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Review Article

Systematic Review of Medical Optimisation of Polytrauma Patients Undergoing Surgery

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ABSTRACT

Background: Polytrauma patients undergoing surgery frequently present with hemorrhage, coagulopathy, hypothermia, metabolic disturbance, respiratory compromise, and competing operative priorities. Objective: To synthesize current evidence regarding medical and physiological optimization of adults with polytrauma undergoing surgery. Methods: A mixed-evidence systematic review with narrative synthesis was conducted using PubMed/MEDLINE, Scopus, Embase, Web of Science, the Cochrane Library, and Google Scholar. Evidence published principally from 2021 onward was considered, with clinically relevant landmark publications identified through reference screening. Eligible sources examined resuscitation, operative timing, imaging, anaesthesia, infection prevention, multidisciplinary care, or rehabilitation. Results: Twenty publications were included. The evidence consistently prioritized hemorrhage control, haemostatic resuscitation, correction of coagulopathy and hypothermia, individualized imaging and anaesthetic management, and repeated physiological reassessment. Damage-control strategies were most applicable to unstable patients, whereas early definitive surgery was supported after adequate physiological recovery. Whole-body computed tomography aided injury detection and planning in appropriately selected patients. Evidence for universal operative-readiness thresholds and broad antibiotic prophylaxis remained uncertain. Conclusion: Perioperative optimization in polytrauma should be individualized and physiology-guided rather than based on fixed surgical timelines. Keywords: Polytrauma; Multiple Trauma; Medical Optimization; Damage-Control Resuscitation; Damage-Control Surgery; Perioperative Care; Surgical Timing; Trauma-Induced Coagulopathy.

INTRODUCTION

Polytrauma involves severe injuries affecting multiple anatomical regions or organ systems, frequently accompanied by physiological instability and an increased risk of early mortality, organ dysfunction, prolonged intensive care, and long-term disability. Its management extends beyond the treatment of individual injuries because hemorrhage, hypoperfusion, hypothermia, metabolic acidosis, trauma-induced coagulopathy, respiratory compromise, and systemic inflammation may interact and amplify perioperative risk. Contemporary trauma care therefore requires simultaneous resuscitation, diagnostic assessment, operative prioritization, and prevention of secondary physiological injury (1,2).

Initial management is generally based on structured trauma assessment, with immediate attention to airway protection, ventilation, circulatory support, hemorrhage control, neurological status, and environmental exposure. Once immediately life-threatening conditions have been addressed, the clinical team must determine whether the patient can tolerate definitive surgery or requires abbreviated operative management followed by continued physiological restoration. This decision is particularly important in patients with major extremity, pelvic, thoracic, cranial, or spinal injuries, in whom the benefits of early anatomical stabilization must be balanced against the additional inflammatory, metabolic, and hemodynamic burden of prolonged surgery (2–4).

The evolution of damage-control resuscitation, Damage Control Surgery, and Damage Control Orthopedics has substantially changed the operative management of unstable polytrauma patients. These approaches prioritize rapid control of hemorrhage and contamination, temporary stabilization of major injuries, correction of physiological derangements, and delayed definitive reconstruction after recovery. Conversely, Early Appropriate Care supports definitive fixation during the early post-injury period when the patient has achieved sufficient hemodynamic and metabolic stability. Early fixation may facilitate mobilization, respiratory recovery, pain control, and rehabilitation, but definitive surgery performed before adequate resuscitation may increase the risk of secondary physiological deterioration and organ dysfunction. Accordingly, operative timing should be based on the patient's evolving physiological condition rather than on a fixed interval after injury (3–6).

Hemorrhagic shock and trauma-induced coagulopathy are major determinants of perioperative morbidity and mortality. Current resuscitation principles emphasize rapid hemorrhage control, restricted use of crystalloids, balanced blood-component therapy where indicated, early recognition of hypofibrinogenemia and coagulopathy, maintenance of normothermia, correction of clinically important hypocalcemia, and repeated assessment of tissue perfusion. Tranexamic acid may be incorporated into early hemorrhage management in appropriately selected patients, whereas vasopressor support should not replace definitive hemorrhage control and adequate blood-product resuscitation. Physiological targets must also be individualized because strategies such as permissive hypotension may be unsuitable in patients with traumatic brain injury or other conditions requiring maintenance of cerebral or organ perfusion (1,2,7).

Diagnostic optimization is closely linked to resuscitation and operative planning. Whole-body computed tomography can rapidly identify occult thoracic, abdominal, pelvic, spinal, and vascular injuries in appropriately selected patients and may reduce diagnostic delay when incorporated into organized trauma pathways. Its use should nevertheless be guided by hemodynamic status, injury mechanism, clinical findings, radiation exposure, contrast-related considerations, and the availability of immediate operative or interventional management. Protocol optimization and structured radiological reporting may improve diagnostic efficiency while limiting unnecessary exposure (8,9).

Anaesthetic management represents another essential component of surgical readiness. Polytrauma patients may present with a difficult airway, ongoing hemorrhage, pulmonary injury, traumatic brain injury, major metabolic abnormalities, or unstable spinal and pelvic injuries. Perioperative priorities include preservation of oxygenation and organ perfusion, avoidance of preventable hypotension, appropriate blood-product replacement, temperature control, individualized fluid administration, analgesia, and continuous physiological monitoring. In patients with traumatic brain injury, anaesthetic and surgical decisions must additionally protect cerebral perfusion and avoid secondary hypoxic or hypotensive injury (2,10).

Infection prevention, nutritional support, pain management, and rehabilitation form part of the broader optimization pathway, although their timing and intensity depend on the injury pattern and clinical trajectory. Antibiotic prophylaxis is especially relevant to open fractures, contaminated wounds, and selected emergency operations, but antimicrobial selection and duration should reflect the site and degree of contamination, local resistance patterns, surgical source control, and antimicrobial-

stewardship principles. Early enteral nutrition, respiratory care, mobilization, physiotherapy, and psychological support may contribute to recovery when introduced after adequate stabilization and in accordance with the patient's operative and critical-care requirements (11–14).

Successful optimization also depends on coordinated decision-making among emergency physicians, trauma and orthopaedic surgeons, anaesthesiologists, intensivists, radiologists, transfusion services, rehabilitation professionals, nurses, and other relevant specialties. Organized trauma systems and multidisciplinary co-management may improve the continuity and efficiency of care, but the applicability of individual protocols varies across institutions, injury phenotypes, and resource settings (13,15). Furthermore, the existing literature is distributed across injury-specific reviews, clinical guidelines, observational studies, and broader trauma-system analyses, which complicates the formulation of a unified perioperative approach.

