

Review began 09/06/2022

Review ended 09/13/2022

Published 09/16/2022

© Copyright 2022

Varma et al. This is an open access article distributed under the terms of the Creative Commons Attribution License CC-BY 4.0., which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

# Surgical Versus Non-surgical Treatment of Unstable Lateral Compression Type I (LC1) Injuries of the Pelvis With Complete Sacral Fractures in Non-fragility Fracture Patients: A Systematic Review

Jonny R. Varma<sup>1</sup>, Michael Foxall-Smith<sup>1</sup>, Richard L. Donovan<sup>2</sup>, Michael R. Whitehouse<sup>3</sup>, Chris Rogers<sup>3</sup>, Mehool Acharya<sup>1</sup>

1. Trauma and Orthopaedics, North Bristol NHS Trust, Bristol, GBR 2. University of Bristol, Musculoskeletal Research Unit, Bristol, GBR 3. Musculoskeletal Research Unit, University of Bristol, Bristol, GBR

**Corresponding author:** Jonny R. Varma, jonny.varma@doctors.org.uk

---

## Abstract

Lateral compression type 1 (LC1) injuries comprise two-thirds of pelvic fractures. Approximately one-third of LC1 fractures are unstable and may benefit from surgical fixation to improve stability but it is not clear if this leads to better clinical or cost-effectiveness outcomes. This study explores differences in patient-reported outcomes, complications, time-to-mobilisation, cost-effectiveness, and length of hospital stay between surgically and non-surgically treated unstable LC1 non-fragility fractures.

We performed a systematic review to determine whether surgical or non-surgical treatment yielded better clinical and cost-effectiveness outcomes for the treatment of unstable LC1 pelvic injuries with complete sacral fractures, excluding fragility fractures. We searched Medline, Embase and Cochrane databases from inception to June 2022, as well as clinical trial registries. A formal meta-analysis was not possible due to available study designs and heterogeneity. Therefore, a narrative review of the findings has been provided.

Five observational studies met the inclusion criteria. A total of 183 patients were treated surgically, and 314 patients were treated non-surgically. Patients treated surgically had lower pain levels (Visual Analogue Scale) and fewer days to mobilisation. Quality of life (EuroQol-5 domains and 36-Item Short Form questionnaires) was better in the surgical group, but not statistically significant. No statistical differences in the length of hospital stay or complication rates were found.

This review highlights the low quantity and quality of existing data on patients with unstable LC1 pelvic fractures and the need for a definitive randomised controlled trial to determine whether surgical or non-surgical care should be the preferred treatment concerning clinical and cost-effective care.

---

**Categories:** Orthopedics, Trauma

**Keywords:** screw fixation, pelvic surgery, pelvic ring, pelvic ring injury, closed pelvic fracture

## Introduction And Background

Lateral compression (LC) fractures are the most common type of pelvic fracture, with lateral compression type 1 (LC1) injuries accounting for two-thirds of all pelvic fractures [1,2]. Unstable LC1 fractures are synonymous with the 61B2.1 pelvic ring fractures of the Orthopaedic Trauma Association (OTA)/AO Foundation (AO) classification [3]. LC1 fractures typically result from a lateral force, which frequently leads to pubic rami fractures of the anterior pelvic ring and an associated sacral impaction fracture [4]. The mortality rate of LC1 fractures during index hospital admission is reported to be between 5% and 9% [2].

LC1 fractures may be stable or unstable, which has caused controversy over the optimal management strategy for this injury pattern [5-7]. There is currently no high-quality evidence or agreed surgical strategy for their management. Sagi et al. reported that up to 37% of LC1 fractures are unstable, highlighting the potential role of surgical stabilisation [8]. Surgical fixation may improve time to mobilisation, reduce complications associated with prolonged immobility, and improve long-term functional outcomes [9-11]. Despite this, the risk of surgical site infection, neurovascular injury, reoperation, and the risks of general anaesthesia are potential risks of surgical intervention [10].

Historically, LC1 injuries have been managed non-surgically with restricted weight-bearing, physiotherapy, and walking aids [4]. The contemporary rationale for surgical management of LC1 injuries is to achieve stability, but this depends on the independent clinical judgment of the stability of the injury, which has been demonstrated to be inconsistent among surgeons [9,12]. Uncertainty concerning the definition of 'instability' remains; some surgeons state it depends on the tendency of the fracture to displace over time,

### How to cite this article

Varma J R, Foxall-Smith M, Donovan R L, et al. (September 16, 2022) Surgical Versus Non-surgical Treatment of Unstable Lateral Compression Type I (LC1) Injuries of the Pelvis With Complete Sacral Fractures in Non-fragility Fracture Patients: A Systematic Review. Cureus 14(9): e29239. DOI 10.7759/cureus.29239

while others define it in terms of excessive pain on mobilisation regardless of the bone position (adopting the definition of 'functional' instability) [6,12].

This study aims to systematically review the existing literature to explore if there are any differences in patient-reported outcomes, complications, time-to-mobilisation, cost-effectiveness, and length of hospital stay between surgically and non-surgically treated unstable LC1 non-fragility fractures.

## Review

### Methodology

#### *Data Sources and Search Strategy*

We performed a systematic review per the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines based on a pre-defined methodology registered with the International Prospective Register of Systematic Reviews (PROSPERO ID: CRD42021256075). We systematically searched Medline, Embase and Cochrane (Central) databases from inception to 5 June 2022 for studies reporting on patient-reported outcome measures following surgical versus non-surgical management of unstable LC1 pelvic fractures. The International Clinical Trial Registry Platform was also searched for completed, ongoing, and registered trials. The search terms included a combination of Medical Subject Heading (MeSH) terms, synonyms, and related terms for LC fracture, surgical fixation, and non-surgical management. The detailed search strategies are outlined in Appendix 1. The results of the searches were then integrated into Rayyan [13] online bibliographic software.

