16.6	20.1 ± 17.9	2.0 ± 1.4	1.3 ± 1.3
t result; significance	t = 0.591; 0.557	t = 0.751; 0.456	t = -0.768; 0.446	t = 0.578; 0.566	t = 0.706; 0.483	t = 0.708; 0.482	t = 5.339; < 0.001	t = 1.692; 0.096

BMI = body mass index.

Table 6. Short Musculoskeletal Function Assessment (SMFA) comparison at 6 months, 1 year, and 2 years in patients with and without associated lower extremity injury

SMFA	6 months		Significance		12 months		Significance		24 months		Significance		Norm
	Without	With LE	Without	With LE	Without	With LE	Without	With LE	Without	With LE	Without	With LE	
Daily activity	30.2 ± 26.0	44.5 ± 29.7	t = -1.993; p = 0.050	29.3 ± 25.2	40.0 ± 25.5	t = -1.656; p = 0.102	18.3 ± 21.3	35.8 ± 26.5	t = -2.976; p = 0.004	11.85 ± 19.2			
Emotional	35.7 ± 21.3	43.9 ± 25.3	t = -1.383; p = 0.171	38.2 ± 25.8	41.7 ± 21.7	t = -0.557; p = 0.579	29.6 ± 22.5	41.1 ± 26.8	t = -1.873; p = 0.066	20.54 ± 18.4			
Arm/hand	8.2 ± 12.7	12.2 ± 15.3	t = -1.127; p = 0.264	6.6 ± 9.5	10.9 ± 19.4	t = -1.282; p = 0.204	5.2 ± 9.4	10.5 ± 15.9	t = -1.510; p = 0.140	6.02 ± 12.26			
Mobility	26.8 ± 20.9	49.0 ± 20.9	t = -3.954; p < 0.001	29.7 ± 22.3	43.6 ± 17.2	t = -2.453; p = 0.017	18.8 ± 17.9	41.8 ± 20.4	t = -4.746; p < 0.001	13.61 ± 18.31			
Dysfunction	24.1 ± 18.0	39.0 ± 19.9	t = -3.056; p = 0.003	25.2 ± 18.9	30.6 ± 16.5	t = -1.146; p = 0.255	17.4 ± 16.1	31.7 ± 19.2	t = -3.259; p = 0.002	12.70 ± 15.59			
Bother	27.5 ± 23.1	23.1 ± 24.8	t = -2.473; p = 0.016	31.2 ± 26.1	33.4 ± 22.3	t = -0.343; p = 0.732	20.5 ± 21.9	34.7 ± 24.2	t = -2.440; p = 0.018	13.77 ± 18.59			
SMFA ?22 Sex	2.7 ± 1.5	3.2 ± 1.5	t = -2.547; p = 0.013	1.9 ± 1.2	2.7 ± 1.6	t = -2.124; p = 0.037	1.8 ± 1.3	2.6 ± 1.6	t = -2.167; p = 0.034				
SMFA ?46 Pain	2.8 ± 1.2	3.6 ± 1.3	t = -2.368; p = 0.021	3.0 ± 1.4	3.2 ± 1.1	t = -0.650; p = 0.518	2.6 ± 1.3	3.2 ± 1.4	t = -1.856; p = 0.068				

LE = lower extremity.

Table 7. Persistent neurologic dysfunction after operative treatment of lateral compression fractures

Neurologic dysfunction	Number	Percent
Numbness	4	3.4
Numbness and motoric lesion	2	1.7
Motoric lesion	4	3.4
Erectile dysfunction	3	2.5
Paraplegia	2	1.7

Discussion

Unstable pelvic fractures create a burden of injury to the patient [54]. To reduce this burden, reduction and stabilization are considered resuscitative measures [43] and fixation of unstable LC fractures has been advocated. In dealing with pelvic trauma, thorough knowledge of pelvic anatomy, fracture mechanism/pattern, and stabilization techniques is necessary [10]. Surgeons must be aware of typical pathologies associated with pelvic trauma and of

Fig. 3 Functional outcome measurements, SMFA, for operatively treated LC pelvic ring injuries show improvement but does not return to normal.**Fig. 4** Functional outcome of bother index and dysfunction index of operatively treated LC pelvic ring injuries shows persistent impairment compared with normative data and other orthopaedic conditions. UE = upper extremity; LE = lower extremity; fx = fracture.

possible complications. They should also be able to estimate outcome after surgical treatment [42]. Many studies have been performed to elucidate the expected clinical outcome [5, 8, 14, 17, 22, 28, 33–35, 42, 46, 52, 53]. Most studies only include a limited number of patients (range, 23–122), different injury patterns (Table 8), and are difficult to interpret because of poor followup, heterogeneity of the injury pattern associated with visceral and neurologic injury, and the lack of a reliable outcome measure for pelvic injuries [9].

