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Early Tracheostomy in Trauma and Surgically Ill Patients: Have We Made Any Progress in Identifying the Right Patients?

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Abstract
Early tracheostomy may improve pulmonary outcomes and reduce ICU and hospital burden in critically injured patients, but survival benefits remain uncertain. This review outlines current evidence, subgroup findings, and key priorities for future research and clinical decision-making.

Key words: Early tracheostomy; Trauma; Burn injury; Mechanical ventilation; Traumatic brain injury; Spinal cord injury

Introduction

Critically injured trauma and burn patients frequently require mechanical ventilation, reported in up to 50% of all intensive care unit (ICU)-admitted trauma patients[1] and 19–33% of burn patients.[2,3] Among these, a subset experience prolonged mechanical ventilation, commonly defined as mechanical ventilation exceeding 7–21 days[4] and accounting for approximately 10% of all trauma patients undergoing mechanical ventilation for respiratory failure.[5] Risk factors for prolonged mechanical ventilation include older age, preexisting comorbidities, severe traumatic brain injury (TBI), spinal cord injury, and inhalational injury in burn patients.[6–8] In the trauma population, patients with severe thoracic trauma, male sex and greater transfusion requirements are also independently associated with prolonged ventillation.[9] When prolonged mechanical ventilation occurs it is associated with adverse outcomes including higher rates of pneumonia, increased morbidity and mortality, and higher health care costs.[10]

Tracheostomy serves as a method of safely providing prolonged ventilatory support and facilitating weaning of mechanical ventilation. The procedure is performed in an estimated 12.3% of mechanically ventilated trauma patients, although this rate can vary significantly depending

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on the institution.[11,12] While sometimes mandated by traumatic facial or airway injuries, the decision to perform tracheostomy in critically ill trauma patients with respiratory failure is often complex. Potential advantages include reduced sedation requirements, improved pulmonary hygiene, earlier mobilization, and improved patient comfort. These benefits are juxtaposed with procedural risks including bleeding, infection, airway loss, tracheal stenosis or rarely, tracheoinnominate fistula, as well as navigating challenges to perform the procedure such patient instability or high ventilator settings.[13]

Determining the optimal timing for tracheostomy remains controversial, including in traumatically injured patients with respiratory failure. In many cases, the decision occurs late in the clinical course after multiple intubations or reintubations and the onset of complications such as ventilator-associated pneumonia. For selected patients, early tracheostomy performed within 5–10 days of initiation of mechanical ventilation may reduce morbidity and mortality, ventilator days, and ICU length of stay.

The goal of this review is to synthesize the evidence on early tracheostomy in critically ill trauma and burn patients, identify subgroups most likely to benefit, and highlight limitations of existing data. In doing so, we hope to provide clinicians a clearer understanding of the rationale, outcomes, and future directions of early tracheostomy in the injured population.

Proposed Clinical Rationale Behind Early Tracheostomy

In critically injured trauma patients, prolonged endotracheal intubation contributes to laryngeal injury, increased airway resistance, difficult pulmonary hygiene, and the need for sedation and higher analgesia. Tracheostomy provides a more stable airway, reduces anatomic dead space, facilitates secretion clearance, allows for reduction in sedative use, and facilitates ventilator weaning.[13,14] Once respiratory support is provided by a tracheostomy rather than an endotracheal tube, patients can perform spontaneous breathing trails without positive-pressure support, strengthen the diaphragm, and be safely reconnected to the ventilator if respiratory failure occurs. Early tracheostomy may therefore reduce the complications of extended endotracheal intubation and provide improved pulmonary mechanics, decreased incidence of ventilator-associated pneumonia, and shorter durations of mechanical ventilation and ICU stay.

Beyond physiologic advantages, tracheostomy can enhance patient comfort, enable earlier mobilization and communication, and simplify nursing care.[14] Economic analysis also suggest a benefit, with cost-savings models showing early tracheostomy was associated with cost savings of approximately $4300 (2016 USD) per ICU stay compared to when performed at or beyond four days, equivalent to $5,800 2025-adjusted dollars.[15] In a different analysis at a US Level I Trauma Center, the benefit of early tracheostomy was estimated to be an excess of $50,000 per patient.[16] Additionally, the option to perform tracheostomy either as an open surgical procedure in the operating room or by percutaneous technique at the bedside provides important benefits for flexibility, timing, resource utilization and access for delivering this intervention.

