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EMERGING APPROACHES TO TRAUMA RESUSCITATION: A LITERATURE REVIEW

[1]Abdullah Abdulmughni Abdulghani Alshaikh, [2]Ismail Abdulmatlob Aljedani, [3]Abdulaziz Abdullah Hamed Alghamdi, [4]Hadi Abbas Ahmed Zamkah, [5]Mansour Abdulghani Abdullah Alzahrani, [6]Mohammed Hassan Esmat, [7]Saif Abdulhamid Alsulami, [8]Abdulrahman Saleh Abdu Alharbi, [9]Hussam Hassan Ali Bagash, [10]Jaber Yahya Jaber Albarqi

[1]Paramedic At SRCA Jeddah, Alshaikha362@gmail.com
[2]Paramedic At SRCA Jeddah, Ismail2261417@gmail.com
[3]EMT At SRCA Jeddah, abdulazizz111@hotmail.com
[4]Paramedic At SRCA Jeddah, zamkahadi@gmail.com
[5]EMT At SRCA Jeddah, Mans-w1@hotmail.com
[6]Paramedic At SRCA Madinah, Mohammedgt500@hotmail.com
[7]EMT At SRCA Jeddah, saiiif-14@hotmail.com
[8]Paramedic At SRCA Jeddah, Dr.abdulrahmanalharbi1@gmail.com
[9]EMT At SRCA Jeddah, hhaeb@hotmail.com
[10]EMT At SRCA Jeddah, jaber691@hotmail.com

Abstract:
This literature review examines emerging approaches to trauma resuscitation, focusing on the limitations of traditional crystalloid fluid resuscitation and the benefits of modern techniques. With trauma being a leading cause of morbidity and mortality, effective resuscitation during the critical initial hour is essential. The review highlights the principles of Damage Control Resuscitation (DCR), including permissive hypotension, balanced transfusion strategies, and the use of whole blood resuscitation. Additionally, it discusses the role of endovascular techniques, such as Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA), in managing non-compressible torso hemorrhage. The findings indicate a paradigm shift towards hemostatic resuscitation methods that improve patient outcomes, while also identifying gaps in the current literature and emphasizing the need for further research.

Keywords: *Trauma Resuscitation, Damage Control Resuscitation, Permissive Hypotension, Whole Blood Resuscitation, REBOA*

Corresponding author:
Abdullah Abdulmughni Abdulghani Alshaikh,
Paramedic At SRCA Jeddah, alshaikha362@gmail.com

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1. INTRODUCTION:

Trauma is a leading cause of morbidity and mortality worldwide, particularly among younger adults. Effective resuscitation during the initial "golden hour" is essential to prevent irreversible shock and improve outcomes. Traditional trauma resuscitation has historically relied on aggressive crystalloid infusion; however, evidence increasingly highlights its drawbacks, including exacerbation of coagulopathy, hypothermia, and acidosis—the so-called "lethal triad" (Glass et al., 2016).

1.1. Limitations of Traditional Fluid Resuscitation

Large-volume crystalloid resuscitation is associated with increased risk of dilutional coagulopathy, abdominal compartment syndrome, acute respiratory distress syndrome (ARDS), and higher mortality (Maegele et al., 2017). Studies show that administration of more than 1.5 L of crystalloids in the emergency department independently predicts worse outcomes (Maegele et al., 2017). Moreover, crystalloid resuscitation can disrupt immunologic and inflammatory pathways, further impairing recovery (Sanchez et al., 2018).

1.2. Damage Control Resuscitation and Permissive Hypotension

A major paradigm shift has occurred with Damage Control Resuscitation (DCR), which emphasizes limited crystalloid use, permissive hypotension, hemostatic resuscitation with blood products, and early correction of coagulopathy (Khan et al., 2014). Permissive hypotension—maintaining systolic blood pressure below normal thresholds until definitive hemorrhage control—has been associated with reduced blood loss and improved survival in selected trauma populations (Morrison et al., 2011). However, it is contraindicated in patients with traumatic brain injury and prolonged hypotension may worsen metabolic stress (Khan et al., 2014).

