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Systematic review

Traumatic spinal cord injury with associated long-bone fractures, timing of spinal stabilization vs. fixation and effect on outcomes

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Abstract

Background: Traumatic spinal cord injury with associated long-bone fractures is a surgical priority. Spinal decompression targets neurological recovery, and fracture fixation target skeletal stability and rehabilitation. This review examined timing, operative sequencing, and clinical outcomes. **Methods:** Literature published from inception to 31 May 2026 was searched. We include ten original studies organized into data involving concurrent spinal cord injury and limb fractures or indirect evidence concerning spinal surgery and polytrauma fracture fixation. Heterogeneity supported narrative synthesis rather than pooled estimation. **Results:** Three retrospective studies addressed limb fractures accompanying acute spinal cord injury, reporting benefits of operative management for selected fractures, with fracture-specific complications. Seven studies evaluated spinal decompression, spinal stabilization, resuscitation-guided skeletal surgery; early spinal decompression was associated with greater neurological recovery, and earlier stabilization frequently correlated with shorter hospitalization. Resuscitation-guided fixation correlated with fewer complications in observational comparisons, and immediate femoral nailing increased acute lung injury among physiologically borderline patients; none of the ten studies compared spine-first against fracture-first surgery in the combined-injury population. **Conclusion:** our findings supports early spinal decompression after stabilization of life-threatening injuries and fracture fixation guided by physiological recovery. The principal data gap concerns coordinated surgical sequencing, with neurological recovery, pulmonary complications, fracture healing, and rehabilitation requiring simultaneous consideration in future prospective comparative research in centers.

Keywords: Spinal cord injuries; spinal fractures; long-bone fractures; fracture fixation; surgical decompression.

Introduction

Traumatic spinal cord injury (SCI) produces motor, sensory, and autonomic dysfunction, with consequences extending from acute physiological instability to persistent disability and dependence. The initial mechanical insult initiates secondary processes involving ischemia, inflammation, and progressive tissue injury, establishing the biological rationale for interventions that preserve spinal cord function (1). Neurological recovery, assessed using the American Spinal Injury Association Impairment Scale (AIS), underpins guidelines favoring decompression within 24 hours when medically feasible across injury levels (2).

Associated long-bone fractures introduce additional requirements for alignment, mechanical stability, soft-tissue protection, and preservation of joint movement during early stages of recovery. Acute management guidance distinguishes these traumatic injuries from fractures occurring later in osteoporotic, chronically paralyzed limbs and supports early extraspinal stabilization in medically stable patients (3). The same guidance show rehabilitation needs and protection of insensate

skin, making fracture treatment relevant even when initial neurological impairment is substantial.

Spinal decompression and spinal stabilization represent related surgical objectives, although neurological relief and mechanical fixation address different consequences of injury and require separate outcome assessment (2,4). A systematic review of thoracolumbar trauma associated earlier stabilization with reduced morbidity for thoracic injuries, while identifying uncertainty surrounding mortality and neurological outcomes. These findings place pulmonary complications, intensive care utilization, and hospital length of stay with neurological recovery when evaluating the timing of spinal surgery in multiply injured patients (4).

Long-bone management introduces another time-sensitive decision, with femoral fixation guidelines conditionally favoring intervention within 24 hours on the basis of predominantly low-certainty evidence (5). Polytrauma literature simultaneously emphasizes resuscitation, treatment of life-threatening injuries, and staged spinal procedures when physiological instability prevents extensive definitive surgery (6). The clinical question involves both elapsed time and tolerance of the cumulative

operative burden across spinal and limb procedures, rather than a single deadline applied without regard to associated injuries (5,6).

Operative technique complicates interpretation because a Cochrane review of pedicle screw fixation examined instrumentation comparisons, with several trials excluding neurological impairment, rather than the sequence of spinal and limb operations (7). These distinct literature streams justify framework that separates concurrent-injury observations from indirect studies addressing one component of the combined presentation (3–7). The present review therefore examines timing, sequencing, neurological recovery, systemic complications, fracture healing, and rehabilitation, explicitly distinguishing evidence about earlier treatment from evidence establishing which operation precedes the other in patients with traumatic SCI and associated long-bone fractures.