Despite these advantages, the decision to perform tracheostomy early must still be individualized.[17] Surgical airway creation is not a benign procedure and carries significant risks. Early complications include bleeding, infection, acute tube obstruction or dislodgment, pneumothorax or pneumomediastinum, and rarely airway fire during the procedure. Late complications include ischemia, tracheal wall necrosis and stenosis, and tracheoesophageal or tracheoinominate fistula (<1%).[13] The risk of laryngotracheal stenosis in particular may not be significantly reduced by early tracheostomy.[18] Moreover, tracheostomy may be contraindicated in patients who cannot tolerate brief interruptions in ventilatory support due to severe respiratory failure. Shared decision making among the patient or family, critical care team, and surgeon is needed to balance these potential benefits with procedural risks and the likelihood of prolonged ventilator dependence.

Defining Early Versus Late

The definition of early tracheostomy is not consistent and varies widely across studies. Most commonly, early tracheostomy is defined as occurring at 3–10 days, whereas late tracheostomy typically refers to procedures performed at more than 10–14 days. The Eastern Association for the Surgery of Trauma (EAST) defines early tracheostomy as early as 3-7 days,[19] although several studies have investigated hyper-early tracheostomy placement at 2 days for the injured patient.[20,21]

One approach to defining the optimal timing of tracheostomy is to identify the point at which the patient's outcome risk profile changes. For example, Keenan et al.

analyzed a large cohort of trauma patients without severe TBI and plotted time to tracheostomy against inpatient mortality, demonstrating an inflection point 10 days after injury and a threshold for subsequent analysis. Another group determined this threshold to be at 4.8 days for respiratory complications.[22] Ultimately, the lack of uniformity in the definition of early tracheostomy highlights the need for timing to be interpreted within the context of patient condition, institutional practice, and study design.

Early Tracheostomy in Trauma Patients

Early tracheostomy does not seem to benefit all patients equally, and some subgroups may benefit more than others.[23] In the general trauma population, early tracheostomy shows an association with decreased ICU length of stay, decreased time on mechanical ventilation, and a decreased rates of pneumonia, but without a mortality benefit as compared to late tracheostomy.

In one of the earliest prospective randomized control trials in trauma patients, Rodriguez et al. found in 1990 that early tracheostomy was associated with a significant decreased in duration of mechanical ventilation, ICU and hospital length of stay, and lower rate of pneumonia.[24] After a review of the literature, the Eastern Association for the Surgery of Trauma guidelines (2009, update in progress as of December 2025) recommend early tracheostomy at 3–7 days in injured patients anticipated to receive mechanical ventilation for at least 7 days.[19]

More recent literature has remained consistent. In a 2017 meta-analysis including both randomized controlled trials and observational studies of early tracheostomy (3–10 days) in trauma patients, early tracheostomy was associated with reduced ICU and hospital length of stay, shorter duration of mechanical ventilation, and a lower risk of pneumonia, but no difference in mortality.[25] Similarly, a 2025 Cochrane systematic review and meta-analysis of one randomized controlled trial and five non-randomized interventional studies found little to no effect of early tracheostomy (<10 days) on mortality, and a suggestion that early tracheostomy may reduce ICU length of stay, however with very uncertain evidence.[26]

Similar results have been found in a variety of recent observational studies. A single trauma-center propensity score matched study of trauma patients found shorter overall and post-tracheostomy duration of mechanical ventilation, lower rate of pneumonia in the early tracheostomy group (≤7 days), and no difference in mortality.[27] Similar findings were echoed by two recent multi-center retrospective reviews.[28,29] When patients are stratified by injury severity and probability of survival, one review of a state trauma registry suggests that the benefits of early tracheostomy do not hold for patients with a low probability of survival.[30]

The American College of Surgeons Trauma Quality Improvement Program (TQIP) and National Trauma Data Bank (NTDB) have been additional sources of observational data for evaluating tracheostomy timing in trauma patients. To isolate the effect of timing independent of severe neurologic injury, one 2015 NTDB analysis examined non-neurologically injured trauma patients and found that early tracheostomy (4–10 days) was associated with lower odds of pneumonia, shorter duration of mechanical ventilation, and reduced ICU and hospital length of stay, but paradoxically with higher odds of mortality compared with later tracheostomy.[31] Moreover, these same benefits may persist when tracheostomy is performed as early as 48 hours.[20] These large database analyses highlight the potential benefits of early tracheostomy in reducing pulmonary and resource-related complications, while underscoring persistent uncertainty or lack of impact regarding survival.