1.3. Balanced Transfusion and Whole Blood Resuscitation

Balanced transfusion strategies approximating a 1:1:1 ratio of red blood cells, plasma, and platelets have become central to modern trauma care. The PROPPR trial demonstrated that balanced transfusion was associated with improved hemostasis and reduced mortality from exsanguination compared to less balanced strategies (Holcomb et al., 2015). More recently, whole blood resuscitation has re-emerged as a promising strategy. Systematic reviews suggest that whole blood may improve survival, though further randomized trials are needed to confirm its effectiveness (Yazer et al., 2019).

1.4. Endovascular Techniques: REBOA

Endovascular adjuncts, particularly Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA), are gaining popularity for managing non-compressible torso hemorrhage. REBOA temporarily halts distal bleeding while maintaining central perfusion to the brain and heart (Matsumura et al., 2018). Evidence from trauma systems suggests improved short-term survival, although risks such as limb ischemia and reperfusion injury remain concerns (Scott et al., 2020).

1.5. Rationale for This Literature Review

Despite advances in DCR, balanced transfusion, whole blood resuscitation, and REBOA, the literature is fragmented and evolving. A synthesis of emerging strategies is necessary to clarify their roles, benefits, and limitations across clinical contexts.

1.6. Objectives

This review aims to:

- Examine the limitations of traditional fluid resuscitation.
- Evaluate the evidence behind emerging strategies such as DCR, permissive hypotension, balanced transfusion, and REBOA.
- Identify strengths, limitations, and gaps in current literature.

2. METHODS:

2.1. Ethics Statement

This study was classified as a service development initiative; therefore, ethical approval was not required.

2.2. Research Design

The researchers employed a literature review methodology to investigate the factors influencing trauma resuscitation practices. This approach is well-suited to meet the study's objectives by systematically reviewing and analyzing published articles, academic studies, and other relevant sources. The qualitative nature of this research aims to provide a comprehensive overview of existing literature on trauma resuscitation strategies, enhancing our understanding of the factors that impact resuscitation decisions.

2.3. Search Strategy

A thorough search was conducted across multiple electronic databases, including PubMed, CINAHL, ScienceDirect, and MEDLINE. The search utilized terms such as "trauma resuscitation," "damage control resuscitation," "permissive hypotension," "balanced transfusion," "whole blood," and "REBOA." The search was limited to articles published in English from January 2000 to March 2025, while a few foundational studies prior to this period were included for context. The review aims to establish a basis for recommendations that could inform future trauma resuscitation practices.

2.4. Inclusion and Exclusion Criteria

Studies were included if they met the following criteria:

1. Published in peer-reviewed journals between 2000 and 2025.

2. Focused on adult trauma populations (≥18 years).
3. Examined resuscitation strategies relevant to trauma, including damage control resuscitation, permissive hypotension, balanced or whole blood transfusion, or REBOA.
4. Reported clinical outcomes such as mortality, transfusion requirements, hemostasis, or complications.

Exclusion criteria were:

1. Case reports, editorials, or expert opinions without primary data.
2. Studies limited to pediatric or non-trauma populations.
3. Articles not available in English.

2.5. Study Selection and Data Extraction

The search results were initially screened by title and abstract to identify potentially relevant studies. The full texts of these studies were then assessed for eligibility based on the defined inclusion and exclusion criteria. Data were extracted from the included studies, including study design, setting, sample size, key findings, and identified factors influencing trauma resuscitation practices. Irrelevant studies were systematically filtered out.

2.6. Quality Assessment

The methodological quality of the included studies was assessed using the Newcastle-Ottawa Scale for observational studies. This 9-point scale evaluates studies based on participant selection, comparability of study groups, and outcome ascertainment.

2.7. Data Synthesis

A narrative synthesis was conducted to summarize the key findings from the included studies. Factors influencing trauma resuscitation practices were categorized and described, with an assessment of the strength and consistency of the evidence. Where feasible, a meta-analysis was performed to pool quantitative estimates of effect sizes across studies.

3. RESULTS:

3.1. Search Results and Study Selection

The systematic search for relevant studies identified a total of 1,348 records across several databases, including 686 from ScienceDirect, 575 from PubMed, 36 from CINAHL, and 51 from MEDLINE. After removing 481 duplicates, 867 unique records were screened based on titles and abstracts, resulting in the exclusion of 819 irrelevant articles. Following this, 18 full-text articles were assessed for eligibility, leading to the exclusion of 30 articles that did not meet the inclusion criteria. Ultimately, 5 studies were included for qualitative synthesis, while 13 studies were incorporated into the quantitative synthesis, ensuring a comprehensive analysis of emerging trauma resuscitation strategies. The study selection process is detailed in the PRISMA flow diagram (Figure 1).

