Research Article
E-ISSN : 3048-1368
Volume 36, Issue No. 02. 2026
P-ISSN : 3048-1376

The International Journal of Medical Science and Health Research

What is The Effectiveness of Early Versus Delayed Surgical Fixation of Orthopaedic Injuries on Mortality and Functional Outcomes in Multiply Injured Patients? : A Systematic Review

[1] Kenny Yose Timisela

[1] Mimika Regency Regional General Hospital, Indonesia / Graduate of Faculty of Medicine, Indonesian Christian University, Indonesia

Corresponding Email : timiselakenny@gmail.com

Article History :

Received date	: 2025/12/23
Revised date	: 2026/01/09
Accepted date	: 2026/02/18
Published date	: 2026/03/24

E-ISSN :
ISSN 3048-1368
9 773048 136000

P-ISSN
ISSN 3048-1376
9 773048 137007

ABSTRACT

Introduction: The optimal timing for surgical fixation of orthopedic injuries in multiply injured patients remains controversial, with conflicting evidence regarding early versus delayed intervention. This review synthesizes current evidence on the effectiveness of early compared to delayed surgical fixation on mortality and functional outcomes in polytrauma patients.

Methods: A comprehensive review of 80 studies examining timing of surgical fixation in multiply injured patients was conducted. Studies included randomized controlled trials, cohort studies, systematic reviews, and meta-analyses. Early fixation was variably defined as within 24-72 hours, delayed beyond these cutoffs. Outcomes assessed included mortality, complications (ARDS, pneumonia, multiple organ failure), healthcare utilization, and functional outcomes.

Results: Early definitive fixation was not associated with increased mortality in adequately resuscitated patients (1.4% vs 1.6%, p=0.78) (1). However, early surgery in specific high-risk populations—particularly thoracic spine fractures with hemoglobin <10 mg/dL—showed significantly increased mortality (p<0.01) (14). Early fixation consistently reduced ARDS (1.7% vs 5.3%, p=0.048) (1), pneumonia (8.6% vs 15.2%, p=0.07), hospital length of stay (10.5 vs 14.3 days, p=0.001), and ICU days (5.1 vs 8.4 days, p=0.006). Damage control orthopedics offered no survival advantage over early total care (OR 0.92) and increased complications (39). Functional outcome data were limited, though early spinal decompression improved neurological recovery (log OR 0.82, p<0.001) (18).

Discussion: Benefits of early fixation depend on adequate resuscitation, with subclinical hypoperfusion (lactate ≥2.5 mmol/L) predicting poor outcomes (13). Injury pattern significantly influences optimal timing, with thoracic spine injuries requiring caution while lumbar and extremity fractures benefit from early intervention.

Conclusion: Early fixation within 24-48 hours is safe and beneficial in adequately resuscitated polytrauma patients but should be avoided in those with subclinical hypoperfusion or specific high-risk injury combinations. A physiology-driven, injury pattern-specific approach optimizes outcomes.

Keywords: Polytrauma, fracture fixation, surgical timing, damage control orthopedics, mortality, functional outcomes

INTRODUCTION

Background

Multiply injured patients presenting with orthopedic injuries requiring surgical fixation represent a complex clinical challenge in trauma care. The optimal timing for definitive fracture stabilization has been debated for decades, with evolving paradigms from "early total care" to "damage control orthopedics" and more recently "early appropriate care" (1,4,36). Polytrauma patients—defined as those with two or more significant injuries affecting different body systems—experience a systemic inflammatory response that can be exacerbated by major surgical procedures, potentially leading to complications including acute respiratory distress syndrome (ARDS), multiple organ failure (MOF), and death (15,36).

The historical approach of delayed fixation, with patients maintained in traction until physiologic stability, was challenged in the 1980s by studies demonstrating benefits of early stabilization, particularly for femoral shaft fractures (3). Subsequent concerns about "second hit" phenomenon from intramedullary nailing in patients with chest injuries led to the damage control orthopedics (DCO) concept, utilizing temporary external fixation followed by delayed definitive fixation (36,61). More recently, the early appropriate care (EAC) protocol has emerged, emphasizing physiologic parameters rather than absolute time cutoffs to guide surgical timing decisions (20,38).

Problem Statement

Despite extensive research, significant controversy persists regarding the optimal timing for surgical fixation in multiply injured patients. Studies report conflicting findings—some demonstrating improved outcomes with early fixation (1,3,4), others showing increased complications or mortality (14,15,43), and still others finding no significant differences (9,55). This inconsistency may reflect heterogeneity in patient populations, injury patterns, timing definitions, and outcome measures across studies. Furthermore, the majority of available evidence comes from retrospective cohort studies with inherent confounding by indication, where the most severely injured patients may be selected for either early or delayed intervention based on institutional protocols and clinical judgment.

Research Gap

Several critical gaps remain in the literature. First, the interaction between specific injury patterns and optimal timing has been inadequately characterized—whether thoracic spine fractures, pelvic ring injuries, and femoral shaft fractures should be managed with identical timing protocols remains unclear (14,30,44). Second, the role of physiologic parameters beyond vital signs (lactate, base deficit, inflammatory markers) in guiding timing decisions requires further elucidation (13,35). Third, functional outcome data comparing early versus delayed fixation are remarkably sparse, with most studies focusing on short-term morbidity and mortality (17,18). Fourth, the applicability of findings from high-volume trauma centers to diverse clinical settings remains uncertain.

Novelty

This review provides a comprehensive synthesis of the most recent evidence (including 2024-2025 publications) examining timing of orthopedic fixation in polytrauma patients, with particular emphasis on injury pattern-specific considerations and the emerging role of physiologic end-points in surgical decision-making. By systematically analyzing 80 studies across multiple injury types, this review offers a granular, context-dependent framework for clinical decision-making rather than a simplistic "early versus late" dichotomy.

Hypothesis

We hypothesize that early surgical fixation (within 24-48 hours) in adequately resuscitated multiply injured patients is associated with reduced mortality, lower complication rates, shorter hospital and ICU stays, and improved functional outcomes compared to delayed fixation. However, we also hypothesize that specific patient subgroups—particularly those with subclinical hypoperfusion, severe chest trauma with thoracic spine fractures, or traumatic brain injury requiring neurosurgical intervention—may experience worse outcomes with early intervention.

Research Objectives

1. To compare mortality rates between early and delayed surgical fixation in multiply injured patients

2. To evaluate complication rates (ARDS, pneumonia, MOF, thromboembolic events) associated with timing of fixation
3. To assess healthcare utilization outcomes including hospital and ICU length of stay, ventilator days
4. To examine functional outcome differences between early and delayed fixation groups
5. To identify patient and injury characteristics that modify the relationship between surgical timing and outcomes
6. To develop an evidence-based framework for determining optimal fixation timing based on injury pattern and physiologic status

Research Benefits

This review aims to provide clinicians with practical guidance for surgical decision-making in complex polytrauma patients. By synthesizing the best available evidence, we seek to reduce practice variation, optimize patient outcomes, and inform future research directions. The findings may also contribute to development of institutional protocols and potentially reduce healthcare costs through decreased complications and hospital utilization.

METHODS

Protocol

The study strictly adhered to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) 2020 guidelines to ensure methodological rigor and accuracy. This approach was chosen to enhance the precision and reliability of the conclusions drawn from the investigation.

Criteria for Eligibility

This systematic review aims to evaluate What is The Effectiveness of Early Versus Delayed Surgical Fixation of Orthopaedic Injuries on Mortality and Functional Outcomes in Multiply

Injured Patients?

Screening

We screened in sources based on their abstracts that met these criteria:

- **Population - Multiple Trauma**: Does this study involve multiply injured patients (polytrauma patients with two or more significant injuries affecting different body systems) who have sustained orthopaedic injuries requiring surgical fixation?
- **Intervention - Timing Comparison**: Does this study compare early versus delayed surgical fixation of orthopaedic injuries with clearly defined timing parameters (e.g., early defined as within 24-48 hours, delayed as beyond this timeframe)?
- **Outcomes - Clinical Endpoints**: Does this study report at least one clinical outcome such as mortality (in-hospital, 30-day, or longer-term) or functional outcomes (validated functional assessment scales, return to work, quality of life measures, disability scores)?
- **Study Design - Adequate Methodology**: Is this study one of the following designs: randomized controlled trial, non-randomized controlled trial, cohort study (prospective or retrospective), case-control study, systematic review, or meta-analysis?
- **Population Age - Adult Focus**: Does this study include adult patients (16 years or older) rather than focusing exclusively on pediatric populations?
- **Intervention Focus - Surgical Timing**: Does this study examine surgical timing considerations rather than focusing solely on non-surgical management or comparing different surgical techniques without timing considerations?
- **Publication Uniqueness**: Is this publication unique (not a duplicate report of the same patient cohort or dataset already included in the review)?

We considered all screening questions together and made a holistic judgement about whether to screen in each paper.

Search Strategy

The keywords used for this research based PICO :

Komponen PICO	**Keyword 1**	**Keyword 2 (Sinonim)**	**Keyword 3 (Sinonim)**	**Keyword 4 (Sinonim)**
Population	**Multiple Trauma**	Polytrauma	Multiply Injured	Severe Injury
Intervention	**Early Surgical Fixation**	Early Fracture Fixation	Early Total Care (ETC)	Immediate Stabilization
Comparison	**Delayed Surgical Fixation**	Late Fracture Fixation	Staged Surgery	Damage Control Orthopedics (DCO)
Outcome	**Mortality**	Survival Rate	Death	In-hospital Mortality
Outcome	**Functional Outcomes**	Recovery of Function	Quality of Life	Neurological Outcome

The Boolean MeSH keywords inputted on databases for this research are: *("Multiple Trauma" OR "Polytrauma" OR "Multiply Injured" OR "Severe Injury") AND ("Early Surgical Fixation" OR "Early Fracture Fixation" OR "Early Total Care" OR "Immediate Stabilization") AND ("Delayed Surgical Fixation" OR "Late Fracture Fixation" OR "Staged Surgery" OR "Damage Control Orthopedics") AND ("Mortality" OR "Survival Rate" OR "Death" OR "In-hospital Mortality") AND ("Functional Outcomes" OR "Recovery of Function" OR "Quality of Life" OR "Neurological Outcome")*

Data extraction

- **Study Design**:

Extract study design and key methodological details for comparing early versus delayed surgical fixation in multiply injured patients, including:

  - Study type (RCT, cohort, etc.)
  - Sample size for each timing group
  - Study period and setting
  - Inclusion/exclusion criteria specific to multiple injuries
  - How patients were allocated to early vs delayed groups

- **Patient Characteristics**:

  Extract characteristics of multiply injured patients with orthopedic injuries, including:

  - Age and demographics
  - Injury Severity Score (ISS) or equivalent severity measures
  - Specific injury patterns and body regions affected
  - Hemodynamic status on presentation
  - Glasgow Coma Scale (if head injury present)
  - Any factors that influenced timing decisions

- **Orthopedic Injuries**:

  Extract details about the specific orthopedic injuries treated in multiply injured patients, including:

  - Type and location of orthopedic injuries (femur, pelvis, spine, etc.)

  - Fracture classification or injury severity
  - Surgical procedures performed
  - Approach used (open, minimally invasive, etc.)
  - Any damage control orthopedics or staged procedures

- **Timing Definitions**:

  Extract how early versus delayed surgical fixation was defined in multiply injured patients, including:

  - Specific time cutoffs used to define 'early' treatment
  - Specific time cutoffs used to define 'delayed' treatment
  - Whether damage control orthopedics was a separate category
  - Time from injury to surgery for each group
  - Rationale for timing decisions provided

- **Mortality Outcomes**:

  Extract all mortality data for early versus delayed surgical fixation in multiply injured patients, including:

  - Mortality rates in each timing group
  - Time points when mortality was assessed (in-hospital, 30-day, etc.)
  - Specific causes of death when reported
  - Statistical comparisons between groups

  - Confidence intervals and p-values

- **Functional Outcomes**:

  Extract functional outcome measures for early versus delayed surgical fixation in multiply injured patients, including:

  - Specific functional assessment tools used
  - Functional outcome scores or measures for each timing group
  - Time points when functional outcomes were assessed
  - Return to work or activities of daily living
  - Quality of life measures
  - Neurological outcomes (if applicable)
  - Statistical comparisons between groups

- **Complications & Safety**:

  Extract all complications and safety outcomes for early versus delayed surgical fixation in multiply injured patients, including:

  - Systemic complications (ARDS, MODS, sepsis, PE, DVT)
  - Surgical complications
  - Pulmonary complications and ventilator days
  - Infection rates
  - Blood loss and transfusion requirements

  - Any complications specifically attributed to timing of surgery

- **Healthcare Utilization**:

  Extract healthcare utilization outcomes for early versus delayed surgical fixation in multiply injured patients, including:

  - Hospital length of stay
  - ICU length of stay
  - Days on mechanical ventilation
  - Need for additional surgeries or interventions
  - Discharge disposition
  - Statistical comparisons between timing groups

