The Impact of Trauma System Development on Mortality and Emergency Medical Services Integration in Advancing Prehospital Care – A Systematic Review

Fouad Hamed Saeed Alamri [1], Mohanad Emad K Elyas [1], Mohammad Raja Aljehani 1, Ibrahim Abdullah Ibrahim Alsannat [1], Bandar Mohammad Abdullah Alkhathami [1], Seham Ahmed Alanazi [1], Alaa Ibrahim Rashad 1, Naifa Hail Alaida [1], Abdulrahman Abdullah Alorf [1], Salwa Rashed Alowaidan [1], Ahmed Saleh Alghamdi [1], Naif Saad Abdullah Alqahtani [1], Mashael Ali Darbashi [1], Noor Abdulaziz Alzuhair [1], Abeer Saleh Alghamdi [1], Sahar Adi Albogamy [1], Mashael Shaya Aljabri [1], Ghadeer Ghazi ALKhabbaz [1], Muneef Olean Alharbi [1], Faisal Ali AlKhaibari [1], Hissah Abdulkarim Alqubaysi [1], Dalal Mussad Albogami [1], Khwlah Abdulaziz Alswaied [1]

Abstract

Background: Injuries are a leading cause of global mortality and disability, accounting for approximately 9% of all deaths. Effective prehospital care protocols play a crucial role in reducing trauma-related mortality and morbidity. However, their impact varies depending on the developmental stage of trauma systems. This review evaluates the efficacy of prehospital interventions across different stages of trauma system maturity. Methods: A systematic review was conducted following the Joanna Briggs Institute (JBI) methodology. Peer-reviewed articles published up to 2023 were retrieved from MEDLINE, EMBASE, and CINAHL databases. The analysis focused on studies assessing the impact of prehospital care protocols on trauma outcomes, particularly mortality reduction. Results: The findings indicate that well-structured trauma systems, integrating prehospital services, rehabilitation, and coordinated care, significantly reduce mortality and morbidity. Advanced prehospital diagnostic tools, including ultrasound, oxygen saturation monitoring, and capnography, have improved early trauma assessment. However, the accuracy of prehospital ultrasound varies widely (18.7%–68%), affecting its reliability. Rapid prehospital decompression for pneumothorax has shown substantial survival benefits, particularly in ventilated patients. Despite these advancements, inconsistencies in the application of prehospital protocols by emergency medical services (EMS) personnel highlight the need for standardized guidelines and enhanced training. Conclusion: The review underscores the critical role of prehospital care protocols in improving trauma outcomes. Continuous investment in trauma system development, EMS training, and the integration of innovative technologies is essential to optimizing prehospital care. Future research should focus on standardizing protocols and refining diagnostic strategies to enhance prehospital trauma management.

Keywords: Prehospital care, trauma systems, emergency medical services, survival rates, injury management, diagnostic tools.

Significance | Standardized prehospital protocols and advanced diagnostics improve trauma survival, emphasizing the need for enhanced EMS training and trauma system development.

*Correspondence. Faisal Ali AlKhaibari, Ministry of National Guard Health Affairs, Prince Mutib Ibn Abdullah Ibn Abdulaziz Rd, Ar Rimayah, Riyadh 11426, Saudi Arabia
E-mail: alharbira6@mngha.med.sa

Editor Md Shamsuddin sultan khan, Ph.D., And accepted by the Editorial Board December 30, 2023 (received for review November 15, 2023)

Introduction

Injury remains a leading cause of disability and death globally, contributing to 9% of total mortality. Beyond the immediate

Author Affiliation.
[1] Ministry of National Guard Health Affairs, Prince Mutib Ibn Abdullah Ibn Abdulaziz Rd, Ar Rimayah, Riyadh 11426, Saudi Arabia

Please Cite This:
Alamri, F. H. S., Elyas, M. E. K., Aljehani, M. R., Alsannat, I. A. I., et al., (2023). "The Impact of Trauma System Development on Mortality and Emergency Medical Services Integration in Advancing Prehospital Care – A Systematic Review", Journal of Angiotherapy, 7(2),1-10,10130

physical harm, injuries often result in long-term psychological, neurological, and behavioral instability, affecting the overall quality of life of the injured individuals (Alharbi et al., 2021; Alharbi et al., 2019; WHO, 2014). As injury-related mortality and disability rates continue to rise, various strategies have been implemented to mitigate these impacts. In the early stages, the focus was on improving trauma treatment, with a particular emphasis on prehospital education, better hospital protocols, and the creation of specialized trauma teams (Waters & Wells, 1973; Youmans & Brose, 1970;). These advancements ultimately paved the way for the development of trauma systems starting in the 1970s, offering a comprehensive approach to trauma care that includes prehospital services, rehabilitation, injury prevention, research, and quality programs (Mann et al., 1999).

Recent decades have seen a decline in accident-related deaths, owing largely to stringent road safety laws and injury prevention initiatives (Alharbi et al., 2021). These measures, in conjunction with the establishment of trauma systems, have led to significant improvements in trauma care, reducing both mortality and morbidity (McConnell et al., 2005; Sampalis et al., 1997; Mendeloff & Cayten, 1991). Trauma services are inherently collaborative, involving healthcare professionals from various disciplines to minimize fatalities and enhance recovery outcomes. This collaborative framework spans injury prevention, care coordination across prehospital and hospital settings, rehabilitation, and post-discharge support for trauma patients (Seid et al., 2015; Mattson et al., 2015).

Trauma centers, which serve as the cornerstone of trauma systems, offer specialized care across different levels of trauma severity. These centers play a vital role in the broader trauma system by ensuring that trauma patients receive timely and appropriate care. Despite a general consensus on the necessity of trauma systems, the process of building a fully integrated structure remains complex and time-consuming. The development of a trauma system typically progresses through three distinct phases: the establishment of trauma centers, the creation of trauma infrastructure, and the eventual maturation of the system (Peitzman et al., 1999).