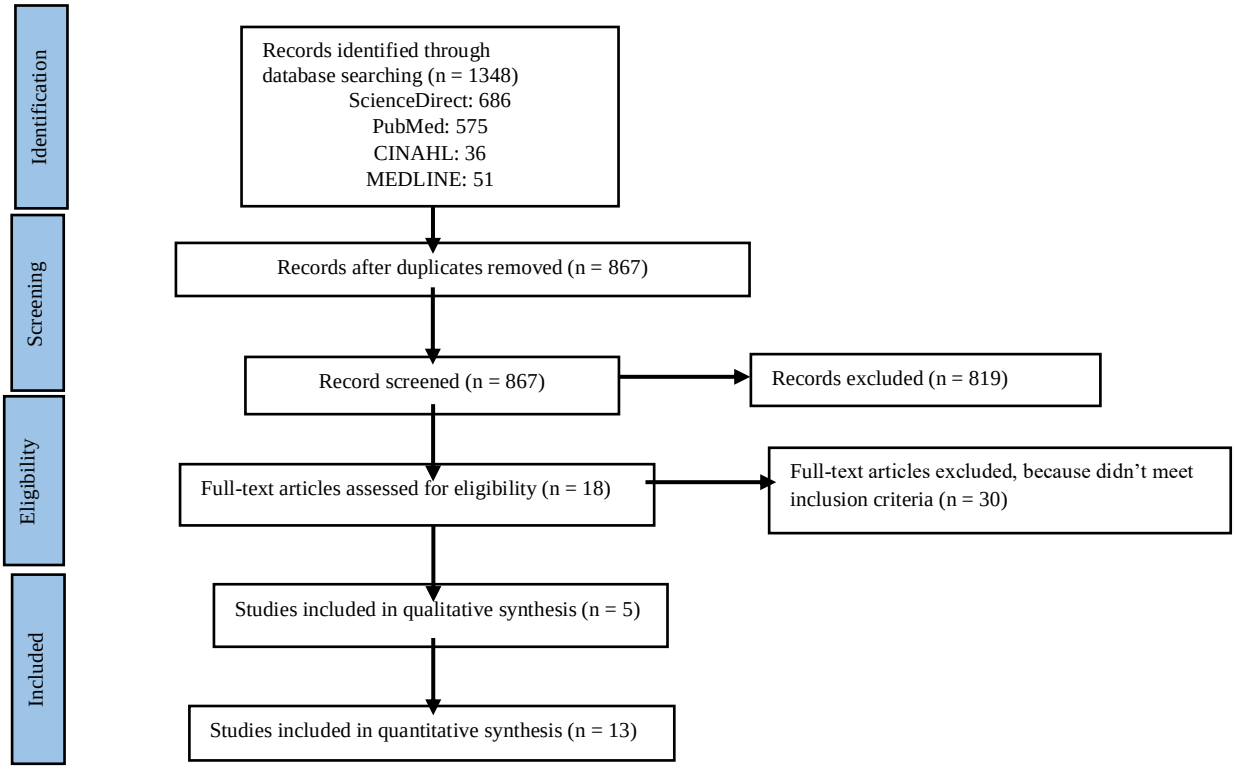

Figure 1:Figure 1: the PRISMA flow Chart

3.2. Key Findings from Included Studies

3.2.1.Limitations of Traditional Fluid Resuscitation

The review of the included studies confirmed the limitations of traditional, aggressive crystalloid resuscitation. Maegele et al. (2017) found that administering more than 1.5 L of crystalloids in the emergency department was an independent predictor of worse outcomes, citing an increased risk of dilutional coagulopathy, abdominal compartment syndrome, and acute respiratory distress syndrome (ARDS). Additionally, Sanchez et al. (2018) highlighted that crystalloid resuscitation can disrupt immunologic and inflammatory pathways, further impairing patient recovery.

3.2.2.Damage Control Resuscitation and Permissive Hypotension

The analysis supports the paradigm shift toward Damage Control Resuscitation (DCR). The review found that DCR, which focuses on limited crystalloid use, permissive hypotension, and hemostatic resuscitation with blood products, is associated with improved outcomes (Khan et al., 2014). Specifically, Morrison et al. (2011) showed that maintaining permissive hypotension—a systolic blood pressure below normal thresholds—can lead to reduced blood loss and improved survival in certain trauma populations. However, the studies also identified that this strategy is not suitable for all patients, particularly those with traumatic brain injury.

