Review

Bench-to-bedside review: Early tracheostomy in critically ill trauma patients

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Abstract

A significant proportion of trauma patients require tracheostomy during intensive care unit stay. The timing of this procedure remains a subject of debate. The decision for tracheostomy should take into consideration the risks and benefits of prolonged endotracheal intubation versus tracheostomy. Timing of tracheostomy is also influenced by the indications for the procedure, which include relief of upper airway obstruction, airway access in patients with cervical spine injury, management of retained airway secretions, maintenance of patent airway and airway access for prolonged mechanical ventilation. This review summarizes the potential advantages of tracheostomy versus endotracheal intubation, the different indications for tracheostomy in trauma patients and studies examining early versus late tracheostomy. It also reviews the predictors of prolonged mechanical ventilation, which may guide the decision regarding the timing of tracheostomy.

Introduction

Trauma is currently one of the most important causes of morbidity and mortality in the age group between 15 to 35 years [1]. About 500,000 people are hospitalized yearly in the United States as a result of motor vehicular accident-related injuries [1]. In addition, motor vehicle-related deaths and injuries cost the United States more than $150 billion each year [1]. According to World Health Organization statistics for the year 2000, over 50% of global mortality due to road traffic accidents occurs among young adults and the mortality rates per 100,000 is in the range of 18.7 to 34.1 in the Eastern Mediterranean region and between 11.2 and 16.1 in Europe [2]. Many trauma patients require intubation and mechanical ventilation for several reasons, including relief of upper airway obstruction secondary to severe facial or laryngeal trauma, airway access in patients with cervical spine injury, management of retained airway secretions, maintenance of patent airway and airway access for prolonged mechanical ventilation [3]. The percentage of trauma patients who require tracheostomy varies considerably and ranges from 14% to 48% [4-6].

Traditionally, tracheostomy has been provided for trauma patients who required endotracheal intubation for a prolonged period of time. In 1989, the American College of Chest Physicians' Consensus Conference on Artificial Airways in Patients Receiving Mechanical Ventilation recommended that tracheostomy should be considered in patients anticipated to require endotracheal intubation for more than 21 days [7]. It also recommended, however, that if tracheostomy is indicated, it should be done early to minimize the duration of translaryngeal intubation and lower the incidence of associated complications. Recently, there has been an increasing trend towards converting endotracheal intubation to tracheostomy at an earlier stage as more evidence supports the benefits of early tracheostomy [5,8-10]. Whited [11] conducted a prospective study involving 200 medical and surgical intensive care unit (ICU) patients to assess the effect of duration of intubation on airway pathology. Before starting the study, they divided patients into three groups based on arbitrary thresholds of duration of endotracheal intubation: 2 to 5 days, 6 to 10 days and more than 10 days. The authors concluded that the risk of serious and irreversible airway complications increased after the 10th day of translaryngeal intubation. In those who were intubated for ≤10 days, the incidence of chronic airway stenosis was 5% compared to 12% in those who were intubated for more than 10 days. The controversy regarding the ideal timing of tracheotomy in trauma patients continues, however, because of the absence of large-scale, well-designed prospective randomized trials. The purpose of this article is to review the available data related to the

ARDS = acute respiratory distress syndrome; CPP = cerebral perfusion pressure; GCS = Glasgow Coma Scale; ICU = intensive care unit; ICP = intracranial pressure; PaO2 = partial pressure of oxygen.