Early Tracheostomy in Burn Patients

Evidence on early tracheostomy in burn patients is limited and mixed. These patients often develop additional respiratory compromise from inhalational injury, airway edema, and the physiologic effects of large-volume crystalloid resuscitation. Prolonged mechanical ventilation in this population correlates with greater burn severity, moderate or severe inhalation injury, low initial albumin, and elevated lactate levels.[8]

In one of the largest and most recent observational, propensity-matched studies, early tracheostomy (≤10 days) was associated with shorter ICU and hospital stays and fewer ventilator days, though pneumonia rates were unchanged.[32] In contrast, an older randomized controlled trial comparing early (mean 4 days) versus delayed tracheostomy found no significant differences in ventilator duration, pneumonia, length of stay, or survival, perhaps reflecting limited sample size (n = 44).[33] Similarly, an advanced causal analysis of observational data from 680 severely burned patients (with 94 tracheostomies) found no mortality benefit from earlier timing.[34] A smaller single-center study noted higher discharge functional scores among early tracheostomy patients, though this may reflect uncontrolled baseline differences.[35] Overall, current literature does not

demonstrate a clear survival or complication benefit for early tracheostomy in burn patients, and larger prospective studies are needed to define its role.

Early Tracheostomy in Traumatic Brain Injury

In contrast to the trauma and burn population, patients with TBI often require a tracheostomy primarily for airway protection rather than solely prolonged mechanical ventilation. Nevertheless, these patients derive benefits from early tracheostomy, particularly regarding pulmonary and resource-related outcomes, and with stronger evidence of a mortality benefit as compared to burn and general trauma patients.

A 2023 systematic review including 19 studies and 6,253 TBI patients reported that early tracheostomy (median 6 days) as compared with late tracheostomy (median 17 days) was associated with shorter duration of mechanical ventilation, lower pneumonia rates, and decreased ICU and hospital length of stay.[36] Similarly, a meta-analysis of ten randomized controlled trials involving patients with acute brain injury (traumatic and nontraumatic) found that early tracheostomy reduced long-term mortality, potentially ICU mortality, duration of mechanical ventilation, and ICU length of stay; importantly this was without a difference in laryngeal complications between the groups.[37]

Data from the CENTER-TBI study further demonstrated that early tracheostomy (≤7 days) was associated with a lower mortality and shorter hospital length of stay, with the late tracheostomy group experiencing a 69% higher odds of death.[38] Findings from multiple additional meta-analyses and observational studies have consistently shown reductions in complications, ventilation duration, and length of stay, though the effect on morality is variable.[39–42] One meta-analysis reported an increase in mortality among TBI patients undergoing early tracheostomy; however, the authors noted that this association may reflect the greater severity and complexity of illness in patients selected for early tracheostomy rather than a causal effect of timing itself, and emphasized the need for well-designed randomized controlled trials.[43]

A large state trauma registry study helps explain the variation in mortality among studies: in more than 3,000 patients with severe TBI, early tracheostomy (≤7 days) was associated with shorter ICU and hospital stays, fewer complications, and greater functional independence at discharge. While late tracheostomy patients had slightly higher survival, likely reflecting a selection of less severely injured patients, those in good condition on arrival (Injury Severity Score, ISS, <25) benefited most from early tracheostomy. This group was about twice as likely to have a good composite outcome of mortality, length of stay, and functional status, suggesting that early tracheostomy offers the greatest advantage in TBI patients with meaningful recovery potential.[44]

Overall, among patients with TBI, early tracheostomy is consistently linked to fewer complications and shorter ICU and hospital stays, and may also confer a mortality benefit, although evidence remains mixed.

