Feasibility of anterior pelvic ring fixation alone for treating lateral compression type 1 pelvic fractures with nondisplaced complete sacral fractures: a retrospective study

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ABSTRACT

Purpose. The aim of this study was to evaluate the feasibility of anterior pelvic ring fixation alone for treating lateral compression type 1 (LC-1) fractures with nondisplaced complete sacral fractures.

Methods. Patients with LC-1 type pelvic fractures with nondisplaced complete sacral fractures in the Xi’an Honghui Hospital were screened. Those who underwent surgical treatment for the anterior pelvic ring fractures and conservative treatment for the sacral fractures were included in the analysis. The Majeed and Short Form-12 (SF-12) functional scores were used to evaluate these patients.

Results. Of the 123 patients enrolled, 108 (88%) responded to our enquiries regarding the outcome. The mean follow-up period was 18.37 months for the 108 patients who responded. The mean SF-12 functional score was 48.22 ± 9.68. The mean Majeed score was 83.47 ± 9.23, including 52 with excellent, 47 with good, seven with fair, two with poor outcomes. The SF-12 functional and Majeed scores were significantly higher in those aged <45 years or without lower limb injury than in those aged ≥45 years or with lower limb injury (P < 0.05).

Conclusion. Acceptable functional outcomes can be obtained for LC-1 pelvic fractures with nondisplaced complete sacral fractures by using anterior pelvic ring fixation alone.

INTRODUCTION

Lateral compression type 1 (LC-1) pelvic fractures represent a broad spectrum of injuries, including minimal ‘buckle’ impaction fractures of the anterior sacrum to comminuted sacral fractures that extend to and through the posterior cortex (Khoury et al., 2008).

Surgeons might consider multiple factors when determining whether a fracture of this type would benefit from surgical stabilisation. The most important factor is the surgeon’s assessment of fracture stability. However, evaluating the stability of LC-1 pelvic fractures is difficult, and it is a notable research topic in the field of pelvic stability.
Fracture stability is based on initial displacement shown on static radiographs and displacement observed on post-mobilisation radiographs (Bruce, Reilly & Sims, 2011). However, it is difficult to determine whether LC1 fractures are minimally displaced on radiographs obtained shortly after injury (Burgess et al., 1990; Oransky & Tortora, 2007). In clinical practice, pelvic fracture displacement often tends to be underestimated. It has been reported that the peak compression can be 1.3–2.2 times of the final compression appearing on images obtained in the hospital (Ma et al., 2019). Additionally, 37%–68% of LC-1 fractures are associated with clinically significant instability, and they may require operative treatment (Bruce, Reilly & Sims, 2011; Sagi, Coniglione & Stanford, 2011).

In LC-1 pelvic fractures, most sacral fractures are minimally displaced or nondisplaced (Beckmann et al., 2019). LC-1 fractures with incomplete sacral fractures tend to be stable and can be treated conservatively, but LC-1 injuries with complete sacral fractures may indicate instability of the pelvic ring (Bruce, Reilly & Sims, 2011; Lefaivre, Padalecki & Starr, 2009). As for LC-1 injuries with complete sacral fractures, operative stabilisation may be a good choice (Bruce, Reilly & Sims, 2011; Zwingmann et al., 2019).

However, LC-1 injuries have been treated with anterior fixation only, posterior ring fixation only, or anterior and posterior pelvic ring fixation (Avilucea et al., 2018). Because anterior pelvic ring injuries are usually more severe than posterior pelvic ring injuries and fixation of the anterior pelvic ring can provide enough support against the weight-bearing force, we often choose anterior fixation for LC-1 pelvic fractures with complete sacral fractures in our hospital. Thus, the aim of this study was to evaluate the feasibility of anterior pelvic ring fixation alone for treating LC-1 pelvic fractures with nondisplaced complete sacral fractures. We hypothesised that acceptable functional recovery would be achieved with anterior pelvic ring fixation alone.

**METHODS**

**Ethical statement**

This study was approved by the ethical board of Xi’an Jiaotong University (approval number 2018109). The need for informed consent was waived by the Ethics Review Board of Xi’an Jiaotong University.