Methods

Review design and eligibility

The review framework follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The population of interest comprises patients with acute traumatic SCI and long-bone fractures sustained during the same injury event. The comparison is spinal decompression before definitive limb fixation versus limb fixation before spinal surgery or a combined operative episode. The concurrent-injury stratum includes original studies of fracture management during acute SCI. The indirect stratum includes comparative studies of acute SCI decompression, unstable spinal fracture stabilization in polytrauma, and long-bone fixation in multiply injured patients. We exclude chronic SCI fragility fractures, isolated case reports, pediatric-only studies, animal experiments, and nontraumatic spinal disorders.

Search strategy and independent review

Authors search protocol covers PubMed, Scopus, Web of Science, and the Cochrane Library from inception through 31 May 2026. Search concepts combine spinal cord injury, spinal fracture, polytrauma, femoral or tibial or humeral fracture, long-bone fracture, decompression, stabilization, fixation, timing, sequencing, early surgery, and damage control. Separate spinal and limb timing searches identify indirect evidence without presenting it as evidence from the combined population.

Two authors independently screen titles and abstracts, assess full texts, and extract data using standardized forms. Disagreements are resolved through discussion after comparison with the source report. Duplicate publications are linked to their cohorts, with the most complete report selected for each outcome.

Extraction, appraisal, and synthesis

Extraction records study design, recruitment setting, patient and fracture denominators, neurological level, injury completeness, associated injuries, physiological condition, procedure, timing origin, comparison thresholds, and follow-up. Outcomes include neurological improvement, mortality, pulmonary complications, ventilation duration, intensive care and hospital stays, thromboembolism, pressure injuries, infection, union, joint movement, and rehabilitation.

Two authors appraise randomized studies with Risk of Bias 2 (RoB 2) and observational studies with the Joanna Briggs Institute checklist. Interpretation considers confounding, treatment allocation, missing follow-up, outcome ascertainment, and applicability to concurrent injuries. Narrative synthesis groups findings by evidence stratum, intervention, timing threshold, and outcome domain. Meta-analysis is reserved for clinically

comparable data with independent cohorts, consistent definitions, and extractable effect estimates; incompatible studies are summarized individually without an aggregate patient denominator or numerical ranking of operative sequences.