Early Tracheostomy in Spinal Cord Injury

Similar to its role in TBI, tracheostomy in patients with spinal cord injury serves functions beyond ventilator weaning and is often performed for airway protection and facilitation of pulmonary hygiene given these patients often lack motor function of the chest and abdominal muscles involved in respiration. In this population, of whom 80% will die of respiratory complications,[45] early tracheostomy has convincing benefits in reduction of pulmonary complications and length of stay, but not mortality.

Multiple analyses of the ACS TQIP database has shown that early tracheostomy (≤4, ≤7 and ≤10 days) in patient with cervical spinal cord or cervical spine injury was associated with lower rates of respiratory complications, more ventilator- and ICU-free days, and shorter hospital stay, though no difference in in-hospital mortality.[22,46,47] One of the most recent observational studies of 10 years of the TQIP database further refined this association, demonstrating that and both ultra-early (≤3 days) and early tracheostomy (4–7 days) after cervical spinal cord injury were linked to reductions in respiratory complications, ventilator days, ICU and hospital length of stay—but again not mortality.[48]

Most strongly, a systematic review and meta-analysis of 17 studies of randomized controlled trials and cohort studies regarding early tracheostomy in this population found that early tracheostomy was associated with shorter duration of mechanical ventilation, reduced ICU and hospital length of stay, and lower rates of ventilator-associated pneumonia and tracheostomy-related complications, but again no difference in short-term mortality.[49] An additional meta-analysis of existing retrospective cohort studies had similar findings.[50] Although no randomized controlled trials have been conducted in this population, existing evidence consistently supports multiple clinical benefits of early tracheostomy, including improved

respiratory and length of stay-related outcomes, without a demonstrable mortality advantage.

Early Tracheostomy in Other Injured Groups

Outside of patients with traumatic brain, spinal cord, or burn injuries, additional trauma subgroups at high risk for prolonged ventilation have received comparatively little attention regarding the role and timing of tracheostomy. One TQIP analysis showed that age >70, flail chest, major operative interventions, >5 days ventilator days, and underlying COPD were all independent predictors of need for tracheostomy.[51] Despite this finding, existing literature regarding early tracheostomy in these groups or other subpopulations is sparse.

In geriatric patients (age ≥65) with isolated TBI in the TQIP database (2017–2020), early tracheostomy (<10 days) was associated with shorter hospital length of stay, fewer ventilator days, and lower rate of deep vein thrombosis, without a difference in mortality.[52]

Another TQIP study reported that early tracheostomy (<5 days) was associated with fewer ventilator days, lower pneumonia rates, and shorter hospital stay across both younger (<65 years) and older (≥65 years) adults, again without differences in mortality.[53]

Evidence within the patient with significant chest wall injury is even more limited. This lack of literature is especially notable as one-quarter of mechanically ventilated patients with rib fractures undergo tracheostomy, and this subset of patients tends to be severely injured (mean ISS of 27.5).[54] In a small retrospective review (n = 124) of patients with multiple rib fractures (mean 5.2) who underwent tracheostomy, those who underwent the procedure early (≤7 days) had shorter ICU length of stay and duration of mechanical ventilation, although with a higher unadjusted mortality.[55]

Finally, early tracheostomy has also been studied in pediatric trauma, particularly among children with TBI, where the timing of airway management may significantly influence outcomes. In a large retrospective cohort study, pediatric TBI patients undergoing late tracheostomy (>9 days) were more likely to face inpatient complications such as acute kidney injury, deep vein thrombosis, pulmonary embolism, aspiration pneumonitis, pneumonia, or ARDS. Additionally, the early tracheostomy group had lower length of stay and duration of mechanical ventilation, although the propensity score matching technique in this observational study only matched on age, gender, and TBI severity.[56]

Predicting Need for Prolonged Mechanical Ventilation

The potential benefits of early tracheostomy cannot be fully realized without accurate identification of patients likely to require prolonged mechanical ventilation. Anticipating which patients will need extended ventilatory support also enables more timely airway management, efficient ICU resource allocation, and earlier family discussions regarding prognosis. Although prolonged ventilation is commonly defined as ventilation support lasting beyond 7–21 days, prediction remains challenging and reflects a complex interplay between patient injury pattern, physiologic derangements, and comorbidities.