One reviewer (JV) reviewed the titles and abstracts of retrieved studies for inclusion suitability and then obtained the full texts of potentially relevant articles for further evaluation. Two reviewers (JV, MFS) independently evaluated the full texts of the articles identified, and any disputes regarding eligibility criteria were discussed with and resolved by a third author (RLD).

#### *Eligibility Criteria and Data Extraction*

Randomised controlled trials (RCTs) and observational studies were eligible for inclusion. The primary outcome was patient-reported outcome measures (PROMs) such as the Iowa Pelvic Score, 36-Item Short Form Health Survey (SF-36), Oxford Hip Score, EuroQol-5 domains-3 level (EQ-5D-5L), and Majeed Pelvic Score; and patient-reported pain (Visual Analogue Scale (VAS), Brief Pain Inventory). Secondary outcomes included complications (wound complications, infections, neurovascular injuries, venous thromboembolic (VTE) events, such as deep vein thrombosis (DVT) and pulmonary embolism, chest infection, metalwork failure, non-union, malunion); re-hospitalisation; mortality; cost-effectiveness; and length of hospital stay.

Studies that (i) included patients with fragility fractures resulting from low-energy trauma (fall from standing height or less); (ii) included children aged 16 years or younger; or (iii) included animals or cadavers were excluded. Two authors (JV, MFS) independently extracted the relevant data from eligible studies. Any disputes were explored and resolved by a third author (RLD).

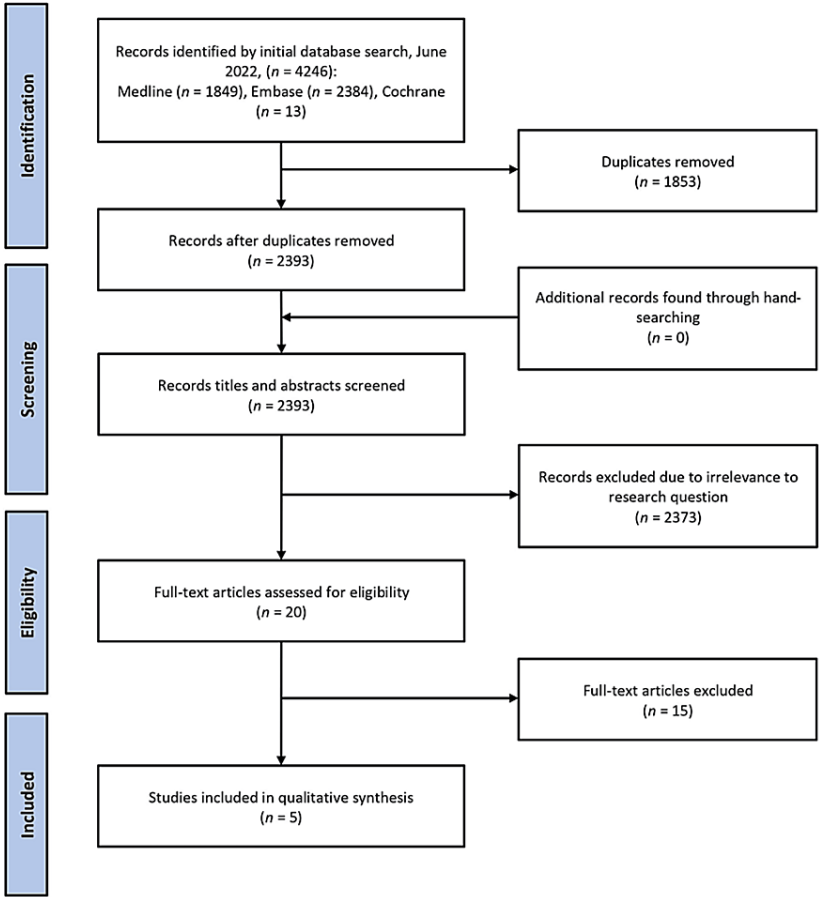
#### *Risk of Bias and Data Synthesis*

The Cochrane Risk of Bias in Non-randomised Studies - of Interventions (ROBINS-I) tool [14], a validated tool for assessing the quality of non-randomised studies, was selected to assess the risk of bias in observational studies. Continuous variables were represented as mean differences (MDs) or standardised mean differences (SMDs) with 95% confidence intervals (CIs). Risk estimates (risk ratios) were used as the standard measure of association across studies for dichotomous variables with 95% CIs. A two-sided statistical significance of 0.05 was used. Due to a paucity of data, we were unable to conduct a formal meta-analysis and have, therefore, provided a narrative review of the findings.

## Results

#### *Study Identification*

The PRISMA flowchart in Figure 1 summarises the study identification and selection process in detail. After removing 1,853 duplicates from the initial searches, 2,393 studies were screened; 2,373 studies were removed after screening titles and abstracts, and an additional 15 studies were excluded after full-text evaluation. Finally, five studies [15-19] were included in this systematic review.



**FIGURE 1: PRISMA flowchart.**

PRISMA: Preferred Reporting Items for Systematic Review and Meta-Analysis

*Study Characteristics*

Table 1 summarises the characteristics of the studies included in the review. The included papers were published between 2016 and 2021. A total of 490 LC1 (or equivalent) injuries were included, of which 183 (37%) were treated surgically. Four studies were retrospective observational studies [15-18], and one was a prospective study [19]. All studies compared surgical versus non-surgical treatment of LC1 (or equivalent) injuries. Most patients were female and in their third or fourth decades of life. Two studies were performed in the United States and three in Europe (Germany and Lithuania). Three studies used shorter-term follow-up time points ranging from 24-48 hours [15] to 1-12 weeks [16,19] post-injury, one study had a mean follow-up period of 47 months (standard deviation (SD): 13-82 months) [17], and the largest follow-up duration was a mean of 52 months (SD: 48-84 months) [18]. Primary outcome data from the five individual papers are listed in Table 2.