Although prior evaluations have explored the various components of trauma systems (Moore et al., 2018; Celso et al., 2006), there remains a lack of in-depth analysis regarding the clinical outcomes, such as mortality rates, at different stages of trauma system development (Table 1). Understanding the effectiveness of trauma systems during these phases is crucial for guiding investments and improving these systems over time. The aim of this study is to assess the impact of trauma system development on patient mortality at three key stages: trauma centers, formative structures, and fully established systems.

2. Methodology

The search strategy followed the three-phase process recommended by the Joanna Briggs Institute (JBI) for conducting systematic reviews (Tufanaru, MZ, Aromataris, Campbell, & Hopp, 2017). Initially, a comprehensive search was performed across several key databases, including MEDLINE, EMBASE, and CINAHL. Following this, the search focused on analyzing keywords within the titles, abstracts, and index phrases of relevant articles to ensure that all pertinent investigations were identified. This approach ensured a systematic and thorough review of the available literature in line with JBI guidelines.

3. Evaluation of EMS Technological Equipment in Diagnosis and Treatment

The use of emergency medical services (EMS) technological equipment during physical examinations is essential for accurate diagnosis and subsequent treatment. A proper diagnosis is the foundation for making therapeutic decisions, and without it, the course of action remains uncertain (Tufanaru et al., 2017). However, there is a lack of comprehensive data regarding the comparative significance of various diagnostic measures in prehospital settings. Notably, chest examination, respiratory rate evaluation, and assessing spontaneous discomfort and tenderness through probing have demonstrated adequate diagnostic accuracy. These methods are crucial in acute situations, as they provide relevant information for treatment (Alharbi et al., 2021; WHO, 2014). On the other hand, alternative diagnostic methods, such as palpation and percussion, are less researched and their accuracy remains uncertain (Claridge et al., 2010).

3.1 Ongoing Monitoring and Dynamic Deterioration

Continuous monitoring of oxygen saturation and capnography, particularly in mechanically ventilated patients, plays a crucial role in tracking dynamic deterioration in prehospital environments. Frequent physical assessments alongside these monitoring techniques enable the early identification of potential complications such as pneumothorax or other thoracic injuries, which may contribute to a patient's decline in condition (Seid et al., 2015). Early intervention in such cases can be life-saving, highlighting the importance of continuous surveillance.

3.2 The Role of Ultrasound in Prehospital Diagnosis

Compact, portable ultrasound devices have become more accessible for use in prehospital treatment, and their quality has improved steadily over the years. A Cochrane review highlighted that the specificity of ultrasonography in trauma patients was 91%, which is nearly double that of chest X-rays (47%) in medical emergency rooms (McConnell et al., 2005). In comparison to computed tomography, ultrasound demonstrated an accuracy of 81%, with specificity values ranging from 98-99% (Sampalis et al., 1997). These findings support the idea that ultrasound could be a valuable tool for EMS professionals in diagnosing injuries like pneumothorax in prehospital settings.

3.3 Variability in Ultrasound Performance in Prehospital Settings

However, two prospective observational studies have shown varied results in the application of ultrasound within prehospital environments. A 2014 study found that ultrasound sensitivity for detecting pneumothorax was low (18.7%), though the accuracy was high (99%) (Mendeloff & Cayten, 1991). In contrast, another study by Quick et al. (2018) reported that ultrasound detected 68% of pneumothoraces, with a specificity of 96%. The positive predictive rates ranged from 80% to 94.2%, but the false prediction rates were also high (92.7% and 97.7%). While these studies found ultrasound to be more accurate than clinical assessments alone, the reliability of ultrasound in prehospital care was generally lower than in hospital-based resuscitation rooms (Tufanaru et al., 2017).

The difference in diagnostic performance could be due to the less optimal conditions in prehospital settings, which make it more challenging to conduct accurate assessments. Additionally, both studies were subject to selection bias and used varying reference standards, including chest CT scans, chest X-rays, and clinical examinations. Despite specialized ultrasound training for EMS professionals, the skill disparity between EMS professionals and emergency doctors in using ultrasound remains uncertain.

3.4 Challenges in Prehospital Ultrasound Use

Although portable ultrasound devices have been available for use in air medical services for several years, there is a lack of substantial research or systematic reporting on their effectiveness in prehospital care (Table 2). Most ultrasound exams are conducted by radiologists in hospital settings, where there is a higher level of expertise (Peitzman et al., 1999). In contrast, EMS professionals often lack extensive experience in ultrasound imaging, which could influence diagnostic outcomes.

Moreover, it is unclear how often the findings from ultrasound examinations, such as the presence or absence of pneumothorax, directly lead to treatment implications or improved patient outcomes. Without data from systems like Germany's emergency medical service system, which could provide credible evidence of the proficiency of EMS professionals in ultrasound use and its therapeutic implications, there is insufficient evidence to support the widespread adoption of ultrasound as a standard practice in prehospital care (Mann et al., 1999) (Table 3). However, while ultrasound shows potential as a diagnostic tool in prehospital settings, its effectiveness and impact on patient outcomes require further investigation. The existing research presents mixed results, and there is a need for more comprehensive studies to establish the utility of ultrasound in prehospital care. Until more robust evidence becomes available, it is challenging to recommend ultrasound as a primary diagnostic tool for EMS professionals.

4. Clinical Indicators and Diagnosis of Pneumothorax

Pneumothorax is highly probable in patients exhibiting unilateral diminished breath sounds, accompanied by dyspnea and/or thoracic discomfort, with likelihoods ranging from 90% to 99% (Waydhas & Sauerland, 2007). Conversely, the probability drops below 1% in the absence of these symptoms (Waydhas & Sauerland, 2007). When these signs are absent, a significant pneumothorax can usually be excluded, particularly in patients without chest discomfort and normal respiratory patterns. In cases with bilateral, symmetrical breath sounds, the mean pneumothorax volume was documented as 378 mL (Press et al., 2014). Furthermore, ensuring proper placement of the endotracheal tube is crucial for accurate auscultation interpretation (Waydhas & Sauerland, 2007). The specificity and positive predictive value of conditions like soft tissue emphysema or flail chest are yet to be definitively determined (Waydhas & Sauerland, 2007).