Despite advances in resuscitation, imaging, anaesthesia, fracture stabilization, and critical care, uncertainty remains regarding the optimal combination and sequencing of interventions before definitive surgery. Definitions of physiological readiness are not uniform, operative strategies are inconsistently classified, and reported outcomes vary across studies. Existing evidence also differs in directness and methodological quality, with some recommendations based on injury-specific populations or multidisciplinary consensus rather than comparative studies involving broadly defined polytrauma populations.

This systematic review therefore aimed to synthesize current evidence on the medical optimization of adults with polytrauma undergoing surgery. The review evaluated preoperative physiological stabilization, damage-control resuscitation, correction of hemorrhage-related abnormalities, imaging and anaesthetic optimization, infection prevention, multidisciplinary coordination, and physiology-guided timing of definitive surgery. The principal outcomes of interest were mortality, perioperative complications, organ dysfunction, intensive care and hospital length of stay, timing of definitive intervention, and functional recovery.

MATERIALS AND METHODS

This mixed-evidence systematic review was conducted and reported in accordance with the principles of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020 statement. The review was designed to synthesize evidence from primary clinical studies, systematic reviews, meta-analyses, and clinical practice guidelines addressing medical and physiological optimization before or during surgical management of adult polytrauma. Because the available literature included heterogeneous injury populations, optimization strategies, operative approaches, and outcome definitions, the review used a structured narrative synthesis rather than statistical pooling.

The target population comprised adults aged 18 years or older with severe injuries involving multiple anatomical regions or organ systems who required operative management. Studies of mixed trauma populations were considered when findings relevant to adults with polytrauma or multisystem injury could be distinguished. Eligible evidence examined one or more components of perioperative optimization, including airway and respiratory stabilization, hemodynamic resuscitation, hemorrhage control, trauma-induced coagulopathy, transfusion strategies, temperature and acid–base management, physiological readiness for surgery, Damage Control Surgery, Damage Control Orthopedics, Early Appropriate Care, definitive fracture stabilization, diagnostic imaging, anaesthetic management, antimicrobial prophylaxis, critical-care support, nutritional care, multidisciplinary coordination, or early rehabilitation.

Eligible outcomes included mortality, hemorrhage-related outcomes, organ dysfunction, respiratory complications, infectious complications, thromboembolic events, neurological deterioration, need for reoperation, intensive care unit stay, total hospital stay, duration of mechanical ventilation, time to

definitive surgery, mobilization, functional recovery, and health-related quality of life. Evidence was excluded when it was restricted to pediatric populations, isolated minor trauma, animal or laboratory models, case reports, editorials, conference abstracts without sufficient methodological information, or reports that did not address perioperative management or clinically relevant outcomes. Non-English publications were excluded. Narrative sources were considered only when they provided clinically relevant synthesis in an area for which higher-level evidence was limited; their conclusions were interpreted separately from those of systematic reviews, guidelines, and comparative primary studies.

A comprehensive literature search was undertaken in PubMed/MEDLINE, Scopus, Embase, Web of Science, the Cochrane Library, and Google Scholar. The principal search focused on literature published from 2021 onward to capture contemporary trauma practice, while earlier landmark evidence identified through reference-list screening was retained when it remained clinically relevant to current resuscitation or operative strategies. Reference lists of eligible publications were manually reviewed to identify additional potentially relevant studies. The search strategy combined controlled vocabulary, where supported by the database, with free-text terms relating to multiple trauma, polytrauma, physiological optimization, perioperative care, resuscitation, hemorrhage, coagulopathy, damage-control surgery, damage-control orthopaedics, early appropriate care, fracture fixation, imaging, anaesthesia, antibiotic prophylaxis, rehabilitation, surgical timing, complications, and mortality. Boolean operators were adapted to the syntax of each database. The core search concepts were represented by combinations of terms equivalent to “polytrauma” or “multiple trauma,” “medical” or “physiological optimization,” “damage-control resuscitation” or “damage-control surgery,” and “operative” or “surgical management.” Broader combinations were used to avoid excluding studies that addressed an individual optimization domain without using the exact phrase “medical optimization.”

Retrieved records were consolidated and duplicate citations were removed before screening. Titles and abstracts were independently evaluated by two reviewers against the prespecified eligibility criteria. Publications considered potentially relevant underwent full-text assessment. Disagreements at either stage were resolved through discussion and consensus, with consultation of an additional reviewer when consensus could not be reached. Multiple reports describing the same underlying study population were treated as linked publications to minimize duplication of evidence. Reasons for exclusion at the full-text stage were categorized for presentation in the study-selection flow diagram.

Data were extracted using a standardized form developed for the review. Extracted information included the author, year, country, study design, clinical setting, sample size, participant and injury characteristics, definition of polytrauma, optimization intervention or management strategy, comparator where applicable, operative procedure, timing of surgery, physiological eligibility criteria for definitive intervention, outcome definitions, follow-up period, mortality, complications, intensive care and hospital stay, functional outcomes, and principal conclusions. For systematic reviews and guidelines, information was also recorded on the search period, number and types of included studies, target population, recommendation-development method, certainty or strength of evidence, and relevance to the present review question. Data extraction was checked by a second reviewer, and disagreements were resolved by reference to the full publication.

Methodological appraisal was selected according to the design of each included source. Systematic reviews and meta-analyses were assessed using AMSTAR 2, clinical practice guidelines were evaluated using the AGREE II framework, cohort studies were assessed using the Newcastle–Ottawa Scale or an appropriate Joanna Briggs Institute critical-appraisal checklist, and other observational designs were evaluated with the corresponding Joanna Briggs Institute tool. Appraisal focused on participant selection, exposure or intervention classification, outcome assessment, control of confounding, completeness of follow-up, transparency of synthesis, and applicability to adult polytrauma. Appraisal findings were interpreted at the domain level rather than converted into an unsupported universal

numerical score. Review-level conclusions were also examined for indirectness, inconsistency, imprecision, and dependence on observational evidence.

