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Challenges and Strategies in "Spinal Damage Control" as a Treatment Modality for Unstable Vertebral Fractures in Polytrauma Patients: A Narrative Literature Review and a Proposed Algorithm

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Abstract

Introduction: Trauma is the leading cause of death in individuals aged 5 to 44 years in developed countries. Although various orthopedic protocols have been developed for treating long bone fractures, managing vertebral fractures in polytraumatized patients remains a clinical challenge. This is evidenced by the fact that mortality among these patients has remained virtually unchanged over the past 20 years.

Methods: A literature search was conducted in the PubMed, Google Scholar, and Scielo databases, covering the years 2011 to 2024. Articles most relevant to the management of unstable vertebral fractures in polytrauma patients were included. Both Spanish and English articles were reviewed.

Pathophysiology: Polytraumatized patients exhibit unique physiological responses, characterized by an exaggerated inflammatory reaction following trauma, subsequently transitioning to an immunosuppressive counter-regulatory response in an effort to achieve homeostasis. While "windows of opportunity" for intervention have been extensively studied for long bone fractures, the literature on vertebral injuries remains sparse.

Management: Leveraging the extensive literature on polytrauma physiology, timely intervention opportunities, the specific characteristics of vertebral trauma, and the demonstrated benefits of damage control orthopedic surgery, we propose a management algorithm. This algorithm classifies polytraumatized patients with vertebral fractures into three groups (stable, borderline, and unstable) to determine candidates for early definitive osteosynthesis versus those who would benefit from vertebral external fixation.

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Highlights

1. Protocols have been developed over time to classify unstable fractures and initiate treatment promptly. Despite these advancements, spinal trauma often remains enigmatic and is relegated to a secondary focus.
2. Research consistently supports the benefits of early intervention for polytraumatized patients with vertebral fractures. This article aims to integrate physiological variables, such as lactate levels and vital signs, to identify the optimal timing for reintervention within the "window of opportunity" (up to 72 hours post-trauma). Increasingly, the literature suggests that the earlier the intervention, the better. In 2018, guidelines for managing patients with severe/multiple injuries recommended that the first intervention occur within 24 hours post-trauma. For cervical fractures, anterior approaches were preferred, while posterior approaches were recommended for thoracolumbar fractures [1,2].
3. Surgical intervention must be guided by three key pillars: restoring anatomical alignment, achieving vascular and neural decompression, and stabilizing the spinal segment. These principles were described by Bliemel et al. in 2014 [3].

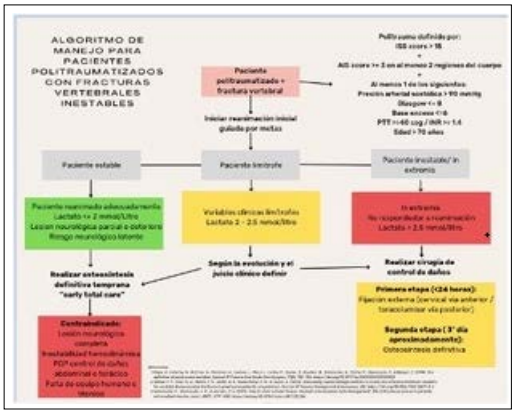
Introduction

Trauma is the leading cause of death among individuals aged 5 to 44 years in developed countries [4]. Vertebral injuries have an incidence of up to 46% in polytraumatized patients [5].

Managing polytraumatized patients has significantly evolved over recent years. In orthopedics, considerable progress has been made in treating long bone fractures. However, managing spinal trauma in polytraumatized patients remains challenging due to factors such as distracting injuries during clinical examination and the selection of radiological studies, which can hinder diagnosis. This, in turn, allows vertebral fractures to become "hidden fractures," increasing pain and morbidity/mortality [6].