Table 1. Article Search Strategy

Database	Keywords	Hits
Pubmed	*("Multiple Trauma") AND ("Early Surgical Fixation" AND "Delayed Surgical Fixation" AND "Mortality" OR "Survival Rate" OR "Death" OR "In-hospital Mortality" AND "Functional Outcomes" OR "Recovery of Function" OR "Quality of Life" OR "Neurological Outcome")*	513
Semantic Scholar	*("Multiple Trauma" OR "Polytrauma" OR "Multiply Injured" OR "Severe Injury") AND ("Early Surgical Fixation" OR "Early Fracture Fixation" OR "Early Total Care" OR "Immediate Stabilization") AND ("Delayed Surgical Fixation" OR "Late Fracture Fixation" OR "Staged Surgery" OR "Damage Control Orthopedics") AND ("Mortality" OR "Survival Rate" OR "Death" OR "In-hospital Mortality") AND ("Functional Outcomes" OR "Recovery of Function" OR "Quality of Life" OR "Neurological Outcome")*	250
Springer	*("Multiple Trauma" OR "Polytrauma" OR "Multiply Injured" OR "Severe Injury") AND ("Early Surgical Fixation" OR "Early Fracture Fixation" OR "Early Total Care" OR "Immediate Stabilization") AND ("Delayed Surgical Fixation" OR "Late Fracture Fixation" OR "Staged Surgery" OR "Damage Control Orthopedics") AND ("Mortality" OR "Survival Rate" OR "Death" OR "In-hospital Mortality") AND ("Functional Outcomes" OR "Recovery of Function" OR "Quality of Life" OR "Neurological Outcome")*	38
Google Scholar	*("Multiple Trauma" OR "Polytrauma" OR "Multiply Injured" OR "Severe Injury") AND ("Early Surgical Fixation" OR "Early Fracture Fixation" OR "Early Total Care" OR "Immediate Stabilization") AND ("Delayed Surgical Fixation" OR "Late Fracture Fixation" OR "Staged Surgery" OR "Damage Control Orthopedics") AND ("Mortality" OR "Survival Rate" OR "Death" OR "In-hospital Mortality") AND ("Functional Outcomes" OR "Recovery of Function" OR "Quality of Life" OR "Neurological Outcome")*	802
Wiley Online Library	*("Multiple Trauma" OR "Polytrauma" OR "Multiply Injured" OR "Severe Injury") AND ("Early Surgical Fixation" OR "Early Fracture Fixation" OR "Early Total Care" OR "Immediate Stabilization") AND ("Delayed Surgical Fixation" OR "Late Fracture Fixation" OR "Staged Surgery" OR "Damage Control Orthopedics") AND ("Mortality" OR "Survival Rate" OR "Death" OR "In-hospital Mortality") AND ("Functional Outcomes" OR "Recovery of Function" OR "Quality of Life" OR "Neurological Outcome")*	5

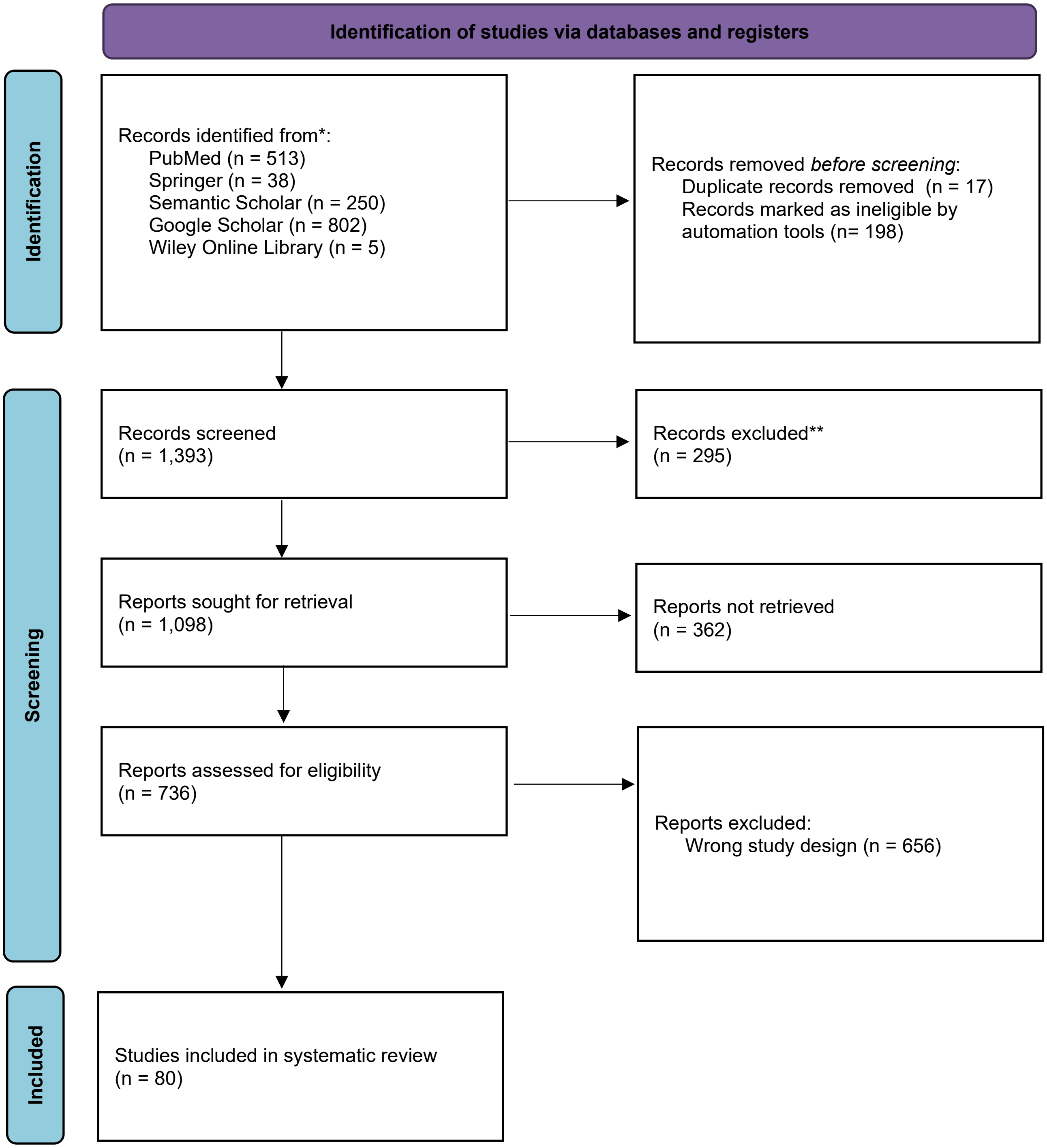

Figure 1. Article search flowchart

RESULTS

Characteristics of Included Studies

The review identified 80 studies examining the timing of surgical fixation in multiply injured patients. The majority were retrospective cohort studies, randomized controlled trials. Sample sizes ranged from small single-center studies to large database analyses with over 100,000 patients. Most studies defined early fixation as within 24 hours of injury or admission, though some used cutoffs of 36, 48, or 72 hours [1, 2, 21–23].

Study	Sample size (early/delayed)	Early cutoff	Delayed cutoff	ISS/injury severity
Nickolas J. Nahm et al., 2012 [24]	Not mentioned	Not mentioned	Not mentioned	Not mentioned
H. Vallier et al., 2013 [1]	572/433	Within 24h	After 24h	Mean ISS 30.6 [1]
Nickolas J. Nahm et al., 2011 [25]	656/not mentioned	Within 24h	After 24h	Mean ISS 23.7 [25]
H. Pape et al., 2007 [15]	94/71	Within 24h	Conversion to IMN	Mean ISS 25.8 [15]
D. Rojas et al., 2020 [26]	37/81	≤36h	>36h	ISS ≥16 [26]

Study	Sample size (early/delayed)	Early cutoff	Delayed cutoff	ISS/injury severity
Natalie Enninghorst et al., 2010 [27]	18/27	<24h	>24h	ISS 30 vs 24.5 [27]
H. Vallier et al., 2010 [4]	233/412	Within 24h	>24h	Mean ISS 25.6 [4]
Eva Steinfeld et al., 2025 [28]	335 total	<24h	>24h	ISS ≥16 [28]
Sebastian Ndlovu et al., 2025 [22]	Not mentioned	Within 72h	After 72h	Not mentioned
Krishna Oochit et al., 2025 [2]	2918 total	Within 24h	>24h	ISS >15 [2]
K. Oochit et al., 2024 [29]	Not mentioned	Within 24h	>24h	ISS >15 [29]
P. Kobbe et al., 2020 [21]	49 within 24h, 75 within 72h	Within 24h/72h/96h	Beyond cutoff	Mean ISS 24.8 [21]
Julia Dormann et al., 2025 [8]	165/253	<24h	>24h	Not mentioned
M. Konieczny et al., 2015 [14]	22/16	≤72h	>72h	ISS ≥16 [14]

Study	Sample size (early/delayed)	Early cutoff	Delayed cutoff	ISS/injury severity
Sacha Halvachizadeh et al., 2024 [30]	85 ETC/665 SDS/721 DC	<24h/<48h	>48h	Mean ISS 23.1 [30]
T. Sangkomkamhang et al., 2018 [31]	415/<24h, 335/24-48h, 474/>48h	<24h, 24-48h	>48h	Mean ISS 8.5 [31]
Meng Jiang et al., 2016 [32]	277 early/893 delayed	Within 24h	Beyond 24h	ISS ≥18 [32]
C. Bliemel et al., 2014 [23]	68.2% early/31.8% late	<72h	>72h	ISS ≥16 [23]
Joseph Gutbrod et al., 2024 [33]	Not specified by group	Within 24h/24-48h	>48h	Fragility ISS <16, Polytrauma ISS ≥16 [33]

Study	Sample size (early/delayed)	Early cutoff	Delayed cutoff	ISS/injury severity
Nina E. Glass et al., 2017 [34]	32/49	Mean 4.4 days	Mean 11.8 days	Not mentioned
J. Richards et al., 2020 [35]	160/119	<24h	≥24h	ISS >15 [35]
H. Pape et al., 2004 [36]	Not specified	<8h for primary stabilization	Various	Not mentioned
D. Lubelski et al., 2017 [37]	32 protocol/14 breach	Within 36h	Beyond 36h	ISS >16 [37]
J. Tan et al., 2020 [38]	52/51	Within 4 days	>4 days	Not mentioned
B. Coimbra et al., 2025 [39]	Not specified	Not mentioned	Not mentioned	ISS >15 [39]

Study	**Sample size (early/delayed)**	**Early cutoff**	**Delayed cutoff**	**ISS/injury severity**
S. Halva et al., 2024 [40]	21 ETC/284 SDS/222 DC	<24h/<72h	>48h	Mean ISS 26.9 [40]
Emanuele Lagazzi et al., 2023 [41]	430 early/611 total	<72h	≥72h	Not mentioned
P. Stahel et al., 2013 [6]	42/70	Within 24h	Delayed	ISS >15 [6]
M. Sewell et al., 2018 [16]	40/55	<24h	>24h	Not mentioned
David G. Rojas et al., 2019 [42]	49/148/88 DCO	Within 36h	>36h	ISS >15 [42]
Jakob Hax et al., 2023 [43]	Not specified	<48h	>48h	ISS ≥16 [43]
Sven Hager et al., 2020 [44]	976 early/362 late	Within 72h	After 72h	Mean ISS 26.6 [44]

Study	Sample size (early/delayed)	Early cutoff	Delayed cutoff	ISS/injury severity
Y. Kalbas et al., 2025 [19]	88 SDS/151 DFC	<24h	>24h	ISS >16 [19]
O. Burianov et al., 2020 [45]	51/56	≥24h ≤5 days	>5 days	ISS 30.4 vs 31.1 [45]
F. Lavini et al., 2007 [46]	13/11/15	4-7 days	4-6 months	ISS >20 [46]
Natalie Enninghorst et al., 2009 [47]	17/29	<24h	5 days median	ISS 30 vs 24.5 [47]
Rafik Abu-Ramadan et al., 2015 [48]	33 ETC/3 DCO	Within 24-48h	5th-10th days	Not mentioned
H. Pape et al., 2012 [49]	94/71	Not mentioned	Not mentioned	Mean ISS not mentioned
G. Volpin et al., 2011 [50]	99/38	Within 24h	Not defined	ISS 22.6 vs 32.2 [50]
J. Harvin et al., 2012 [3]	1032/344	<24h	≥24h	Median ISS 10 vs 17.5 [3]

Study	**Sample size (early/delayed)**	**Early cutoff**	**Delayed cutoff**	**ISS/injury severity**
C. Probst et al., 2007 [51]	Not specified	Day 0	>Day 3	ISS ≥16 [51]
A. Enocson et al., 2023 [9]	194/225	Within 72h	>72h	Not mentioned
Suzanne C. Arnold et al., 2024 [10]	702/416	Within 24h	>24h	Median ISS 16 vs 25 [10]
Giles L. Devaney et al., 2020 [52]	341 total	Not specified	Not specified	ISS 20 median [52]
J. Godzik et al., 2019 [53]	731/1648	≤24h	>24h	Average ISS 19.5 [53]
Teng-fei Zhu et al., 2018 [54]	23 DCO/27 ETC	Not mentioned	Not mentioned	NISS 27.7 vs 31.1 [54]
G. Feldman et al., 2021 [55]	44 DCO/52 ETC	Within 12h	After acute phase	Median ISS 31.5 vs 29 [55]
Y. Zhang et al., 2017 [56]	1224 EFF/1717 LFF	Not mentioned	Not mentioned	Not mentioned