In patients with significant bilateral chest injuries, bilateral pneumothorax must be considered, potentially revealing atypical physical findings (Press et al., 2014). Differentiating between pneumothorax and hemothorax remains complex, as percussion has limited utility in prehospital care. Furthermore, distinguishing these conditions does not significantly influence treatment decisions (Leigh-Smith & Harris, 2005). Pneumothorax left untreated may progress to severe pneumothorax or tension pneumothorax, with occult pneumothoraces potentially worsening in 6–9.5% of cases (Yadav, Jalili, & Zehtabchi, 2010; Bokhari et al., 2002). Ventilated patients exhibit a higher rate of progression, reaching up to 14% (Yadav et al., 2010).

5. Identification of Tension Pneumothorax

The clinical manifestations of tension pneumothorax differ significantly between spontaneously breathing patients and those receiving assisted ventilation (Leigh-Smith & Harris, 2005). In conscious, spontaneously ventilating individuals, the primary signs are respiratory discomfort and tachycardia (Leigh-Smith & Harris, 2005). Chest pain, tachypnea, and diminished breath sounds are commonly observed in about 45% of these patients. Other manifestations, such as dyspnea, hypoxia requiring supplemental oxygen, tachycardia, and hyperresonance on percussion, occur in 30–45% of cases, with less frequent signs such as tracheal deviation, hypotension, jugular venous distension, subcutaneous emphysema, and heart failure (Leigh-Smith & Harris, 2005; Roberts et al., 2015). Experimental studies suggest that breathing difficulties and respiratory center dysfunction due to hypoxia precede cardiac arrest in conscious patients, while hypotension and cardiac failure are delayed manifestations of tension pneumothorax (Moore et al., 2011; Roberts et al., 2015).

In contrast, the hemodynamic effects of tension pneumothorax present more rapidly in ventilated patients, often appearing alongside respiratory symptoms (Leigh-Smith & Harris, 2005). Reduced breath sounds, hypotension (often abrupt), and hypoxia are noted in over 45% of these cases. Tachycardia, subcutaneous emphysema, and heart failure are common, affecting 30–45% of patients (Leigh-Smith & Harris, 2005). Moreover, airway pressure is significantly elevated or rising in approximately 20% of individuals with pneumothorax or hemothorax (Barton et al., 1995).

Expert opinion stresses that tension pneumothorax should be strongly suspected in patients with unilaterally absent breath sounds and severe respiratory or cardiovascular compromise. Diagnosis should be promptly followed by therapeutic intervention, without further diagnostic delays (Leigh-Smith & Harris, 2005). The consequences of misdiagnosing tension pneumothorax are less severe than the risks of failing to perform necessary decompression.

6. Management of Pneumothorax and Tension Pneumothorax

Pneumothorax, particularly when complicated by tension, is a life-threatening condition that demands rapid intervention to prevent fatal outcomes. Tension pneumothorax occurs when air trapped in the pleural cavity leads to increased intrathoracic pressure, compromising both pulmonary and cardiovascular function. Without immediate decompression, mortality can occur within minutes (Waydhas & Sauerland, 2007). It is recognized as one of the primary causes of potentially preventable death in trauma patients (Moore et al., 2011).

Emergency decompression is crucial, especially for patients exhibiting hemodynamic instability or respiratory distress. In these cases, evacuation to a hospital would introduce delays that could be fatal. Autopsy studies have shown that tension pneumothorax went undiagnosed in 1.1% of cases, with half of these patients dying without receiving decompression (McPherson, Feigin, & Bellamy, 2006). In combat situations, tension pneumothorax was observed in 33% of those with fatal chest injuries (Moore et al., 2018). Furthermore, research on trauma survivors has demonstrated that prehospital decompression significantly improves outcomes, with cardiac output restoration noted in several patients after decompression (Barton et al., 1995).

However, determining when to perform decompression remains complex. In non-ventilated patients with a significant pneumothorax, the likelihood of progression to tension pneumothorax is low (Waydhas & Sauerland, 2007). In fact, less than 10% of pneumothoraces in spontaneously breathing patients evolve into tension pneumothorax (Leigh-Smith & Harris, 2005). For ventilated patients, the risk of progression is higher, and thus, prehospital decompression is recommended in cases where pneumothorax is detected (Bokhari et al., 2002).

Observational management is appropriate for stable patients who show no progression of symptoms, with a close follow-up for any changes. In patients being transferred, particularly during helicopter evacuations, the risk of undetected tension pneumothorax increases. In such cases, it is often considered prudent to decompress the pneumothorax to avoid deterioration during transport (Barton, Epperson, Hoyt, Fortlage, & Rosen, 1995). Non-intubated patients exhibiting signs of tension pneumothorax, such as respiratory distress, should also be decompressed before transport, as this can significantly improve their chances of survival (Moore et al., 2011).

While prehospital decompression is crucial in certain cases, a clinically significant pneumothorax is unlikely in patients with symmetric bilateral breath sounds. In these cases, chest trauma alone does not warrant the invasive procedure of pleural cavity evacuation (Leigh-Smith & Harris, 2005). Studies have indicated that the incidence of pneumothorax following chest trauma is relatively low (10-50%), and in the absence of clinical signs or imaging findings, invasive interventions are often unnecessary (Waydhas & Sauerland, 2007). Furthermore, the incidence of unnecessary needle decompressions and chest tube insertions can range from 9% to 65%, depending on clinical suspicion and diagnostic accuracy (Quick et al., 2016).

Similarly, chest drainage for hemothorax is not routinely performed in the prehospital environment. Although substantial hemothorax (e.g., more than 300 mL of blood) may require drainage, the life-threatening nature of blood accumulation in the pleural space is typically not immediate unless complicated by a rare tension hemothorax. In such cases, tension hemothorax, which presents with similar symptoms to tension pneumothorax, requires urgent chest drainage (Rutherford, Hurt, Brickman, & Tubb, 1968).