Source and study design	Participants and characteristics	Fracture classification	Intervention and comparator	Length of follow-up	Fixation technique
Hagen et al. (2016), United States. Retrospective observational study [15]	Age - Surgical: Mean = 35 (SD = 13.4). Non-Surgical: Mean = 41 (SD = 21); Sex - Surgical: 21 male; 30 female. Non-surgical: 53 male; 54 female	Sample size Young & Burgess - LC1 = 158	Surgical - n = 51. Non-surgical - n = 107	Post-injury - Time points at 24 hours and 48 hours after admission, and 24 hours before discharge, respectively; Time to Mobilisation - Timepoint at which patient achieved independent transfer from the bed to the chair	Posterior percutaneous fixation with or without anterior fixation (n = 51)
Höch et al. (2018), Germany. Retrospective observational study [17]	Age - Surgical: Mean = 39 (SD = 13.2). Non-Surgical: Mean = 35.6 (SD = 14.7); Sex - Surgical: 19 male; 17 female. Non-Surgical: 19 male; 16 female	Sample size OTA/Tile - Type B2.1 = 71	Surgical - n = 36; Non-surgical - n = 35	Post-injury - At least at 1 year, mean 47 months	Isolated percutaneous sacroiliac screw fixation (n = 25), isolated stabilisation of the anterior pelvic ring using plate osteosynthesis (n = 8), isolated percutaneous anterior screw fixation of the pubic rami (n = 1) with sacroiliac screw fixation (n = 1), external fixation only (n = 1)
Petryla et al. (2021), Lithuania. Retrospective observational study [16]	Age - Surgical: Mean = 35.84 (SD = 12.22). Non-Surgical: Mean = 40.11 (SD = 16.56); Sex - Surgical: 10 male; 27 female. Non-Surgical: 3 male; 15 female	Sample size OTA/Tile - Type B2.1 = 55	Surgical - n = 37; Non-surgical - n = 18	Post-injury - Timepoint I - before injury (pre-traumatic condition). Timepoint II - 10 weeks following injury	Anterior and posterior pelvic ring fixation (n = 23), posterior ring fixation only (n = 13), external fixation only (n = 1)
Tornetta et al. (2019), United States. Prospective observational study [19]	Age - Surgical: Mean = 40.1. Non-Surgical: Mean = 38.2; Sex - Surgical: 18 male; 26 female. Non-surgical: 53 male; 84 female	Sample size Young & Burgess - LC1 = 187, Combined = 1, Unknown = 6	Surgical - n = 50; Non-surgical - n = 144	Post-injury - Timepoints: 24 hours, 1 week, 3 weeks, 6 weeks, 12 weeks	Anterior and posterior fixation (n = 29), posterior fixation only (n = 19), anterior fixation only (n = 2)
Zwingmann et al. (2019), Germany. Retrospective observational study [18]	Age - Surgical: Mean = 43 (SD = 22.5). Non-surgical: Mean = 45.5 (SD = 25.1); Sex - Surgical: 2 male; 7 female, Non-surgical: 5 male; 5 female	Sample size OTA/Tile - Type B2 = 19	Surgical - n = 9; Non-surgical - n = 10	Post Injury - Mean 4.3 years (range = 2–7; SD = 2)	Sacroiliac screw fixation (n = 9)

**TABLE 1: Characteristics of the included studies.**

LC1: lateral compression 1; SD: standard deviation

Study	PROMs	Pain	Other secondary outcomes	Length of hospital stay
Hagen et		10-point VAS - Change in pain from pre-treatment to post-treatment (Surgical treatment effect): 0.02 (SD = 0.4; 95% CI = -0.8 to 0.8; p = 0.96); Post-treatment to discharge (Surgical treatment effect): 1.85 (SD = 0.6; 95% CI = -0.7 to 3.0; p = 0.002); Last 24 hours of admission (Surgical treatment effect): 1.2 (SD = 0.5; 95%	Days-to-mobilisation - Surgical treatment	Not

al. [15]	Not measured	CI = 0.2 to 2.2; p = 0.021); 48 hours into admission (Surgical treatment effect): -0.15 (SD = 0.5; 95% CI = -1.1 to 0.8; p = 0.764); Narcotic use (mg) – 48 hours into admission (Surgical treatment effect): 3.9 (SD = 16.1; 95% CI = -28.1 to 35.9; p = 0.811); Last 24 hours of admission (Surgical treatment effect): -0.49 (SD = 8.7; 95% CI = -17.7 to 16.7; p = 0.955)	effect: -1.7 (SD 0.08; 95% CI -3.3 to -0.01; p=0.034)	reported
Höch et al. [17]	EQ-5D - Surgical: 91.8 (SD = 9.3), non-surgical: 89.5 (SD = 18.4); SF-36 - entire cohort PCS Mean: 44.8 (SD 10), entire cohort MCS Mean: 52.6 (SD = 15) (no significant difference between surgical/non-surgical cohorts)	10-point VAS - Surgical: 2.6 (SD = 2.1), non-surgical: 2.8 (SD = 2.5)	Overall complication rate (%) - Surgical: 6 (SD = 16.7), non-surgical: 4 (SD = 11.5; p > 0.5); Infection to anterior plate – n = 1; injury to bladder - Surgical: n = 1, non-surgical: n = 1	Surgical: Mean = 14 days (range = 1–71), non-surgical: Mean = 13 days (range = 3–35; p > 0.05)
Petryla et al. [16]	Majeed score - Change in score with surgical management: -34.08 (SD = 18.95), change in score with non-surgical management: -31.44 (SD = 14.41; p = 0.542); SF-36 - Change in PCS with surgical management: -19.45 (SD = 9.95), Change in PCS with non-surgical management: -19.36 (SD = 7.88; p = 0.687), change in MCS with surgical management: -6.38 (SD = 11.04), Change in MCS with non-surgical management: -7.23 (SD = 10.86, p = 0.816)	Bodily pain score (of SF-36) - Change in score with surgical management: -47.3 (SD = 29.02), Change in score with non-surgical management: -40.72 (SD = 25.58; p = 0.445)	Surgical complications - Complication rate: 18.9%, wound infection (n = 1), screw migration (n = 2), S1 neuropathy (n = 4)	Not reported
Tornetta et al. [19]	Not measured	10-point VAS - 6 weeks post-surgical: 3.5, 6 weeks post non-surgical: 5.2 (p = 0.033); 12 weeks post-surgical: 2.9, 12 weeks post non-surgical: 4 (p = 0.019)	Not measured	Not reported
Zwingmann et al. [18]	EQ-5D - Surgical: 0.88 (SD = 0.14), non-surgical: 0.85 (SD = 0.14; p = 0.965); Merle d'Aubigne score - surgical: 15.9 (SD = 2.2), non-surgical: 16.3 (SD = 2.2; p = 0.768)	10-point VAS - Surgical: 7.1 (SD = 2.0), non-surgical: 7.7 (SD = 2.1, p = 0.508)	Not measured	Surgical: Mean = 16 days (SD = 7.3), non-surgical: Mean = 12.5 days (SD = 7.4; p = 0.315)