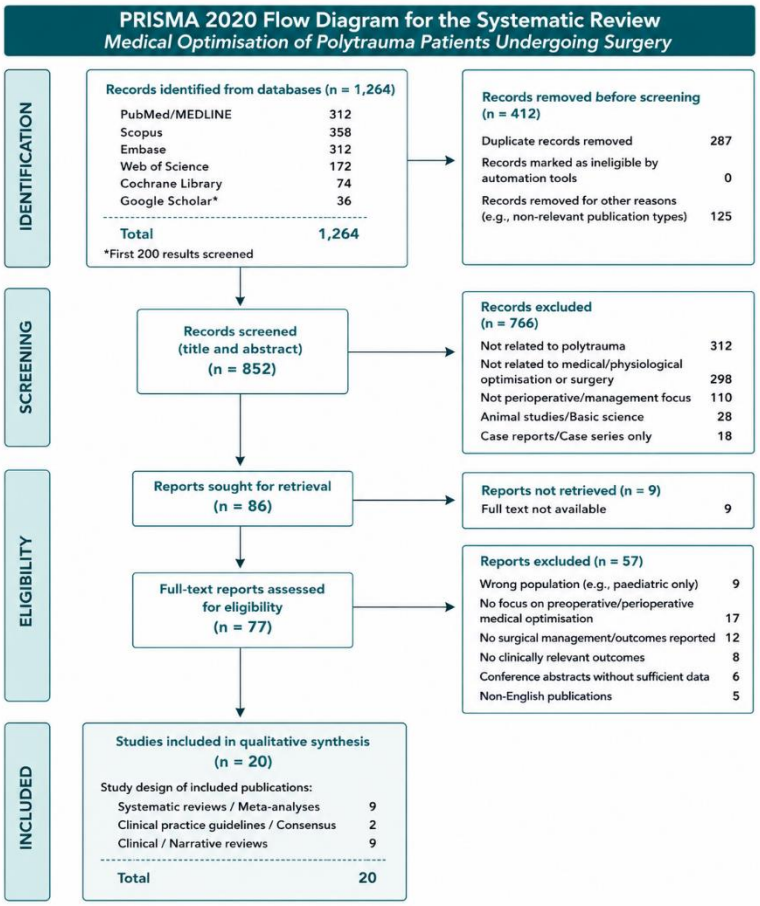

Figure 1 PRISMA Flowchart

Particular attention was given to overlap among systematic reviews because multiple reviews could include the same primary studies. Reviews addressing similar interventions and populations were compared by publication period, search coverage, methodological quality, and included-study composition. Where substantial overlap was apparent, conclusions were not treated as independent confirmations of effect. Greater interpretive weight was assigned to the most methodologically rigorous and recent synthesis, provided that its population and outcomes were directly relevant to adult polytrauma undergoing surgery.

The extracted evidence was organized into prespecified clinical domains: initial resuscitation and hemodynamic stabilization; hemorrhage control and trauma-induced coagulopathy; timing and extent of surgical intervention; fracture and pelvic stabilization; imaging; anaesthetic management; infection prevention; critical-care and nutritional support; multidisciplinary coordination; and rehabilitation. Within each domain, findings were compared according to population, injury severity, intervention, comparator, study design, outcome, and methodological quality. Guideline recommendations, systematic-review findings, and primary-study observations were presented separately to prevent consensus statements from being interpreted as equivalent to comparative effectiveness evidence.

Meta-analysis was not performed because the included evidence differed substantially in population definitions, injury patterns, physiological thresholds, interventions, surgical strategies, comparators, outcome measurements, and follow-up periods. The narrative synthesis therefore emphasized the direction and consistency of findings, numerical effect estimates and confidence intervals where reported, the methodological quality and directness of the evidence, and clinically important sources of

disagreement. Conclusions were phrased cautiously when findings were based on indirect populations, heterogeneous observational studies, expert consensus, or very-low-certainty evidence.

As the review analyzed information available in previously published literature and did not involve the recruitment of participants, collection of identifiable information, or access to individual patient records, new institutional ethics approval and individual informed consent were not required. The review was conducted according to accepted principles of research integrity, transparent evidence selection, and accurate attribution of published sources.

RESULTS

The literature search and supplementary reference screening identified 20 publications that met the eligibility criteria and were included in the narrative synthesis. The included literature was published between 2021 and 2026, comprising six publications from 2021, one from 2022, two from 2023, two from 2024, eight from 2025, and one from 2026. The evidence base included systematic reviews, meta-analyses, clinical practice guidelines, consensus recommendations, narrative or clinical reviews, and broader evidence syntheses addressing perioperative optimization in polytrauma. The included publications examined resuscitation, operative timing, extremity and pelvic fracture stabilization, chest trauma, anaesthesia, imaging, antibiotic prophylaxis, traumatic brain and spinal cord injury, rehabilitation, trauma-system organization, and patient-reported outcomes. Because several publications were secondary evidence syntheses with potentially overlapping primary studies, findings from separate reviews were not interpreted as statistically independent confirmations of effectiveness.

Table 1. Characteristics of the Included Evidence

No.	Publication	Year	Evidence type	Principal clinical domain	Population or context
1	Chamorro et al.	2023	Clinical review	Imaging and management protocols	Patients with severe polytrauma
2	Dabetic et al.	2025	Comprehensive review	Pelvic fracture management	Polytrauma with pelvic fractures
3	Dahms et al.	2025	Systematic review and meta-analysis	Antibiotic prophylaxis	Polytrauma populations
4	Dattatri et al.	2021	Clinical review	Anaesthetic management	Polytrauma undergoing surgery
5	Devendra et al.	2021	Clinical review	Extremity injury management	Polytrauma with extremity injuries
6	Dormann et al.	2025	Systematic review	Timing of pelvic fixation	Polytrauma with pelvic fractures
7	Duncan et al.	2025	Scholarly clinical synthesis	Surgical decision-making	Polytrauma requiring operative management
8	Flammia et al.	2022	Review	Computed-tomography protocol optimization	Polytrauma imaging
9	Iyengar et al.	2023	Clinical review	Management risks and perioperative safety	Polytrauma populations
10	Klingebiel et al.	2025	Systematic review and recommendation	Rehabilitation	Polytrauma rehabilitation
11	Picetti et al.	2021	Narrative review	Perioperative management of traumatic brain injury	Polytrauma with severe traumatic brain injury
12	Picetti et al.	2024	Consensus recommendations	Spinal cord injury management	Polytrauma with spinal cord injury
13	Sahnon et al.	2025	Systematic review	Medical co-management and surgical timing	Multisystem trauma and surgical populations
14	Sathyakumar et al.	2026	Clinical review	Adult polytrauma computed tomography	Adult polytrauma
15	Schreyer et al.	2024	Systematic review and guideline update	Surgical management of chest injuries	Multiple or severe trauma with chest injury
16	Silverstein and Higgins	2021	Systematic review	Health-related quality of life	Survivors of polytrauma
17	Steinfeld et al.	2025	Systematic review and meta-analysis	Timing and technique of extremity stabilization	Polytrauma with extremity fractures
18	Upadhyaya et al.	2021	Clinical review	Evolving polytrauma-management strategies	Polytrauma populations
19	Wang et al.	2025	Systematic literature review	Trauma-system organization	Organized trauma-care systems
20	Wang et al.	2021	Systematic review	Patient-reported outcome assessment	Survivors of polytrauma

The included evidence consistently placed immediate physiological stabilization before prolonged definitive surgery in patients with hemodynamic instability, active hemorrhage, hypothermia, metabolic acidosis, or trauma-induced coagulopathy. The principal components of early optimization were airway protection, adequate ventilation, hemorrhage control, blood-product resuscitation, correction of coagulopathy, temperature management, calcium monitoring, restoration of tissue perfusion, and

repeated reassessment of physiological response. Excessive crystalloid administration was generally discouraged in favor of targeted resuscitation and blood-component replacement when major hemorrhage was present.