There are limitations associated with our study. First, patient followup was limited to complete sets of surveys; these constituted 33% of the total number of operatively treated patients. It is unclear to what degree patients not followed were doing well and chose not to return or doing poorly and sought treatment elsewhere. Thus, the findings could be biased by either over- and underreporting of disability. However, all patients had pre- and postoperative radiographic and CT evaluation of screw placement and fracture reduction quality. All surveys were prospectively gathered at predetermined time intervals. Second, our data were generated from a single trauma center with similarly fellowship-trained orthopaedic surgeons treating the patient cohort. Limited variations might have biased the treatment indications and outcomes and thus affected the generalizability of the data. On the other hand, consistency and predictability of operative indication, implant type, and rehabilitation regimen likely lessened variability. Third, because the pain score was modified from SMFA Question 46, bias and misinterpretation of the question might have resulted. Fourth, one of the problems using general health scores is the lack of discriminating ability when assessing patients with multiple injuries [53]. Postoperatively, although the SMFA has been validated for orthopaedic injuries, the SMFA score may not adequately address the complication or additional medical treatment required after the injury, but compared with the SF-36, it does inquire about sexual function.

LC fractures are usually a result of high-energy trauma. We found a heterogeneous distribution of posterior injury patterns with almost 50% being true sacral fractures, which is in concordance with previously described 45% sacral fractures in pelvic ring disruptions [32]. Historically, varying prognoses for functional healing and outcome were related to these injury patterns [8, 25]. Diagnosis of the posterior injury pattern is essential [2, 36, 49] and the surgical procedure needs to correspond to the injury pattern, soft tissue integrity, and associated injuries [13]. Comparing injury patterns, we found no difference in SMFA scores in the final followup for patients with true sacral fractures compared with patients with sacroiliac joint disruptions, iliac wing fractures, or bilateral lesions. Appropriate surgical treatment leads to a reliable functional and clinical outcome.

Pelvic fractures in elderly patients have been related to higher mortality and worse outcome [7]. In our study, patients younger than 60 years old had higher pain levels, but no differences in SMFA and all subscores were found for patients ≥ 60 years compared with younger patients. Difficulties in operative treatment of pelvic fractures in obese patients have been described [4] and higher complication and reoperation rates have been reported [45]. In contrast to published series, we found no differences in clinical outcome for patients with increasing obesity. When interviewed after a pelvic ring fracture, 45% of women reported feeling less sexually attractive as a result of their injury and 39% reported a decrease in sexual pleasure [31]. Our series did not demonstrate a difference related to sexual functioning or all other subscores between male and female patients.

Residual posterior displacement has been reported to influence postoperative outcome [8, 14, 29, 30]. Near anatomic reduction of the posterior elements can be achieved and should be expected. We found no persistent posterior displacement > 1 cm. Comparing reduction quality, patients with > 5 mm persistent displacement had more difficulty with sexual intercourse at the 6-month interval. This is consistent with previous findings [6]. No other correlation with any functional outcome measurement or return to work was observed.

Twenty-six percent of our patients had an associated fracture of the L5 transverse process. Injuries of this kind may be frequently underestimated or missed, because routine radiologic diagnostic efforts do not provide adequate information to evaluate this area or the examiner's eye does not focus on these injuries. In historic studies, the overall incidence of pelvic ring injuries with associated lumbosacral lesions was 6% and the recognition was clinically relevant [19]. L5/S1 joint dislocation, subluxation, or displacement can impede successful closed reduction attempts of the associated sacral fracture [19]. Isler [19] stated that traumatic destruction and subsequent posttraumatic degeneration of lumbosacral facet joints might be an important etiologic factor for the lumbosacral pain that frequently persists after pelvic ring injuries. We found no difference in chronic back pain in patients with or without L5/S1 involvement. Further analysis with larger studies might elucidate differences in outcomes in fractures with L5/S1 involvement.