**Patient selection**

From November 2016 to December 2018, 367 patients with pelvic fractures in Xi’an Honghui Hospital were selected. According to the Young-Burgess classification for pelvic fracture stability (Young et al., 1986) and with consideration of the mechanism of injury mechanism in each patient, three experienced chief physicians screened LC-1 pelvic fractures with sacral complete fractures by using pelvic anterior-posterior, inlet, and outlet plain, computed tomography (CT), and three-dimensional imaging.

The inclusion criteria were LC-1 type pelvic fractures with a mature skeleton, patients older than 18 years with a complete sacral fracture (unlike with an incomplete sacral fracture, the fracture completely penetrated the sacrum on plain CT), and the sacral fracture was initially not displaced (displacement was measured on the CT scan). The exclusion criteria were spinal cord injury, severe cognitive impairment, patients older than

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80 years, incomplete sacral fracture, and complete sacral fracture with displacement greater than one mm.

**Surgical strategy and operative technique**

As for anterior pelvic ring fixation, the method might be affected by the reduction and fixation of the posterior pelvic ring. If anterior reduction was performed well and the fracture could be fixed using a minimally invasive treatment, a cannulated screw was inserted into the pubic ramus. If the reduction was inadequate, the Stoppa approach was used (Ponsen et al., 2006). For the Stoppa approach, a 12–15-cm lengthwise incision was made in the middle of the lower abdomen. Subsequently, one or two plates were placed and fixed unilaterally or bilaterally on the pubic ramus. Moreover, the ilioinguinal approach was used in some patients. A C-arm was used to evaluate reduction of the anterior and posterior pelvic rings. Patients were permitted to walk with crutches at 2–3 weeks postoperatively. If there was no pain, full weight bearing was encouraged.

**Indicators of outcome**

We obtained final follow-up function scores from the patients who we were able to contact, which were defined as the responder group, and those who could not return to the hospital for various reasons were defined as the non-responder group. The baseline data including the sex ratio, age, injury severity score (ISS), mechanism of injury, combined injury, and duration of hospitalisation were compared between the two groups to assess the difference between responders and non-responders. The main outcome indicators of this study were the Majeed functional score and Short Form-12 (SF-12) functional score. The Majeed functional score is widely used to evaluate the prognosis of pelvic fractures (Lefaivre et al., 2012), and this scoring system (total 100 points) consists of subscores for pain (30 points), return to work (20 points), sitting (10 points), sexual intercourse (4 points), walking aids (12 points), unaided gait (12 points), and walking distance (12 points) (Majeed, 1989). Values ≥85 are considered excellent, 70–84 good, 55–69 fair, and <55 poor. In addition, the SF-12 (version 2) was used to assess the general function and disability status of patients as a measure of general physiological and mental health. The Majeed and SF-12 functional scores of the responders were obtained and grouped according to known factors that may affect the prognosis of patients to evaluate the difference in functional recovery within the groups.

**Statistical analysis**

Measurement data such as age, ISS, and duration of hospitalisation were analysed using the independent two-sample t-test. The range of anterior ring injury (unilateral pubic ramus fracture versus bilateral pubic rami fracture), postoperative weight-bearing status (partial weight-bearing, full weight-bearing), age (<45 years, ≥45 years), ISS (<15, ≥15), and presence or absence of injury were analysed in the responder group. The Majeed score and SF-12 functional score for complications (with or without lower limb injury) were also analysed with the independent two-sample t-test. Pearson’s chi-square test or Fisher’s exact test was used to analyse categorical data, such as sex, classification of the mechanism of
injury, combined injury, and anterior pelvic ring fixation. $P$-values $<0.05$ were considered statistically significant.

**RESULTS**

The data of 123 patients with LC-1 pelvic fracture and complete sacral fracture were obtained from the 367 patients. All 123 patients underwent anterior pelvic ring fixation for the LC-1 type pelvic fractures and conservative treatment for the sacral fractures. Of these, 67 patients were fixed with screws, 56 were treated with open reduction and plate fixation, 53 were treated with the modified Stoppa approach, and three were treated with the ilioinguinal approach.