Damage-control resuscitation was principally described as an integrated strategy rather than an isolated intervention. The reported components included rapid identification and control of bleeding, restricted crystalloid exposure, early blood-product administration, tranexamic acid in appropriately selected patients, correction of fibrinogen and coagulation abnormalities, prevention of hypothermia, and management of clinically important hypocalcemia. Vasopressor therapy was regarded as an adjunct in selected patients with persistent hypotension rather than a substitute for hemorrhage control or adequate circulating-volume replacement.

The literature also indicated that resuscitation targets should be individualized. Permissive hypotension could be considered during uncontrolled hemorrhage in selected patients but was not considered universally appropriate, particularly when traumatic brain injury or another condition requiring preservation of organ perfusion was present. Trends in lactate, base deficit, pH, temperature, coagulation status, vasopressor requirement, and hemodynamic stability were repeatedly identified as clinically relevant indicators when evaluating readiness for definitive surgery.

Table 2. Evidence Synthesis of Medical Optimization Domains

Optimization domain	Reported clinical objective	Principal evidence synthesis	Important qualification
Airway and respiratory stabilization	Prevent hypoxia and respiratory deterioration	Early airway assessment, ventilation support, and treatment of thoracic injury were consistently prioritized	Airway and ventilation strategies require modification for chest, facial, cervical-spine, and neurological injuries
Hemorrhage control	Limit exsanguination and restore perfusion	Rapid operative, interventional, or mechanical hemorrhage control formed the foundation of optimization	Resuscitation cannot compensate for uncontrolled bleeding
Blood-component resuscitation	Replace circulating volume and haemostatic components	Balanced, protocol-driven transfusion was favored over excessive crystalloid administration in major hemorrhage	Component ratios and targets varied across protocols and populations
Trauma-induced coagulopathy	Reduce ongoing bleeding and transfusion burden	Early laboratory or viscoelastic assessment and targeted correction were repeatedly recommended	Evidence varied regarding specific products, thresholds, and algorithms
Temperature management	Prevent worsening coagulopathy and physiological deterioration	Active prevention and correction of hypothermia were consistently incorporated into damage-control care	Temperature targets were not reported uniformly
Acid–base and perfusion assessment	Evaluate adequacy of resuscitation and surgical readiness	Lactate, base deficit, pH, hemodynamic response, and vasopressor requirement were used as dynamic indicators	No single threshold was consistently supported across all injury patterns
Imaging	Identify occult injuries and support operative planning	Whole-body computed tomography improved diagnostic coverage in appropriately selected patients	Hemodynamic status, transfer delay, radiation, and contrast exposure must be considered
Anaesthetic optimization	Preserve oxygenation, perfusion, and physiological stability	Individualized fluid, transfusion, monitoring, temperature, and analgesic strategies were emphasized	Traumatic brain injury required particular avoidance of hypoxia and hypotension
Antibiotic prophylaxis	Reduce infection in selected contaminated injuries	Early prophylaxis was supported principally for open fractures and contaminated wounds	Evidence for broader routine prophylaxis and patient-important outcomes remained uncertain
Multidisciplinary coordination	Improve prioritization and continuity of care	Trauma-team and co-management models supported integrated decision-making	Direct evidence specific to polytrauma varied across healthcare settings
Nutritional and critical-care support	Support recovery and reduce secondary complications	Early enteral nutrition was favored when clinically feasible after stabilization	Timing depended on hemodynamic, gastrointestinal, and operative considerations
Rehabilitation	Improve mobility, respiratory recovery, and long-term function	Early staged rehabilitation was supported across acute, post-acute, and long-term phases	Intervention intensity depended on physiological and surgical stability

The evidence supported a physiology-guided approach to operative timing rather than the routine use of a fixed time threshold. Damage Control Surgery and Damage Control Orthopedics were most applicable to patients with persistent hemodynamic instability, uncontrolled hemorrhage, severe coagulopathy, hypothermia, marked metabolic disturbance, or a high anticipated physiological burden from definitive surgery. These approaches involved abbreviated life-saving procedures or temporary stabilization followed by critical-care resuscitation and delayed definitive reconstruction.

Early Appropriate Care was applied when physiological recovery had progressed sufficiently to permit definitive fixation without exposing the patient to excessive secondary operative stress. The included

literature associated appropriately selected early fixation with earlier mobilization, improved respiratory management, and shorter recovery pathways. Nevertheless, the definitions of adequate physiological recovery varied, and the evidence did not support a single universally applicable threshold.

Early Total Care remained relevant for selected stable patients in whom definitive management could be completed safely during the initial operative period. Its application was more limited in patients with major hemorrhage, severe chest trauma, traumatic brain injury, coagulopathy, hypothermia, or evolving organ dysfunction. Across the evidence base, operative strategy was determined by the interaction of injury burden, physiological status, anticipated duration and invasiveness of surgery, and access to critical-care resources.

Table 3. Comparison of Operative Strategies in Polytrauma

Strategy	Typical clinical context	Operative approach	Principal intended benefit	Main limitation or risk
Damage Control Surgery	Hemodynamic instability, uncontrolled hemorrhage, contamination, or severe physiological derangement	Abbreviated life-saving surgery followed by intensive resuscitation and later definitive treatment	Rapid control of immediate threats while limiting additional physiological stress	Requires staged procedures and exposes the patient to repeated intervention
Damage Control Orthopedics	Unstable or borderline polytrauma with major skeletal injury	Temporary external or limited stabilization followed by delayed definitive fixation	Reduces the burden of prolonged early orthopaedic surgery	Delayed fixation may prolong immobility and requires additional surgery
Early Appropriate Care	Physiological improvement after resuscitation	Definitive fixation during the early post-injury period after acceptable recovery	Facilitates mobilization and definitive management while limiting avoidable delay	Readiness criteria vary and may be applied inconsistently
Early Total Care	Stable, adequately resuscitated patient with a tolerable operative burden	Definitive treatment during the initial surgical phase	Completes treatment in one stage and may accelerate rehabilitation	Unsuitable when prolonged surgery may aggravate physiological instability

The evidence concerning pelvic and extremity fractures emphasized that the potential benefits of early stabilization depended on adequate resuscitation and careful patient selection. Pelvic fixation required coordination with hemorrhage-control strategies, including mechanical stabilization, operative intervention, or interventional radiology when indicated. Extremity stabilization was similarly influenced by injury severity, soft-tissue condition, vascular compromise, contamination, and the patient's physiological response to initial treatment.