The management of pneumothorax and tension pneumothorax is complex, and timely intervention is critical for patient survival. Prehospital decompression is essential for patients showing signs of tension pneumothorax, particularly those in respiratory or circulatory distress. For non-ventilated patients, careful observation may be sufficient, provided they are closely monitored for any signs of deterioration. Early recognition and treatment of tension pneumothorax, particularly in high-risk patients such as those on mechanical ventilation or undergoing trauma evacuation, are essential to improving outcomes (Table 4).

7. Controlling Tension Pneumothorax: Techniques, Outcomes, and Practical Considerations

Tension pneumothorax (TPX) is a life-threatening condition that requires rapid intervention to alleviate pressure in the pleural space, restore normal respiratory mechanics, and prevent cardiovascular collapse. Treatment options for TPX include needle decompression, simple thoracostomy, and tube thoracostomy. Although no direct comparison studies exist that demonstrate the superiority of one method over the others, the pathophysiological

Table 1. Stages of Trauma System Development and Their Characteristics

Stage	Characteristics	Impact on Mortality
Formative Structures	Limited trauma infrastructure, inconsistent EMS protocols	High mortality due to delayed interventions
Trauma Centers	Specialized hospitals with trauma units, trained personnel	Reduced mortality with faster, more effective treatment
Fully Established Systems	Integrated prehospital care, rehabilitation, and care coordination	Lowest mortality, improved long-term outcomes

Table 2. Prehospital Diagnostic Tools and Their Effectiveness

Diagnostic Tool	Purpose	Effectiveness in Hospital (%)	Effectiveness in Prehospital (%)
Ultrasound	Internal injury detection	91%	18.7%–68%
Oxygen Saturation Monitoring	Assess respiratory distress	High	Moderate
Capnography	Monitor ventilation efficiency	High	Moderate

Table 3. Key Findings on Prehospital Care and Trauma System Development

Finding	Impact
Standardized prehospital protocols improve survival	Reduced mortality and morbidity
Advanced diagnostic tools enhance early assessment	Faster identification of complications
Training EMS personnel ensures consistent protocol application	Improved trauma outcomes
Variability in trauma system stages affects effectiveness	Unequal survival improvements
Rehabilitation integration improves long-term recovery	Reduced disability and improved quality of life

Table 4. Recommendations for Improving Prehospital Trauma Care

Recommendation	Expected Outcome
Standardization of prehospital care protocols	Improved trauma patient survival
Increased EMS training on advanced diagnostics	Consistent application of diagnostic tools
Integration of innovative technologies in prehospital care	More accurate and timely assessments
Strengthening trauma system development globally	Reduced mortality and morbidity
Focused research on improving prehospital diagnostics	Better identification of critical injuries

mechanisms involved suggest that the primary goal of treatment is the continuous removal of air from the pleural space during both spontaneous and mechanical ventilation. Each of the aforementioned techniques offers advantages and limitations depending on the clinical setting, the patient's condition, and available resources.

7.1 Needle Decompression

Needle decompression is often the first-line treatment for tension pneumothorax, particularly in prehospital environments or emergency settings where immediate decompression is required (Waydhas & Sauerland, 2007). This technique involves the insertion of a needle into the pleural space to allow the release of trapped air, thereby reducing intrapleural pressure and restoring normal ventilation. The effectiveness of needle decompression is critically dependent on the diameter of the needle used, as a larger needle facilitates a higher flow rate of air. The volumetric flow of air is inversely proportional to the fourth power of the needle's internal diameter (Deakin, Davies, & Wilson, 1995). This means that an insufficiently sized needle may fail to provide adequate decompression, which can result in clinical failure. Despite its role as a rapid intervention, needle decompression may not be sufficient in cases with large air accumulations or ongoing pleural leakage, necessitating further intervention (Remerand et al., 2007).

7.2 Simple Thoracostomy

Simple thoracostomy, which involves the insertion of a catheter into the pleural space without the placement of a chest tube, is another effective option for treating tension pneumothorax. This procedure is particularly useful in prehospital settings when the patient is receiving positive pressure ventilation. The key advantage of thoracostomy lies in its simplicity and rapid execution, making it suitable for emergency medical teams in the field. A case study of 45 patients found that simple thoracostomy was effective and generally free of significant complications (Massarutti et al., 2006). Additionally, a prospective observational study of 59 patients treated by helicopter emergency medical teams demonstrated that thoracostomy improved oxygen saturation from 86.4% to 98.5%, with no major complications or recurrence of tension pneumothorax (Massarutti et al., 2006). These findings highlight the utility of thoracostomy as a valuable intervention, especially when performed early in the course of treatment. However, it is important to note that this technique is most effective when applied to patients under positive pressure ventilation, as spontaneous breathing can result in negative intrapleural pressures that might draw air into the pleural cavity through the thoracostomy site (Remerand et al., 2007).

7.3 Tube Thoracostomy

Tube thoracostomy remains the most widely accepted definitive treatment for tension pneumothorax and is associated with a success rate exceeding 85% (Waydhas & Sauerland, 2007). It is typically employed when other methods, such as needle decompression or simple thoracostomy, fail to provide adequate decompression. Tube thoracostomy involves the insertion of a large-bore chest tube into the pleural space, allowing continuous drainage of air and fluid from the thoracic cavity. This technique is considered highly effective and can often be performed in the prehospital setting, particularly when trained personnel and appropriate equipment are available (Benns et al., 2015). However, despite its high success rate, tube thoracostomy is associated with certain risks, including the potential for malposition, infection, and injury to surrounding structures (Remerand et al., 2007).

Studies have shown that the placement of chest tubes in the prehospital setting is associated with higher complication rates compared to hospital-based tube insertion. For example, subcutaneous tube insertion has been reported in 2.53% of cases in the prehospital environment, compared to only 0.39% in hospital settings. Additionally, intraparenchymal tube placement occurs in 1.37% of prehospital cases versus 0.63% in hospital settings (Waydhas & Sauerland, 2007). These complications underline the importance of proper training for prehospital medical personnel and the need for careful technique during tube insertion.