Protocols have been developed over time to classify unstable fractures and initiate treatment promptly. Despite these advancements, spinal trauma often remains enigmatic and is relegated to a secondary focus. The primary issue is that failure to diagnose vertebral injuries early exponentially increases the risk of neurological deficits. Since 1987, it has been documented that neurological deficits in patients with early-diagnosed vertebral injuries occur in 1.5% of cases compared to 10% in late diagnoses [7].

Given this context, conducting a narrative literature review is deemed essential. Based on this review and clinical experience at a trauma referral hospital in southwestern Colombia, we propose a management algorithm for unstable vertebral fractures in polytraumatized patients.



Methods

A literature search was performed in the PubMed, Google Scholar, and Scielo databases for the period 2011 to 2024. The search focused on relevant articles addressing the management of unstable vertebral fractures in polytraumatized patients. Articles in both Spanish and English were included in the review.

Epidemiology

According to data from the United Kingdom's Trauma Audit and Research Network (TARN), the incidence of vertebral fractures/dislocations in polytraumatized patients is 9.58% [8]. Among these, 24.5% involve cervical vertebrae, which are significant as cervical injuries account for 45.42% of all spinal cord injuriesn [6,8].

A 2011 European cohort study involving 250,584 patients with spinal trauma reported that 24.5% of fractures affected cervical vertebrae, 28.06% thoracic vertebrae, and 37.09% lumbar vertebrae, with 10.35% presenting multilevel injuries [8]. Cervical vertebral fractures accounted for 45% of spinal cord injuries, thoracic vertebrae for 29.43%, and lumbar vertebrae for 29.43% [8].

The most common concomitant injuries in patients with vertebral fractures included limb injuries (26.5%), thoracic injuries (17.78%), head injuries (12.32%), abdominal injuries (4.98%), and pelvic injuries (3.92%) (5). Mortality among this subset of polytraumatized patients with spinal injuries is approximately 17%, a rate that has remained relatively stable over the past 20 years [8].

Pathophysiology

Polytraumatized patients experience a systemic inflammatory response syndrome (SIRS), characterized by an early and excessive activation of innate immunity, resulting in hyperinflammation. Subsequently, a compensatory anti-inflammatory response syndrome (CARS) arises in an effort to achieve homeostasis, increasing susceptibility to infections, sepsis, and multiple organ failure (MOF) [9-11].

In 2005, Keel et al. described the "two-hit" theory. The "first hit" refers to immunological and inflammatory responses caused by organ injuries, soft tissue trauma, or fractures. The ensuing inflammatory cascade leads to a "second hit," categorized as endogenous (e.g., respiratory distress, cardiovascular instability, metabolic acidosis, ischemia/reperfusion injuries, tissue necrosis, or catheter/tube contamination) or exogenous (e.g., excessive tissue trauma during surgical interventions, hypothermia, massive hemorrhage, delayed surgical intervention, or delayed access to intensive care) [9]. This theory aims to raise awareness among healthcare professionals regarding "second-hit" injuries, where interventions can significantly impact outcomes.

These insights have prompted modifications in the clinical and surgical procedures performed on polytraumatized patients. Protocols have been designed to align with the unique physiology of these patients, emphasizing the necessity of minimizing surgical trauma and reducing the immune response. The goal is to decrease the incidence of the "lethal diamond"—a combination of coagulopathy, hypothermia, metabolic acidosis, and hypocalcemia. These protocols are known as "damage control orthopedics" (DCO) and have been primarily developed for long bone and pelvic fractures. However, as previously mentioned, spinal injuries are often relegated to secondary consideration.

The DCO concept involves staged fracture management, starting with initial external fixation to stabilize the fracture while minimizing additional trauma to soft tissues, vascular, and/or neural structures. This approach alleviates pain and allows a transition to definitive surgery during the "physiological window of opportunity."