LC forces acting on the pelvis occur commonly as a result of high-energy injury [15] and are therefore often related to other injuries [38]. We found 94% of the patients were involved in a high-energy mechanism leading to ISS greater than 15 in 40% of the patients. Surprisingly, the clinical outcome between polytraumatized and nonpolytraumatized patients was similar. Associated LE injuries were associated with worsened clinical outcome, especially in the mechanically relevant subscores (daily activity,

Table 8. Studies related to clinical outcome after lateral compression fractures are difficult to compare because of their heterogeneity

Author	Year	Journal	Number of pelvic fractures	Followup (months)	Inclusion criteria (classification)	Treatment posterior	Treatment anterior	Radiographic measurement	Survey used
Henderson [17]	1989	J Orthop Trauma	26 LC 17	104 (60–188)	AP disruptions	Nonoperative	Nonoperative	Vertical and AP displacement	Not specified
Gruen et al. [14]	1995	J Trauma	48 LC 7	17.5	Tile B and C	ORIF	Based on anterior injury pattern	None	Sickness Impact Profile (SIP)
Tornetta et al. [52]	1996	Clin Orthop Relat Res	29 LC ?	39 (12–84)	APC and LC	?	ORIF	Displacement	Not specified
Totterman et al. [53]	2007	Spine	31 LC 0	16.8 (12–30)	OTA Type C 2 isolated sacral fractures	Operative	Based on anterior injury pattern	Residual displacement	SF-36
Oliver et al. [35]	1996	Injury	35 LC 6	24 (16–28)	Tile B and C	Operative	Based on anterior injury pattern	None	SF-36
Majeed [28]	1989	J Bone Joint Surg Br	42 LC 11	40 (12–72)	APC, LC, VS, CM	External fixator	External fixator	Residual displacement	Majeed
Rommens and Hessmann [42]	2002	J Orthop Trauma	122 LC 24	21.6 (12–73)	Overall Tile B2/3	Surgical treatment	Based on anterior injury pattern	Residual displacement	None
Cole et al. [5]	1996	Clin Orthop Relat Res	52	36 (5–74)	Tile Type C	Percutaneous iliosacral screws	Based on anterior injury pattern	Residual displacement	SF-36 and self-created 40-point scale
Miranda et al. [33]	1996	Clin Orthop Relat Res	80	Minimum 60	Tile A, B, C (31 Class B)	61% external fixation 39% nonoperative	61% external fixation 39% nonoperative	None	SF-36 Iowa pelvic score and questionnaire outcome score
Krappinger et al. [22]	2007	J Orthop Trauma	23	20 (7–57)	OTA Type C	Operative	83.9% ORIF 16.1% nonoperative	Residual displacement	Hannover pelvic outcome score
Suzuki et al. [46]	2007	J Trauma	57 LC 38	Minimum 24	Tile B and C	23 nonoperative, 22 external fixation, 12 internal fixation	Not specified	Residual displacement	Majeed, SF-36, Iowa pelvic score
Mullis and Sagi [34]	2008	J Orthop Trauma	23	(13–120)	VS combined with SI dislocation	Operative	Operative	Residual displacement	Majeed, SF-36, SMFA, IPS
Dujardin et al. [8]	1998	J Orthop Trauma	88 LC 22	55 (18–129)	Tile B and C	36 external fixation 52 nonoperative	12 ORIF 76 nonoperative	Residual displacement	Majeed

APC = AP compression; LC = lateral compression; OTA = Orthopaedic Trauma Association; VS = vertical shear; CM = combined; SI = sacroiliac; ORIF = open reduction and internal fixation.

mobility, dysfunction, and bother). Larger numbers may elucidate which LE injuries determined or weighted the worst outcomes. Urologic injuries were related to LC pelvic injuries in 12% of the cases. This supports earlier studies [9, 27]. A strong association between urethral disruption and subsequent impotence is well documented, but erectile dysfunction appeared associated with distraction rather than compressive injuries [16, 21]. We observed 7.6% of persistent urologic problems, which were not related to any worsening of SMFA index.

Previous studies showed improved short-term outcome with pelvic stabilization [12, 23], but also continued poor outcomes have been reported [40, 55]. In this study, improvements of all functional outcome measurements (except hand/arm as expected) with time were noted. Compared with normative data, patients with LC pelvic injuries had worse mechanical and subjective (bother and emotional) subscores at all time intervals. The indirect or economic costs of an injury are difficult to measure. Chronic pain with less than 50% returning to previous work status has been reported [9]. We could show that a majority of patients were able to predictably return to work. Therefore, surgical expertise treating these fractures may reduce overall costs. The 6-month pain score of four or higher, on a 10-point visual analog scale, determined a worse final pain score and emotional outcome measurement. Further analysis into pain and how patients interpret pain should be performed and could direct treatment, rehabilitation, and activity status.

Our data suggest surgically treated unstable LC pelvic injuries improve with time but result in persistent impairment and permanent long-term disability based on validated outcome measurements. With SMFA, patients with LC fractures reported impaired health with the majority of subscores compared with the general population, illustrating the severity of disability after these injuries. These findings were consistent in both genders. This indicates these injuries affect patients across all major dimensions of health, not only physical, but also mental and social functioning. Although the findings need to be confirmed in studies with high rates of followup, patients with unstable LC pelvic injuries should be counseled concerning long-term function.

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