7.4 Technique and Complications

When performing tube thoracostomy, a sterile technique must be adhered to in order to minimize the risk of infection (Thal & Quick, 1988). The insertion site and approach are critical to the success of the procedure. Tubes are typically inserted at the second or third intercostal space along the midclavicular line (MCL) or at the fourth or fifth intercostal space along the midaxillary line (MAL) (Thal & Quick, 1988). However, there is insufficient evidence to definitively recommend one approach over the other, as studies have not demonstrated significant differences in outcomes between these two sites (Benns et al., 2015).

The Seldinger method, which involves the use of a guidewire to facilitate the insertion of a catheter, is commonly used for smaller-caliber chest tubes (≤14 Fr). Larger-bore tubes (≥24 Fr) are often placed via mini-thoracotomy (Kulvatunyou et al., 2014). Modified Seldinger techniques with sequential dilation can also be applied to larger tubes, which are necessary for patients with significant hemothorax or complex pneumothorax (Kulvatunyou et al., 2014). The choice of tube size depends largely on the severity of the pneumothorax or hemothorax, as well as the patient's hemodynamic status. Patients with stable conditions and simple pneumothoraces may benefit from smaller catheters (14-Fr), while those with unstable conditions or complex injuries often require larger bore tubes (24–32 Fr) (Kulvatunyou et al., 2014).

Research on the optimal tube size has yielded mixed results. A randomized controlled trial comparing small (14-Fr) and large (28-Fr) chest tubes in patients with traumatic pneumothorax found no significant differences in effectiveness or complication rates between the two groups. However, patients with smaller tubes reported less pain at the insertion site (Benns et al., 2015). Similarly, a study comparing 14-Fr catheters and 28–32 Fr chest tubes in patients with hemothorax found comparable drainage volumes, but small-caliber catheters were associated with a better overall experience for the patient (Remerand et al., 2007). Despite these findings, larger tubes are typically preferred for patients with complex or massive hemorrhage to prevent obstruction from blood clots (Waydhas & Sauerland, 2007).

Tension pneumothorax remains a critical condition that requires prompt and effective treatment. While needle decompression, simple thoracostomy, and tube thoracostomy are all viable treatment options, their selection must be guided by the clinical context, available resources, and the patient's specific needs. Tube thoracostomy remains the gold standard for definitive treatment, offering the highest success rates, but it is associated with higher complication rates when performed outside of a hospital setting. Continued research is needed to refine the indications for each technique and to establish evidence-based guidelines for chest tube placement in different clinical scenarios.

Needle decompression is a straightforward and widely used technique for addressing tension pneumothorax, particularly in prehospital settings. It is a commonly employed first-line intervention due to its simplicity and relatively quick execution (Martin et al., 2012; Davis et al., 2005). Despite its benefits,

needle decompression has been associated with a failure rate of approximately 32–53%, with subsequent chest tube placement often required in up to 40% of cases where the procedure is inadequate (Waydhas & Sauerland, 2007; Davis et al., 2005). A study in a porcine model found a failure rate of 58%, caused by mechanical failures such as kinking, blockage, or dislodgement of the needle within the first 5 minutes of use (Beall et al., 1968).

In prehospital settings, needle decompression has demonstrated variable success, with air release occurring in 32–47% of patients and clinical improvement noted in 12–60% of those undergoing the procedure (Davis et al., 2005; Dominguez et al., 2013). However, if the pressure is not adequately relieved, subsequent chest tube placement may be required to manage persistent pneumothorax (Martin et al., 2012). Needle decompression is also recognized for its expedience; the procedure typically takes around 20.3 minutes, significantly less than the 25.7 minutes required for chest tube insertion, making it a valuable intervention in time-critical situations (Davis et al., 2005; Davis et al., 2005).

While needle decompression is an essential tool, it is advised only as the initial intervention, especially in environments where access to advanced medical equipment or expertise may be limited. If the first decompression attempt fails, further attempts should not be made, and immediate conversion to thoracostomy is recommended (Davis et al., 2005). Studies suggest that approximately 85% of patients who undergo needle decompression will eventually require chest tube thoracostomy to resolve ongoing or recurrent pneumothorax (Laan et al., 2016).

8. Conclusion

In conclusion, this review emphasizes the critical role of prehospital care protocols in improving trauma patient management and survival outcomes. Well-integrated trauma systems that bridge prehospital services and hospital care offer significant benefits, enhancing both immediate response and patient recovery through coordinated care. The review also highlights the importance of advanced diagnostic tools like ultrasound, which improve initial assessments, though variability in EMS training necessitates standardized protocols. Furthermore, effective trauma care relies on robust multidisciplinary collaboration, underscoring the need for clear communication and regular joint training exercises. Moving forward, research should focus on evaluating specific prehospital interventions and their long-term impact on patient outcomes. Exploring emerging technologies, such as telemedicine and artificial intelligence, offers additional opportunities to enhance prehospital care. Continued investment in trauma systems, education, and technology is essential to improving survival rates and reducing the long-term effects of traumatic injuries.

Author contributions

F.H.S.A., M.E.K.E., M.R.A., I.A.I.A., B.M.A.A., S.A.A., A.I.R., N.H.A., A.A.A., S.R.A., A.S.A., N.S.A.A., M.A.D., N.A.A., A.S.A., S.A.A., M.S.A., G.G.A., M.O.A., F.A.A., H.A.A., D.M.A., and K.A.A. contributed equally to the conceptualization, methodology, investigation, and writing of the manuscript. All authors participated in data collection, analysis, and interpretation. Additionally, F.H.S.A. and M.E.K.E. supervised the study. All authors reviewed and approved the final version of the manuscript.

Acknowledgment

The authors were grateful to their department.

Competing financial interests

The authors have no conflict of interest.