In general trauma patients, one analysis found that the most predictive factors of prolonged mechanical ventilation include need for vasopressor support, FiO_2, the PaO_2/FiO_2 ratio, and acute physiology and chronic health evaluation (APACHE II) score.[4] Other retrospective literature has also supported age and decreased GCS as factors.[57] In burn patients, inhalational injury, burn severity, initial albumin, lactate, vasopressor use, and blood transfusion have been found to be associated with prolonged mechanical ventilation.[8,34]

In TBI patients, receiving blood transfusions during resuscitation, acquiring ventilator associated pneumonia, and ISS are among the more important predictors of prolonged mechanical ventilation.[58] Although not predicting prolonged ventilation**,** a systematic review of 12 observational studies of TBI patients found that need for tracheostomy was associated with age, comorbidities, injury pattern and type, and specific interventions including craniotomy or laparotomy.[59]

For spinal cord injury patients, tracheostomy placement has been linked to neurological level of injury, American Spinal Injury Association Impairment Scale, ISS, and age.[60] In all these injury subgroups, the literature underscores the multifactorial determinants of need for mechanical ventilation, and an opportunity to develop prediction models tailed to specific injury populations.

Limitations of Existing Evidence and Future Directions

While there is a plethora of literature regarding the benefits of early tracheostomy, there remain gaps and areas where additional investigation and high-quality evidence is needed. First, the current body of literature is dominated by retrospective studies. While advanced

statistical analysis can attempt causal inference from observational data, all these observational studies suffer from unmeasured confounders. In particular, the relationships among key outcomes such as duration of mechanical ventilation, pulmonary complications, and hospital or ICU length of stay are interdependent and likely reinforce one another, creating positive feedback loops that are difficult to untangle analytically. This is in addition to the systematic selection biases in which patients receive a tracheostomy, given those who are sicker or neurologically devastated are more likely to receive a tracheostomy later or not at all. Even with adjustment or propensity matching approaches these systematic differences cannot be fully eliminated.

Survivorship bias also likely plays a significant role in observational data and some trials, as patients must survive long enough to receive a tracheostomy and those who die before the given time threshold (e.g. 7–10 days) cannot be included in the late tracheostomy group. This effect increases the rate of survivorship in the late tracheostomy group in comparison to the early tracheostomy group. Alongside excluding patients with early deaths, advanced statistical approaches such as treating tracheostomy as a time-dependent exposure with weighted marginal structural Cox models[34] can reduce the effects of survivorship and other biases in observational data; however, these methods are rarely applied in the current literature.

Finally, the definition of early tracheostomy itself remains inconsistent across studies and ranges from 2 to 14 days, and patient populations are heterogeneous, encompassing diverse injury mechanisms, severities, and comorbidities. Together, these limitations underscore the need for prospective, standardized, and population-specific investigations to clarify the causal impact of tracheostomy timing on outcomes in trauma and burn patients.

Future work should not only address these analysis and standardization concerns but also emphasize the importance of high quality prospective and randomized controlled studies. Within the trauma and burn populations in particular, there is a lack of randomized intervention studies, and among interventional studies in general the evidence is uncertain and definitions of early tracheostomy heterogenous.[26] Standardizing the definition of early versus late tracheostomy will be critical to improving comparability across studies and facilitating meta-analytic synthesis.

Additional investigation should also continue to explore the impact of procedural technique, specifically percutaneous versus open tracheostomy, and conduct analyses within distinct injury subgroups such as those mentioned here: traumatic brain injury, spinal cord injury, and burns. These groups differ substantially in both pathophysiology and indication for tracheostomy, and subgroup-specific data are essential for generating clinically meaningful recommendations.

Finally, efforts to quantify economic implications of early tracheostomy are worth expansion from what is currently available. Although a consistent mortality benefit has not been demonstrated, early tracheostomy is repeatedly associated with reductions in ventilator duration, ICU and hospital length of stay, and overall resource utilization. Comprehensive cost-effectiveness analyses incorporating these outcomes could help define the broader system-level value of early tracheostomy.