For thoracic trauma, surgical stabilization was considered in selected patients with clinically significant chest-wall instability or respiratory compromise. The decision depended on the severity of chest injury, pulmonary function, associated injuries, ventilatory requirements, and overall operative risk. In patients with traumatic brain or spinal cord injury, surgical timing and anaesthetic management required preservation of oxygenation, blood pressure, cerebral perfusion, spinal alignment, and neurological assessment.

Whole-body computed tomography was the principal imaging strategy evaluated in the included literature. It offered rapid assessment of multiple anatomical regions and supported identification of occult injuries, prioritization of surgical procedures, and multidisciplinary planning. Its use was most clearly supported in hemodynamically stable or sufficiently stabilized patients with a mechanism or clinical presentation suggesting multisystem injury.

The evidence did not support indiscriminate imaging irrespective of clinical status. The potential diagnostic benefit had to be balanced against transfer time, interruption of resuscitation, radiation exposure, contrast administration, local workflow, and immediate access to operative or interventional treatment. Protocol optimization and structured reporting were identified as strategies for reducing unnecessary radiation and improving the clinical utility of imaging.

Anaesthetic management focused on maintenance of oxygenation, ventilation, perfusion, temperature, haemostasis, and adequate analgesia throughout surgery. Invasive monitoring and goal-directed haemodynamic assessment were used selectively according to injury severity and physiological instability. Fluid administration was individualized, and blood products were used when hemorrhage and coagulopathy required replacement.

Traumatic brain injury introduced additional perioperative risk because hypoxia and hypotension could worsen secondary neurological injury. Preservation of cerebral perfusion, prevention of marked haemodynamic fluctuation, and coordination between anaesthetic, neurosurgical, trauma, and critical-care teams were therefore emphasized. Patients with thoracic or spinal injury similarly required injury-specific airway, positioning, ventilation, and monitoring strategies.

The literature supported prompt antimicrobial prophylaxis in open fractures, contaminated wounds, and selected emergency surgical procedures. Antibiotic choice depended on the anatomical site, degree and type of contamination, anticipated organisms, local resistance patterns, renal function, and institutional protocols. Surgical debridement and source control remained fundamental and could not be replaced by antimicrobial therapy.

Evidence supporting routine broad-spectrum prophylaxis across all polytrauma patients was less certain. The available review-level evidence did not demonstrate uniform benefit across mortality, overall clinical status, or all infection outcomes. Therefore, antimicrobial conclusions were interpreted cautiously, and prolonged or unnecessarily broad treatment was not supported without a defined clinical indication.

Multidisciplinary coordination was a recurrent component of successful optimization. Trauma surgeons, orthopaedic surgeons, anaesthesiologists, intensivists, emergency physicians, radiologists, transfusion services, nursing teams, rehabilitation professionals, and relevant medical specialists contributed to repeated evaluation of operative priorities and physiological readiness. Organized trauma systems supported more coordinated imaging, hemorrhage control, transfer, surgery, intensive care, and rehabilitation pathways.

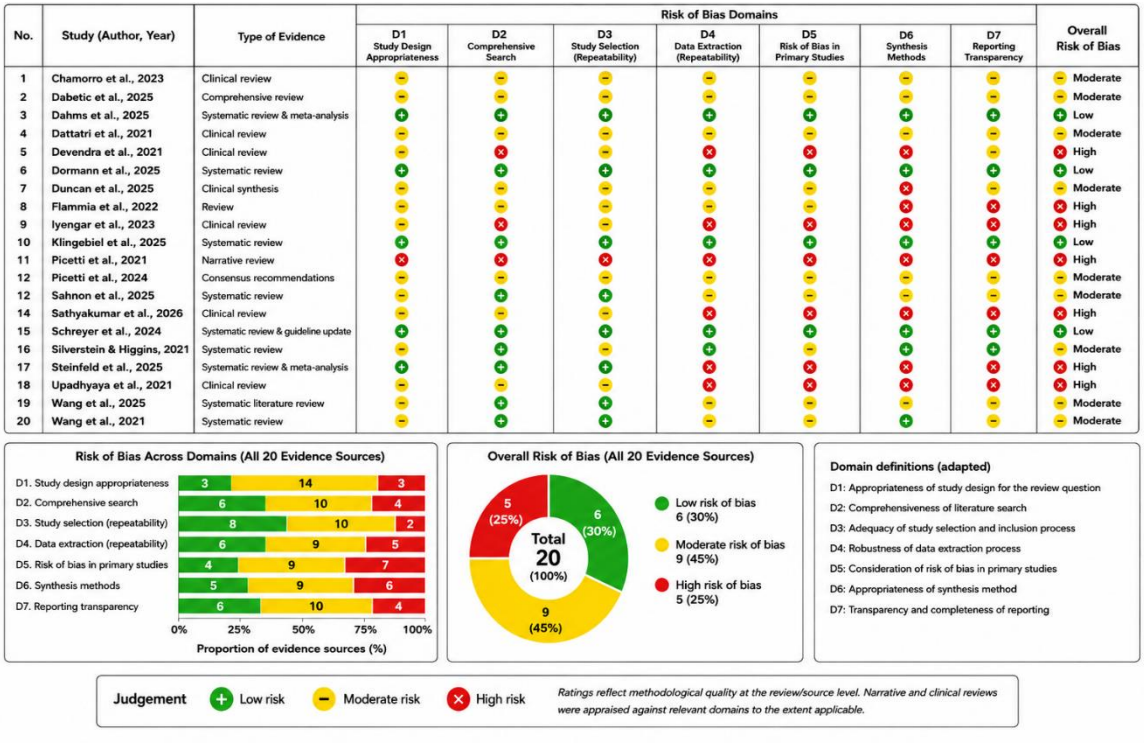

Figure 2 Risk of Bias Summary

Rehabilitation was described as a staged process beginning during acute hospitalization when clinically feasible and continuing through post-acute and long-term recovery. Respiratory physiotherapy, positioning, prevention of contracture and pressure injury, nutritional support, mobilization, functional training, pain management, and psychological care were incorporated according to the patient's physiological and surgical condition. Health-related quality of life and patient-reported outcomes were considered important long-term endpoints, although their measurement varied across studies.