Study	Sample size (early/delayed)	Early cutoff	Delayed cutoff	ISS/injury severity
M. Tuttle et al., 2009 [57]	42 ETC/55 DCO	Not mentioned	Not mentioned	Not mentioned
G. Taeger et al., 2005 [58]	75 DCO/334 control	Not mentioned	Not mentioned	ISS 37.3 vs 30.4 [58]
J. Dimar et al., 2010 [59]	Not mentioned	Not mentioned	Not mentioned	Not mentioned
H. Vallier et al., 2013a [20]	869 within 24h/574 after 24h	Within 24h	After 24h	Mean ISS 24.7 [20]
S. Cimbanassi et al., 2019 [60]	Not specified	Not specified	Not specified	Not mentioned
Marjorie C. Wang et al., 2007 [17]	Not specified	≤24h	>24h	Not mentioned
T. Scalea et al., 2004 [61]	43 EF/284 IMN	Not mentioned	Not mentioned	ISS 26.8 [61]

Study	Sample size (early/delayed)	Early cutoff	Delayed cutoff	ISS/injury severity
H. Vallier et al., 2015 [62]	251 early/54 delayed	Within 36h	Mean 90h	Mean ISS 26.4 [62]
R. Gandhi et al., 2014 [11]	Not specified	<24h	>24h	Not mentioned
R. Pfeifer et al., 2024 [63]	Not applicable	Within 24h	Not mentioned	Not mentioned
B. Grey et al., 2013 [13]	17 normal lactate/19 raised lactate	Within 48h	Not mentioned	NISS >16 [13]
Mazin Osman et al., 2025 [64]	273,683 total	Within 24-48h	Beyond 48h	Not mentioned
F. Klingebiel et al., 2025 [65]	96-3069 per study	≤24h	>24h	ISS 16.8-39.85 [65]
H. Pakzad et al., 2011 [66]	Not specified	Within 24h	After 24h	Mean ISS 27.1 [66]

Study	Sample size (early/delayed)	Early cutoff	Delayed cutoff	ISS/injury severity
L. Scaramuzzo et al., 2013 [67]	Not specified	Within 72h	After 72h	Not mentioned
L. Bone et al., 2011 [68]	Not specified	Within 24h	7-10 days traction	Not mentioned
Saam Morshed et al., 2015 [69]	>50% within 12h	Multiple cutoffs	Multiple cutoffs	ISS ≥15 [69]
C. Schinkel et al., 2005 [5]	Not specified	Within 72h	>72h	Not mentioned
T. Frangen et al., 2007 [70]	Not specified	<72h	>72h	Mean ISS 41 [70]
H. Pape et al., 2003 [71]	17 IMN/18 DCO	Within 24h	Secondary conversion	ISS >16 [71]
P. Weninger et al., 2007 [72]	45 early/107 control	Within 24h	Not applicable	ISS ≥18 [72]

Study	Sample size (early/delayed)	Early cutoff	Delayed cutoff	ISS/injury severity
H. J. Iqbal et al., 2018 [73]	65 early/37 delayed	Within 48h	After 48h	Not mentioned
Ki-Chul Park et al., 2014 [74]	Not specified	Within 72h	>72h	ISS categorized [74]
R. Yamamoto et al., 2021 [75]	16,119 early/not specified	Within 24h	Not mentioned	Not mentioned
J. Byrne et al., 2017 [76]	17,993 total, 26% delayed	Within 24h	≥24h	Median ISS 13 [76]
Gustavo Sardinha Lisboa Leite et al., 2025 [77]	Not specified	<8h	>8h	ISS ≥25 vs <25 [77]
Victor S. Ritter et al., 2022 [78]	395 nonoperative/1346 Day 1/1318 Day 2+	Day 1	Day 2+	44-58% ISS ≥14 [78]

Study	Sample size (early/delayed)	Early cutoff	Delayed cutoff	ISS/injury severity
Ahmad S. Alobaidi et al., 2016 [79]	156/151	<12h	≥12h	Not mentioned
Mohamed E. El-Abtah et al., 2025 [7]	Not specified	<72h	>72h	Not mentioned
Mitchel R Obey et al., 2021 [12]	74.2% <24h/16.5% 24-48h/9.4% >48h	<24h	>48h	Not mentioned
S. Bhamre et al., 2024 [80]	34 ETC/30 DCO	Within 24h	Not specified	Comparable ISS [80]
Karen HQ Toh et al., 2025 [18]	43 studies	<48h	Not mentioned	Not mentioned

The included studies examined various orthopedic injury patterns in multiply injured patients. The most common fracture types were femoral shaft fractures [3, 15, 25, 28, 32, 50, 55, 68, 76], pelvic ring fractures [2, 4, 9, 27, 42], acetabular fractures [4, 9, 42], and spinal fractures [5, 6, 18, 21, 23, 43, 44, 59, 66, 74]. Multiple studies examined combinations of these injury patterns in polytrauma cohorts [1, 20, 30, 40].

Mortality Outcomes

Early definitive surgical fixation was generally not associated with increased mortality in multiply injured patients. Multiple large studies found no significant difference in mortality rates between early and delayed fixation groups [1, 2, 7, 9–11, 32, 55]. In a study of 1,005 patients with ISS ≥18, mortality was 1.4% in the early fixation group compared to 1.6% in the delayed group (p=0.78) [1]. Similarly, in pelvic and acetabular fractures, early fixation showed comparable 30-day mortality (2.1% vs. 2.2%, p=1.0) and 1-year mortality (4.1% vs. 7.6%, p=0.2) [9].

However, several studies reported concerning findings in specific patient populations. In a prospective study of thoracic spine fractures in polytrauma patients, early surgery (≤72 hours) was associated with a significantly higher mortality rate than delayed surgery (p<0.01) [14]. Patients with initial hemoglobin <10 mg/dL who received early surgery had particularly poor outcomes, with 67% mortality [14]. In patients with cervical spine injuries and concomitant traumatic brain injury, early surgery (<48 hours) was associated with higher mortality (9.7% vs. 6.3%) [43].

When timing was examined in relation to specific injury patterns, several studies found improved mortality with selective timing strategies. Early stabilization within 72 hours of thoracic spine injuries resulted in significantly reduced mortality compared to delayed stabilization (expected 16% vs. documented 6%, p<0.05) [5]. Analysis of timing in relation to pelvic fracture fixation showed mortality rates of 18% for early (day 0), 19% for intermediate (days 1-3), and 4% for late (>day 3) surgery (p=0.019) [51].

In the largest studies examining femoral shaft fractures, delayed fixation beyond 48 hours was associated with significantly increased mortality risk. Analysis of 108,825 patients showed that fixation delayed >48 hours resulted in a 3.6-fold increase in mortality odds (OR 3.60; 95% CI 3.13-4.14) [12]. Another large study of femoral fractures found mortality of 0.4% with early fixation compared to 1.7% with delayed fixation (p<0.01) [3].

A systematic review comparing damage control orthopedics (DCO) to early total care (ETC) for femoral shaft fractures found no survival advantage for DCO (OR 0.92), contrary to the rationale for this approach [39]. Overall mortality in their cohort was 2.1% [39].

Complications and Safety Outcomes

Acute Respiratory Distress Syndrome (ARDS)

Early definitive fixation was consistently associated with lower rates of ARDS across multiple injury types. In a study of 1,005 patients with multiple injuries including pelvis, acetabulum, femur, and spine fractures, early fixation (<24 hours) resulted in significantly fewer cases of ARDS (1.7% vs. 5.3%, p=0.048) [1]. This finding was replicated in pelvic ring fractures, where early definitive fixation showed lower ARDS incidence (RR=0.50; 95% CI: 0.26-0.96, p=0.04) [2].

The protective effect of early fixation against ARDS was particularly pronounced in more severely injured patients. In patients with ISS >18, early fixation of pelvis and acetabulum fractures led to significantly less ARDS (4.8% vs. 12.6%, p=0.019) [4]. Similarly, early stabilization of unstable pelvis and acetabulum fractures decreased ARDS risk (RR 0.38, 95% CI 0.18-0.81) [8].

For femoral shaft fractures specifically, a meta-analysis of seven retrospective cohort studies found that early intramedullary nailing did not significantly increase the risk of ARDS (OR 0.65; 95% CI 0.38-1.13) [32]. However, in severely injured patients with chest trauma, early intramedullary nailing was associated with higher rates of ARDS compared to external fixation (15.1% vs. 9.1%) [36].

In spinal injuries, early surgical stabilization showed consistent benefits. Early fixation of thoracic and lumbar spine fractures within 72 hours resulted in reduced ARDS rates, particularly for thoracic spine fractures where primary minimally invasive posterior stabilization was recommended [44]. A systematic review of thoracolumbar spine fractures found early fixation (<72 hours) reduced ARDS compared to delayed fixation [7].

Conversely, damage control orthopedics with temporary external fixation followed by delayed definitive fixation showed higher ARDS rates in some studies. DCO for femoral shaft fractures was associated with a significantly increased risk of ARDS (OR 1.64) compared to early total care [39].

Pulmonary Complications and Pneumonia

Beyond ARDS, broader pulmonary complications were also reduced with early definitive fixation. Early fixation was associated with fewer pneumonia cases (8.6% vs. 15.2%, p=0.070) [1]. In pelvic ring injuries, delayed fixation resulted in higher pneumonia incidence (20% vs. 0%, p=0.004), with 11 of the 16 pneumonia cases associated with chest injury [26].

Early fixation within 48 hours of rib fractures in patients with traumatic brain injury resulted in fewer cases of pneumonia (p=0.001), reduced duration of mechanical ventilation (p=0.03), and fewer tracheostomies (p=0.02) [73]. For thoracolumbar spine injuries, early decompression was associated with fewer respiratory complications and shorter ventilation time (mean difference -2.41 days, p=0.01) [18].

A meta-analysis comparing early versus delayed definitive fixation of lower extremity fractures found that operation within 24-48 hours had 6.67 times fewer complications compared to early treatment before 24 hours (95% CI: 3.03-10.00, p<0.001) [31]. This suggests an optimal window exists for definitive fixation.

Multiple Organ Failure and Sepsis

Early definitive fixation reduced rates of multiple organ failure across various injury patterns. In pelvis and acetabular fractures, early fixation resulted in less MOF (1.8% vs. 4.3%) compared to delayed fixation [4]. However, the difference in MOF rates did not reach statistical significance in all studies examining pelvic fractures [2, 42].

Sepsis rates were lower with early definitive stabilization in several studies. Early fixation of multiple injuries resulted in lower sepsis incidence (1.7% vs. 5.3%, p=0.054) [1]. For spinal injuries, delayed surgical fixation was associated with significantly higher sepsis rates (p=0.023 for >24h, p<0.005 for >96h) [21].

A standardized spine damage-control protocol for unstable thoracic and lumbar fractures, with fixation within 24 hours, resulted in significantly lower urinary tract infection rates (4.8% vs. 21.4%) [6] and lower pulmonary complication rates (14.3% vs. 25.7%) [6] compared to delayed definitive fixation.

Thromboembolic Complications

Deep venous thrombosis (DVT) and pulmonary embolism (PE) rates varied across studies. In bilateral femoral shaft fractures, early definitive fixation was associated with lower rates of DVT (2.2% vs. 6.5%, p=0.012) [10]. Analysis of a large trauma database found that delayed fixation beyond 24 hours resulted in higher rates of pulmonary embolism (2.6% vs. 1.3%; RR 2.0; 95% CI 1.2-3.2; p=0.005) [76].

However, damage control orthopedics for femoral shaft fractures showed increased DVT risk (OR 1.64) compared to early total care [39]. No significant differences in thromboembolic complications were found in some pelvic and acetabular fracture studies [9, 42].

Blood Loss and Transfusion Requirements

Damage control approaches generally resulted in less initial blood loss but variable overall transfusion requirements. External fixation as a bridge to intramedullary nailing resulted in significantly less estimated blood loss during the initial procedure (37 mL vs. 330 mL for immediate IMN) [57]. Similarly, DCO for femoral fractures had minimal blood loss (<50 mL) compared to early total care (472 mL) [58].

However, total transfusion requirements over the entire hospital course were sometimes higher with DCO. The DCO group required more fluids (6.2 vs. 2.2 PRBC units) in one study, though estimated blood loss during the conversion procedure was less than immediate definitive fixation (90 cc vs. 400 cc) [80]. Early definitive pelvic fracture fixation showed a trend toward reduced 24-hour transfusion requirements (4.7±5 U vs. 6.6±4 U) [27].

Subclinical Hypoperfusion and Metabolic Status

Several studies identified that the physiologic state of the patient, rather than absolute timing, may be the critical factor. Early fracture fixation in patients with subclinical hypoperfusion (normal vital signs but lactate ≥2.5 mmol/L) was associated with significant postoperative morbidity, including higher SOFA scores on day 3 (p=0.003) and increased need for inotropic support (p=0.02) [13]. These patients also required on average 10 days longer on mechanical ventilation [13].