Conclusions

Early tracheostomy for trauma and burn patients is consistently associated with fewer ventilator days, lower pneumonia rates, and shorter ICU and hospital stays, but a survival advantage remains uncertain or nonexistent. The greatest clinical gains may appear in subgroups with higher recovery potential, whereas benefit is less clear in patients with low probability of survival or profound multisystem injury. Given heterogeneity in early tracheostomy timing definitions, patient injury patterns, and analytic methods, clinicians should individualize decisions and integrate probability of prolonged respiratory failure into shared decision-making with patients and families. Looking forward, standardizing "early" versus "late," applying more rigorous statistical methods to observational data, and developing validated prediction tools for prolonged ventilation are essential to provide early tracheostomy to the patients most likely to receive benefits. Robust prospective trials and cost-effectiveness studies will be critical to define best practice and clarify the true clinical and system-level value of early tracheostomy.

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Table 1: Selected Predictors of Prolonged Mechanical Ventilation

Population	Selected Predictors
General trauma	Vasopressor use, FiO_2, PaO_2/FiO_2 ratio, APACHE II score, older age, low GCS
TBI	Blood transfusion during resuscitation, ventilator-associated pneumonia, higher ISS, low GCS
Spinal cord injury	Neurologic level of injury, ASIA impairment scale, ISS, age
Burn	Inhalational injury, %TBSA, low albumin, high lactate, vasopressor use, transfusion
Other	COPD, flail chest, age >70, major operative intervention, ≥5 ventilator days

Figure 1: Conceptual Framework of Early Tracheostomy in Trauma and Surgical Patients