Regarding spinal fracture fixation in non-polytraumatized patients, Croce et al. conducted a retrospective analysis of a database comprising 291 patients with unstable spinal fractures requiring surgical fixation [12]. Patients were classified by the timing of their fracture fixation: "early" fixation (within 3 days, n=142) versus "late" fixation (after 3 days, n=149). The authors found that early fixation of thoracic spinal fractures resulted in a lower incidence of pneumonia, fewer days on mechanical ventilation, shorter ICU stays, and reduced hospital costs [12].

More recently, Cengiz et al., in a prospective pilot randomized controlled trial, studied 27 patients with unstable fractures in the thoracolumbar region (T8–L2). They divided the patients into two groups: Group 1 underwent early fracture fixation (<8 hours), while Group 2 underwent late fixation (>3 days). Results showed that patients who received early fixation had significantly lower pneumonia rates, fewer ICU days, and shorter hospital stays compared to those with delayed fixation [13].

One of the most comprehensive reviews on this topic, conducted by Hax et al. in 2023, retrospectively analyzed 12,596 polytraumatized patients with spinal injuries. The study highlighted that the highest incidence of spinal injuries occurs in patients with cervical fractures. It also demonstrated that patients undergoing surgery within 48 hours had better outcomes, despite higher mortality in cervical fractures treated within this time frame (9.7% vs. 6.3% when treated after 48 hours). Early intervention was associated with fewer ICU days, lower rates of sepsis and thromboembolic events,

and reduced ventilator dependence. The authors emphasized the need for individualized patient assessments prior to surgery to improve outcomes and reduce mortality [14].

Management

Surgical intervention must be guided by three key pillars: restoring anatomical alignment, achieving vascular and neural decompression, and stabilizing the spinal segment. These principles were described by Bliemel et al. in 2014 [3].

With these principles established, the optimal timing for the first surgical intervention must be determined. Evidence strongly supports early intervention (<3 days) in polytraumatized patients with vertebral fractures. However, it is essential to incorporate clinical and laboratory variables to comprehensively evaluate each patient and decide between definitive surgery or damage control surgery. In 2002, Pape et al. provided a classification based on physiological conditions (e.g., hypovolemia, coagulation status, temperature, pulmonary function, thoracic trauma, and pelvic trauma) to determine the appropriate surgical approach [15].

Nevertheless, applying this classification in the acute trauma setting can be challenging and may delay interventions. In 2017, Giannoudis et al. proposed the "Prompt-Individualized-Safe Management" (PR.I.S.M.) strategy, which integrates various prior frameworks (e.g., Pape and Vallier's findings) to classify patients based on lactate levels, pH, and base deficit. Patients are categorized into three groups:

- **Stable Patients:** Responders to initial resuscitation, with lactate <2 mmol/L, are candidates for early total care (definitive osteosynthesis).
- **Borderline Patients:** Hemodynamic variables are borderline or fluctuating, with lactate levels between 2.0–2.5 mmol/L. These patients may benefit from damage control surgery or early appropriate care (definitive osteosynthesis with cautious monitoring of hemodynamic status and lactate levels).
- **Unstable Patients:** Hemodynamically unstable or in extremis, with lactate >2.5 mmol/L, require damage control surgery [16].

Research consistently supports the benefits of early intervention for polytraumatized patients with vertebral fractures. This article aims to integrate physiological variables, such as lactate levels and vital signs, to identify the optimal timing for reintervention within the "window of opportunity" (up to 72 hours post-trauma). Increasingly, the literature suggests that the earlier the intervention, the better. In 2018, guidelines for managing patients with severe/multiple injuries recommended that the first intervention occur within 24 hours post-trauma. For cervical fractures, anterior approaches were preferred, while posterior approaches were recommended for thoracolumbar fractures [1,2].

Conclusion

Vertebral fractures in polytraumatized patients are relatively common, with mortality rates remaining stable over the past 20 years. However, a consensus on their treatment has yet to be established. Clinical and paraclinical variables are utilized to design a treatment algorithm aimed at promoting comprehensive management of polytraumatized patients, based on current evidence [17].

Declarations of Interest

None

Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

None

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