Studies evaluating resuscitation parameters found that correction of pH to >7.25 within 8 hours was associated with fewer pulmonary complications [20]. Greater injury severity (measured by ISS) and depth of shock (measured by 24-hour time-weighted lactate) were independently associated with delayed fixation [35]. An uncomplicated course was associated with the absence of chest injury and definitive fixation within 24 or 48 hours [20].

Healthcare Utilization Outcomes

Hospital Length of Stay

Early definitive fixation consistently reduced total hospital length of stay across multiple injury types. In patients with pelvis, acetabulum, femur, and spine fractures, early fixation (<24 hours) resulted in significantly shorter hospitalization (10.5±9.8 days vs. 14.3±11.4 days, p=0.001) [1]. This pattern was replicated in pelvic ring fractures, where early definitive fixation led to a reduced length of hospital stay (WMD=-3.52 days; 95% CI: -5.43 to -1.62, p<0.0003) [2].

The magnitude of reduction varied by injury type and timing cutoff. For femoral shaft fractures, early fixation (<24 hours) resulted in median hospital stays of 6 days compared to 10 days for delayed fixation (p<0.001) [3]. In patients with bilateral femoral shaft fractures, early definitive fixation was associated with shorter hospital stays (10 days vs. 15 days, p<0.001) [10].

Spinal injuries showed particularly pronounced benefits from early stabilization. Early fixation of thoracic and lumbar spine fractures resulted in significantly reduced hospital stays (14.1 days vs. 32.6 days, p<0.05) [6]. For thoracolumbar spine injuries specifically, early fixation (<72 hours) was associated with a mean reduction of 3.59 days in hospital length of stay (95% CI: -6.44 to -0.75) [7].

However, not all studies found significant differences. In pelvic and acetabular fractures stabilized early versus delayed, median hospital length of stay was 10 days in both groups (p=0.6) [9]. Some studies noted that patients with more complex or severe injuries often had delayed fixation, confounding comparisons [52].

ICU Length of Stay

Intensive care unit utilization showed similar patterns favoring early definitive fixation. Early fixation within 24 hours was associated with significantly reduced ICU stays (5.1±8.8 days vs. 8.4±11.1 days, p=0.006) [1]. For pelvic and acetabular fractures, early fixation resulted in shorter ICU stays (8.1 days vs. 9.9 days, p=0.03) [4].

The reduction in ICU utilization was particularly notable in spinal injuries and severe polytrauma. Early surgical stabilization of thoracic spine fractures led to significantly reduced ICU stays (8 days early vs. 16 days delayed, p=0.001) [5]. In patients with thoracolumbar spine fractures, early fixation within 72 hours resulted in mean ICU stay reduction of 1.21 days (95% CI: -2.0 to -0.41) [7].

For rib fractures with concomitant traumatic brain injury, early surgical stabilization resulted in significantly shorter ICU stays (p=0.01) [73]. Similarly, cervical and upper thoracic spine injuries treated according to an early appropriate care protocol (within 36 hours) had significantly fewer total ICU days (16 days delayed vs. 9 days protocol, p=0.03) [37].

Some studies found no significant difference in ICU length of stay between early and delayed groups, particularly when comparing damage control approaches to early total care [55, 57].

Days on Mechanical Ventilation

Mechanical ventilation duration was consistently reduced with early definitive fixation. Early fixation of multiple injuries resulted in significantly fewer ventilator days [1], though the specific reduction varied by injury pattern. For spinal injuries, early fixation led to substantial reductions in mechanical ventilation requirements (2.2 days vs. 9.1 days, p<0.05) [6].

In thoracic spine injuries with severe concomitant trauma, early stabilization within 72 hours resulted in significantly reduced ventilator dependence (median 2 days vs. 5 days, p=0.02) [5]. For thoracolumbar spine fractures, early fixation was associated with a mean reduction of 3.43 days on mechanical ventilation (95% CI: -6.07 to -0.78) [7].

Femoral shaft fractures showed similar benefits. Early fixation within 24 hours resulted in significantly fewer ventilator days compared to delayed fixation (median 0 days vs. median 0 days with higher interquartile range, p<0.001) [3]. Analysis of 108,825 femoral shaft fractures found that delayed fixation beyond 48 hours significantly increased ventilator days (OR 5.38; CI 4.89-5.91) [12].

Patients with cervical spine injuries and concomitant chest trauma who underwent early surgery (<24 hours) had significantly fewer ventilator days (13 days vs. 6 days, p=0.02) [37]. For rib fractures with traumatic brain injury, delay to surgical fixation was associated with increased ventilation time (β=0.026, p<0.001) [41].

Surgical Efficiency and Operating Time

Damage control approaches with initial external fixation required significantly less operative time than immediate definitive fixation. External fixation averaged 22 minutes compared to 125 minutes for intramedullary nailing [57]. Mean surgical time for damage control external fixation was 62±30 minutes [58].

However, when considering the total surgical burden including conversion procedures, damage control approaches often required more total operative time and additional surgeries. Patients undergoing early definitive surgery had a significantly lower mean number of operations (4.3 vs. 5.3, p=0.037) and shorter time until completion of reconstructive operations (10 days vs. 15 days, p=0.013) [19].

Functional Outcomes

Functional outcome data was limited across the included studies, with few utilizing standardized assessment tools. Most studies focused on short-term morbidity and healthcare utilization rather than long-term functional recovery.

In patients with cervical spinal cord injury and concomitant chest trauma, functional outcomes were assessed using the ASIA Impairment Scale at 6 months [16]. The early surgery group (<24 hours) showed: 52.5% no improvement, 32.5% one-grade improvement, and 15% two-grade improvement [16]. The late surgery group (>24 hours) demonstrated: 58% no improvement, 34.5% one-grade improvement, 5.5% two-grade improvement, and 2% three-grade improvement [16]. Neurological recovery was more likely in younger patients and those with incomplete spinal cord injury [16].

For patients with traumatic brain injury and orthopedic fractures, early surgery (≤24 hours) was associated with better composite neuropsychological scores at 6 months postinjury on adjusted analysis [17]. However, no significant differences were found in return to work or Glasgow Outcome Score between early and late surgery groups [17].

In spinal injuries without cord involvement, functional outcomes were assessed using the Glasgow Outcome Scale. Early surgical intervention for spinal fractures in polytrauma patients was associated with better Glasgow Outcome Scale scores at hospital discharge compared to late surgical intervention [44].

For thoracolumbar spine injuries, early decompression was associated with increased odds of neurological improvement (log odds ratio = 0.82, $p<0.001$) [18]. The effects were greater in studies including severely injured patients, suggesting that timely intervention may mitigate the physiological impact of polytrauma [18].

Quality of life measures were rarely reported. One study mentioned use of the SF-36 scale but did not provide comparative data between early and delayed groups [45]. Return to work and activities of daily living were not systematically assessed across the majority of studies.

Synthesis

The evidence base for timing of surgical fixation in multiply injured patients reveals complex interactions between injury patterns, physiological status, and timing strategies. Rather than identifying a single optimal timepoint, the literature suggests context-dependent benefits and risks that vary by specific injury combinations and patient physiology.

Reconciling Heterogeneous Findings on Mortality

The apparent contradiction between studies showing mortality benefits for early fixation [3, 5, 12] and those reporting increased mortality with early intervention [14, 43] can be explained through examination of patient selection and injury characteristics. Studies reporting mortality benefits of early fixation generally included stable or adequately resuscitated patients, often with isolated or predominantly skeletal injuries [3, 76]. In contrast, studies finding increased mortality with early surgery specifically examined patients with severe concomitant injuries requiring intensive resuscitation.

The prospective study by Konieczny et al. that found significantly higher mortality with early thoracic spine surgery ($p<0.01$) [14] identified two critical risk factors: initial hemoglobin less than 10 mg/dL and presence of thoracic drains, with 75% mortality in patients having both [14]. This suggests that early surgery in the presence of ongoing hemorrhage and severe thoracic trauma represents a distinct high-risk scenario not captured by injury severity scores alone.

Similarly, the finding of higher mortality with early cervical spine surgery in polytrauma patients (9.7% vs. 6.3%) [43] must be considered in the context that these patients had significantly more severe concomitant injuries. The injury severity score and presence of traumatic brain injury requiring neurosurgical intervention were identified as major factors influencing timing decisions [19]. Early cervical spine fixation in patients requiring neurosurgical procedures was associated with 5.59 times higher odds of delayed fracture care [19], suggesting that the sickest patients were paradoxically being selected for early intervention in some centers.

When physiological parameters rather than absolute timing guide decision-making, the picture becomes clearer. Studies that controlled for adequacy of resuscitation consistently showed benefits or equipoise for early fixation [20, 38]. Patients with normal vital signs but persistent subclinical hypoperfusion (lactate $\geq$2.5 mmol/L) had significantly worse outcomes with early surgery [13], indicating that apparent hemodynamic stability may mask inadequate resuscitation.

Injury Pattern-Specific Considerations

The divergent findings on timing also reflect fundamental differences in injury biomechanics and surgical stress. Pelvic ring fractures with ongoing hemorrhage require immediate stabilization for hemodynamic control, explaining why some "early" fixation is actually damage control rather than definitive treatment [27, 60]. Conversely, isolated femoral shaft fractures in stable patients represent low-risk scenarios where early definitive fixation consistently shows benefits [3, 10, 76].

Spinal injuries demonstrate particularly complex timing considerations based on anatomical location. Thoracic spine injuries, especially with severe concomitant chest trauma and low hemoglobin, showed poor outcomes with early surgery [14]. However, thoracolumbar injuries without severe chest trauma benefited from early fixation with reduced ICU stays and complications [5, 44]. Lumbar spine injuries consistently showed benefits from early intervention across multiple studies [7, 44]. This gradient likely reflects the greater respiratory compromise from high thoracic procedures combined with chest injuries, versus the more straightforward mechanical benefits of early lumbar stabilization.

The distinction between open and closed fractures adds another layer of complexity. Open fractures were treated one day earlier than closed fractures on average but had one day longer hospital stays, suggesting that infection risk and soft tissue injury severity complicate the timing equation beyond skeletal considerations alone [76].

Dose-Response and Diminishing Returns

Multiple studies identified non-linear relationships between timing and outcomes, suggesting optimal windows rather than earlier-is-always-better. The observation that fixation within 24-48 hours had 6.67 times fewer complications than fixation before 24 hours ($p<0.001$) [31] indicates that very early surgery before adequate resuscitation may be harmful. Conversely, fixation delayed beyond 48 hours showed increasing complications [12, 33], suggesting a therapeutic window.

Analysis of timing in pelvic fractures found the highest mortality with day 0 surgery (18%) and intermediate timing (19% for days 1-3), with lowest mortality for surgery after day 3 (4%, $p=0.019$) [51]. This pattern likely reflects confounding by indication, where the most unstable patients received immediate surgery, moderately injured patients received surgery within 1-3 days, and stable patients with isolated pelvic fractures could safely wait longer. However, after controlling for injury severity in other studies, early fixation within 36 hours showed clear benefits [2, 26].

The concept of diminishing returns appears in hospital utilization data. While early fixation reduced hospital stay by 3-4 days in most studies [1, 2], the marginal benefit decreased in less severely injured patients [9]. This suggests resource utilization benefits are most pronounced in polytrauma patients where complications and prolonged ICU stays drive costs.

Damage Control versus Early Total Care

The damage control orthopedics literature reveals a paradigm shift influenced by the specific populations studied. Early studies from the 1980s-1990s showing ARDS and MOF with immediate definitive fixation [36] led to DCO strategies. However, contemporary studies with improved critical care and patient selection show that DCO offers no mortality advantage and increases complications compared to early total care [39].

This reversal can be explained by three factors. First, the "borderline" patient concept emerged, recognizing that some patients are too unstable for immediate definitive surgery regardless of timing [15]. In these borderline patients, early intramedullary nailing showed 6.69 times higher odds of acute lung injury compared to external fixation [15]. However, stable patients benefited from primary femoral nailing with shorter ventilation times [15]. The challenge lies in identifying borderline patients before surgery rather than in retrospect after complications develop.

Second, critical care advances reduced baseline complication rates, changing the risk-benefit calculation. The significant reduction in MOF and ARDS from the early total care era (1981-1989) through the intermediate period (1990-1992) to the DCO era (1993-2000) occurred independent of surgical timing [36], suggesting that improvements in intensive care, trauma resuscitation, and air rescue contributed substantially to better outcomes.

Third, the additional surgical burden of conversion from external fixation to definitive fixation creates opportunities for complications. Pin-track infections, delayed unions, and the need for a second major procedure all represent potential failure points [46, 58]. Studies showing lower infection rates with early definitive fixation versus delayed fixation after DCO (3.1% vs. 30.6%, p=0.002) [34] suggest that damage control should be reserved for truly unstable patients rather than applied broadly.

Synthesis for Specific Clinical Scenarios

Based on the available evidence, several injury pattern-physiology combinations can be delineated:

Stable patients with isolated skeletal injuries (femoral shaft, tibial shaft, simple pelvic ring fractures): Early definitive fixation within 24 hours shows consistent benefits including reduced ARDS [1], shorter hospital stays [1, 3], fewer complications [3], and lower costs [3]. No mortality differences were found, likely due to overall low mortality in this population [1, 10]. Delaying surgery beyond 48 hours increases complications without benefit [12, 33].