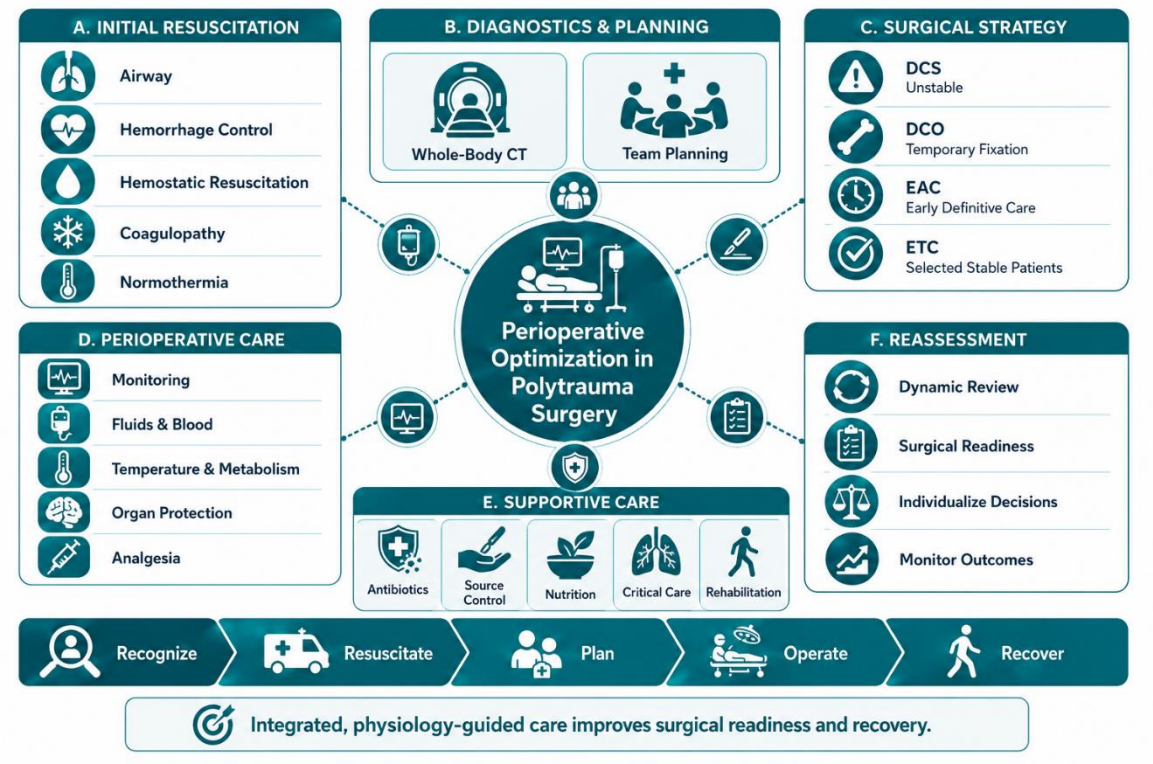

Figure 3 Integrated, physiology guided care improvement surgical readiness and recovery

The evidence base was methodologically heterogeneous. Several publications were systematic reviews or guideline-based syntheses, whereas others were narrative or clinical reviews. The directness of evidence varied because some sources focused specifically on adult polytrauma, while others examined injury-specific subgroups, multisystem surgical populations, or organized trauma systems. Comparability was further limited by differences in polytrauma definitions, physiological readiness criteria, operative strategies, outcomes, and follow-up periods.

The strongest consistency was observed for the general principles of early hemorrhage control, correction of physiological abnormalities, avoidance of unnecessary definitive surgery during persistent instability, and multidisciplinary reassessment. Greater uncertainty remained regarding universal thresholds for operative readiness, the optimal timing of pelvic or extremity fixation, detailed transfusion protocols, broad antibiotic prophylaxis, and the comparative effectiveness of specific co-management models. Consequently, the findings supported individualized and protocol-informed care but did not establish a single optimization algorithm applicable to all polytrauma patients.

DISCUSSION

This mixed-evidence systematic review synthesized 20 publications addressing medical and physiological optimization in adults with polytrauma undergoing surgical treatment. The evidence consistently supported an integrated approach centered on rapid hemorrhage control, restoration of physiological stability, correction of trauma-induced coagulopathy and hypothermia, appropriate diagnostic imaging, individualized anaesthetic management, multidisciplinary coordination, and repeated reassessment before definitive surgery. The review also demonstrated that the timing and extent of operative intervention should be guided by the patient's physiological response and anticipated operative burden rather than by injury pattern or a fixed post-injury interval alone. However, considerable heterogeneity in patient definitions, injury severity, treatment protocols, readiness criteria, and outcome reporting limited the formulation of a single universally applicable optimization pathway.

The central finding was that immediate control of life-threatening physiological abnormalities should take precedence over prolonged definitive procedures in unstable patients. Damage-control resuscitation was consistently described as an integrated process combining hemorrhage control, judicious fluid

administration, blood-component therapy, correction of coagulopathy, temperature management, and restoration of tissue perfusion. This approach represented a transition from aggressive crystalloid-based resuscitation toward targeted haemostatic resuscitation and repeated physiological assessment. Previous reviews similarly emphasized that excessive crystalloid administration may worsen tissue oedema, dilutional coagulopathy, hypothermia, and abdominal or extremity compartment pressures, whereas timely blood-product administration and correction of haemostatic abnormalities may better support recovery from hemorrhagic shock (4,9,18).

Trauma-induced coagulopathy remained a major determinant of ongoing bleeding and adverse outcomes. The reviewed literature supported early coagulation assessment and targeted correction using conventional laboratory testing or viscoelastic methods where available. Tranexamic acid, fibrinogen replacement, plasma, platelets, red-cell transfusion, calcium replacement, and active warming were commonly incorporated into contemporary protocols, although specific thresholds and component ratios varied among institutions and patient populations. These interventions should therefore be guided by the clinical context, ongoing blood loss, laboratory findings, transfusion response, and local massive-transfusion protocols rather than applied as uniform treatments to all trauma patients (4,9,18).

The evidence also reinforced the distinction between Damage Control Surgery, Damage Control Orthopedics, Early Appropriate Care, and Early Total Care. Damage-control approaches were most applicable to patients with persistent shock, active bleeding, hypothermia, severe coagulopathy, metabolic acidosis, or a high anticipated physiological burden from definitive surgery. In these patients, abbreviated procedures or temporary skeletal stabilization limited the duration of the initial operation and allowed further resuscitation in the intensive care setting. Early Appropriate Care was more suitable after demonstrable physiological improvement, while Early Total Care remained applicable to carefully selected stable patients who could tolerate complete definitive treatment during the initial operative period (5–7,17,18).