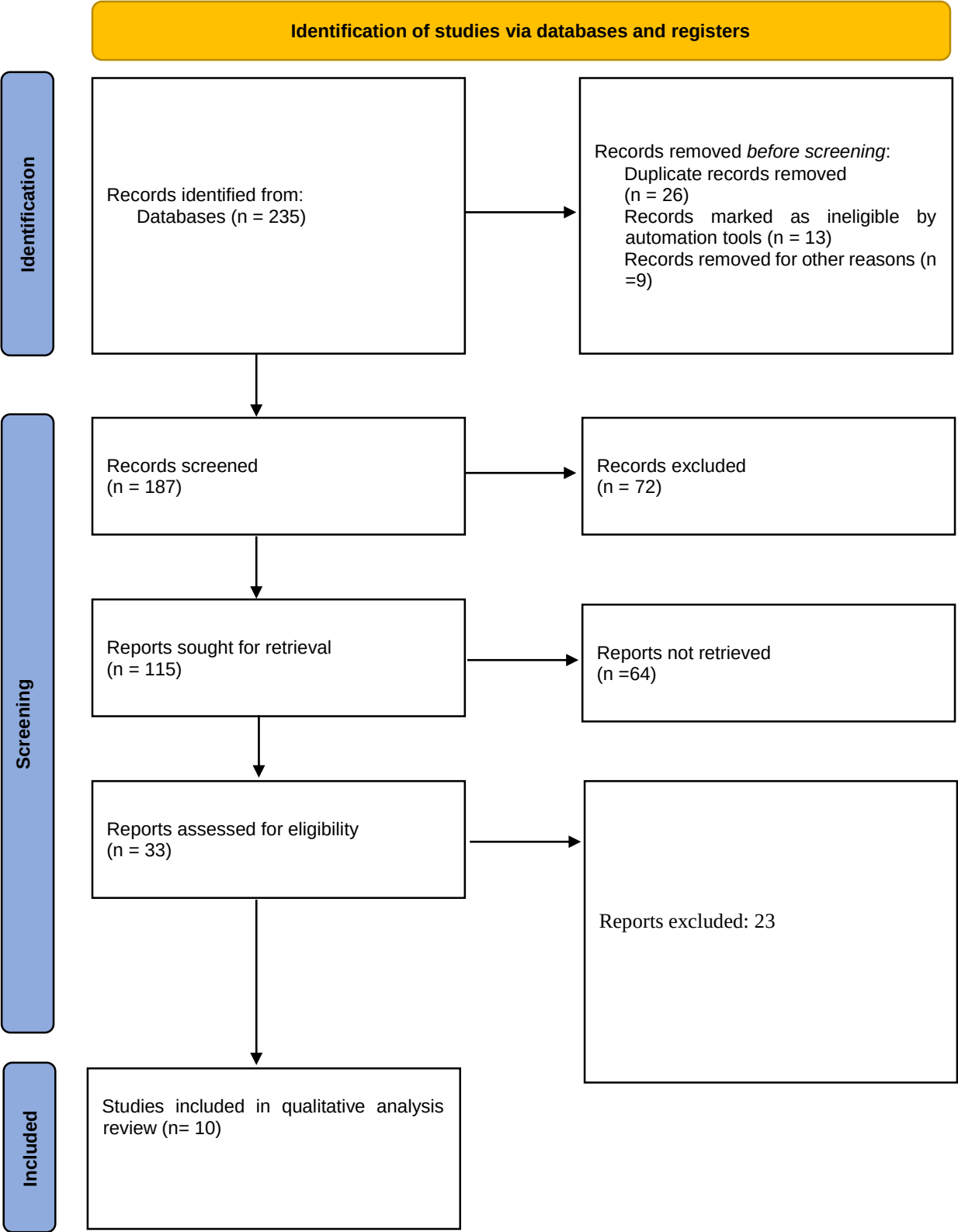


Figure 1: PRISMA flow chart

Results

The concurrent-injury stratum comprised three retrospective reports of limb fracture management during acute SCI, beginning with Garland and colleagues' study of 27 femoral shaft fractures in 23 patients (8). Their tibial study examined 34 fractures in 28 patients and distinguished nonoperative treatment, early internal fixation, and severe open injuries (9). A third report compared operative and nonoperative treatment of 53 upper-extremity long-bone fractures in 46 patients (10).

In the femoral series, all eight fractures treated operatively within six weeks united, whereas four patients in the delayed operative group required manipulation for restricted knee movement (8). In the tibial series, healing complications occurred in nine of 17 nonoperatively managed fractures and one of 11 fractures undergoing early internal fixation, with average union times of 6.5 months and 12 weeks, respectively (9). Upper-extremity medical complications occurred in 28% of nonoperatively treated cases and 4% of operatively treated cases, although results differed across fracture patterns and operative complications included forearm synostosis (10).

The Surgical Timing in Acute Spinal Cord Injury Study (STASCIS) enrolled 313 patients with cervical SCI; among 222 with six-month follow-up, improvement of at least two AIS grades occurred in 19.8% after decompression within 24 hours and 8.8% after later surgery (11). Haghnegahdar and colleagues reported 73 protocol-treated patients with thoracic or thoracolumbar SCI, with corresponding twelve-month improvements of 24.3% and 5.6% for surgery before 24 hours versus 24–72 hours (12). The latter trial found no statistically significant difference in improvement of at least one AIS grade, distinguishing its positive two-grade endpoint from other endpoints (12). STASCIS excluded life-

threatening injuries preventing early decompression, restricting applicability to patients requiring immediate competing emergency procedures (11).

Croce and colleagues analyzed 291 patients undergoing spinal fracture fixation, associating stabilization within three days with reduced pneumonia and resource use, particularly in thoracic injuries (13). Sousa and colleagues examined 50 injured patients and reported shorter ventilation, intensive care, and hospital stays with stabilization within 72 hours. Their duration analyses excluded inpatient deaths, and mortality did not differ between timing groups (14).