Polytrauma patients with adequate resuscitation (lactate <2.5 mmol/L, pH >7.25, base excess >-5.5): Early definitive surgery within 36-48 hours is safe and reduces complications [1, 38]. Benefits include reduced ARDS [1], pneumonia [1], ICU days [1], and hospital days [1]. Specific injury patterns warrant consideration: lumbar spine injuries can be addressed early [44], isolated pelvic fractures benefit from fixation within 36 hours [2], and femoral fractures should be stabilized definitively within 24-48 hours [10].

Borderline patients with marginal physiology (lactate ≥2.5 mmol/L despite normal vital signs, ongoing resuscitation, severe chest trauma with low hemoglobin): These patients require damage control approaches with initial external fixation or provisional stabilization [13, 15]. Early intramedullary nailing in borderline patients increases acute lung injury risk 6.69-fold [15]. Conversion to definitive fixation should await physiologic recovery, typically 5-10 days [48, 55]. However, DCO should not delay definitive treatment beyond 5 days once stable, as prolonged external fixation increases infection risk [46].

Severe thoracic spine injuries with chest trauma and anemia: This represents a uniquely high-risk scenario where early surgery significantly increases mortality, particularly in patients with hemoglobin <10 mg/dL and thoracic drains [14]. Delayed stabilization after initial resuscitation and chest injury management is warranted. The distinction between thoracic and lumbar spine is critical, as lumbar injuries do not share this risk profile [44].

Cervical spine injuries with traumatic brain injury requiring neurosurgical intervention: While some studies suggest early fixation is safe [65], the presence of intracranial trauma requiring neurosurgical procedures strongly predicts delayed fracture care (OR 5.59) [19] and may increase mortality [43]. Fracture fixation should be coordinated with neurosurgical priorities, and intracranial pressure must be controlled (≤20 mmHg) with adequate cerebral perfusion pressure (>60-70 mmHg) before proceeding [65].

Open fractures and mangled extremities: Early debridement within 24 hours is recommended [60], but definitive reconstruction timing must balance infection risk against physiologic stability. Grade I, II, and IIIa open fractures can undergo early closure [60], while more severe injuries may require staged reconstruction. The observation that open fractures were treated earlier but had longer hospital stays [76] suggests that soft tissue injury severity, not just timing, drives outcomes.

This synthesis demonstrates that optimal timing is not a fixed number but rather a decision framework incorporating injury patterns, physiologic status, and surgical complexity. The consistent finding across studies is that inadequately resuscitated patients fare poorly with early definitive surgery, while adequately resuscitated patients benefit from intervention within 24-48 hours. The challenge for clinicians lies in accurately assessing resuscitation adequacy using physiologic parameters beyond vital signs, including lactate clearance, base deficit correction, and organ perfusion markers.

DISCUSSION

Mortality Outcomes: Reconciling Heterogeneous Findings

The relationship between surgical timing and mortality in multiply injured patients is complex and context-dependent. Our synthesis reveals that early definitive fixation is generally not associated with increased mortality in adequately resuscitated patients, with multiple large studies demonstrating comparable mortality rates between early and delayed groups (1,2,9,11). Vallier et al. reported mortality of 1.4% in early fixation versus 1.6% in delayed groups ($p=0.78$) among 1,005 patients with ISS ≥18 (1). Similarly, Enocson and Lundin found no significant difference in 30-day (2.1% vs 2.2%, $p=1.0$) or 1-year mortality (4.1% vs 7.6%, $p=0.2$) for pelvic and acetabular fractures (9).

However, the apparent contradiction posed by studies reporting increased mortality with early intervention (14,43) requires careful examination of patient selection and injury characteristics. Konieczny et al.'s prospective study of thoracic spine fractures found significantly higher mortality with early surgery (≤72 hours) ($p<0.01$), particularly in patients with initial hemoglobin <10 mg/dL and thoracic drains, where mortality reached 75% (14). This finding illuminates a critical principle: early surgery in the presence of ongoing hemorrhage and severe thoracic trauma represents a distinct high-risk scenario not adequately captured by injury severity scores alone.

Similarly, Hax et al. reported higher mortality with early cervical spine surgery in polytrauma patients (9.7% vs 6.3%), but these patients had significantly more severe concomitant injuries, including traumatic brain injury requiring neurosurgical intervention (43). Kalbas et al. identified that patients requiring neurosurgical procedures had 5.59 times higher odds of delayed fracture care, suggesting that the sickest patients were paradoxically selected for early intervention in some centers (19). This confounding by indication—where severity drives timing decisions—complicates interpretation of observational studies and may explain apparent associations between early surgery and worse outcomes.

The largest studies examining femoral shaft fractures provide compelling evidence that delayed fixation increases mortality risk. Obey et al., analyzing 108,825 patients, found that fixation delayed beyond 48 hours resulted in a 3.6-fold increase in mortality odds (OR 3.60; 95% CI 3.13-4.14) (12). Harvin et al. reported mortality of 0.4% with early fixation compared to 1.7% with delayed fixation ($p<0.01$) (3). These findings suggest that for isolated or predominant extremity injuries, the benefits of early stabilization outweigh risks, provided patients are appropriately selected.

The damage control orthopedics literature reveals a paradigm shift. Coimbra et al.'s meta-analysis comparing DCO to early total care for femoral shaft fractures found no survival advantage for DCO (OR 0.92), contrary to the rationale for this approach (39). This finding challenges the widespread adoption of DCO for femoral fractures and suggests that early definitive fixation may be preferable in appropriately selected patients.

Complications and Safety Outcomes

ARDS and Pulmonary Complications

The most consistent finding across studies is the protective effect of early definitive fixation against ARDS and pulmonary complications. Vallier et al. demonstrated significantly fewer ARDS cases with early fixation (<24 hours) (1.7% vs 5.3%, $p=0.048$) in patients with multiple injuries including pelvis, acetabulum, femur, and spine fractures (1). This finding was replicated in pelvic ring fractures (RR=0.50; 95% CI: 0.26-0.96, p=0.04) by Oochit et al. (2) and in unstable pelvis and acetabulum fractures (RR 0.38, 95% CI 0.18-0.81) by Dormann et al. (8).

The protective effect appears particularly pronounced in more severely injured patients. Vallier et al. found that in patients with ISS >18, early fixation of pelvis and acetabulum fractures led to significantly less ARDS (4.8% vs 12.6%, p=0.019) (4). This suggests that the patients at highest risk for pulmonary complications derive the greatest benefit from early stabilization.

However, the relationship between timing and pulmonary outcomes varies by injury pattern. For femoral shaft fractures specifically, Jiang et al.'s meta-analysis found that early intramedullary nailing did not significantly increase ARDS risk (OR 0.65; 95% CI 0.38-1.13) (32). Yet in severely injured patients with chest trauma, Pape et al. found that early intramedullary nailing was associated with higher ARDS rates compared to external fixation (15.1% vs 9.1%) (36). This discrepancy highlights the importance of considering concomitant injuries—specifically chest trauma—when planning femoral fracture fixation.

Spinal injuries demonstrate consistent pulmonary benefits with early stabilization when appropriately timed. Schinkel et al. found that early stabilization of thoracic spine fractures within 72 hours significantly reduced ARDS (5). Hager et al., analyzing the TraumaRegister DGU®, confirmed that early fixation of thoracic and lumbar spine fractures reduced ARDS, particularly for thoracic fractures where primary minimally invasive posterior stabilization was recommended (44). El-Abtah et al.'s meta-analysis of thoracolumbar spine fractures found early fixation (<72 hours) reduced ARDS compared to delayed fixation (7).

Conversely, DCO with temporary external fixation followed by delayed definitive fixation showed higher ARDS rates in some studies. Coimbra et al. found DCO for femoral shaft fractures was associated with significantly increased ARDS risk (OR 1.64) compared to early total care (39). This finding challenges the assumption that DCO is inherently protective against pulmonary complications.

Pneumonia and Infectious Complications

Beyond ARDS, broader pulmonary complications are reduced with early definitive fixation. Vallier et al. reported fewer pneumonia cases with early fixation (8.6% vs 15.2%, p=0.070) (1).

Rojas et al. found that in pelvic ring injuries, delayed fixation resulted in higher pneumonia incidence (20% vs 0%, p=0.004), with 11 of 16 pneumonia cases associated with chest injury (26). Iqbal et al. demonstrated that early fixation within 48 hours of rib fractures in patients with traumatic brain injury reduced pneumonia (p=0.001), mechanical ventilation duration (p=0.03), and tracheostomy rates (p=0.02) (73).

For thoracolumbar spine injuries, Toh et al.'s meta-analysis found early decompression was associated with fewer respiratory complications and shorter ventilation time (mean difference -2.41 days, p=0.01) (18). Stahel et al.'s standardized spine damage-control protocol for unstable thoracic and lumbar fractures (fixation within 24 hours) resulted in significantly lower urinary tract infection rates (4.8% vs 21.4%) and pulmonary complication rates (14.3% vs 25.7%) compared to delayed fixation (6).

Sangkomkamhang et al.'s meta-analysis comparing early versus delayed definitive fixation of lower extremity fractures found that operation within 24-48 hours had 6.67 times fewer complications compared to treatment before 24 hours (95% CI: 3.03-10.00, p<0.001) (31). This finding suggests an optimal window exists—very early surgery before adequate resuscitation may be harmful, while delaying beyond 48 hours increases complications.

Multiple Organ Failure and Sepsis

Early definitive fixation reduces MOF rates across various injury patterns. Vallier et al. found less MOF with early fixation of pelvis and acetabular fractures (1.8% vs 4.3%) (4). However, this difference did not reach statistical significance in all pelvic fracture studies (2,42), possibly reflecting inadequate power for this relatively uncommon outcome.

Sepsis rates are consistently lower with early definitive stabilization. Vallier et al. reported lower sepsis incidence with early fixation of multiple injuries (1.7% vs 5.3%, p=0.054) (1). Kobbe et al. found that delayed spinal surgical fixation was associated with significantly higher sepsis rates (p=0.023 for >24h, p<0.005 for >96h) (21). These findings suggest that prolonged hospitalization and immobility associated with delayed fixation may increase susceptibility to nosocomial infections.

Thromboembolic Complications

Evidence regarding thromboembolic complications is mixed. Arnold et al. found lower DVT rates with early definitive fixation of bilateral femoral shaft fractures (2.2% vs 6.5%, p=0.012) (10). Byrne et al., analyzing a large trauma database, found delayed femoral fracture fixation beyond 24 hours resulted in higher pulmonary embolism rates (2.6% vs 1.3%; RR 2.0; 95% CI 1.2-3.2; p=0.005) (76).

However, Coimbra et al. found DCO for femoral shaft fractures increased DVT risk (OR 1.64) compared to early total care (39), while several pelvic and acetabular fracture studies found no significant differences in thromboembolic complications (9,42). The variability may reflect differences in thromboprophylaxis protocols, injury patterns, and surveillance methods across studies.

Blood Loss and Transfusion Requirements

Damage control approaches consistently result in less initial blood loss but variable overall transfusion requirements. Tuttle et al. found external fixation as a bridge to intramedullary nailing resulted in significantly less estimated blood loss during the initial procedure (37 mL vs 330 mL for immediate IMN) (57). Taeger et al. similarly reported DCO for femoral fractures had minimal blood loss (<50 mL) compared to early total care (472 mL) (58).

However, total transfusion requirements over the entire hospital course may be higher with DCO. Bhamre and Ibrahim found the DCO group required more fluids (6.2 vs 2.2 PRBC units), though estimated blood loss during conversion procedure was less than immediate definitive fixation (90 cc vs 400 cc) (80). Enninghorst et al. found early definitive pelvic fracture fixation showed a trend toward reduced 24-hour transfusion requirements (4.7±5 U vs 6.6±4 U) (27). These findings suggest that while DCO minimizes initial surgical blood loss, the cumulative burden of multiple procedures may negate this advantage.

Subclinical Hypoperfusion and Physiologic Status

Perhaps the most clinically relevant emerging concept is that the patient's physiologic state, rather than absolute timing, is the critical determinant of outcomes. Grey et al. prospectively studied patients with normal vital signs but subclinical hypoperfusion (lactate ≥2.5 mmol/L) undergoing early fracture fixation (13). These patients experienced significant postoperative morbidity, including higher SOFA scores on day 3 (p=0.003), increased need for inotropic support (p=0.02), and required on average 10 days longer mechanical ventilation compared to patients with normal lactate (13). This study elegantly demonstrates that apparent hemodynamic stability may mask inadequate resuscitation, and operating on such patients precipitates poor outcomes.

Vallier et al., in developing the Early Appropriate Care protocol, found that correction of pH to >7.25 within 8 hours was associated with fewer pulmonary complications (20). Richards et al. identified that greater injury severity and depth of shock (measured by 24-hour time-weighted lactate) were independently associated with delayed fixation, suggesting that clinicians appropriately defer surgery in the sickest patients (35). Tan et al. demonstrated that borderline patients who respond to resuscitation can safely undergo definitive surgery, with outcomes comparable to stable patients (38). These studies collectively support a physiology-driven approach rather than rigid time-based protocols.