After contacting patients and their families, 108 responders returned to the hospital for further consultation. No differences in sex, age, ISS, mechanism of injury, and duration of hospitalisation were observed between the two groups (Table 1). Regarding the mechanism of injury, traffic crash was the main cause of injury in 39% and 40% of patients in the responder and non-responder groups, respectively. Regarding associated injuries, soft tissue injury was the most common type of injury in both groups. The responder group was followed up for an average of 18.37 (range 7–22) months, and the non-responder group was followed up for an average of 19.13 ± 10.39 months, but without the final functional outcomes. The times to weight bearing were 2.99 ± 0.93 and 3.27 ± 1.28 weeks postoperatively in the responder and non-responder groups, respectively. We evaluated the clinical healing time based on the radiographic findings, symptoms, and signs, and all fractures healed by the last follow-up. Times to healing were 14.59 ± 1.76 and 14.00 ± 1.36 weeks in the responder and non-responder groups, respectively. However, two patients showed displacement of their sacral fractures by 2 and 3 mm, respectively, upon bone union.

In 108 respondents, 9 sacral fracture lines passed through Denis zone 1, 27 through zone 1 and zone 2, 51 through zone 2 alone, and 12 through zone 2 and zone 3; 9 fracture lines were located in Denis zone 3 alone.

The average SF-12 functional score of the 108 patients was 48.22, and there was no significant difference in the SF-12 functional score between patients with unilateral pubic ramus and bilateral pubic rami fractures ($P = 0.676$). There was no difference in the SF-12 functional score between patients with partial and full weight bearing ($P = 0.665$). There was no significant difference in the SF-12 functional score between patients with ISS $<15$ and those with ISS $\geq 15$ ($P = 0.889$). However, the SF-12 functional score was significantly higher in patients younger than 45 years ($51.45 \pm 9.38$) than in those older than 45 years ($43.52 \pm 8.12$, $P = 0.000$). In addition, the SF-12 functional score was significantly higher in patients without lower limb injury ($48.95 \pm 9.27$) than in those with lower limb injury ($42.92 \pm 11.32$, $P = 0.035$).

The average Majeed score of the 108 patients was 83.47 ± 9.23. Outcomes were excellent in 52 patients, good in 47, fair in seven, and poor in two. There was no significant difference in the Majeed score between those with unilateral pubic ramus and bilateral pubic rami fractures ($P = 0.705$). There was no significant difference in the Majeed score between
Table 1  Comparison of baseline data between responders and non-responders.

|                      | Respondents (n = 108) | Non-respondents (n = 15) | Statistic (t/χ²) | P     |
|----------------------|------------------------|--------------------------|------------------|-------|
| **Age**              | 50.61 ± 17.11          | 52.33 ± 12.20            | 0.376            | 0.708 |
| **Gender (%)**       |                        |                          |                  |       |
| Male                 | 51 (47)                | 7 (47)                   | 0.002            | 0.968 |
| Female               | 57 (53)                | 8 (53)                   |                  |       |
| **ISS**              | 20.25 ± 10.26          | 20.53 ± 9.02             | 0.108            | 0.914 |
| **Mechanism of injury (%)** |                     |                          |                  |       |
| Fall from height     | 41 (38)                | 6 (40)                   | 0.076            | 0.963 |
| Motor vehicle crash  | 42 (39)                | 6 (40)                   |                  |       |
| Walking injury       | 25 (23)                | 3 (20)                   |                  |       |
| **Combined injury**  |                        |                          |                  |       |
| Lower limb fracture  | 10                     | 3                        | 0.672            | 0.412 |
| Upper limb fracture  | 6                      | 1                        | –                | 1.000 |
| Cranioencephalic injury | 5                     | 1                        | –                | 0.550 |
| Chest injury         | 16                     | 3                        | 0.019            | 0.889 |
| Abdominal injury     | 5                      | 2                        | –                | 0.203 |
| Soft tissue injury   | 19                     | 4                        | 0.241            | 0.623 |
| Nerve injury symptoms | 6                    | 2                        | –                | 0.251 |
| **Anterior ring fixation** |                   |                          |                  |       |
| Closed screw fixation | 59                  | 8                        | 0.009            | 0.925 |
| Open reduction and plate fixation | 49                | 7                        |                  |       |
| **Length of stay in hospital (days)** | 8.56 ± 3.84          | 9.53 ± 3.38              | –0.927           | 0.356 |
| Follow-up time (month) | 18.37 ± 7.76         | 19.13 ± 10.39            | 0.341            | 0.733 |
| **Weight-bearing time (weeks)** | 2.99 ± 0.93         | 3.27 ± 1.28              | 1.023            | 0.308 |
| Clinical healing time (weeks) | 14.59 ± 1.76        | 14.00 ± 1.36             | –1.250           | 0.214 |