The reviewed evidence did not identify one validated physiological threshold that could determine surgical readiness in every patient. Lactate, base deficit, pH, body temperature, coagulation status, hemodynamic response, oxygenation, vasopressor requirement, injury severity, and anticipated operative duration were all relevant, but their interpretation depended on the injury phenotype and clinical trajectory. A single laboratory result should not therefore be used independently to authorize or defer definitive surgery. Serial trends and multidisciplinary reassessment appear more clinically informative than isolated values. This is particularly important in borderline patients whose apparent initial stability may deteriorate during transport, imaging, anaesthesia, or prolonged operative intervention.

Findings related to pelvic and extremity stabilization supported early definitive management when adequate physiological recovery had been achieved. Early fixation may facilitate nursing care, respiratory management, pain control, mobilization, and rehabilitation, while reducing complications associated with prolonged immobilization. Nevertheless, premature definitive fixation in a patient with unresolved shock or inflammatory instability may impose an additional physiological insult. Reviews of pelvic and extremity injuries therefore favored individualized timing rather than unrestricted early fixation, especially in patients with severe chest injury, traumatic brain injury, ongoing transfusion requirements, or multiple major operative priorities (2,5,6,17).

Thoracic injury required similarly individualized management. Surgical stabilization of clinically important chest-wall injuries may improve respiratory mechanics and facilitate ventilatory management in selected patients, but its timing depends on pulmonary status, associated injuries, hemodynamic stability, and the anticipated benefit relative to operative risk. The clinical practice guideline addressing severe chest injury supported surgery in appropriately selected cases while recognizing that not every rib or chest-wall injury requires operative stabilization (15). These findings indicate that chest surgery

should be incorporated into the overall prioritization of injuries rather than considered independently from systemic physiological status.

Imaging was an important component of optimization because missed injuries can delay hemorrhage control, alter operative sequencing, and increase the need for unplanned intervention. Whole-body computed tomography provided rapid and comprehensive anatomical assessment in appropriately selected patients and supported multidisciplinary surgical planning (1,8,14). However, its benefits should be balanced against transfer time, interruption of resuscitation, contrast administration, radiation exposure, and the potential risk of moving an unstable patient away from immediate operative or interventional treatment. Imaging pathways should consequently remain integrated with clinical assessment and local trauma-system capabilities.

Anaesthetic optimization was essential throughout emergency and definitive surgery. The included literature emphasized airway security, adequate oxygenation and ventilation, preservation of perfusion, temperature control, haemostatic resuscitation, individualized fluid administration, analgesia, and continuous physiological monitoring (4,9). Anaesthetic management was particularly complex in patients with traumatic brain injury, in whom hypotension and hypoxia could contribute to secondary neurological damage. Maintenance of cerebral perfusion and avoidance of major hemodynamic fluctuations therefore required close coordination among anaesthesiology, trauma, neurosurgical, and critical-care teams (11).

Patients with spinal cord injury presented additional challenges related to neurological assessment, spinal alignment, airway management, blood-pressure support, positioning, and timing of decompression or stabilization. Consensus recommendations emphasized coordinated care and avoidance of secondary neurological injury, although several recommendations were based on heterogeneous evidence and expert consensus rather than high-certainty comparative trials (12). These findings illustrate a broader limitation of the polytrauma literature: many clinically important decisions cannot be evaluated easily in randomized trials because of time-critical treatment, injury heterogeneity, and ethical constraints.

The findings concerning antibiotic prophylaxis were less definitive than those for hemorrhage control and physiological stabilization. Prompt antimicrobial prophylaxis remained appropriate for open fractures, contaminated wounds, and selected emergency operations, but the available evidence did not support indiscriminate broad-spectrum treatment for every patient with polytrauma. The effectiveness of prophylaxis varied across infection outcomes, and the certainty of review-level evidence was limited (3). Antimicrobial selection and duration should therefore reflect injury location, contamination, debridement, local resistance patterns, renal function, and institutional stewardship policies. Antibiotic therapy cannot replace timely debridement and surgical source control.

Multidisciplinary coordination was a recurrent feature of effective trauma care. The interaction of emergency medicine, trauma surgery, orthopaedics, anaesthesiology, intensive care, radiology, transfusion services, rehabilitation, and relevant medical specialties allowed operative priorities to be reconsidered as the patient's physiology evolved. Evidence from trauma-system and co-management reviews suggested that structured multidisciplinary pathways may improve coordination, reduce avoidable delays, and support management of comorbidities, although some evidence was derived from broader surgical or multisystem populations rather than exclusively from polytrauma cohorts (13,19). Direct application to all trauma settings should therefore account for institutional resources and differences in trauma-system organization.

Rehabilitation was not limited to the period after definitive surgery. Respiratory physiotherapy, positioning, prevention of pressure injury and contracture, nutritional care, mobilization, psychological support, and functional training could begin during acute hospitalization when clinically feasible. The reviewed rehabilitation literature described recovery as a staged process extending from acute

stabilization through post-acute and community reintegration (10). Patient-reported outcomes and health-related quality of life were also important because survival and anatomical repair do not fully reflect long-term recovery after severe multisystem injury (16,20). However, variation in assessment instruments and follow-up periods restricted comparison across studies.

This review had several strengths. It examined perioperative optimization across the full trauma pathway rather than focusing exclusively on one injury, operation, or resuscitation intervention. It also differentiated damage-control strategies from physiology-guided definitive care and considered imaging, anaesthesia, infection prevention, multidisciplinary coordination, and rehabilitation alongside surgical timing. Furthermore, review-level findings, guideline recommendations, consensus statements, and broader clinical evidence were interpreted according to their directness and methodological limitations rather than treated as equivalent forms of evidence.

Several limitations should also be recognized. The included publications were heterogeneous in design, population, injury definition, intervention, comparator, and outcome assessment. Some sources were systematic reviews or guidelines, whereas others were narrative or clinical reviews, which limited direct comparison and prevented quantitative pooling. Overlap of primary studies across systematic reviews may have resulted in repeated representation of the same evidence. Several publications focused on specific injuries or broader surgical populations rather than exclusively on adult polytrauma, thereby reducing directness. The English-language restriction may have introduced language bias, and publication bias could not be formally assessed. The available literature also lacked standardized physiological readiness criteria, common outcome definitions, and consistent reporting of long-term functional outcomes.