**TABLE 2: Summary of primary outcome data.**

CI: confidence interval; EQ-5D: EuroQol-5D Score; MCS: mental component score; PROMs: patient-reported outcome measures; PCS: physical component score; SF-36: 36-Item Short Form Survey; SD: standard deviation; VAS: Visual Analogue Score

#### *Risk of Bias*

Two studies had a serious risk of bias due to confounding, while the remaining three had a moderate risk of bias, according to the ROBINS-I tool. Appendix 2 contains the detailed risk of bias assessments for the

included studies.

### Primary Outcome Analysis

Patient-reported outcome measures: quality of life (QoL): PROMs were measured in three studies; two studies used the EQ-5D-3L questionnaire [18,19], two employed the SF-36 [17,18], and two reported the Majeed score and Merle d'Aubigne hip score [17,19].

The EQ-5D questionnaire is a standardised scoring system that assesses a patient's QoL across five domains, including physical and mental health (scale: -0.594 to 1.000, where 0 represents death, and less than 0 represents a QoL worse than death). After a follow-up of at least one year, Höch et al. observed no significant difference in EQ-5D between surgical (mean: 91.8, SD: 9.3) and non-surgical (mean: 89.5, SD: 18.4;  $p > 0.05$ ) treatment groups (EQ-5D scores were multiplied by 100). Similarly, after a mean follow-up of 4.3 years, Zwingmann et al. reported no significant differences in EQ-5D scores between the surgical (mean: 0.88, SD: 0.14) and non-surgical groups (mean: 0.85, SD: 0.14;  $p = 0.965$ ).

The SF-36 questionnaire (scale: 0-100, where the lower limit represents extreme disability/symptoms, and the upper limit represents no disability/symptoms) is another standardised scoring system that assesses a patient's QoL. Petryla et al. measured the SF-36 scores of the respective cohorts at two time points (pre-injury and 10 weeks post-injury) and found no statistically significant differences in the change of the mental component summary (MCS) (surgical mean: -6.38, SD: 11.04; non-surgical mean: -7.23, SD: 10.86;  $p = 0.816$ ) or physical component summary (PCS) (surgical mean: -19.45, SD: 9.95; non-surgical mean: -19.36, SD: 7.88;  $p = 0.687$ ). Höch et al. also evaluated the SF-36 at least one year post-injury, and there was no statistically significant difference in mean MCS and PCS SF-36 scores ( $p > 0.05$ ) between treatment groups.

Patient-reported outcome measures: function: Zwingmann et al. used the Merle d'Aubigne hip score (scale of 0-6 for each domain of walking, pain, and mobility, where 6 represents the best condition and 0 represents the worst condition), and Petryla et al. used the Majeed score (a standardised survey to assess functional outcomes after pelvic fractures, with domains focused on mobility, sexual intercourse, and pain, scored from 0 to 100, where  $<55$  represents poor function, and  $\geq 85$  represents excellent function) to assess functional status. Zwingmann et al. discovered no statistically significant differences in functional status between treatment groups after a mean 4.3-year follow-up (surgical mean: 15.9, SD: 2.2; non-surgical mean: 16.3, SD: 2.2;  $p = 0.768$ ). Similarly, when assessed 10 weeks post-injury by Petryla et al., the Majeed score showed no statistical difference between cohorts (surgical mean change: -34.08, SD: 18.95; non-surgical mean change: -31.44, SD: 14.41;  $p = 0.542$ ).

Pain: Four studies assessed pain using the VAS (scale: 0-10, where 0 represents no pain, and 10 represents the worst pain) [15,16,18,19]. Some results were presented as an overall surgical treatment effect, a single figure denoting the difference between the mean score in the non-surgical cohort versus the surgical cohort. The surgical cohort in Hagen et al. had a statistically significant improvement in VAS pain scores from post-treatment to discharge from the hospital (surgical treatment effect [non-surgery score minus surgery score]: 1.85, SD: 0.6, 95% CI: -0.7 to 3.0;  $p = 0.002$ ) and in the last 24 hours of admission (surgical treatment effect: 1.2, SD: 0.5, 95% CI: 0.2 to 2.2;  $p = 0.021$ ) compared to the non-surgical cohort. In addition to the VAS, Hagen et al. also measured narcotic usage 48 hours into the admission (surgical treatment effect: 3.9, SD: 16.1, 95% CI: -28.1 to 35.9;  $p = 0.811$ ) and in the last 24 hours of admission (surgical treatment effect: -0.49, SD: 8.7, 95% CI: -17.7 to 16.7;  $p = 0.955$ ) but these results yielded no statistical significance.