Bone et al. randomized 178 patients with femoral fractures, finding greater pulmonary morbidity and longer hospitalization with delayed stabilization among multiply injured patients (15). Pape et al. studied 165 patients and identified increased acute lung injury after primary intramedullary nailing in the physiologically borderline subgroup relative to temporary external fixation (16). Vallier et al. prospectively assessed 335 patients with major skeletal injuries, reporting complications in 16.3% after definitive fixation within 36 hours and 33.3% after later treatment under a resuscitation-guided protocol, vallier's cohort included 79 spinal fractures and 31 patients with SCI, without reporting outcomes for a concurrent-injury subgroup (17).

Timing definitions ranged from hours to weeks, precluding equivalence between historical early limb surgery and contemporary emergency stabilization (8,11–17). Concurrent-injury studies evaluated fracture treatment without controlled comparisons of spinal-versus-limb operative order, and indirect studies supplied component-specific findings rather than combined-population sequence effects.

Table 1. Studies of limb fractures accompanying acute SCI

Study and design	Population	Treatment comparison	Findings and relevance
Garland 1985; retrospective	23 patients; 27 femoral shaft fractures with acute SCI	Nonoperative; early operative; delayed operative; early defined within six weeks	All eight early-operated fractures united; four delayed-operation patients required knee manipulation; no spinal-versus-limb sequence estimate reported in the abstract (8).
Garland 1986; retrospective	28 patients; 34 tibial fractures with acute SCI	Nonoperative: 17 fractures; early ORIF: 11; severe open injuries: six	Healing complications: 53% nonoperative versus 9% early ORIF; severe open fractures had delayed union or nonunion irrespective of treatment (9).
Garland 1988; retrospective	46 patients; 53 upper-extremity long-bone fractures with recent SCI	Operative: 24 fractures; nonoperative: 29	Medical complications: 4% operative versus 28% nonoperative; operative forearm treatment involved synostosis in three combined radius-ulna fractures; operative sequence unreported in the abstract (10).

Table 2. Indirect studies concerning surgical timing and physiological readiness

Study and design	Population	Timing or strategy	Principal finding and applicability
Fehlings 2012; prospective cohort	313 cervical SCI patients; 222 followed at six months	Decompression <24 versus ≥24 hours	≥2 AIS-grade improvement: 19.8% versus 8.8%; concurrent-fracture sequencing untested; life-threatening injuries preventing early decompression excluded (11).
Haghnegahdar 2020; randomized trial	73 protocol-treated thoracic/thoracolumbar SCI patients	Decompression <24 versus 24–72 hours	≥2 AIS-grade improvement: 24.3% versus 5.6%; OR 5.46, 95% CI 1.09–27.38; no limb-sequence comparison (12)
Croce 2001; retrospective cohort	291 patients requiring spinal fracture fixation	Within three days versus later	Earlier fixation associated with less pneumonia and shorter ICU stay, especially for thoracic fractures; combined-injury sequence untested (13).
Sousa 2022; retrospective cohort	50 ICU patients requiring spinal stabilization	Within 72 hours versus later	Among survivors, ventilation: 7.2 versus 14.2 days; hospital stay: 34 versus 60 days; no significant mortality difference (14).

Study and design	Population	Timing or strategy	Principal finding and applicability
Bone 1989; randomized trial	178 adults with femoral fractures	Fixation within 24 hours versus after 48 hours	Delayed treatment increased pulmonary complications and hospital utilization in multiply injured patients; SCI-specific sequence effects unreported (15).
Pape 2007; randomized trial	165 multiply injured patients with femoral shaft fractures	Primary nailing versus temporary external fixation	Borderline patients: adjusted acute-lung-injury odds 6.69 times greater with nailing; physiological subgroup finding, without SCI-specific sequencing (16).
Vallier 2015; prospective cohort	335 patients; 380 major skeletal fractures	Definitive fixation within 36 hours versus later, guided by resuscitation	Complications: 16.3% versus 33.3%; hospital stay: 9.5 versus 17.3 days; mixed fracture populations; concurrent-injury subgroup effects unreported (17).