Healthcare Utilization Outcomes

Hospital Length of Stay

Early definitive fixation consistently reduces total hospital length of stay across multiple injury types. Vallier et al. found early fixation (<24 hours) resulted in significantly shorter hospitalization (10.5±9.8 days vs 14.3±11.4 days, p=0.001) (1). Oochit et al.'s meta-analysis of pelvic ring fractures confirmed reduced hospital stay with early fixation (WMD=-3.52 days; 95% CI: -5.43 to -1.62, p<0.0003) (2).

The magnitude of reduction varies by injury type. For femoral shaft fractures, Harvin et al. found median hospital stays of 6 days with early fixation versus 10 days with delayed fixation (p<0.001) (3). Arnold et al. reported similar findings for bilateral femoral shaft fractures (10 days vs 15 days, p<0.001) (10). Spinal injuries show particularly pronounced benefits—Stahel et al. found early fixation of thoracic and lumbar spine fractures reduced hospital stays from 32.6 days to 14.1 days (p<0.05) (6), while El-Abtah et al.'s meta-analysis found a mean reduction of 3.59 days for thoracolumbar spine fractures (95% CI: -6.44 to -0.75) (7).

However, not all studies found significant differences. Enocson and Lundin reported median hospital stay of 10 days in both early and delayed pelvic and acetabular fracture groups (p=0.6) (9).

Devaney et al. noted that patients with more complex injuries often had delayed fixation, confounding comparisons (52). This heterogeneity underscores the importance of risk adjustment when interpreting observational data.

ICU Length of Stay

ICU utilization shows similar patterns favoring early fixation. Vallier et al. found reduced ICU stays with early fixation (5.1±8.8 days vs 8.4±11.1 days, p=0.006) (1). For pelvic and acetabular fractures, Vallier et al. reported shorter ICU stays (8.1 days vs 9.9 days, p=0.03) (4).

Spinal injuries demonstrate particularly notable ICU benefits. Schinkel et al. found early stabilization of thoracic spine fractures reduced ICU stays from 16 days to 8 days (p=0.001) (5). El-Abtah et al. reported mean ICU stay reduction of 1.21 days for thoracolumbar spine fractures (95% CI: -2.0 to -0.41) (7). Lubelski et al. found that cervical and upper thoracic spine injuries treated according to an early appropriate care protocol (within 36 hours) had significantly fewer total ICU days (16 days delayed vs 9 days protocol, p=0.03) (37).

For rib fractures with concomitant traumatic brain injury, Lagazzi et al. found that delay to surgical fixation was associated with increased ICU stay ($\beta=0.026$, $p<0.001$) (41). Iqbal et al. similarly reported significantly shorter ICU stays with early rib fracture stabilization (p=0.01) (73).

Days on Mechanical Ventilation

Mechanical ventilation duration is consistently reduced with early fixation. Vallier et al. reported significantly fewer ventilator days with early fixation of multiple injuries (1). Stahel et al. found substantial reductions in ventilator requirements with early spinal fixation (2.2 days vs 9.1 days, $p<0.05$) (6). Schinkel et al. reported reduced ventilator dependence with early thoracic spine stabilization (median 2 days vs 5 days, p=0.02) (5).

El-Abtah et al.'s meta-analysis found early thoracolumbar spine fixation was associated with a mean reduction of 3.43 days on mechanical ventilation (95% CI: -6.07 to -0.78) (7). For femoral shaft fractures, Harvin et al. found early fixation resulted in significantly fewer ventilator days (median 0 days vs median 0 days with higher interquartile range, $p<0.001$) (3). Obey et al., analyzing 108,825 femoral shaft fractures, found that delayed fixation beyond 48 hours significantly increased ventilator days (OR 5.38; CI 4.89-5.91) (12).

Patients with cervical spine injuries and concomitant chest trauma who underwent early surgery (<24 hours) had significantly fewer ventilator days (13 days vs 6 days, p=0.02) in Lubelski et al.'s study (37). For rib fractures with traumatic brain injury, Lagazzi et al. found delay was associated with increased ventilation time (β=0.026, p<0.001) (41).

Surgical Efficiency

Damage control approaches with initial external fixation require significantly less operative time than immediate definitive fixation—Tuttle et al. reported external fixation averaged 22 minutes compared to 125 minutes for intramedullary nailing (57). Taeger et al. found mean surgical time for damage control external fixation was 62±30 minutes (58).

However, considering the total surgical burden including conversion procedures, damage control approaches often require more total operative time and additional surgeries. Kalbas et al. found patients undergoing early definitive surgery had a significantly lower mean number of operations (4.3 vs 5.3, p=0.037) and shorter time until completion of reconstructive operations (10 days vs 15 days, p=0.013) (19). This additional surgical burden creates opportunities for complications, including pin-track infections, delayed unions, and anesthesia-related risks.

Functional Outcomes

Functional outcome data are notably limited across included studies, representing a significant evidence gap. Most studies focus on short-term morbidity and healthcare utilization rather than long-term functional recovery, quality of life, or return to pre-injury function.

Sewell et al. assessed patients with cervical spinal cord injury and concomitant chest trauma using the ASIA Impairment Scale at 6 months (16). The early surgery group (<24 hours) showed 52.5% no improvement, 32.5% one-grade improvement, and 15% two-grade improvement. The late surgery group (>24 hours) demonstrated 58% no improvement, 34.5% one-grade improvement, 5.5% two-grade improvement, and 2% three-grade improvement. Neurological recovery was more likely in younger patients and those with incomplete spinal cord injury (16). While not statistically significant, the trend toward greater two-grade improvement in the early group (15% vs 5.5%) suggests potential neurological benefit from timely decompression.

Wang et al. examined patients with traumatic brain injury and orthopedic fractures, finding that early surgery (≤24 hours) was associated with better composite neuropsychological scores at 6 months postinjury on adjusted analysis (17). However, no significant differences were found in return to work or Glasgow Outcome Score between early and late surgery groups (17). This dissociation between neuropsychological testing and functional outcomes highlights the complexity of assessing recovery in multiply injured patients.

For spinal injuries without cord involvement, Hager et al. found early surgical intervention was associated with better Glasgow Outcome Scale scores at hospital discharge compared to late intervention (44). Toh et al.'s meta-analysis of thoracolumbar spine injuries found early decompression was associated with increased odds of neurological improvement (log odds ratio = 0.82, p<0.001), with greater effects in studies including severely injured patients (18). This suggests that timely intervention may mitigate the secondary physiological impact of polytrauma on neural tissue.

Quality of life measures are rarely reported. Burianov et al. mentioned using the SF-36 scale but did not provide comparative data between early and delayed groups (45). Return to work and activities of daily living were not systematically assessed across the majority of studies. This represents a critical gap, as mortality and complication differences may not correlate with patient-centered outcomes such as functional independence and quality of life.

Injury Pattern-Specific Considerations

The synthesis reveals that optimal timing varies significantly by injury pattern, reflecting differences in biomechanics, surgical stress, and associated injuries.

Pelvic ring fractures with ongoing hemorrhage require immediate stabilization for hemodynamic control, representing damage control rather than definitive treatment (27,60). Once resuscitated, early definitive fixation within 24-36 hours reduces ARDS (RR 0.38-0.50) (2,8), hospital stay (WMD -3.52 days) (2), and shows trends toward reduced mortality (2,51). Probst et al.'s analysis of pelvic fracture timing found the highest mortality with day 0 surgery (18%), intermediate with days 1-3 (19%), and lowest with surgery after day 3 (4%, p=0.019) (51), likely reflecting confounding by indication where the most unstable patients received immediate surgery. After controlling for injury severity, early fixation within 36 hours shows clear benefits (2,26).

Femoral shaft fractures represent the most extensively studied injury. In stable or adequately resuscitated patients, early fixation within 24 hours reduces pulmonary complications (3,76), hospital stay (3,10), and mortality (3,12). The large database study by Obey et al. demonstrating 3.6-fold increased mortality with fixation beyond 48 hours provides compelling evidence against unnecessary delay (12). However, in borderline patients with chest trauma and marginal physiology, damage control with external fixation reduces acute lung injury risk (OR 6.69 for IMN vs external fixation) (15). The challenge lies in preoperative identification of borderline patients rather than retrospective recognition after complications develop.

Thoracic spine fractures represent a uniquely high-risk scenario. Konieczny et al.'s finding of significantly increased mortality with early surgery ($p<0.01$), particularly in patients with hemoglobin <10 mg/dL and thoracic drains (75% mortality with both risk factors) (14), mandates caution. The respiratory compromise from thoracic procedures combined with chest injuries creates a "double hit" that poorly tolerated patients cannot withstand. Conversely, Schinkel et al. found that early stabilization within 72 hours reduced ARDS and ICU stay in appropriately selected patients (5). The critical distinction appears to be patient selection—early surgery benefits stable patients but harms those with ongoing hemorrhage and severe thoracic trauma.

Lumbar spine fractures consistently benefit from early intervention. Hager et al. found early fixation reduced ARDS, hospital stay, and improved Glasgow Outcome Scale scores (44). El-Abtah et al.'s meta-analysis confirmed reduced ARDS, ventilator days, ICU stay, and hospital stay with early thoracolumbar fixation (7). The less direct respiratory impact of lumbar procedures compared to thoracic procedures likely explains this differential benefit.

Cervical spine injuries with traumatic brain injury present complex coordination challenges. While some studies suggest early fixation is safe (65), Kalbas et al. found that intracranial trauma requiring neurosurgical procedures strongly predicts delayed fracture care (OR 5.59) (19). Hax et al. reported higher mortality with early cervical surgery in polytrauma patients (43). Klingebiel et al.'s systematic review concluded that fracture fixation should be coordinated with neurosurgical priorities, and intracranial pressure must be controlled (≤20 mmHg) with adequate cerebral perfusion pressure (>60-70 mmHg) before proceeding (65).

Rib fractures with concomitant injuries benefit from early stabilization. Iqbal et al. found early fixation within 48 hours in patients with traumatic brain injury reduced pneumonia, ventilator days, ICU stay, and tracheostomy rates (73). Lagazzi et al.'s nationwide analysis confirmed that delay increased ventilation time and ICU stay (41). The mechanical benefits of chest wall stabilization appear to outweigh surgical risks, even in patients with associated injuries.

Open fractures require early debridement within 24 hours (60), but definitive reconstruction timing must balance infection risk against physiologic stability. Grade I, II, and IIIa open fractures can undergo early closure (60), while more severe injuries may require staged reconstruction. Byrne et al. observed that open fractures were treated earlier but had longer hospital stays, suggesting soft tissue injury severity drives outcomes beyond timing alone (76).

Damage Control Orthopedics Versus Early Total Care

The evolution from early total care to damage control orthopedics and back toward early appropriate care reflects increasing sophistication in patient selection. Early studies from the 1980s-1990s showing ARDS and MOF with immediate definitive fixation (36) led to DCO strategies. However, contemporary studies with improved critical care demonstrate that DCO offers no mortality advantage and increases complications compared to early total care in appropriately selected patients (39).

This reversal can be explained by several factors. First, the "borderline" patient concept recognizes that some patients are too unstable for immediate definitive surgery regardless of timing (15). In these patients, early intramedullary nailing showed 6.69 times higher odds of acute lung injury compared to external fixation (15). However, stable patients benefited from primary femoral nailing with shorter ventilation times (15). The critical issue is accurate preoperative identification of borderline patients.

Second, critical care advances have reduced baseline complication rates, changing the risk-benefit calculation. Pape et al. documented significant reductions in MOF and ARDS from the early total care era (1981-1989) through the DCO era (1993-2000) independent of surgical timing (36), suggesting that improvements in intensive care, trauma resuscitation, and air rescue contributed substantially to better outcomes.

Third, the additional surgical burden of conversion from external fixation to definitive fixation creates opportunities for complications. Lavini et al. reported pin-track infections, delayed unions, and need for second major procedures as potential failure points (46). Glass et al. found lower infection rates with early definitive fixation versus delayed fixation after DCO (3.1% vs 30.6%, p=0.002) (34), suggesting that damage control should be reserved for truly unstable patients rather than applied broadly.

Physiologic Parameters as Decision Guides

The synthesis strongly supports using physiologic parameters rather than absolute time cutoffs to guide surgical timing decisions. Grey et al.'s demonstration that patients with subclinical hypoperfusion (lactate ≥2.5 mmol/L despite normal vital signs) have significantly worse outcomes with early surgery (13) provides an objective, measurable criterion for identifying high-risk patients. Vallier et al.'s Early Appropriate Care protocol, incorporating pH >7.25 within 8 hours, identifies patients safe for early fixation (20). Tan et al.'s finding that borderline patients who respond to resuscitation can safely undergo definitive surgery (38) supports a dynamic, response-guided approach.

Richards et al. identified that greater injury severity and depth of shock (measured by 24-hour time-weighted lactate) independently predict delayed fixation (35), suggesting that clinicians appropriately defer surgery in sicker patients. This finding validates current practice while highlighting opportunities for standardization—if clinicians are already using physiologic parameters implicitly, making these criteria explicit could reduce practice variation and improve outcomes.