Tornetta et al. observed that the surgical cohort had better VAS scores six weeks post-injury (surgical mean: 3.5; non-surgical mean: 4;  $p = 0.033$ ) and 12 weeks post-injury (surgical mean: 2.9; non-surgical mean: 4;  $p = 0.019$ ). Conversely, in the two studies where patients were followed up over a longer period, the changes in VAS score were negligible; this was noted in Zwingmann et al. (surgical: 7.1, SD: 2.0; non-surgical: 7.7, SD: 2.1;  $p = 0.508$ ) and Höch et al. (surgical: 2.6, SD: 2.1; non-surgical: 2.8, SD: 2.5;  $p > 0.05$ ) after a mean follow-up of 52 months and 47 months, respectively.

### Secondary Outcome Analysis

Length of hospital stay: Two studies reported the length of hospital stay [17,18]. Höch et al. reported a mean length of 14 days (range: 1-71) for the surgical cohort and 13 days (range: 3-35) for the non-surgical cohort, with no statistical difference ( $p > 0.05$ ). Zwingmann et al. reported no significant difference between treatment groups (surgical mean: 16 days, SD: 7.3; non-surgical mean: 12.5 days, SD: 7.4;  $p = 0.315$ ).

Associated complications: Complications after treatment of LC1 injuries were discussed in two studies [16,17]. Höch et al. were the only researchers to detail complication rates in both treatment groups. The surgical cohort had a complication rate of 6% versus 4% in the non-surgical cohort, with no statistical significance ( $p > 0.05$ ). Bladder injury, pneumonia, acute respiratory distress syndrome, surgical malpositioning, and infected metalwork were among the reported complications. Petryla et al. only reported the complications in the surgical cohort, including wound infection ( $n = 1$ ), screw migration ( $n = 2$ ) and S1 neuropathy ( $n = 4$ ), yielding a total surgical complication rate of 18.9%.

Days to mobilisation: Hagen et al. measured the number of days required for the patient to transfer independently from the bed to the chair. The surgical treatment group had a mean reduction of 1.7 days to independent mobilisation compared to the non-surgical group (mean difference (surgical minus non-surgical): -1.7 days, SD: 0.08, 95% CI: -3.3 to -0.01;  $p = 0.034$ ).

## Discussion

This is the first systematic review to investigate the surgical versus non-surgical treatment of unstable LC1 injuries in the non-fragility fracture population. Five observational studies were eligible for inclusion in this study. Two of the included studies displayed a serious risk of bias, with the remainder deemed to display moderate risk.

Three studies used the SF-36 or EQ-5D to assess QoL, with no statistical differences between treatment groups. Two studies also demonstrated no correlations between functional outcomes at a mean follow-up of ten weeks and four months, respectively.

Surgical fixation was positively correlated with reduced pain in the short term, particularly from the postoperative period to discharge from the hospital and up to 12 weeks post-injury. Surgical fixation was also found to reduce the time to mobilisation by 1.7 days, measured in one study. However, in two studies investigating longer-term outcomes, there was no statistical difference in pain between treatment groups after four to five years. Despite these results, there is ongoing debate regarding the minimal clinically important difference (MCID) for VAS in patients with these injuries. The VAS MCID for pain due to osteoarthritis of the knee, for example, has been demonstrated to be a 2.5 score reduction for surgical or rehabilitative therapy [20]. In the aforementioned study, the differences in VAS were 1.7 and 1.1 at six weeks and 12 weeks follow-up, respectively. Nonetheless, the VAS has proven reliable for pain measurement among patients of all ages and educational levels [21].

Few studies investigated post-treatment complications but found no statistical difference in their results, albeit they are likely to be underpowered for determining true statistical significance. In Höch et al., although the overall complication rate was negligible between the non-surgical and surgical cohorts (11.5 vs. 16.7%,  $p > 0.5$ ), 8% of the complications in the surgical group were directly related to the surgery.

Although LC1 injuries include both unstable and stable fractures, this review has focused on those with unstable injury patterns. Currently, there are conflicting views on what constitutes an unstable LC1 injury, with some authors basing their criteria on the degree of fracture displacement [22] and others on the patient's pain, for example [12]. A recent cadaveric study also revealed that the displacement of LC1 injuries may be related to pubic rami fracture morphology with oblique pubic rami fractures being most susceptible to displacement over time [23].

Treatment of LC1 injuries varies with no agreed algorithm for determining whether patients would be better off receiving surgical or non-surgical care [24]. Beckmann et al. used the expert opinion of 111 orthopaedic surgeons to develop a validated radiographic scoring system for LC1 fractures [24]. Specific parameters, such as ramus displacement, Denis classification, and sacral displacement, were included in the system, with a score greater than nine out of 14 indicating the need for surgery [25]. Similar efforts have been proposed by Sagi et al. suggesting  $>1$  cm and Giannoudis et al. advising  $\geq 2$  cm of pubic rami displacement as cut-offs for surgical intervention [8,26]. Despite these efforts, Hadeed et al. outlined that fellowship-trained orthopaedic surgeons often exhibit inconsistent measurement of sacral fracture completeness in LC1 injuries [27].

Although there have been attempts to study the optimum management algorithm, only one clinical trial has been published to date. In patients with minimally displaced LC fractures of the pelvis, Slobogean et al. discovered that surgical fixation results in a minor but sustained improvement in pain and function for up to 12 months. Patients with a 5 mm displacement were the best surgical candidates, with the most short-term pain relief after surgery [28]. However, because the cohort contained both LC1 and LC2 fractures, this study was excluded from our review.

Lykomiros et al. demonstrated that patients with sacral fractures treated non-surgically had better SF-36 scores in all domains than those treated surgically. The authors highlighted that patients treated surgically had more concomitant injuries, resulting in a higher Injury Severity Score (ISS), a possible confounder for the lack of improvement in QoL following surgical management [29]. Similarly, Tosounidis et al. reported that surgical stabilisation of LC1 injuries reduced pain and analgesic requirements significantly in the immediate post-injury period [26]. However, this study was excluded from our review due to the absence of complete sacral fractures in the non-surgical comparison group.