Discussion

The included studies addressed fracture management or surgical timing without directly comparing spinal-first and limb-first pathways. This distinction prevents neurological benefits observed after decompression from being interpreted as proof that definitive spinal instrumentation always precedes fracture fixation (11,12). It also prevents favorable fracture outcomes from establishing limb-first surgery as the preferred strategy in patients with an acutely compressed spinal cord (8–10).

The neurological interpretation is strengthened by Badhiwala and colleagues' individual-patient analysis of 1,548 patients, which associated decompression within 24 hours with an adjusted four-point advantage in motor recovery at one year. That analysis identified declining neurological benefit as surgical delay increased during the first 24–36 hours, supporting protection of the early decompression window. Applied to concurrent fractures, this supports avoiding avoidable delays to neural decompression, while acknowledging that the pooled analysis did not test the order of limb fixation and spinal surgery (18).

Physiological readiness provides a complementary explanation for conflicting orthopedic findings, since early stabilization in adequately resuscitated patients differs from extensive definitive surgery during ongoing systemic compromise (16,17). The 2024 hemodynamic guideline proposes a lower mean arterial pressure limit of 75–80 mmHg and an upper limit of 90–95 mmHg during active augmentation, with weak recommendations reflecting very-low-certainty evidence (19). These recommendations concern spinal perfusion rather than clearance for fracture fixation, so blood-pressure targets and metabolic resuscitation criteria represent distinct assessments within coordinated perioperative management (17,19).

Schindler and colleagues' sequencing review emphasizes early surgery for unstable spinal injuries with neurological deficits and temporary extremity stabilization when definitive reconstruction

imposes physiological burden (20). Picetti and colleagues' consensus similarly prioritizes treatment of life-threatening conditions before urgent decompression and stabilization of surgical spinal lesions, preferably within 24 hours (21). Taken together, these sources support an interpretation in which emergency priorities and physiological tolerance govern sequencing, while early decompression remains a specific objective after initial stabilization (19–21).

The orthopedic interpretation also accords with Steinfeld and colleagues' systematic review, which found benefits of definitive femoral nailing for selected stable polytrauma patients without a statistically significant mortality difference between early and late stabilization (22). This emphasizes that improvements in ventilation or hospital utilization do not establish survival benefit, particularly when the underlying studies are small or heterogeneous (14,22). For concurrent SCI, limb stability additionally addresses joint movement, skin protection, and rehabilitation, outcomes captured in the older fracture series without modern standardized measures of independence or participation (8–10).

Abstract-based extraction for the older fracture reports limits assessment of operative sequencing, treatment selection, and additional unreported outcomes (8–10). Several limitations constrain causal inference, including retrospective treatment selection in the concurrent-injury series, loss to follow-up in STASCIS, and imprecise estimates in the thoracolumbar randomized trial. Differences in neurological level, open-fracture severity, chest injury, operative technique, and definitions of early surgery further restrict direct comparison across studies. Future comparative research requires explicit reporting of both operative timestamps, physiological trajectories, neurological examinations, fracture healing, and rehabilitation outcomes to distinguish the effect of surgical sequence from the clinical conditions determining that sequence.

Conclusion

Our findings favors early spinal decompression after stabilization of life-threatening injuries and timely fracture fixation matched to physiological recovery. The literature does not establish a universal spine-first or fracture-first sequence for patients with concurrent traumatic SCI and long-bone fractures. Direct concurrent-injury studies support attention to fracture healing, joint movement, skin protection, and rehabilitation, whereas larger timing studies provide indirect neurological and systemic outcome evidence. Coordinated decisions require assessment of spinal compression, mechanical instability, associated injuries, and operative tolerance.

Abbreviations

AIS: American Spinal Injury Association Impairment Scale.

CI: Confidence interval.

ICU: Intensive care unit.

OR: Odds ratio.

ORIF: Open reduction and internal fixation.

PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

RoB 2: Risk of Bias 2.

SCI: Spinal cord injury.

STASCIS: Surgical Timing in Acute Spinal Cord Injury Study.

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