Future research should use standardized definitions of polytrauma, physiological instability, and operative readiness. Prospective multicentre studies should compare clearly defined damage-control and definitive-care pathways while stratifying participants by injury severity, traumatic brain injury, chest trauma, hemorrhage burden, and metabolic status. Core outcomes should include mortality, organ dysfunction, infectious and thromboembolic complications, ventilator duration, intensive care and hospital stay, reoperation, time to mobilization, functional recovery, and quality of life. Studies should also report adverse effects and resource implications because interventions that improve early anatomical management may not necessarily improve patient-centered outcomes.

Overall, the evidence indicated that medical optimization in polytrauma is not a single intervention or numerical threshold but a dynamic, multidisciplinary process. The most defensible clinical approach is to control immediate threats, restore and monitor physiology, select diagnostic and operative interventions according to evolving risk, and proceed to definitive surgery when the expected benefits outweigh the additional physiological burden.

CONCLUSION

Medical optimization of adults with polytrauma undergoing surgery requires integrated hemorrhage control, haemostatic resuscitation, correction of hypothermia and metabolic disturbances, appropriate imaging, individualized anaesthetic management, and repeated multidisciplinary assessment. Damage-control strategies remain appropriate for physiologically unstable patients, whereas early definitive treatment may be undertaken after adequate recovery in carefully selected patients. Current evidence supports physiology-guided rather than time-based surgical decision-making, but heterogeneous definitions, protocols, and outcomes prevent establishment of a single universal optimization algorithm.

REFERENCES

1. Chamorro EM, Sanz LI, Barrio AB. Patients with severe polytrauma: management and imaging protocols. Radiologia (Engl Ed). 2023;65.

2. Dabetic U, Grupkovic J, Zagorac S. Advances in managing pelvic fractures in polytrauma: a comprehensive review. J Clin Med. 2025;14.

3. Dahms K, et al. Effectiveness of antibiotic prophylaxis in polytrauma patients: a systematic review and meta-analysis. Eur J Trauma Emerg Surg. 2025;51:105. doi:10.1007/s00068-025-02789-8.

4. Dattatri R, Jain VK, Iyengar KP, Vaishya R. Anaesthetic considerations in polytrauma patients. J Clin Orthop Trauma. 2021;21.

5. Devendra A, Raja SDC, Dheenadhayalan J. Current updates in management of extremity injuries in polytrauma. J Clin Orthop Trauma. 2021;17.

6. Dormann J, et al. The optimal timing for definitive operative stabilization of pelvic fractures in polytrauma patients: effects on clinical outcomes—a systematic review. Eur J Trauma Emerg Surg. 2025;51.

7. Duncan A, Isak E, Ahmeti M, Duncan A. Surgical decision-making in the management of polytrauma patients. Springer; 2025.

8. Flammia F, et al. Optimization of CT protocol in polytrauma patients: an update. Eur Rev Med Pharmacol Sci. 2022;26.

9. Iyengar KP, Venkatesan AS, Jain VK. Risks in the management of polytrauma patients: clinical insights. J Multidiscip Healthc. 2023;16.

10. Klingebiel FKL, et al. The three stages of polytrauma rehabilitation—a recommendation and a systematic literature review on behalf of SICOT. Int Orthop. 2025.

11. Picetti E, et al. Perioperative management of polytrauma patients with severe traumatic brain injury undergoing emergency extracranial surgery: a narrative review. J Clin Med. 2021;10(23).

12. Picetti E, et al. Spinal cord injury in patients with polytrauma: a consensus and clinical recommendations jointly developed by the World Society of Emergency Surgery. World J Emerg Surg. 2024.

13. Sahnon ASA, et al. Timing of surgery and medical optimization in multisystem trauma: a systematic review of outcomes based on internal medicine co-management. Cureus. 2025;17.

14. Sathyakumar K, Purushothaman V, James JD. CT in adult patients with polytrauma: current practices, protocol optimization, structured reporting and future directions. Emerg Radiol. 2026.

15. Schreyer C, et al. Surgical management of chest injuries in patients with multiple and/or severe trauma—a systematic review and clinical practice guideline update. Eur J Trauma Emerg Surg. 2024;50:2061–71.

16. Silverstein LA, Higgins JT. Health-related quality of life after polytrauma: a systematic review. J Trauma Nurs. 2021;28(5).

17. Steinfeld E, et al. Optimal timing of stabilization and operative technique for extremity fractures in polytrauma patients: a systematic review and meta-analysis. Eur J Trauma Emerg Surg. 2025;51.

18. Upadhyaya GK, Iyengar KP, Jain VK, Garg R. Evolving concepts and strategies in the management of polytrauma patients. J Clin Orthop Trauma. 2021;17.

19. Wang Z, Rostami-Tabar B, Haider J. A systematic literature review of trauma systems: an operations management perspective. Adv Mech Eng. 2025.

20. Wang Z, et al. Assessment of patient-reported outcomes after polytrauma—instruments and methods: a systematic review. BMJ Open. 2021;11.

21. Dattatri R, Jain V, Iyengar K, Vaishya R, Garg R. Anaesthetic considerations in polytrauma patients. Journal of Clinical Orthopaedics and Trauma. 2020.

22. Iyengar K, Venkatesan A, Jain V, Shashidhara MK, Elbana H, Botchu R. Risks in the Management of Polytrauma Patients: Clinical Insights. Orthopedic Research and Reviews. 2023.

23. Kalbas Y, Heining S, Kaiser A, Klingebiel F, Pfeifer R, Wanner GA, et al. Fracture fixation in polytraumatized patients—From an interdisciplinary early total/appropriate care to the safe definitive surgery concept. Frontiers in Medicine. 2024.

24. Kanna RM, Shetty AP, Rajasekaran S. Timing of intervention for spinal injury in patients with polytrauma. Journal of Clinical Orthopaedics and Trauma. 2020.

25. Lee C, Rasmussen T, Pape H, Gary J, Stannard J, Haller JM. The polytrauma patient: Current concepts and evolving care. OTA International. 2021.

26. Pape H, Leenen L. Polytrauma management - What is new and what is true in 2020 ? Journal of Clinical Orthopaedics and Trauma. 2020.

27. Pape H, Moore E, McKinley T, Sauaia A. Pathophysiology in patients with polytrauma. Injury. 2022.

28. Pfeifer R, Klingebiel F, Halvachizadeh S, Kalbas Y, Pape H. How to Clear Polytrauma Patients for Fracture Fixation: Results of a systematic review of the literature. Injury. 2022.

29. Sacks B, Mughal H, Ahluwalia A, Rudran B, Parmar KR. The BOAST recommendations for care of the older or frail orthopaedic trauma patient. British journal of hospital medicine. 2020.

30. Upadhyaya G, Iyengar K, Jain V, Garg R. Evolving concepts and strategies in the management of polytrauma patients. Journal of Clinical Orthopaedics and Trauma. 2020.