The existing literature is very limited in the reporting of function and postoperative complication outcomes. A feasibility study has been conducted [30], demonstrating that it would be feasible to recruit into a definitive RCT comparing the surgical and non-surgical treatment of LC1 fractures. A trial could further investigate PROMs, function, pain, QoL, complications, and economic evaluations.



Our review has several limitations. All of the included studies were observational, inherently increasing the risk of confounding and selection bias; this was emphasised in the risk of bias assessment, as all studies were of moderate-to-serious risk of bias. The severity of concomitant injuries was not controlled for; for example, a polytraumatised patient may be more likely to undergo surgical intervention than a patient with an isolated unstable LC1 fracture. The surgical group tended to have more severe injuries, perhaps more significant pain, and reduced QoL. We were unable to perform a formal meta-analysis due to heterogeneity of the time points at which outcomes were measured in individual studies and a lack of consistency in reporting. There were variations in surgical technique, which further increased the risk of confounding. Furthermore, there is no widely accepted protocol for LC1 fracture management, and each study had variable eligibility criteria for surgical intervention: some placing greater emphasis on pain and mobility, and others on initial displacement on static radiographs to aid decision-making.

## Conclusions

Unstable LC1 fractures are a heterogenous injury pattern, with no current agreed protocol for surgical intervention. The studies that met our eligibility criteria demonstrated small improvements in short-term pain and days-to-mobilisation with surgical fixation, but no statistically significant differences in functional outcomes or QoL; however, all included studies were of moderate-to-serious risk of bias. This review highlights the low quantity and quality of existing data on patients with unstable LC1 pelvic non-fragility fractures and the need for a definitive RCT to determine whether surgical or non-surgical care should be the preferred treatment in terms of clinical and cost-effective care.

## Appendices

### Appendix 1: Detailed search strategy

Search strategy for Ovid MEDLINE(R) ALL

From inception to 21 June 2021

- 1 Fractures, Compression (2538)
- 2 Pelvic Bones (9923)
- 3 1 and 2 (47)
- 4 "LC1" or "LC-1" mp. (806)
- 5 "lateral compression" adj3 fractur\$.mp. (71)
- 6 "pelvic ring" adj3 fractur\$.mp. (791)
- 7 "lateral compression" adj3 injur\$.mp. (77)
- 8 or/4-7 (1689)
- 9 3 or 8 (1711)

Search strategy for Embase

From inception to 21 June 2021

- 1 compression fracture/ (6665)
- 2 pelvis fracture/ (7236)
- 3 1 and 2 (137)
- 4 "LC1" or "LC-1" .mp. (1092)
- 5 "lateral compression" adj3 fractur\$.mp. (86)
- 6 "pelvic ring" adj3 fractur\$.mp. (913)
- 7 "lateral compression" adj3 injur\$.mp. (85)
- 8 or/4-7 (2111)



9 3 or 8 (2204)

Search strategy for Cochrane Central

From inception to 21 June 2021

#1 MeSH descriptor: [Fractures, Compression] explode all trees (154)

#2 MeSH descriptor: [Pelvis] explode all trees (978)

#3 #1 and #2 (0)

#4 "LC1" or "LC-1" (50)

#5 "lateral compression" (20)

#6 "pelvic" or "pelvis" (17472)

#7 (#4 or #5) AND 6 (10)

Search strategy for Ovid Medline(R) All

From inception to 05 June 2022

1 Fractures, Compression (2883)

2 Pelvic Bones/ (10359)

3 1 and 2 (56)

4 "LC1" or "LC-1" mp. (863)

5 "lateral compression" adj3 fractur\$.mp. (79)

6 "pelvic ring" adj3 fractur\$.mp. (859)

7 "lateral compression" adj3 injur\$.mp. (86)

8 or/4-7 (1825)

9 3 or 8 (1849)

10 limit 9 to last year (229)

Search strategy for Embase

From inception to 05 June 2022

1 compression fracture/ (7245)

2 pelvis fracture/ (7750)

3 1 and 2 (147)

4 "LC1" or "LC-1" .mp. (1169)

5 "lateral compression" adj3 fractur\$.mp. (94)

6 "pelvic ring" adj3 fractur\$.mp. (1003)

7 "lateral compression" adj3 injur\$.mp. (90)

8 or/4-7 (2283)

- 93 or 8 (2384)
- limit 9 to last year (275)
- Search strategy for Cochrane Central
- From inception to 05 June 2022
- #1MeSH descriptor: [Fractures, Compression] explode all trees (170)
- #2MeSH descriptor: [Pelvis] explode all trees (1080)
- #3#1 and #2 (2)
- #4“LC1” or “LC-1” (52)
- #5“lateral compression” (24)
- #6“pelvic” or “pelvis” (18759)
- #7(#4 or #5) AND 6 (13)