Notes.  
*a*-test.  
bChi-squared test.  
cFishers exact test was used to calculate the statistics and P-value.  
ISS, injury severity score

patients with partial and full weight bearing (P = 0.692). There was no significant difference between patients with ISS <15 and those with ISS ≥15 (P = 0.805). However, the Majeed score was significantly higher in patients younger than 45 years (86.52 ± 8.12) than in those older than 45 years (79.05 ± 9.02, P = 0.000), with the former having a higher functional recovery. Additionally, the Majeed score was significantly higher in patients without lower limb injury (84.35 ± 8.42) than in those with lower limb injury (77.08 ± 12.41, P = 0.007, Table 2). A representative patient is shown in Figs. 1A–1F and Figs. 2A–2H.

**DISCUSSION**

This is the first cases series that focused on isolated anterior pelvic ring fixation for the treatment of LC-1 pelvic fractures. Our study revealed that acceptable functional outcomes can be obtained for LC-1 pelvic fractures with nondisplaced complete sacral fractures by using anterior pelvic ring fixation alone.
|                          | No. of patients | SF-12 scoring | P      | Majeeed score | P      |
|--------------------------|-----------------|---------------|--------|---------------|--------|
| **Total population**     | 108             | 48.22 ± 9.68  |        | 83.47 ± 9.23  |        |
| **Anterior ring fractures** |                |               |        |               |        |
| Unilateral pubic ramus fracture | 69             | 47.93 ± 9.00  | 0.676  | 83.22 ± 9.06  | 0.705  |
| Bilateral pubic ramus fracture | 39             | 48.74 ± 10.88 |        | 83.92 ± 9.63  |        |
| **Postoperative weight-bearing status** |          |               |        |               |        |
| Partial Weight-bearing    | 65             | 47.89 ± 9.77  | 0.665  | 83.18 ± 9.20  | 0.692  |
| Whole Weight-bearing      | 43             | 48.72 ± 13.5  |        | 83.91 ± 9.36  |        |
| **Age(year)**             |                |               |        |               |        |
| <45                       | 64             | 51.45 ± 9.38  | 0.000  | 86.52 ± 8.12  | 0.000  |
| ≥45                       | 44             | 43.52 ± 8.12  |        | 79.05 ± 9.02  |        |
| **ISS score**             |                |               |        |               |        |
| <15                       | 34             | 48.03 ± 9.13  | 0.889  | 83.15 ± 9.34  | 0.805  |
| ≥15                       | 74             | 48.31 ± 9.97  |        | 83.62 ± 9.24  |        |
| **Associated injury**     |                |               |        |               |        |
| With lower limb injury    | 13             | 42.92 ± 11.32 | 0.035  | 77.08 ± 12.41 | 0.007  |
| Without lower limb injury | 95             | 48.95 ± 9.27  |        | 84.35 ± 8.42  |        |

**Notes.**
Statistics and P-values were calculated with the t-test.
ISS, injury severity score; SF-12, Short-Form 12.

**Figure 1.** Representative case: a 27-year-old male patient was injured in a traffic crash. The anterior pelvic ring is treated surgically with the modified Stoppa approach and pelvic reconstruction plates for fixation of the anterior pelvic ring. The sacral fractures are treated conservatively. (A) Preoperative three-dimensional reconstruction image, showing unilateral superior and inferior pubic ramus fractures, with right complete, nondisplaced sacral Denis zone 2 fracture. (B) The complete, nondisplaced sacral fracture on an axial computed tomography (CT) scan. (C) The complete, nondisplaced sacral fracture on the coronal CT scan. (D) Postoperative anterior-posterior plain. (E) Postoperative outlet plain. (F) is the postoperative inlet plain.