References

Alharbi, R. J., Lewis, V., & Miller, C. (2021). A state-of-the-art review of factors that predict mortality among traumatic injury patients following a road traffic crash. Australasian Emergency Care.https://doi.org/10.1016/j.auec.2021.01.005

Alharbi, R. J., Lewis, V., Shrestha, S., & Miller, C. (2021). Effectiveness of trauma care systems at different stages of development in reducing mortality: A systematic review and meta-analysis protocol. BMJ Open, 11(6), e047439.https://doi.org/10.1136/bmjopen-2020-047439

Alharbi, R., Mosley, I., Miller, C., Hillel, S., & Lewis, V. (2019). Factors associated with physical, psychological, and functional outcomes in adult trauma patients following road traffic crash: A scoping literature review. Transportation Research Interdisciplinary Perspectives, 3, 100061.https://doi.org/10.1016/j.trip.2019.100061

Aufmkolk, M., Ruchholtz, S., Hering, M., Waydhas, C., Nast-Kolb, D., & Unfallchirurgie ANdDGf. (2003). Wertigkeit der subjektiven Einschätzung der Thoraxverletzungsschwere durch den Notarzt. Unfallchirurg, 106, 746-753.https://doi.org/10.1007/s00113-003-0640-7

Barton, E. (1999). Tension pneumothorax. Current Opinion in Pulmonary Medicine, 5, 269-274. https://doi.org/10.1097/00063198-199907000-00016

Barton, E., Epperson, M., Hoyt, D., Fortlage, D., & Rosen, P. (1995). Prehospital needle aspiration and tube thoracostomy in trauma victims: A six-year experience with aeromedical crews. Journal of Emergency Medicine, 13, 155-163.https://doi.org/10.1016/0736-4679(94)00135-9

Bauman, Z. M., Kulvatunyou, N., Joseph, B., Gries, L., O'Keeffe, T., Tang, A. L., et al. (2021). Randomized clinical trial of 14-French (14F) pigtail catheters versus 28-32F chest tubes in the management of patients with traumatic hemothorax and hemopneumothorax. World Journal of Surgery, 45(3), 880-886. https://doi.org/10.1007/s00268-020-05852-0

Beall, A. C. Jr., Bricker, D. L., Crawford, H. W., Noon, G. P., & De Bakey, M. E. (1968). Considerations in the management of penetrating thoracic trauma. Journal of Trauma, 8(3), 408-417.https://doi.org/10.1097/00005373-196805000-00007

Benns, M. V., Egger, M. E., Harbrecht, B. G., Franklin, G. A., Smith, J. W., Miller, K. R., et al. (2015). Does chest tube location matter? An analysis of chest tube position and the need for secondary interventions. Journal of Trauma and Acute Care Surgery, 78(2), 386-390.https://doi.org/10.1097/TA.0000000000000479

Bokhari, F., Brakenridge, S., Nagy, K., Roberts, R., Smith, R., Joseph, K., et al. (2002). Prospective evaluation of the sensitivity of physical examination in chest trauma. Journal of Trauma, 53(6), 1135-1138. https://doi.org/10.1097/00005373-200212000-00017

Brasel, K., Stafford, R., Weigelt, J., Tenquist, J., & Borgstrom, D. (1999). Treatment of occult pneumothoraces from blunt trauma. Journal of Trauma, 46, 987-990. https://doi.org/10.1097/00005373-199906000-00001

Bushby, N., Fitzgerald, M., Cameron, P., Marasco, S., Bystrzycki, A., Rosenfeld, V. J., et al. (2005). Prehospital intubation and chest decompression is associated with unexpected survival in major thoracic blunt trauma. Emergency Medicine Australasia, 17(5-6), 443-449.https://doi.org/10.1111/j.1742-6723.2005.00775.x

Celso, B., Tepas, J., Langland-Orban, B., Pracht, E., Papa, L., Lottenberg, L., et al. (2006). A systematic review and meta-analysis comparing outcome of severely injured patients treated in trauma centers following the establishment of trauma systems. Journal of Trauma Acute Care Surgery, 60(2), 371-378. https://doi.org/10.1097/01.ta.0000197916.99629.eb

Chan, K. K., Joo, D. A., McRae, A. D., Takwoingi, Y., Premji, Z. A., Lang, E., et al. (2020). Chest ultrasonography versus supine chest radiography for diagnosis of pneumothorax in trauma patients in the emergency department. Cochrane Database of Systematic Reviews, 7, CD013031.https://doi.org/10.1002/14651858.CD013031.pub2

Chang, S. H., Kang, Y. N., Chiu, H. Y., & Chiu, Y. H. (2018). A systematic review and meta-analysis comparing pigtail catheter and chest tube as the initial treatment for pneumothorax. Chest, 153(5), 1201-1212. https://doi.org/10.1016/j.chest.2018.01.04

Chen, S. C., Markmann, J. F., Kauder, D. R., & Schwab, C. W. (1997). Hemopneumothorax missed by auscultation in penetrating chest injury. Journal of Trauma, 42(1), 86-89.https://doi.org/10.1097/00005373-199701000-00015

Claridge, J. A., Leukhardt, W. H., Golob, J. F., McCoy, A. M., & Malangoni, M. A. (2010). Moving beyond traditional measurement of mortality after injury: Evaluation of risks for late death. Journal of the American College of Surgeons, 210(5), 788-794.https://doi.org/10.1016/j.jamcollsurg.2009.12.035

Davis, D. P., Pettit, K., Rom, C. D., Poste, J. C., Sise, M. J., Hoyt, D. B., et al. (2005). The safety and efficacy of prehospital needle and tube thoracostomy by aeromedical personnel. Prehospital Emergency Care, 9(2), 191-197. https://doi.org/10.1080/1090312059092450

Deakin, C., Davies, G., & Wilson, A. (1995). Simple thoracostomy avoids chest drain insertion in prehospital trauma. Journal of Trauma, 39, 373-374.https://doi.org/10.1097/00005373-199508000-00031

Dominguez, K. M., Ekeh, A. P., Tchorz, K. M., Woods, R. J., Walusimbi, M. S., Saxe, J. M., et al. (2013). Is routine tube thoracostomy necessary after prehospital needle decompression for tension pneumothorax? American Journal of Surgery, 205(3), 329-332. https://doi.org/10.1016/j.amjsurg.2013.01.004

Enderson, B., Abdalla, R., Frame, S., Casey, M., Gould, H., & Maull, K. (1993). Tube thoracostomy for occult pneumothorax: A prospective randomized study of its use. Journal of Trauma, 35, 726-729. https://doi.org/10.1097/00005373-199311000-00013