The consistent finding across studies is that inadequately resuscitated patients fare poorly with early definitive surgery, while adequately resuscitated patients benefit from intervention within 24-48 hours. The clinical challenge lies in accurately assessing resuscitation adequacy using parameters beyond vital signs, including lactate clearance, base deficit correction, and organ perfusion markers.

CONCLUSION AND RECOMMENDATIONS

Summary of Findings

This comprehensive review of 80 studies examining timing of surgical fixation in multiply injured patients reveals that the optimal approach is not a fixed time point but rather a context-dependent decision framework incorporating injury patterns, physiologic status, and surgical complexity. Early definitive fixation within 24-48 hours in adequately resuscitated patients is associated with reduced ARDS (1.7% vs 5.3%), pneumonia (8.6% vs 15.2%), hospital length of stay (10.5 vs 14.3 days), ICU days (5.1 vs 8.4 days), and ventilator days compared to delayed fixation, with no increase in mortality. Damage control orthopedics offers no survival advantage over early total care and may increase complications.

However, specific patient subgroups experience worse outcomes with early intervention. Patients with subclinical hypoperfusion (lactate ≥2.5 mmol/L despite normal vital signs) undergoing early surgery have significantly higher morbidity, including prolonged ventilation and increased inotropic requirements. Thoracic spine fractures in patients with hemoglobin <10 mg/dL and thoracic drains represent a uniquely high-risk scenario with 75% mortality when operated early. Cervical spine injuries with traumatic brain injury requiring neurosurgical intervention require coordinated timing with intracranial pressure control. These findings support a physiology-driven, injury pattern-specific approach rather than universal early or delayed protocols.

Clinical Recommendations

Based on the synthesized evidence, we propose the following framework for clinical decision-making:

1. **Adequately resuscitated patients** (lactate <2.5 mmol/L, pH >7.25, base excess >-5.5) with any injury pattern should undergo early definitive fixation within 24-48 hours to reduce complications and healthcare utilization.

2. **Borderline patients** with marginal physiology (lactate ≥2.5 mmol/L despite normal vital signs, ongoing resuscitation requirements) should receive damage control orthopedics with

temporary external fixation or provisional stabilization, followed by conversion to definitive fixation after physiologic recovery (typically 5-10 days).

3. **Thoracic spine fractures** warrant special caution—early surgery should be avoided in patients with hemoglobin <10 mg/dL or thoracic drains, and delayed stabilization after initial resuscitation is recommended.

4. **Cervical spine injuries with traumatic brain injury** require multidisciplinary coordination with neurosurgery, ensuring intracranial pressure ≤20 mmHg and cerebral perfusion pressure >60-70 mmHg before proceeding.

5. **Open fractures** require early debridement within 24 hours, with definitive reconstruction timing determined by soft tissue injury severity and physiologic status.

6. **Healthcare systems** should implement early appropriate care protocols incorporating physiologic parameters to standardize decision-making and reduce practice variation.

Research Recommendations

Future research should address the following priorities:

1. Prospective validation of physiologic cutoffs (lactate, base deficit, inflammatory markers) for safe early fixation across diverse injury patterns

2. Long-term functional outcome studies using validated instruments (SF-36, return to work, activities of daily living) to complement mortality and complication data

3. Comparative effectiveness research comparing early appropriate care protocols to traditional time-based or damage control approaches

4. Development and validation of risk prediction models incorporating injury pattern, physiologic status, and surgical complexity to guide individualized timing decisions

5. Investigation of optimal conversion timing from damage control to definitive fixation in borderline patients

Concluding Statement

The question of early versus delayed surgical fixation in multiply injured patients cannot be answered with a single time cutoff applicable to all patients and injuries. The evidence supports a paradigm shift from time-based protocols to physiology-driven, injury pattern-specific decision-making. Adequately resuscitated patients benefit from early fixation within 24-48 hours, while those with subclinical hypoperfusion or specific high-risk injury combinations require delayed or staged approaches. By integrating physiologic assessment with injury pattern recognition, clinicians can optimize outcomes for this complex patient population.

REFERENCES

1. H. Vallier, D. Super, T. Moore, J. Wilber (2013) Do Patients With Multiple System Injury Benefit From Early Fixation of Unstable Axial Fractures? The Effects of Timing of Surgery on Initial Hospital Course. Journal of Orthopaedics and Trauma. https://doi.org/10.1097/BOT.0b013e3182820eba
2. Krishna Oochit, M. A. Imran, A. Marsh (2025) Early vs. late definitive fixation of pelvic ring fractures in resuscitated polytraumatized patients: a systematic review and meta-analysis. Archives of Orthopaedic and Trauma Surgery. https://doi.org/10.1007/s00402-025-06152-9
3. J. Harvin, William H Harvin, E. Camp, et al (2012) Early femur fracture fixation is associated with a reduction in pulmonary complications and hospital charges: A decade of experience with 1,376 diaphyseal femur fractures. Journal of Trauma and Acute Care Surgery. https://doi.org/10.1097/TA.0b013e3182782696
4. H. Vallier, B. Cureton, Charles Ekstein, et al (2010) Early definitive stabilization of unstable pelvis and acetabulum fractures reduces morbidity. Journal of Trauma. https://doi.org/10.1097/TA.0b013e3181e50914

5. C. Schinkel, T. Frangen, A. Kmetič, et al (2005) Timing of thoracic spine stabilization in trauma patients: impact on clinical course and outcome. Journal of Trauma. https://doi.org/10.1097/01.TA.0000222669.09582.EC
6. P. Stahel, Todd F Vanderheiden, M. Flierl, et al (2013) The impact of a standardized "spine damage-control" protocol for unstable thoracic and lumbar spine fractures in severely injured patients: A prospective cohort study. Journal of Trauma and Acute Care Surgery. https://doi.org/10.1097/TA.0b013e31827d6054
7. Mohamed E. El-Abtah, M. J. Roach, Michael L. Kelly (2025) Meta-analysis of early versus late fixation of traumatic unstable thoracolumbar spine fractures in patients with or without spinal cord injury. Journal of clinical neuroscience. https://doi.org/10.1016/j.jocn.2025.111238
8. Julia Dormann, K. Horst, Karolina Dahms, et al (2025) The optimal timing for definitive operative stabilization of pelvic fractures in polytrauma patients: effects on clinical outcomes – a systematic review. European Journal of Trauma and Emergency Surgery. https://doi.org/10.1007/s00068-025-02774-1
9. A. Enocson, Natalie Lundin (2023) Early versus late surgical treatment of pelvic and acetabular fractures a five-year follow-up of 419 patients. BMC Musculoskeletal Disorders. https://doi.org/10.1186/s12891-023-06977-8
10. Suzanne C. Arnold, Emanuele Lagazzi, R. K. Wagner, et al (2024) Two big bones, one big decision: When to fix bilateral femur fractures. Injury. https://doi.org/10.1016/j.injury.2024.111610
11. R. Gandhi, Tiffany L. Overton, E. Haut, et al (2014) Optimal timing of femur fracture stabilization in polytrauma patients: A practice management guideline from the Eastern Association for the Surgery of Trauma. Journal of Trauma and Acute Care Surgery. https://doi.org/10.1097/TA.0000000000000434
12. Mitchel R Obey, D. Clever, D. Bechtold, et al (2021) In-Hospital Morbidity and Mortality With Delays in Femoral Shaft Fracture Fixation. Journal of Orthopaedics and Trauma. https://doi.org/10.1097/BOT.0000000000002271
13. B. Grey, R. Rodseth, D. Muckart (2013) Early fracture stabilisation in the presence of subclinical hypoperfusion. Injury. https://doi.org/10.1016/j.injury.2012.08.062

14. M. Konieczny, J. Strüwer, B. Jettkant, et al (2015) Early versus late surgery of thoracic spine fractures in multiple injured patients: is early stabilization always recommendable? The spine journal. https://doi.org/10.1016/j.spinee.2013.07.469

15. H. Pape, D. Rixen, J. Morley, et al (2007) Impact of the Method of Initial Stabilization for Femoral Shaft Fractures in Patients With Multiple Injuries at Risk for Complications (Borderline Patients). Annals of Surgery. https://doi.org/10.1097/SLA.0b013e3181485750

16. M. Sewell, K. Vachhani, Asif Alrawi, Richard Williams (2018) Results of Early and Late Surgical Decompression and Stabilization for Acute Traumatic Cervical Spinal Cord Injury in Patients with Concomitant Chest Injuries. World Neurosurgery. https://doi.org/10.1016/j.wneu.2018.06.146

17. Marjorie C. Wang, N. Temkin, R. Deyo, et al (2007) Timing of surgery after multisystem injury with traumatic brain injury: effect on neuropsychological and functional outcome. Journal of Trauma. https://doi.org/10.1097/01.TA.0000215581.50234.56

18. Karen HQ Toh, Tim Cheok, R. Martin, Henrik Baecker (2025) CLINICAL OUTCOMES FOLLOWING EARLY VERSUS DELAYED DECOMPRESSION IN PATIENTS WITH THORACOLUMBAR SPINE INJURIES: A SYSTEMATIC REVIEW AND META-ANALYSIS. Orthopaedic Proceedings. https://doi.org/10.1302/1358-992x.2025.16.037

19. Y. Kalbas, Yannik Stutz, F. Klingebiel, et al (2025) Criteria to clear polytrauma patients with traumatic brain injury for safe definitive surgery (<24 h). Injury. https://doi.org/10.1016/j.injury.2025.112149

20. H. Vallier, Xiaofeng Wang, T. Moore, et al (2013) Timing of Orthopaedic Surgery in Multiple Trauma Patients: Development of a Protocol for Early Appropriate Care. Journal of Orthopaedics and Trauma. https://doi.org/10.1097/BOT.0b013e31829efda1

21. P. Kobbe, Patrick Krug, H. Andruszkow, et al (2020) Early Spinal Injury Stabilization in Multiple-Injured Patients: Do All Patients Benefit? Journal of Clinical Medicine. https://doi.org/10.3390/jcm9061760

22. Sebastian Ndlovu, Stanley Masunda, Emmanuel Oladeji, et al (2025) Early versus late surgical stabilisation of unstable thoracolumbar spine fractures in adult polytrauma patients: a

systematic review and meta-analysis. Health Sciences Review. https://doi.org/10.1016/j.hsr.2025.100217

23. C. Bliemel, R. Lefering, B. Buecking, et al (2014) Early or delayed stabilization in severely injured patients with spinal fractures? Current surgical objectivity according to the Trauma Registry of DGU: Treatment of spine injuries in polytrauma patients. Journal of Trauma and Acute Care Surgery. https://doi.org/10.1097/TA.0b013e3182aafd7a

24. Nickolas J. Nahm, H. Vallier (2012) Timing of definitive treatment of femoral shaft fractures in patients with multiple injuries: A systematic review of randomized and nonrandomized trials. Journal of Trauma and Acute Care Surgery. https://doi.org/10.1097/TA.0b013e3182701ded

25. Nickolas J. Nahm, John J Como, J. Wilber, H. Vallier (2011) Early appropriate care: definitive stabilization of femoral fractures within 24 hours of injury is safe in most patients with multiple injuries. Journal of Trauma. https://doi.org/10.1097/TA.0b013e3181fc93a2

26. D. Rojas, J. Coleman, E. Moore, et al (2020) The Association of Surgical Timing and Injury Severity With Systemic Complications in Severely Injured Patients With Pelvic Ring Injuries. Journal of Orthopaedics and Trauma. https://doi.org/10.1097/BOT.0000000000001946

27. Natalie Enninghorst, László Tóth, K. King, et al (2010) Acute definitive internal fixation of pelvic ring fractures in polytrauma patients: a feasible option. Journal of Trauma. https://doi.org/10.1097/TA.0b013e3181d27b48

28. Eva Steinfeld, K. Horst, Kelly Ansems, et al (2025) Optimal timing of stabilization and operative technique for extremity fractures in polytrauma patients: a systematic review and meta-analysis. European Journal of Trauma and Emergency Surgery. https://doi.org/10.1007/s00068-024-02762-x

29. K. Oochit, A. Imran, A. Marsh (2024) 9 Early vs Late Definitive Fixation of Pelvic Ring Fractures in Polytraumatized Patients. a Systematic Review and Meta-Analysis. British Journal of Surgery. https://doi.org/10.1093/bjs/znae163.185

30. Sacha Halvachizadeh, R. Pfeifer, James Duncan, et al (2024) Does the injury pattern drive the surgical treatment strategy in multiply injured patients with major fractures? Journal of Trauma and Acute Care Surgery. https://doi.org/10.1097/TA.0000000000004252

31. T. Sangkomkamhang, W. Thinkhamrop, B. Thinkhamrop, W. Laohasiriwong (2018) Incidence and risk factors for complications after definitive skeletal fixation of lower extremity in multiple injury patients: a retrospective chart review. F1000Research. https://doi.org/10.12688/f1000research.14825.1

32. Meng Jiang, Chang-Li Li, Cheng-la Yi, Shao-tao Tang (2016) Early intramedullary nailing of femoral shaft fracture on outcomes in patients with severe chest injury: A meta-analysis. Scientific Reports. https://doi.org/10.1038/srep30566