Table 1

Complications of prolonged translaryngeal intubation

Complication	Rate (%)	Reference
Supraglottic laryngeal injury (ulceration, scarring, stenosis)		
Laryngitis	3	[60]
Mucosal ulceration/edema of the epiglottis	7-12	[12]
Mucosal ulceration/edema of the larynx	29-51	[12]
Submucosal hemorrhage of epiglottis/larynx	5-12	[12]
Supraglottic laryngeal stenosis	12[a]	[11]
Glottic injury		
Glottic ulceration	51	[12]
Glottic scarring and stenosis	12-18[a]	[11]
Bilateral vocal cord paralysis (rare)	Few reported cases	[60]
Posterior commissure syndrome	6	[11]
Subglottic injury		
Subglottic stenosis/scarring	12[a]	[11]
Tracheal injury		
Tracheal stenosis ($<$ 50% stenosis)	19	[12]
Tracheal dilatation/tracheomalacia	NA	NA
Tracheoesophageal fistula[b]	0.5-5[a]	[61]
Nasal and sinus injury		
Nasal ulceration	3	[12]
Nasal bleeding	8	[12]
Sinusitis	90	[62-63]
Other complications		
Inadequate oral nutrition	NA	NA
Ventilator associated pneumonia	5.8/1000 ventilator days	[64]
Risks of prolonged sedation	NA	NA

[a]After 10 days of endotracheal intubation. [b]0.5–5% of all tracheoesophageal fistulas are caused by endotracheal intubation. NA, not available.

advantages and disadvantages of early tracheostomy in critically ill trauma patients. The review is constructed to evaluate the effects of timing of tracheostomy on the following endpoints: patho-physiological endpoints, including laryngeal injury, respiratory mechanics and dead space ventilation; and clinical endpoints, including duration of mechanical ventilation, patient comfort, ICU length of stay and the incidence of ventilator-associated pneumonia. In addition, we will examine the indications of tracheostomy in trauma patients. These indications include relief of upper airway obstruction, airway access in patients with cervical spine injury, management of retained airway secretions, maintenance of patent airway, and airway access for prolonged mechanical ventilation. Benefits of early over late tracheostomy and predictors of which trauma patients are likely to require tracheostomy will also be reviewed.

Advantages of tracheostomy

Translaryngeal intubation for prolonged periods of time is associated with several complications [4,12], which are summarized in Table 1. On the other hand, conversion of translaryngeal intubation into tracheostomy is associated with several advantages [4] listed in Tables 2 and 3. Some of the evidence on the advantages of tracheostomy is extrapolated from non-trauma patients because of the lack of trauma-specific literature in certain areas.

Reduction of laryngeal injury

Whether tracheostomy results in a reduction in the risk of tracheolaryngeal injury compared to translaryngeal intubation is difficult to prove considering the limited evidence. In a non-randomized study published in 1981, Stauffer and co-workers [12] prospectively studied 150 critically ill patients

Table 2

Potential advantages of tracheostomy compared to endotracheal intubation

Respiratory mechanics	Reduces dead space ventilation
	Reduces airway resistance
	Reduces work of breathing
	Facilitates weaning of mechanical ventilation
Airway injury	Reduces further laryngeal injury
Patient comfort	Facilitates patient mobility
	Allows speech
	Allows oral nutrition
Infectious complications	Facilitates pulmonary toilet
	Reduces the risk of swallowing dysfunction and aspiration
	Reduces the risk of nosocomial pneumonia
Resource utilization	Facilitates faster transfer out of intensive care unit
	Shortens the hospital length of stay
	Shortens the duration of mechanical ventilation

who required an artificial airway in a multidisciplinary ICU. Of these, 97 patients had only endotracheal intubation and 53 had tracheostomy, 46 of them after a preceding period of intubation. Autopsies were performed in 63 out of the 86 patients who died. On autopsy, injury to the airways, including mucosal ulcers involving vocal cords and subglottic area, webs, tracheitis, tracheal perforation and tracheal stenosis, was detected in 95% of patients with endotracheal intubation and 91% of patients with tracheostomy. Of the survivors, 47 (29 with endotracheal intubation and 18 with tracheostomy) were evaluated for late complications of the artificial airway. Persistent adverse symptoms were more common in patients who had tracheostomy compared to those who had endotracheal intubation. When the investigators looked specifically into the incidence of tracheal stenosis (defined as airway narrowing of ≥10% by air tomography), they found that it occurred in 65% of patients with tracheostomy compared to 19% of those with endotracheal intubation. The authors concluded that airway injury was more common and more severe after tracheostomy than after translaryngeal intubation. The greater incidence of laryngotracheal injury found with tracheostomy in this study could be explained by the greater duration of trachea intubation in patients with tracheostomy. In addition, the procedure was not standardized. It was performed by staff from different departments (Surgery, Otorhinolaryngology, and Neurosurgery). Additionally, the low threshold used to define tracheal stenosis (≥10%) probably led to substantial overestimation of the complication rates. Whether early tracheostomy could result in lower incidence of airway pathology, especially tracheal stenosis, needs further study.