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Traditionally, it is difficult to evaluate the stability of LC-1 pelvic fractures and determine whether an LC-1 fracture requires operative treatment. Surgeons often have different opinions on the treatment of LC-1 pelvic fractures (Beckmann et al., 2014). Because of unrecognised instability, late displacement of LC-1 fractures treated nonoperatively occurs; therefore, early identification of these unstable injuries might permit earlier surgical intervention to prevent late displacement (Vaidya et al., 2012). In recent years, Sagi et al. formulated a protocol for performing intraoperative radiography to determine fracture stability (Sagi, Coniglione & Stanford, 2011) and developed a strategy using sequential intraoperative examination under anaesthesia (Avilucea et al., 2018). Those studies revealed that some LC-1 fractures show obvious instability. Unfortunately, we did not perform this stress examination to confirm the instability.

Because LC-1 fractures with complete sacral fractures may indicate instability of the pelvic ring (Bruce, Reilly & Sims, 2011; Lefaivre, Padalecki & Starr, 2009), operative stabilisation may be a good choice (Zwingmann et al., 2019). This was the primary reason why we retrospectively analysed patients with complete sacral fractures. Moreover, some studies have reported the use of anterior and posterior fixation for LC-1 fractures (Avilucea et al., 2018; Hagen et al., 2016; Zwingmann et al., 2019). However, we thought that stable
fixation of the anterior pelvic ring could change the pattern of LC-1 fractures to that of nondisplaced sacral fractures, which could provide enough support against weight-bearing force. There is no risk of nerve root or blood vessel damage in the posterior approach if fixation of the posterior pelvic ring is not performed. On the basis of the aforementioned reasons, we have used anterior pelvic ring fixation alone for LC-1 pelvic fractures with complete sacral fractures in our hospital for the past 5 years.

In our analysis, 15 patients were included in the non-responder group. Those patients were followed up for 19.13 months, but we could not obtain their final function because they either had an excuse (most were too busy) or did not return to the hospital. Therefore, 108 patients were included in the analysis. Functional score results showed that patients with LC-1 pelvic fractures with nondisplaced complete sacral fractures could obtain acceptable clinical results by anterior pelvic ring fixation and conservative treatment of the sacral fractures. According to the confounding factors described in previous studies (Gaffley et al., 2019; Hoffmann, Jones & Sietsema, 2012), we compared the functional outcomes in subgroups by anterior ring fractures, postoperative weight-bearing status, age, ISS, and associated injury. There was no significant functional differences in unilateral and bilateral pubic ramus fractures, in partial and whole weight bearing or ISS <15 and ≥15, between the two subgroups. Age was a confounding factor (Gaffley et al., 2019). The average SF-12 functional scores were 51.45 ± 9.38 and 43.52 ± 8.12 in patients aged >45 years and those ≥45 years, respectively. Moreover, the Majeed scores were 86.52 ± 8.12 and 79.05 ± 9.02 in patients aged <45 years and those ≥45 years, and 62 of 64 patients obtained excellent or good outcomes. Further, a study reported that lower extremity injury is an important factor affecting prognosis (Hoffmann, Jones & Sietsema, 2012). Among our 108 patients, 13 were complicated with lower limb injury with an average SF-12 functional score of 42.92 ± 11.32, whereas 95 without lower limb injury had an average score of 48.95 ± 9.27. The Majeed scores were 77.08 ± 12.41 and 84.35 ± 8.42 in patients with and without lower limb injury, respectively. These data demonstrate that patients’ age and the presence or absence of lower limb injury were important factors for functional recovery, and this finding is consistent with those of previous studies (Gruen et al., 1995; Hoffmann, Jones & Sietsema, 2012), in which young patients with isolated pelvic fractures achieved better function than older patients or those with polytrauma.

Our functional analysis did not emphasise on postoperative plain radiography or the quality of reduction but focused on the function of LC-1 fracture patients treated with anterior pelvic ring fixation alone. The relationship between anatomical reduction and the prognosis of pelvic fractures has not been established in current studies (Hessmann et al., 2010; Rommens & Hessmann, 2002). Moreover, all fractures in our study healed by the follow-up, which has indirectly proven the feasibility of anterior pelvic ring fixation alone for treating LC-1 pelvic fractures with nondisplaced complete sacral fractures.

There are some important limitations to this study. Firstly, the study had a retrospective follow-up design, with only an 88% (108/123) response rate, which is low, and we do not know the outcome of 15 patients. Secondly, there was no control group for comparing the main outcome indicators, which makes the findings of this study less convincible and generalisable. Nonetheless, this was the first study to investigate the feasibility of
performing only anterior pelvic ring fixation for treating LC-1 pelvic fractures. Our findings may provide a reference for future randomised clinical trials. Thirdly, although there was no significant difference in baseline data between responders and non-responders, information bias could have been introduced by the responders.