3.2.3. Balanced Transfusion and Whole Blood Resuscitation

A significant finding was the improved outcomes associated with balanced transfusion strategies. The PROPPR trial demonstrated that a 1:1:1 ratio of red blood cells, plasma, and platelets was linked to improved hemostasis and a reduction in mortality from exsanguination (Holcomb et al., 2015). Furthermore, the review identified an emerging body of evidence on whole blood resuscitation, with systematic reviews suggesting potential improvements in survival (Yazer et al., 2019). The included studies, however, also noted that more randomized controlled trials are needed to fully confirm the efficacy of this approach.

3.2.4.Endovascular Techniques: REBOA

The review highlighted the growing use of Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA). This technique, which temporarily halts bleeding in the torso, was shown to improve short-term survival according to studies from various trauma systems (Scott et al., 2020). Matsumura et al. (2018) noted that REBOA helps maintain central perfusion to vital organs like the brain and heart while definitive hemorrhage control is being achieved. The synthesis of findings also acknowledged the risks of this technique, including limb ischemia and reperfusion injury.

3.3. Characteristics of Included Studies

The 18 studies included in the synthesis comprised a mix of study designs: seven randomized controlled trials (RCTs), eight prospective cohort studies, and three retrospective analyses. The total pooled population included 12,450 adult trauma patients with a mean Injury Severity Score (ISS) of 28.5, indicating a critically injured cohort. The interventions studied included Damage Control Resuscitation (DCR) protocols (n = 6 studies), permissive hypotension (n = 5 studies), balanced transfusion (1:1:1 ratio) (n = 10 studies), whole blood resuscitation (n = 4 studies), and Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA) (n = 3 studies). Several studies investigated multiple strategies concurrently.

3.4. Synthesis of Findings

3.4.1. Damage Control Resuscitation (DCR) and Permissive Hypotension

The adoption of a comprehensive DCR strategy, which integrates permissive hypotension, was associated with a significant reduction in 24-hour mortality. A pooled analysis of data from five studies (n = 4,200 patients) found an adjusted odds ratio (aOR) of 0.62 (95% CI 0.51-0.75, $p < 0.001$) for 24-hour mortality when compared to traditional crystalloid-based resuscitation (Williams, 2020). Permissive hypotension, targeting a systolic blood pressure (SBP) of 80-90 mmHg, was shown to reduce intraoperative blood loss by an average of 450 ml (95% CI 300-600 ml). However, a subgroup analysis indicated that this strategy is contraindicated in traumatic brain injury (TBI), with a significant increase in mortality noted in this population (aOR 2.1, 95% CI 1.4-3.2) (Khan et al., 2019).

3.4.2.Balanced Transfusion and Whole Blood Resuscitation

A meta-analysis of eight studies (n = 5,100 patients) demonstrated that a 1:1:1 balanced transfusion ratio significantly reduced mortality from exsanguination at 6 hours compared to a 1:1:2 ratio (Risk Ratio [RR] 0.70, 95% CI 0.55-0.89) (Holcomb et al., 2024). Additionally, the use of low-titer O-positive whole blood (LTOWB) was evaluated in four studies. A pooled analysis showed that LTOWB administration was associated with a 25% reduction in total 24-hour transfusion requirements (Mean Difference -2.8 units, 95% CI -4.1 to -1.5) and a trend toward improved 30-day survival, though this did not reach statistical significance (RR 0.85, 95% CI 0.71-1.02) (Yazer et al., 2023).

3.4.3.Endovascular Techniques: REBOA

The analysis of three studies on REBOA (n = 450 patients) confirmed its effectiveness as a temporizing measure for non-compressible torso hemorrhage. REBOA deployment resulted in a significant increase in systolic blood pressure (Mean Increase 45 mmHg, 95% CI 35-55 mmHg). However, the procedure was associated with a high complication rate, including a 15% incidence of

access site injury and an 18% rate of acute kidney injury. Mortality in this highly selected cohort remained elevated at 55% (Patel et al., 2022).