Appendix 2: Risk of bias scores

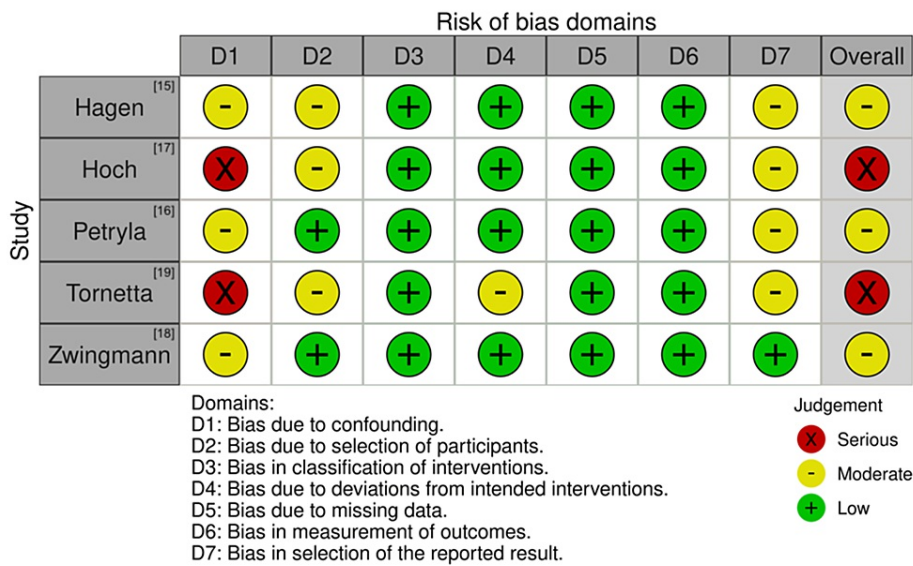


FIGURE 2: Risk of bias scoring.

[15-19].

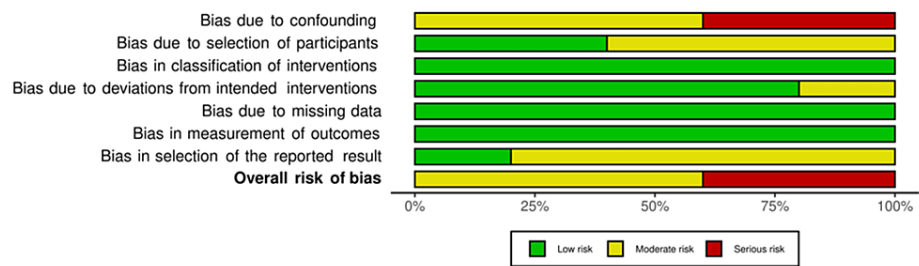


FIGURE 3: Risk of bias scoring.

## Additional Information

### Disclosures

**Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

### Acknowledgements

This study was supported by the NIHR Biomedical Research Centre at University Hospitals Bristol and Weston NHS Foundation Trust and the University of Bristol. The views expressed are those of the author(s) and not necessarily those of the NIHR or the Department of Health and Social Care.

## References

- Young JW, Burgess AR, Brumback RJ, Poka A: Lateral compression fractures of the pelvis: the importance of plain radiographs in the diagnosis and surgical management. *Skeletal Radiol*. 1986, 15:103-9. [10.1007/BF00350202](https://doi.org/10.1007/BF00350202)
- Burgess AR, Eastridge BJ, Young JW, et al.: Pelvic ring disruptions: effective classification system and treatment protocols. *J Trauma*. 1990, 30:848-56.
- Alton TB, Gee AO: Classifications in brief: Young and Burgess classification of pelvic ring injuries. *Clin Orthop Relat Res*. 2014, 472:2338-42. [10.1007/s11999-014-3693-8](https://doi.org/10.1007/s11999-014-3693-8)
- Tile M: Pelvic ring fractures: should they be fixed? *J Bone Joint Surg Br*. 1988, 70:1-12. [10.1302/0301-620X.70B1.3276697](https://doi.org/10.1302/0301-620X.70B1.3276697)
- Khoury A, Kreder H, Skrinkas T, Hardisty M, Tile M, Whyne CM: Lateral compression fracture of the pelvis represents a heterogeneous group of complex 3D patterns of displacement. *Injury*. 2008, 39:893-902. [10.1016/j.injury.2007.09.017](https://doi.org/10.1016/j.injury.2007.09.017)
- Lefaiivre KA, Padalecki JR, Starr AJ: 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. *J Orthop Trauma*. 2009, 23:16-21. [10.1097/BOT.0b013e31818f8a81](https://doi.org/10.1097/BOT.0b013e31818f8a81)
- Bazylewicz D, Konda S: A review of the definitive treatment of pelvic fractures. *Bull Hosp Jt Dis* (2013). 2016, 74:6-11.
- Sagi HC, Coniglione FM, Stanford JH: Examination under anesthetic for occult pelvic ring instability. *J Orthop Trauma*. 2011, 25:529-36. [10.1097/BOT.0b013e31822b02ae](https://doi.org/10.1097/BOT.0b013e31822b02ae)
- Vallier HA, Lowe JA, Agel J, et al.: Surgery for unilateral sacral fractures: are the indications clear? *J Orthop Trauma*. 2019, 33:619-25. [10.1097/BOT.0000000000001587](https://doi.org/10.1097/BOT.0000000000001587)
- Mardanpour K, Rahbar M: The outcome of surgically treated traumatic unstable pelvic fractures by open reduction and internal fixation. *J Inj Violence Res*. 2013, 5:77-83. [10.5249/jivr.v5i2.138](https://doi.org/10.5249/jivr.v5i2.138)
- Vallier HA, Cureton BA, Schubeck D, Wang XF: Functional outcomes in women after high-energy pelvic ring injury. *J Orthop Trauma*. 2012, 26:296-301. [10.1097/BOT.0b013e318221e94e](https://doi.org/10.1097/BOT.0b013e318221e94e)
- Kuršumović K, Hadeed M, Bassett J, Parry JA, Bates P, Acharya MR: Lateral compression type 1 (LC1) pelvic ring injuries: a spectrum of fracture types and treatment algorithms. *Eur J Orthop Surg Traumatol*. 2021, 31:841-54. [10.1007/s00590-021-02935-z](https://doi.org/10.1007/s00590-021-02935-z)
- Rayyan—a web and mobile app for systematic reviews. (2022). <https://www.rayyan.ai/>.
- Sterne JA, Hernán MA, Reeves BC, et al.: ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. *BMJ*. 2016, 355:i4919. [10.1136/bmj.i4919](https://doi.org/10.1136/bmj.i4919)
- Hagen J, Castillo R, Dubina A, Gaski G, Manson TT, O'Toole RV: Does surgical stabilization of lateral compression-type pelvic ring fractures decrease patients' pain, reduce narcotic use, and improve mobilization? *Clin Orthop Relat Res*. 2016, 474:1422-9. [10.1007/s11999-015-4525-1](https://doi.org/10.1007/s11999-015-4525-1)
- Petryla G, Uvarovas V, Bobina R, et al.: Short-term functional outcomes and quality of life after B2.1 type pelvic fractures for surgically and non-surgically treated young patients. *Medicina (Kaunas)*. 2021, 57:513. [10.3390/medicina57060513](https://doi.org/10.3390/medicina57060513)
- Höch A, Schneider I, Todd J, Josten C, Böhme J: Lateral compression type B 2-1 pelvic ring fractures in young patients do not require surgery. *Eur J Trauma Emerg Surg*. 2018, 44:171-7. [10.1007/s00068-016-0676-](https://doi.org/10.1007/s00068-016-0676-)