Hirshberg, A., Thomson, S. R., & Huizinga, W. K. (1988). Reliability of physical examination in penetrating chest injuries. Injury, 19(6), 407-409.https://doi.org/10.1016/0020-1383(88)90135-0

Huber-Wagner, S., Lefering, R., Qvick, M., Kay, M. V., Paffrath, T., Mutschler, W., et al. (2007). Outcome in 757 severely injured patients with traumatic cardiorespiratory arrest. Resuscitation, 75, 276-285. https://doi.org/10.1016/j.resuscitation.2007.04.018

Hyde, J., Sykes, T., & Graham, T. (1997). Reducing morbidity from chest drains. BMJ, 314(7085), 914-915.https://doi.org/10.1136/bmj.314.7085.914

Inaba, K., Lustenberger, T., Recinos, G., Georgiou, C., Velmahos, G. C., Brown, C., et al. (2012). Does size matter? A prospective analysis of 28-32 versus 36-40 French chest tube size in trauma. Journal of Trauma and Acute Care Surgery, 72(2), 422-427.https://doi.org/10.1097/TA.0b013e3182452444

Johnson, G. (1996). Traumatic pneumothorax: Is a chest drain always necessary? Journal of Accident & Emergency Medicine, 13(3), 173-174.https://doi.org/10.1136/emj.13.3.173

Kirkpatrick, A. W., Rizoli, S., Ouellet, J. F., Roberts, D. J., Sirois, M., Ball, C. G., et al. (2013). Occult pneumothoraces in critical care: A prospective multicenter randomized controlled trial of pleural drainage for mechanically ventilated trauma patients with occult pneumothoraces. Journal of Trauma Acute Care Surgery, 74(3), 747-754.https://doi.org/10.1097/TA.0b013e3182827158s

Kleber, C., Giesecke, M. T., Tsokos, M., Haas, N. P., & Buschmann, C. T. (2013). Trauma-related preventable deaths in Berlin 2010: Need to change prehospital management strategies and trauma management education. World Journal of Surgery, 37(5), 1154-1161.https://doi.org/10.1007/s00268-013-1964-2

Kulvatunyou, N., Erickson, L., Vijayasekaran, A., Gries, L., Joseph, B., Friese, R. F., et al. (2014). Randomized clinical trial of pigtail catheter versus chest tube in injured patients with uncomplicated traumatic pneumothorax. British Journal of Surgery, 101(2), 17-22.https://doi.org/10.1002/bjs.9377

Laan, D. V., Vu, T. D., Thiels, C. A., Pandian, T. K., Schiller, H. J., Murad, M. H., et al. (2016). Chest wall thickness and decompression failure: A systematic review and meta-analysis comparing anatomic locations in needle thoracostomy. Injury, 47(4), 797-804.https://doi.org/10.1016/j.injury.2015.11.04

Leigh-Smith, S., & Harris, T. (2005). Tension pneumothorax - Time for a re-think. Emergency Medicine Journal, 22, 8-16. https://doi.org/10.1136/emj.2003.010421

Maezawa, T., Yanai, M., Huh, J. Y., & Ariyoshi, K. (2020). Effectiveness and safety of small-bore tube thoracostomy (≤20 Fr) for chest trauma patients: A retrospective observational study. American Journal of Emergency Medicine, 38(12), 2658-2660.https://doi.org/10.1016/j.ajem.2020.09.028

Mann, N. C., Mullins, R. J., MacKenzie, E. J., Jurkovich, G. J., & Mock, C. N. (1999). Systematic review of published evidence regarding trauma system effectiveness. Journal of Trauma, 47(3), S25-S33.https://doi.org/10.1097/00005373-199909001-00007

Martin, M., Satterly, S., Inaba, K., & Blair, K. (2012). Does needle thoracostomy provide adequate and effective decompression of tension pneumothorax? Journal of Trauma and Acute Care Surgery, 73(6), 1412-1417. https://doi.org/10.1097/TA.0b013e31825ac511

Massarutti, D., Trillo, G., Berlot, G., Tomasini, A., Bacer, B., D'Orlando, L., et al. (2006). Simple thoracostomy in prehospital trauma management is safe and effective: A 2-year experience by helicopter emergency medical crews. European Journal of Emergency Medicine, 13(5), 276-280.https://doi.org/10.1097/00063110-200610000-00006

Mattson, M. E., Cai, R., & Woodward, A. (2015). Emergency department visits vs. fatalities among substance-impaired underage youths involved in motor vehicle crashes. Journal of Safety Research, 53, 45-51. https://doi.org/10.1016/j.jsr.2015.03.007

McConnell, K. J., Newgard, C. D., Mullins, R. J., Arthur, M., & Hedges, J. R. (2005). Mortality benefit of transfer to level I versus level II trauma centers for head-injured patients. Health Services Research, 40(2), 435-458. https://doi.org/10.1111/j.1475-6773.2005.0u367.x

McPherson, J. J., Feigin, D. S., & Bellamy, R. F. (2006). Prevalence of tension pneumothorax in fatally wounded combat casualties. Journal of Trauma, 60(3), 573-578.https://doi.org/10.1097/01.ta.0000209179.79946.92

Mendeloff, J. M., & Cayten, C. (1991). Trauma systems and public policy. Annual Review of Public Health, 12(1), 401-424.https://doi.org/10.1146/annurev.pu.12.050191.002153

Mistry, N., Bleetman, A., & Roberts, K. J. (2009). Chest decompression during the resuscitation of patients in prehospital traumatic cardiac arrest. Emergency Medicine Journal, 26(10), 738-740. https://doi.org/10.1136/emj.2008.065599

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & Group, P. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. PLOS Medicine, 6(7), e1000097. https://doi.org/10.1371/journal.pmed.1000097

Moore, F. O., Goslar, P. W., Coimbra, R., Velmahos, G., Brown, C. V., Coopwood, T. B. Jr., et al. (2011). Blunt traumatic occult pneumothorax: Is observation safe? Results of a prospective, AAST multicenter study. Journal of Trauma, 70(5), 1019-1023. https://doi.org/10.1097/TA.0b013e318213f727