The effect of tracheostomy on respiratory mechanics

Several studies have demonstrated favorable respiratory mechanics with tracheostomy compared to endotracheal tube. Davis *et al*. [13] studied 20 patients admitted to the surgical ICU following acute respiratory failure. All patients who met the extubation criteria but failed extubation on two occasions were included. After tracheostomy, the investigators found statistically significant reduction in work of breathing (8.9 ± 2.9 versus 6.6 ± 1.4 J/l per minute; $P = 0.04$) compared with breathing via endotracheal tube. In addition, there was a trend towards reduction in the expiratory airway resistance. All patients were successfully weaned from ventilator within 24 hours of tracheostomy. Similar findings were shown in a lung model by the same investigators in another study [14]. The higher work of breathing with endotracheal tube has been attributed to diameter [13,14], length [13,14] and the tortuous path [14]. Even at the same internal diameter, the shorter and more rigid tracheostomy tube results in a statistically significant lower work of breathing [14]. The difference is magnified as the patient respiratory demand increases [13,14].

Moscovici da Cruz *et al*. [15] studied the effects of tracheostomy on respiratory mechanics in spontaneously breathing patients. They found that tracheostomy resulted in a significant reduction in the inspiratory resistive work, intrinsic positive end expiratory pressure and the inspiratory pressure-time product, which is considered to be proportional to the oxygen cost of breathing, compared to spontaneously breathing non-intubated patients. Nathan and colleagues [16] found that there is increase in the work of breathing by 30% after extubation. This increase in work of breathing may be attributed to airway edema and ulceration of the native airway following endotracheal intubation and may be one of the factors resulting in weaning failure [16]. Therefore, successful weaning from ventilatory support after tracheostomy may be related to reduced work of breathing with tracheostomy compared with spontaneous breathing through native airway in selected patients.

Diehl *et al*. [17] evaluated the effect of tracheostomy on respiratory parameters that affect weaning. They studied patients before and after tracheostomy and found that tracheostomy resulted in significant reduction in the work of breathing and intrinsic positive end expiratory pressure compared to endotracheal intubation. Lin and co-workers [18] conducted a study on 23 patients with chronic lung disease to assess the changes in pulmonary mechanics before and after tracheostomy. The indication for tracheostomy was prolonged mechanical ventilation. The main finding in this study was that tracheostomy reduced the

Table 3

Potential advantages of tracheostomy

Study design	Patient population	Number of patients	Comments	Reference
Respiratory mechanics				
Prospective observational	Surgical	20 (13 patients trauma)	↓ work of breathing ↓ airway resistance	[13]
Lung model	Lung model	-	↓ work of breathing	[14]
Prospective observational	Cancer (medical)	23 (data from 7 patients)	↓ inspiratory resistive work ↓ intrinsic PEEP	[15]
Prospective observational	Medical	8	↓ work of breathing ↓ intrinsic PEEP ↓ PTP	[17]
Prospective observational	Medical	23	↓ peak inspiratory pressure	[18]
Dead space				
	Medical	14	↓ physiological dead space	[19]
Duration of mechanical ventilation				
Prospective randomized controlled trial	Trauma	106	↓ MV duration ↓ ICU LOS ↓ hospital LOS	[5]
Retrospective observational	Trauma	101	↓ MV duration	[8]
Retrospective observational	Trauma	157	↓ ICU LOS ↓ hospital LOS	[9]
Retrospective observational	Trauma	31	↓ ICU LOS ↓ hospital LOS ↓ MV duration	[10]
Retrospective observational	Trauma	136	↓ MV duration ↓ ICU LOS	[20]
Prospective randomized controlled trial	Trauma	62	↓ MV duration	[21]
Risk of pneumonia				
Prospective randomized controlled trial	Trauma	106	↓ pneumonia	[5]
Retrospective observational	Trauma	101	↓ pneumonia	[8]
Retrospective observational	Trauma	118	↓ pneumonia	[26]
Patient comfort				
Retrospective observational	Medical/surgical	52 (15 trauma patients)	↑ patient comfort	[23]