18. Zwingmann J, Eberbach H, Strohm PC, Südkamp NP, Lauritsen J, Schmal H: Decision-making, therapy, and outcome in lateral compression fractures of the pelvis - analysis of a single center treatment. *BMC Musculoskelet Disord*. 2019, 20:217. [10.1186/s12891-019-2583-3](https://doi.org/10.1186/s12891-019-2583-3)
19. Tornetta P 3rd, Lowe JA, Agel J, et al.: Does operative intervention provide early pain relief for patients with unilateral sacral fractures and minimal or no displacement?. *J Orthop Trauma*. 2019, 33:614-8. [10.1097/BOT.0000000000001578](https://doi.org/10.1097/BOT.0000000000001578)
20. Bodian CA, Freedman G, Hossain S, Eisenkraft JB, Beilin Y: The visual analog scale for pain: clinical significance in postoperative patients. *Anesthesiology*. 2001, 95:1356-61. [10.1097/0000542-200112000-00013](https://doi.org/10.1097/0000542-200112000-00013)
21. Hawker GA, Mian S, Kendzerska T, French M: Measures of adult pain: Visual Analog Scale for Pain (VAS Pain), Numeric Rating Scale for Pain (NRS Pain), McGill Pain Questionnaire (MPQ), Short-Form McGill Pain Questionnaire (SF-MPQ), Chronic Pain Grade Scale (CPGS), Short Form-36 Bodily Pain Scale (SF-36 BPS), and Measure of Intermittent and Constant Osteoarthritis Pain (ICOAP). *Arthritis Care Res (Hoboken)*. 2011, 63 Suppl 11:S240-52. [10.1002/acr.20543](https://doi.org/10.1002/acr.20543)
22. Parry JA, Hadeed MM, Tucker NJ, et al.: Nonoperative management of minimally displaced lateral compression type 1 pelvic ring injuries with and without occult instability. *J Orthop Trauma*. 2022, 36:287-91. [10.1097/BOT.0000000000002300](https://doi.org/10.1097/BOT.0000000000002300)
23. Marengi N, Bang KE, Danelson K, et al.: Contributions of pubic rami fracture morphology and fixation to pelvic ring stability in type 1 lateral compression injuries: a biomechanical cadaveric study. *J Orthop Trauma*. 2022, 36:S7-S11. [10.1097/BOT.0000000000002306](https://doi.org/10.1097/BOT.0000000000002306)
24. Beckmann JT, Presson AP, Curtis SH, Haller JM, Stuart AR, Higgins TF, Kubiak EN: Operative agreement on lateral compression-1 pelvis fractures. A survey of 111 OTA members. *J Orthop Trauma*. 2014, 28:681-5. [10.1097/BOT.0000000000000133](https://doi.org/10.1097/BOT.0000000000000133)
25. Beckmann J, Haller JM, Beebe M, et al.: Validated radiographic scoring system for lateral compression type 1 pelvis fractures. *J Orthop Trauma*. 2020, 34:70-6. [10.1097/BOT.0000000000001639](https://doi.org/10.1097/BOT.0000000000001639)
26. Tosounidis T, Kanakaris N, Nikolaou V, Tan B, Giannoudis PV: Assessment of lateral compression type 1 pelvic ring injuries by intraoperative manipulation: which fracture pattern is unstable?. *Int Orthop*. 2012, 36:2553-8. [10.1007/s00264-012-1685-4](https://doi.org/10.1007/s00264-012-1685-4)
27. Hadeed M, Strage K, Heare A, Stacey SC, Mauffrey C, Parry JA: Sacral fracture completeness in lateral compression type 1 pelvic ring injuries has weak interobserver reliability. *J Orthop Trauma*. 2021, 35:650-3. [10.1097/BOT.0000000000002125](https://doi.org/10.1097/BOT.0000000000002125)
28. Slobogean GP, Gaski GE, Nascone J, et al.: A prospective clinical trial comparing surgical fixation versus nonoperative management of minimally displaced complete lateral compression pelvis fractures. *J Orthop Trauma*. 2021, 35:592-8. [10.1097/BOT.0000000000002088](https://doi.org/10.1097/BOT.0000000000002088)
29. Lykomitros VA, Papavasiliou KA, Alzeer ZM, Sayegh FE, Kirkos JM, Kapetanos GA: Management of traumatic sacral fractures: a retrospective case-series study and review of the literature. *Injury*. 2010, 41:266-72. [10.1016/j.injury.2009.09.008](https://doi.org/10.1016/j.injury.2009.09.008)
30. Barnfield S, Ingram J, Halliday R, et al.: TULIP: a randomised controlled trial of surgical versus non-surgical treatment of lateral compression injuries of the pelvis with complete sacral fractures (LC1) in the non-fragility fracture patient-a feasibility study protocol. *BMJ Open*. 2020, 10:e036588. [10.1136/bmjopen-2019-036588](https://doi.org/10.1136/bmjopen-2019-036588)