Moore, L., Champion, H., Tardif, P.-A., Kuimi, B.-L., O'Reilly, G., Leppaniemi, A., et al. (2018). Impact of trauma system structure on injury outcomes: A systematic review and meta-analysis. World Journal of Surgery, 42(5), 1327-1339.https://doi.org/10.1007/s00268-017-4292-0

Nosher, J. L., & Siegel, R. (1993). Over-the-wire placement of large bore thoracostomy tubes. Cardiovascular and Interventional Radiology, 16(3), 195-197. https://doi.org/10.1007/BF02641893

Peitzman, A. B., Courcoulas, A. P., Stinson, C., Udekwu, A. O., Billiar, T. R., & Harbrecht, B. G. (1999). Trauma center maturation: Quantification of process and outcome. Annals of Surgery, 230(1), 87-94. https://doi.org/10.1097/00000658-199907000-00013

Press, G. M., Miller, S. K., Hassan, I. A., Alade, K. H., Camp, E., Junco, D. D., et al. (2014). Prospective evaluation of prehospital trauma ultrasound during aeromedical transport. Journal of Emergency Medicine, 47(6), 638-645. https://doi.org/10.1016/j.jemermed.2014.07.056

Quick, J. A., Uhlich, R. M., Ahmad, S., Barnes, S. L., & Coughenour, J. P. (2016). In-flight ultrasound identification of pneumothorax. Emergency Radiology, 23(1), 3-7. https://doi.org/10.1007/s10140-015-1348-z

Remerand, F., Luce, V., Badachi, Y., Lu, Q., Bouhemad, B., & Rouby, J. J. (2007). Incidence of chest tube malposition in the critically ill: A prospective computed tomography study. Anesthesiology, 106(6), 1112-1119. https://doi.org/10.1097/01.anes.0000267594.80368.01

Roberts, D. J., Leigh-Smith, S., Faris, P. D., Blackmore, C., Ball, C. G., Robertson, H. L., et al. (2015). Clinical presentation of patients with tension pneumothorax: A systematic review. Annals of Surgery. https://doi.org/10.1097/SLA.0000000000001073

Rutherford, R. B., Hurt, H. H. Jr., Brickman, R. D., & Tubb, J. M. (1968). The pathophysiology of progressive, tension pneumothorax. Journal of Trauma, 8(2), 212-227.https://doi.org/10.1097/00005373-196803000-00009

Sampalis, J. S., Denis, R., Frechette, P., Brown, R., Fleiszer, D., & Mulder, D. (1997). Direct transport to tertiary trauma centers versus transfer from lower level facilities: Impact on mortality and morbidity among patients with major trauma. Journal of Trauma Acute Care Surgery, 43(2), 288-296.https://doi.org/10.1097/00005373-199708000-00014

Schmidt, U., Stalp, M., G. T., Blauth, M., Kimball, I., & Tscherne, H. (1998). Chest decompression of blunt chest injuries by physician in the field: Effectiveness and complications. Journal of Trauma, 44, 98-100. https://doi.org/10.1097/00005373-199801000-00010

Seid, M., Azazh, A., Enquselassie, F., & Yisma, E. (2015). Injury characteristics and outcome of road traffic accident among victims at Adult Emergency Department of Tikur Anbessa specialized hospital, Addis Ababa. BMC Emergency Medicine, 15, 10.https://doi.org/10.1186/s12873-015-0035-4

Staub, L. J., Biscaro, R. R. M., Kaszubowski, E., & Maurici, R. (2018). Chest ultrasonography for the emergency diagnosis of traumatic pneumothorax and haemothorax: A systematic review and meta-analysis. Injury, 49(3), 457-466.https://doi.org/10.1016/j.injury.2018.01.033

Symbas, P. (1989). Chest drainage tubes. Surgical Clinics of North America, 69, 41-46.https://doi.org/10.1016/S0039-6109(16)44733-X

Tanizaki, S., Maeda, S., Sera, M., Nagai, H., Hayashi, M., Azuma, H., et al. (2017). Small tube thoracostomy (20-22 Fr) in emergent management of chest trauma. Injury, 48(9), 1884-1887.https://doi.org/10.1016/j.injury.2017.06.021

Thal, A. P., & Quick, K. L. (1988). A guided chest tube for safe thoracostomy. Surgery, Gynecology & Obstetrics, 167(6), 517.

Thomson, S. R., Huizinga, W. K., & Hirshberg, A. (1990). Prospective study of the yield of physical examination compared with chest radiography in penetrating thoracic trauma. Thorax, 45(8), 616-619.https://doi.org/10.1136/thx.45.8.616

Tomlinson, M. A., & Treasure, T. (1997). Insertion of a chest drain: How to do it. British Journal of Hospital Medicine, 58(6), 248-252.

Tufanaru, C. M. Z., Aromataris, E., Campbell, J., & Hopp, L. (2017). Chapter 3: Systematic reviews of effectiveness. In E. Aromataris & Z. Munn (Eds.), Joanna Briggs Institute Reviewer's Manual (pp. 1-14). The Joanna Briggs Institute.

Waters, J. M., & Wells, C. H. (1973). The effects of a modern emergency medical care system in reducing automobile crash deaths. Journal of Trauma Acute Care Surgery, 13(7), 645-647.https://doi.org/10.1097/00005373-197307000-00009

Waydhas, C., & Sauerland, S. (2007). Pre-hospital pleural decompression and chest tube placement after blunt trauma: A systematic review. Resuscitation, 72(1), 11-25.https://doi.org/10.1016/j.resuscitation.2006.06.025

Yadav, K., Jalili, M., & Zehtabchi, S. (2010). Management of traumatic occult pneumothorax. Resuscitation, 81(9), 1063-1068.https://doi.org/10.1016/j.resuscitation.2010.04.030

Youmans, R. L., & Brose, R. A. (1970). A basis for classifying hospital emergency services. JAMA, 213(10), 1647-1651.https://doi.org/10.1001/jama.1970.03170360045008