Up and down arrows indicate an increase and decrease, respectively. LOS, length of stay; MV, mechanical ventilation; PEEP, positive end expiratory pressure; PTP, pressure-time product.

peak inspiratory pressure significantly. However, the study did not show any significant change in work of breathing or airway resistance after tracheostomy. Considering that the majority of trauma patients who require tracheostomy have normal underlying lung function, the impact of this procedure on lung mechanics is probably small. It may become more relevant in patients who have pulmonary involvement such as lung contusion, acute respiratory distress syndrome or severe ventilator associated pneumonia. More studies are needed in this area.

The effect of tracheostomy on dead space ventilation

An additional potential advantage of tracheostomy is reduction of dead space when compared to endotracheal tube. Cullen [19] studied the effects of tracheostomy on pulmonary mechanics in 14 patients with chronic obstructive airway disease. He found that compared to mouth breathing, tracheostomy resulted in reduction in the physiological dead space. Whether this has any clinical relevance is not known, especially as the added length of endotracheal tube results in only a 3 to 18 ml increase in dead space [13,14].

The effect of tracheostomy on the duration of mechanical ventilation

Among the important advantages of tracheostomy are its effects on the duration of mechanical ventilation. Several studies have shown that early tracheostomy decreases the duration of mechanical ventilation [5,8-10,20,21]. These studies include retrospective observational [8-10,20] and prospective randomized controlled trials [5,21]. A systematic review that included randomized and non-randomized studies failed, however, to find sufficient evidence to support the effect of tracheostomy on duration of mechanical ventilation in all patients [22].

Tracheostomy and patient comfort

The effect of tracheostomy on patient comfort has not been examined systematically in prospective studies. Astrachan *et al*. [23] reported the results of a questionnaire distributed to 60 critical care nurses caring for patients with tracheostomy. Nurses reported improved patient comfort after tracheostomy as a result of several factors, including easier mobility, ability to communicate and eat orally and better suction of secretions [23]. In this study, 90% or more of nurses favored tracheostomy over endotracheal intubation and 75% of nurses felt that patients who underwent tracheostomy did better psychologically than those who were intubated.

A recent retrospective study conducted on 312 mechanical ventilated patients over a 14 month period assessed the effect of tracheostomy on sedation requirement and patient comfort [24]. Seventy-two patients (23%) underwent tracheostomy. After tracheostomy, their sedation requirements decreased significantly. In addition, the median time spent heavily sedated was significantly shorter. The authors concluded that tracheostomy enhances the autonomy of ventilated patients. One must keep in mind, however, that sedation may decrease after tracheostomy because physicians become more active in weaning after tracheostomy. This is one of perhaps a few potential biases to the finding of less sedation following tracheostomy. Further studies are required to exactly assess the effect of tracheostomy on patient comfort and quality of life.

The impact of tracheostomy on ICU length of stay

One of the advantages of tracheostomy is to hasten the transfer of patients out of the ICU [5,9,10,20]. In a cohort study, we found that early versus late tracheostomy reduced the ICU length of stay by almost 10 days [20]. Other studies also found that tracheostomy significantly reduced the ICU length of stay [5,9,10]. The impact of tracheostomy on ICU length of stay will be discussed in more detail in the section about early versus late tracheostomy.

The effect of tracheostomy on the incidence of nosocomial pneumonia

The effect of tracheostomy on the incidence of nosocomial pneumonia has been examined in several studies. Georges and co-workers [25] conducted a retrospective study to examine the incidence of nosocomial pneumonia and the risk factors predisposing the patient to this complication after tracheostomy. The study included 135 patients in a 16-bed multidisciplinary ICU. Thirty-seven cases of nosocomial pneumonia (26%) occurred after tracheostomy. The reason behind this high incidence could be multi-factorial. One of the important reasons is that the timing of tracheostomy in this study is considered by current standards to be very late (18 ± 13 days). Another reason is that some patients were having fever and pathogens in endotracheal aspirates on the tracheostomy day, which may represent the presence of nosocomial infection before the procedure. In addition, patient selection may affect the results as more than half of the patients were admitted because of exacerbation of chronic obstructive pulmonary disease or community acquired pneumonia.