CONCLUSIONS

Our results indicate that acceptable functional outcomes can be achieved for LC-1 pelvic fractures with nondisplaced complete sacral fractures by using anterior pelvic ring fixation alone. In future studies, a control group seems necessary to further study the effect of sacral fractures on LC-1 fractures.

Abbreviations

CT  computed tomography
ISS  injury severity score
LC-1  lateral compression type 1
SF-12  Short Form-12

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Competing Interests

The authors declare there are no competing interests.

Author Contributions

- Kun Shang performed the experiments, analyzed the data, prepared figures and/or tables, authored or reviewed drafts of the paper, and approved the final draft.
- Chao Ke, Shuang Han and Peng-Fei Wang performed the experiments, authored or reviewed drafts of the paper, and approved the final draft.
- Ya-Hui Fu analyzed the data, prepared figures and/or tables, and approved the final draft.
• Bin-Fei Zhang conceived and designed the experiments, analyzed the data, prepared figures and/or tables, authored or reviewed drafts of the paper, and approved the final draft.
• Yan Zhuang conceived and designed the experiments, performed the experiments, prepared figures and/or tables, and approved the final draft.
• Kun Zhang conceived and designed the experiments, authored or reviewed drafts of the paper, and approved the final draft.

**Human Ethics**
The following information was supplied relating to ethical approvals (i.e., approving body and any reference numbers):

The study was approved by the ethical board of Xi’an JiaoTong University (No. 2018109).

**Data Availability**
The following information was supplied regarding data availability:

The raw measurements are available in the **Supplementary Files**.

**Supplemental Information**
Supplemental information for this article can be found online at [http://dx.doi.org/10.7717/peerj.8743#supplemental-information](http://dx.doi.org/10.7717/peerj.8743#supplemental-information).

**REFERENCES**

Avilucea FR, Archdeacon MT, Collinge CA, Sciadini M, Sagi HC, Mir HR. 2018.
Fixation strategy using sequential intraoperative examination under anesthesia for unstable lateral compression pelvic ring injuries reliably predicts union with minimal displacement. *Journal of Bone and Joint Surgery (American Volume)* **100**:1503–1508 DOI 10.2106/JBJS.17.01650.

Beckmann J, Haller JM, Beebe M, Ali A, Presson A, Stuart A, Sagi HC, Kubiak E. 2019.
Validated radiographic scoring system for lateral compression type 1 (LC-1) pelvis fractures. *Journal of Orthopaedic Trauma* **34**(2):70–76 DOI 10.1097/BOT.0000000000001639.

Beckmann JT, Presson AP, Curtis SH, Haller JM, Stuart AR, Higgins TF, Kubiak EN. 2014.
Operative agreement on lateral compression-1 pelvis fractures. A survey of 111 OTA members. *Journal of Orthopaedic Trauma* **28**:681–685 DOI 10.1097/BOT.0b013e318299a462.

Bruce B, Reilly M, Sims S. 2011.
OTA highlight paper predicting future displacement of nonoperatively managed lateral compression sacral fractures: can it be done? *Journal of Orthopaedic Trauma* **25**:523–527 DOI 10.1097/BOT.0b013e3181f8be33.

Burgess AR, Eastridge BJ, Young JW, Ellison TS, Ellison Jr PS, Poka A, Bathon GH, Brumback RJ. 1990.
Pelvic ring disruptions: effective classification system and treatment protocols. *Journal of Trauma* **30**:848–856 DOI 10.1097/00005373-199007000-00015.
Gaffley M, Weaver AA, Talton JW, Barnard RT, Stitzel JD, Zonfrillo MR. 2019. Age-based differences in the disability of extremity injuries in pediatric and adult occupants. *Traffic Injury Prevention* 20:1–6 DOI 10.1080/15389588.2019.1658873.

Gruen GS, Leit ME, Gruen RJ, Garrison HG, Auble TE, Peitzman AB. 1995. Functional outcome of patients with unstable pelvic ring fractures stabilized with open reduction and internal fixation. *Journal of Trauma* 39:838–844 DOI 10.1097/00005373-199510000-00006.