33. Joseph Gutbrod, Dustin L. Stwalley, Anna N. Miller (2024) Effect of surgical fixation timing on in-hospital mortality and morbidity of distal femur fractures. Injury. https://doi.org/10.1016/j.injury.2024.111927

34. Nina E. Glass, C. Burlew, J. Hahnhaussen, et al (2017) Early Definitive Fracture Fixation is Safely Performed in the Presence of an Open Abdomen in Multiply Injured Patients. Journal of Orthopaedics and Trauma. https://doi.org/10.1097/BOT.0000000000000959

35. J. Richards, Andrew J. Medvecz, N. O'Hara, et al (2020) Musculoskeletal Trauma in Critically Injured Patients: Factors Leading to Delayed Operative Fixation and Multiple Organ Failure. Anesthesia and Analgesia. https://doi.org/10.1213/ANE.0000000000005252

36. H. Pape, F. Hildebrand, S. Pertschy, et al (2004) Changes in the Management of Femoral Shaft Fractures in Polytrauma Patients: From Early Total Care to Damage Control Orthopedic Surgery. Journal of Trauma. https://doi.org/10.1097/01.TA.0000025660.37314.OF

37. D. Lubelski, S. Tharin, John J Como, et al (2017) Surgical timing for cervical and upper thoracic injuries in patients with polytrauma. Journal of Neurosurgery : Spine. https://doi.org/10.3171/2017.4.SPINE16933

38. J. Tan, Tianyi Wu, J. Tan, et al (2020) Definitive Surgery Is Safe in Borderline Patients Who Respond to Resuscitation. Journal of Orthopaedics and Trauma. https://doi.org/10.1097/BOT.0000000000001999

39. B. Coimbra, Junsik Kwon, Bishoy L Zakhary, et al (2025) Damage control does not offer a survival advantage and increases the risk of serious complications compared with early total care in

severely injured patients with femoral shaft fractures. Journal of Trauma and Acute Care Surgery. https://doi.org/10.1097/TA.0000000000004594

40. S. Halva, R. Pfeifer, F. Klingebiel, et al (2024) Assessment of Safe Early Fixation Strategies in a Cohort Polytraumatized Patients – How is the Surgical Treatment Influenced by the Injury Pattern? British Journal of Surgery. https://doi.org/10.1093/bjs/znae118.065

41. Emanuele Lagazzi, D. Argandykov, Amory de Roulet, et al (2023) Evaluating the impact of timing to rib fixation in patients with traumatic brain injury: A nationwide analysis. Journal of Trauma and Acute Care Surgery. https://doi.org/10.1097/TA.0000000000004100

42. David G. Rojas, Julia R. Coleman, Ernest E. Moore, et al (2019) Complications Associated With Early Versus Delayed Fixation of Pelvic Ring Injuries. https://doi.org/10.26226/morressier.5cffabaef6074e97f94aae68

43. Jakob Hax, M. Teuben, Sacha Halvachizadeh, et al (2023) Timing of Spinal Surgery in Polytrauma: The Relevance of Injury Severity, Injury Level and Associated Injuries. Global Spine Journal. https://doi.org/10.1177/21925682231216082

44. Sven Hager, H. Eberbach, R. Lefering, et al (2020) Possible advantages of early stabilization of spinal fractures in multiply injured patients with leading thoracic trauma - analysis based on the TraumaRegister DGU®. Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine. https://doi.org/10.1186/s13049-020-00737-6

45. O. Burianov, S. Dubrov, T. Omelchenko, et al (2020) DOES THE TERM OF DEFINITIVE OSTEOSYNTHESIS OF MULTIPLE LONG BONE FRACTURES OF LOWER EXTREMITIES IMPACT ON TREATMENT OUTCOMES IN POLYTRAUMA PATIENTS. EUREKA: Health Sciences. https://doi.org/10.21303/2504-5679.2020.001332

46. F. Lavini, E. Carità, C. Dall'oca, et al (2007) Internal femoral osteosynthesis after external fixation in multiple-trauma patients. Strategies in Trauma and Limb Reconstruction. https://doi.org/10.1007/s11751-007-0012-x

47. Natalie Enninghorst, László Tóth, K. King, et al (2009) TS11 *ACUTE INTERNAL FIXATION OF PELVIC RING FRACTURES: SAFE AND EFFICIENT. https://doi.org/10.1111/J.1445-2197.2009.04934_11.X

48. Rafik Abu-Ramadan, Z. A. Qureshi, S. Majdi (2015) Orthopaedic Approach in Patients with Multiple Injuries

49. H. Pape, D. Rixen, J. Morley, et al (2012) IMPACT OF THE METHOD OF INITIAL STABILISATION FOR FEMORAL FRACTURES IN POLYTRAUMA PATIENTS AT RISK FOR COMPLICATIONS (BORDERLINE PATIENTS): A PROSPECTIVE RANDOMISED ANALYSIS BY THE EPOFF STUDY GROUP

50. G. Volpin, H. Shtarker, Neda Trajkovska, J. Saveski (2011) DAMAGE CONTROL ORTHOPAEDICS IN POLYTRAUMATIZED PATIENTS

51. C. Probst, Tarané Probst, A. Gaensslen, et al (2007) Timing and duration of the initial pelvic stabilization after multiple trauma in patients from the German trauma registry: is there an influence on outcome? Journal of Trauma. https://doi.org/10.1097/TA.0B013E31802EFAEE

52. Giles L. Devaney, J. Bulman, K. King, Z. Balogh (2020) Time to definitive fixation of pelvic and acetabular fractures. Journal of Trauma and Acute Care Surgery. https://doi.org/10.1097/TA.0000000000002860

53. J. Godzik, Jonathan F. Dalton, Courtney Hemphill, et al (2019) Early surgical intervention among patients with acute central cord syndrome is not associated with higher mortality and morbidity. Journal of Spine Surgery. https://doi.org/10.21037/JSS.2019.09.26

54. Teng-fei Zhu, Wengiu Zhao, Han-Lin Zheng, Jia-Xiang Wu (2018) [Application of damage control orthopedics for the treatment of severe multiple fractures]. Zhongguo gu shang = China journal of orthopaedics and traumatology. https://doi.org/10.3969/j.issn.1003-0034.2018.02.010

55. G. Feldman, R. Mosheiff, Khalil Nasrallah, et al (2021) Evolution of treatment of femoral shaft fracture in polytrauma: Did damage control orthopaedics improve the outcome? A retrospective study. Injury. https://doi.org/10.1016/j.injury.2021.04.031

56. Y. Zhang, Kai Sun, Yuling Wang, et al (2017) Early vs late fracture fixation in severe head and orthopedic injuries. American Journal of Emergency Medicine. https://doi.org/10.1016/j.ajem.2017.12.067

57. M. Tuttle, Wade R. Smith, Allison E. Williams, et al (2009) Safety and efficacy of damage control external fixation versus early definitive stabilization for femoral shaft fractures in the multiple-injured patient. Journal of Trauma. https://doi.org/10.1097/TA.0b013e3181aa21c0

58. G. Taeger, S. Ruchholtz, C. Waydhas, et al (2005) Damage control orthopedics in patients with multiple injuries is effective, time saving, and safe. Journal of Trauma. https://doi.org/10.1097/01.TA.0000175088.29170.3E

59. J. Dimar, L. Carreon, J. Riina, et al (2010) Early Versus Late Stabilization of the Spine in the Polytrauma Patient. Spine. https://doi.org/10.1097/BRS.0b013e3181f32bcd

60. S. Cimbanassi, Robert V. O'Toole, M. Maegele, et al (2019) Orthopedic injuries in patients with multiple injuries: Results of the 11th trauma update international consensus conference Milan, December 11, 2017. Journal of Trauma and Acute Care Surgery. https://doi.org/10.1097/TA.0000000000002407

61. T. Scalea, S. Boswell, J. Scott, et al (2004) External Fixation as a Bridge to Intramedullary Nailing for Patients with Multiple Injuries and with Femur Fractures : Damage Control Orthopedics. https://doi.org/10.1097/00005131-200409001-00002

62. H. Vallier, T. Moore, John J Como, et al (2015) Teamwork in Trauma: System Adjustment to a Protocol for the Management of Multiply Injured Patients. Journal of Orthopaedics and Trauma. https://doi.org/10.1097/BOT.0000000000000383

63. R. Pfeifer, F. Klingebiel, Z. Balogh, et al (2024) Early major fracture care in polytrauma—priorities in the context of concomitant injuries: A Delphi consensus process and systematic review. Journal of Trauma and Acute Care Surgery. https://doi.org/10.1097/TA.0000000000004428

64. Mazin Osman, Khald Alhamoud Almatar, Fahad Almatar, et al (2025) Outcomes of Early Versus Delayed Definitive Surgical Intervention in Multisystem Trauma Patients: A Systematic Review of Timing Strategies in General Surgery Emergencies. Cureus. https://doi.org/10.7759/cureus.90136

65. F. Klingebiel, Markus F. Oertel, Y. Kalbas, et al (2025) Timing of definitive fracture fixation in patients with concomitant traumatic brain injuries – A systematic review of the literature

by the IMPACT group. European Journal of Trauma and Emergency Surgery. https://doi.org/10.1007/s00068-025-02981-w

66. H. Pakzad, D. Roffey, H. Knight, et al (2011) Delay in operative stabilization of spine fractures in multitrauma patients without neurologic injuries: effects on outcomes. Canadian journal of surgery Journal canadien de chirurgie. https://doi.org/10.1503/cjs.008810

67. L. Scaramuzzo, F. Tamburrelli, E. Piervincenzi, et al (2013) Percutaneous pedicle screw fixation in polytrauma patients. European spine journal. https://doi.org/10.1007/s00586-013-3011-2

68. L. Bone, P. Giannoudis (2011) Femoral shaft fracture fixation and chest injury after polytrauma. Journal of Bone and Joint Surgery American volume. https://doi.org/10.2106/JBJS.J.00334

69. Saam Morshed, Christopher M. Mikhail, Theodore Miclau III (2015) Timing of Femoral Shaft Fracture Fixation Affects Length of Hospital Stay in Patients with Multiple Injuries. The Open Orthopaedics Journal. https://doi.org/10.2174/1874325001509010324

70. T. Frangen, S. Ruppert, G. Muhr, C. Schinkel (2007) [Respiratory failure in thoracic spine injuries. Does the timing of dorsal stabilization have any effect on the clinical course in multiply injured patients?]. Der Orthopade. https://doi.org/10.1007/S00132-007-1049-8

71. H. Pape, K. Grimme, M. Griensven, et al (2003) Impact of intramedullary instrumentation versus damage control for femoral fractures on immunoinflammatory parameters: prospective randomized analysis by the EPOFF Study Group. Journal of Trauma. https://doi.org/10.1097/01.TA.0000075787.69695.4E

72. P. Weninger, M. Figl, R. Spitaler, et al (2007) Early unreamed intramedullary nailing of femoral fractures is safe in patients with severe thoracic trauma. Journal of Trauma. https://doi.org/10.1097/01.TA.0000243203.38466.E0

73. H. J. Iqbal, J. Alsousou, Sohan Shah, et al (2018) Early Surgical Stabilization of Complex Chest Wall Injuries Improves Short-Term Patient Outcomes. Journal of Bone and Joint Surgery American volume. https://doi.org/10.2106/JBJS.17.01215

74. Ki-Chul Park, Ye-Soo Park, W. Seo, et al (2014) Clinical results of early stabilization of spine fractures in polytrauma patients. Journal of critical care. https://doi.org/10.1016/j.jcrc.2014.03.003

75. R. Yamamoto, K. Udagawa, Yusho Nishida, et al (2021) Clinical parameters and optimal candidates for early definitive fixation of extremity injury: A nationwide study. Journal of Orthopaedic Science. https://doi.org/10.1016/j.jos.2021.10.002

76. J. Byrne, A. Nathens, David Gomez, et al (2017) Timing of femoral shaft fracture fixation following major trauma: A retrospective cohort study of United States trauma centers. PLoS Medicine. https://doi.org/10.1371/journal.pmed.1002336

77. Gustavo Sardinha Lisboa Leite, Diego Olandoski de Oliveira, Mariana Demétrio de Sousa Pontes, C. F. P. S. Herrero (2025) Early vs. late surgery in thoracic spine fractures: impact on clinical outcomes in polytrauma patients. European Journal of Trauma and Emergency Surgery. https://doi.org/10.1007/s00068-025-03003-5

78. Victor S. Ritter, F. Lin, Anna Miller, R. Ostrum (2022) Fixation of humerus shaft fractures in polytrauma patients does not improve short-term outcomes. Injury. https://doi.org/10.1016/j.injury.2022.11.060

79. Ahmad S. Alobaidi, Ammar Al-Hassani, A. El-Menyar, et al (2016) Early and late intramedullary nailing of femur fracture: A single center experience. International Journal of Critical Illness and Injury Science. https://doi.org/10.4103/2229-5151.190649

80. S. Bhamre, Salil Ibrahim (2024) A PROSPECTIVE COMPARATIVE STUDY OF EARLY TOTAL CARE VS DAMAGE CONTROL ORTHOPEDICS IN POLY-TRAUMATIZED PATIENTS. Indian Journal Of Applied Research. https://doi.org/10.36106/ijar/2802957