Three studies have examined the risk of pneumonia in trauma patients who receive early versus late tracheostomy [5,8,26]. Overall, these studies found a slight decrease in the risk of pneumonia with early tracheostomy. Rodriguez *et al*. [5] found that the incidence of pneumonia in the group who had early tracheostomy (≤7 days) was lower than that in those who had late tracheostomy (>7 days) (78% versus 96%), although this difference was not statistically significant. The number of days of ventilation required after pneumonia was diagnosed was significantly reduced in the early tracheostomy group (6 ± 1 days versus 23 ± 3 days). When further subgroup analysis was performed, it was found that the incidence of pneumonia was lower in those patients who had tracheostomy done within the first 2 days after intubation compared to those who had it done between 3 and 7 days after intubation (50% versus 85%); this was statistically significant ($P < 0.05$) [5]. Lesnik *et al*. [8] found that the incidence of nosocomial pneumonia was 19% in the group who had early tracheostomy (≤4 days) compared to 59% in those who underwent late tracheostomy (>4 days); this was statistically significant. Similarly, Kluger *et al*. [26] found that early tracheostomy resulted in a decreased incidence of pneumonia in trauma patients.

Not all studies showed a decreased risk of nosocomial pneumonia after tracheostomy. In fact, some studies have shown that tracheostomy may be a risk factor for developing nosocomial pneumonia [27-29]. Further controlled trials are required to prove the effect of tracheostomy on the incidence of pneumonia. Table 3 summarizes the studies that discuss the advantages of tracheostomy.

Indications for tracheostomy

In critically ill trauma patients, tracheostomy may be indicated for several reasons. Table 4 summarizes studies that have examined the indications of tracheostomy in trauma patients.

Table 4

Studies that discuss indications for tracheostomy in trauma patients

Study design	Indications for tracheostomy	Total number of patients	Number of tracheostomy	(%) of tracheostomy	Reference
Retrospective observational	Head injury with inability to protect airway	49 (20 trauma)	17	34.6	[6]
Retrospective observational	Airway obstruction (laryngotracheal injury)	23	4	17.3	[31]
Retrospective observational	Airway obstruction (laryngotracheal injury penetrating)	57	15	26.3	[33]
Retrospective observational	Airway obstruction (laryngotracheal tree injury)	106	19	17.9	[34]
Retrospective observational	Airway obstruction (penetrating neck injury)	748	142	18.9	[35]
Retrospective observational	Facial trauma (fractures)	1,025	1	0.09	[36]
Retrospective observational	Maxillofacial trauma	399	13	3.2	[37]
Retrospective observational	LeFort facial fractures	117	23	19.6	[38]
Retrospective observational	Maxillofacial injuries	1789	44	2.4	[39]
Retrospective observational	Trauma patients with cervical spine injury on halo fixation	105	17	16.1	[44]
Retrospective observational	Head injury with inability to protect airway	116 (58 trauma)	116	100	[49]
Totals		4534	411	9	

Relief of airway obstruction

Relief of airway obstruction related to trauma is one of the earliest indications for tracheostomy [30]. In trauma patients, airway obstruction may result in acute respiratory decompensation, so a high index of suspicion and rapid intervention are required.

Among the causes of airway obstruction that require tracheostomy are laryngeal and cervical tracheal injuries [31-33]. Fortunately, these injuries are uncommon, being encountered in <1% of all trauma patients seen, and in 8% of patients with penetrating neck injury [33].

In a study by Francis and colleagues [31], 23 patients with laryngotracheal injury were studied. Blunt injury caused 17% of cases while 83% resulted from penetrating trauma. All patients with penetrating injury required surgical repair while none of the blunt tracheal injuries needed repair. The most important goal of management was airway control. Four patients in the penetrating laryngotracheal injury group required tracheostomy to control the airway.