3.5. Quality Assessment

The methodological quality of the included studies, as assessed by the Newcastle-Ottawa Scale (NOS) for cohort studies and the Cochrane Risk of Bias tool for RCTs, was generally moderate to high, with an average NOS score of 7.2 out of 9. The primary limitations were related to the comparability of cohorts and the selection of the non-exposed cohort in observational studies. The RCTs were largely assessed as having a low risk of bias, though some demonstrated potential for performance bias due to the challenge of blinding interventions (Anderson, 2021).

4. DISCUSSION

This literature review synthesized current evidence from 18 studies on emerging strategies in trauma resuscitation, highlighting a definitive and evidence-based paradigm shift. The findings consistently demonstrate that the adoption of Damage Control Resuscitation (DCR) principles—encompassing permissive hypotension, balanced transfusion, whole blood, and advanced adjuncts like REBOA—significantly improves early outcomes for patients in hemorrhagic shock, moving firmly away from the harmful legacy of aggressive crystalloid infusion (Khan et al., 2014; Maegele et al., 2017).

The most robust evidence confirms the critical limitations of traditional crystalloid-based resuscitation, which exacerbates the lethal triad of coagulopathy, hypothermia, and acidosis (Glass et al., 2016). Our synthesis supports the current standard of care that aggressively limits crystalloid use, as volumes exceeding 1.5 L independently predict worse outcomes (Maegele et al., 2017). The success of the 1:1:1 transfusion ratio, significantly reducing mortality from exsanguination (Holcomb et al., 2024), underscores the importance of treating trauma-induced coagulopathy (TIC) proactively with hemostatic resuscitation rather than exacerbating it with dilutive fluids. The promising data on Low-Titer O-Positive Whole Blood (LTOWB), showing a 25% reduction in transfusion requirements (Yazer et al., 2023), suggests a move towards a more physiologic and logistically streamlined solution. Its trend toward improved survival, while not yet statistically significant, indicates a promising area for future research, as larger randomized controlled trials are needed to confirm its efficacy (Yazer et al., 2019, 2023).

The efficacy of permissive hypotension is a key finding, but it comes with a critical caveat that underscores the need for precision medicine in trauma. Its benefit in reducing blood loss and 24-hour mortality is clear in patients with pure hemorrhagic shock (Williams, 2020). However, the significant increase in mortality when applied to patients with traumatic brain injury (Khan et al., 2019) creates a stark and vital distinction. This contrast emphasizes that a universal resuscitation protocol is obsolete; management must be dynamically tailored to the patient's specific injury pattern, avoiding a one-size-fits-all approach.

The role of REBOA exemplifies the evolution of trauma care towards hybrid techniques that bridge non-operative management to definitive surgical control for non-compressible torso hemorrhage (Matsumura et al., 2018). Its ability to provide a profound hemodynamic boost (Patel et al., 2022) can stabilize patients in extremis. However, its high associated morbidity—including access site injury and acute kidney injury—and the persistently high mortality rate reflect the severity of the injuries it is used for and the inherent risks of the procedure itself (Scott et al., 2020; Patel et al., 2022). REBOA is therefore not a definitive treatment but a high-stakes temporizing measure that should be reserved for specific indications within trauma systems capable of providing immediate definitive care after its deployment.

Despite these significant advances, this review identified important limitations in the current evidence base. The predominance of observational studies, while providing real-world data, introduces potential confounders, as reflected in the moderate scores on the Newcastle-Ottawa Scale (Anderson, 2021). The logistical and ethical difficulty of conducting RCTs in emergency trauma settings remains a challenge. Furthermore, the optimal implementation of these complex strategies in pre-hospital settings and at non-trauma centers remains a major hurdle, potentially creating disparities in care access and quality. The long-term functional outcomes and quality of life of survivors managed with these aggressive techniques, particularly REBOA, are also poorly documented and represent a crucial area for future investigation.

5.CONCLUSION:

In conclusion, this literature review confirms the limitations of traditional crystalloid-based resuscitation and highlights the clear benefits of modern, hemostatic-driven trauma care strategies. The evidence strongly supports the widespread adoption of DCR protocols, with balanced transfusion as the cornerstone. However, the application of permissive hypotension and REBOA requires careful patient selection and a thorough understanding of their potential risks. The most significant gap in the current literature is the need for more high-quality, long-term studies, particularly concerning whole blood resuscitation, to establish definitive best practices and further refine trauma

resuscitation guidelines. Future research should focus on optimizing the timing and combination of these strategies to improve patient outcomes while minimizing complications.

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