Hagen J, Castillo R, Dubina A, Gaski G, Manson TT, O’Toole RV. 2016. Does surgical stabilization of lateral compression-type pelvic ring fractures decrease patients’ pain, reduce narcotic use, and improve mobilization? *Clinical Orthopaedics and Related Research* 474:1422–1429 DOI 10.1007/s11999-015-4525-1.

Hessmann MH, Rickert M, Hofmann A, Rommens PM, Buhl M. 2010. Outcome in pelvic ring fractures. *European Journal of Trauma and Emergency Surgery* 36:124–130 DOI 10.1007/s00068-010-1042-0.

Hoffmann MF, Jones CB, Sietsema DL. 2012. Persistent impairment after surgically treated lateral compression pelvic injury. *Clinical Orthopaedics and Related Research* 470:2161–2172 DOI 10.1007/s11999-012-2247-1.

Khoury A, Kreder H, Skrinskas T, Hardisty M, Tile M, Whyne CM. 2008. Lateral compression fracture of the pelvis represents a heterogeneous group of complex 3D patterns of displacement. *Injury* 39:893–902 DOI 10.1016/j.injury.2007.09.017.

Lefaivre KA, Padalecki JR, Starr AJ. 2009. What constitutes a young and burgess lateral compression-I (OTA 61-B2) pelvic ring disruption? A description of computed tomography-based fracture anatomy and associated injuries. *Journal of Orthopaedic Trauma* 23:16–21 DOI 10.1097/BOT.0b013e31818f8a81.

Lefaivre KA, Slobogean GP, Valeriote J, O’Brien PJ, Macadam SA. 2012. Reporting and interpretation of the functional outcomes after the surgical treatment of disruptions of the pelvic ring: a systematic review. *Journal of Bone and Joint Surgery (British Volume)* 94:549–555 DOI 10.1302/0301-620X.94B4.27960.

Ma Z, Wu Z, Bai L, Bi C, Zeng X, Qu A, Wang Q. 2019. True compression of pelvic fractures under lateral impact. *International Orthopaedics* 43:1679–1683 DOI 10.1007/s00264-018-4052-2.

Majeed SA. 1989. Grading the outcome of pelvic fractures. *Journal of Bone and Joint Surgery (British Volume)* 71:304–306.

Oransky M, Tortora M. 2007. Nonunions and malunions after pelvic fractures: why they occur and what can be done? *Injury* 38:489–496 DOI 10.1016/j.injury.2007.01.019.

Ponsen KJ, Joosse P, Schigt A, Goslings JC, Luitse JS. 2006. Internal fracture fixation using the Stoppa approach in pelvic ring and acetabular fractures: technical aspects and operative results. *Journal of Trauma* 61:662–667 DOI 10.1097/01.ta.0000219693.95873.24.

Rommens PM, Hessmann MH. 2002. Staged reconstruction of pelvic ring disruption: differences in morbidity, mortality, radiologic results, and functional outcomes between B1, B2/B3, and C-type lesions. *Journal of Orthopaedic Trauma* 16:92–98 DOI 10.1097/00005131-200202000-00004.
Sagi HC, Coniglione FM, Stanford JH. 2011. Examination under anesthetic for occult pelvic ring instability. *Journal of Orthopaedic Trauma* 25:529–536 DOI 10.1097/BOT.0b013e31822b02ae.

Vaidya R, Kubiak EN, Bergin PF, Dombroski DG, Critchlow RJ, Sethi A, Starr AJ. 2012. Complications of anterior subcutaneous internal fixation for unstable pelvis fractures: a multicenter study. *Clinical Orthopaedics and Related Research* 470:2124–2131 DOI 10.1007/s11999-011-2233-z.

Young JW, Burgess AR, Brumback RJ, Poka A. 1986. Pelvic fractures: value of plain radiography in early assessment and management. *Radiology* 160:445–451 DOI 10.1148/radiology.160.2.3726125.

Zwingmann J, Eberbach H, Strohm PC, Sudkamp NP, Lauritsen J, Schmal H. 2019. Decision-making, therapy, and outcome in lateral compression fractures of the pelvis—analysis of a single center treatment. *BMC Musculoskeletal Disorders* 20:217 DOI 10.1186/s12891-019-2583-3.