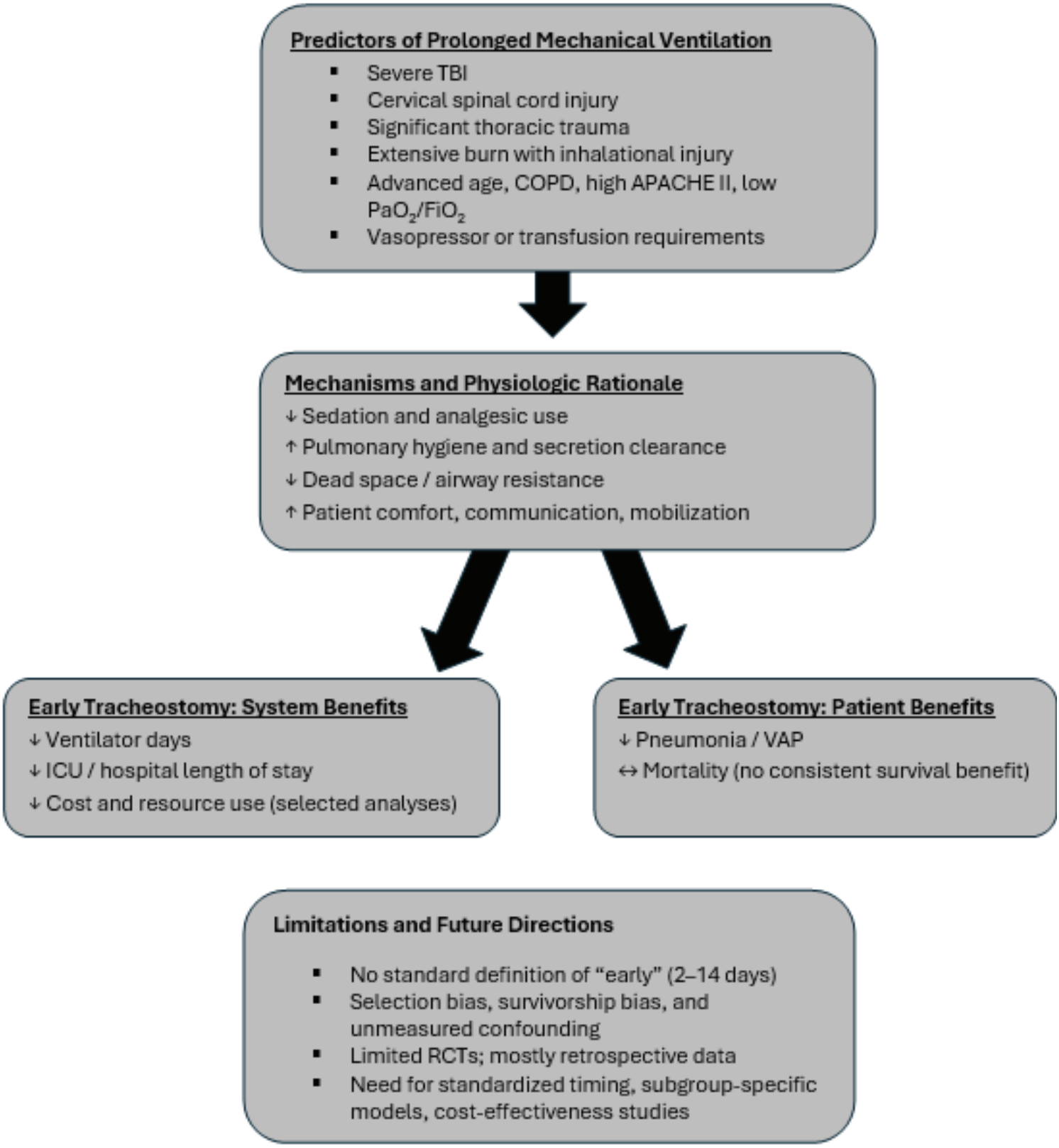


Table 2: Selected Key Studies Evaluating Early vs. Late Tracheostomy in Trauma Populations

Population	Study/Year	Design	Early Definition	Mortality	Pneumonia	Duration of Mechanical Ventilation	ICU / Hospital Length of Stay	Notes
General trauma	Rodriguez et al., 1990	RCT	≤7 days	↔	NA	↓	↓ / ↓	
	EAST, 2009	Expert guidelines	3–7 days	↔	↓	↓	↓ / NA	Level III evidence (mortality is level I)
	Cai et al., 2017	Systematic review/meta-analysis	3–10 days	↔	↓	↓	↓ / ↓	
	Ansems et al., 2025	Systematic review/meta-analysis	<10 days	↔	↔	NA	↔ / NA	Low/uncertain evidence
Burn	Shah et al., 2002	Retrospective review	≤10 days	NA	↔	↓	↓ / ↓	3 large databases included.
	Saffle et al., 2002	RCT	4 days (average)	↔	↔	↔	↔	Small sample size (n = 44)
	Tsuchiya et al., 2018	Retrospective review	≤5 days	↔	NA	NA	NA	Advanced causal analysis
TBI	EAST, 2009	Expert guidelines	3–7 days	↔	NA	↓	↓	Level II evidence (mortality is level I)
	Bertini et al., 2023	Systematic review/meta-analysis	6 days (median)	NA	↓	↓	↓ / ↓	
	McCredie et al., 2017	Systematic review/meta-analysis	≤10 days	↓	↔	↓	↓ / NA	Reduction in long term, but not short term mortality
	Robba et al., 2020	Prospective observational cohort study	≤7 days	↓	NA	NA	↓ / ↓	
	De Franca SA et al., 2020	Systematic review/meta-analysis	5.6 days (average)	↔	↓	↓	↓ / ↓	
	Tavares WM et al., 2023	Systematic review/meta-analysis	7.1 days (average)	↔	↓	↓	↓ / ↓	
	Selvakumar S et al., 2022	Systematic review/meta-analysis	Variable	↔	↓	↓	↓ / ↓	Literature review only, no meta-analysis
	Marra A et al., 2021	Systematic review/meta-analysis	Variable	↑	↓	↓	↓ / ↓	
SCI	Foran SJ et al., 2022	Systematic review/meta-analysis	Variable	↔	↓	↓	↓ / ↓	
	Zameni N et al., 2025	Systematic review/meta-analysis	≤7 days	↓	↓	↓	↓ / ↓	17 studies with 3853 patients
Geriatric patients	Morales RO et al., 2025	Retrospective review	<10 days	↔	↔	↓	↓ / ↓	Age ≥65 with severe TBI
	Zebley JA et al., 2023	Retrospective review	<5 days	↔	↓	↓	↓ / ↓	
Chest wall injury	Fokin AA et al., 2019	Retrospective review	≤7 days	↔	↔	↓	↓ / ↔	Small sample size (n = 124)
Pediatric TBI	Salik I et al., 2023	Retrospective eview	≤8 days	↔	↓	↓	NA / ↓	Limited propensity matching

↔ No effect or uncertain evidence; ↓ decreased; ↑ increased; NA not studied/reported
RCT, randomized controlled trial
EAST, Eastern Association for the Surgery of Trauma
TBI, Traumatic brain injury
SCI, Spinal cord injury