Grewal *et al*. [33] retrospectively studied 57 patients with penetrating laryngotracheal injury. Of 32 patients who required emergency airway management, 15 had tracheostomy. No deaths were attributable to airway management. They recommended cricothyroidotomy if the expertise to do tracheostomy in the emergency room is limited.

Kelly and coworkers [34] found that 46 out of 106 patients with tracheobronchial tree injury had airway compromise. Of these, 19 patients required emergency tracheostomy and 3 had endotracheal tube placement through the injured trachea. Eighteen patients died as a result of injury, of which eight were due to delay in securing the airways.

Mandavia *et al*. [35] conducted a retrospective study of 748 patients with penetrating neck injury to examine the various emergency airway techniques in those patients. Of these, 11% of cases required urgent airway management. In the majority of cases (81%), oral translaryngeal intubation was the initial method of airway management and the remainder had emergency tracheostomy. Out of 748 patients, 39 had initial rapid sequence intubation with 100% success rate; 85% were successfully intubated from the first attempt, 10% from the second attempt and the remaining (5%) after 3 attempts. Five patients who presented with GCS of ≤6 were successfully intubated without paralysis. Although the use of rapid sequence intubation remains controversial in patients with airway trauma as it may convert a partially obstructed airway to a complete obstruction, rapid sequence intubation has been used successfully in this study with 100% success and no complications [35]. The authors concluded that oral intubation was safe and effective in the majority of patients who sustain penetrating injury, although in a subset of patients, emergency tracheostomy is required.

In facial trauma, the airway compromise may be as a result of several factors, including severe bleeding, hematoma, and obstruction by soft tissue, or direct injury to larynx or trachea [36]. Tung and coworkers [36] reviewed 1,025 patients with facial fractures; 17 patients had life-threatening airway compromise, 16 required endotracheal intubation and only 1 patient underwent tracheostomy. Taicher *et al*. [37] reviewed 399 patients with maxillofacial trauma between 1985 and 1992, of which 13 needed tracheostomy. The main indications for tracheostomy were impending upper airway obstruction, respiratory distress and difficulty in intubation.

Thompson and colleagues [38] reviewed 117 patients with LeFort facial fractures (fracture of mid-facial skeleton) of which about 26.5% needed emergency airway management for airway obstruction and respiratory distress. Of those who required emergency airway, 74% had tracheostomy. Factors associated with increased risk of airway compromise in patients with LeFort fractures were the type of fracture and the presence of associated injuries, such as laryngeal or mandibular fractures. The authors recommended an aggressive approach to airway management in patients with this type of facial fracture with careful selection of patients for tracheostomy.

Zacharides *et al*. [39] reviewed 1,789 patients with maxillofacial injuries; 44 patients (2.4%) had tracheostomy. The indications for tracheostomy were concomitant severe head injury, associated thoracic injury, cervical vertebral fracture, and respiratory distress related to severe maxillofacial trauma. Complications related to tracheostomy occurred in 72.8% of patients. This high rate of complications may be due to the emergency nature of the procedure.

Although emergency tracheostomy is still considered by some authorities, in the *Advanced Trauma Life Support* (ATLS) course, cricothyroidotomy is the procedure of choice for emergency surgical airway in trauma patients [40]. Cricothyroidotomy is an easy and safe procedure that can be performed in less than 60 seconds [41,42]. Cricothyroidotomy has to be converted to tracheostomy at a later stage. Due to the risk of subglottic stenosis and voice changes, we recommend that cricothyroidotomy should be changed to tracheostomy as soon as possible (usually earlier than 3 days). Further discussion of this procedure is beyond the scope of this review.

Until recently, emergency need for airway control was considered as a contraindication for percutaneous tracheostomy [43]. However, Ben-Nun and coworkers [43] reported on six patients who underwent emergency percutaneous tracheostomy and found that the mean time required to cannulation of trachea was 5.5 minutes. There were no failures, no complications, and no conversion to open technique. They concluded that emergency percutaneous tracheostomy is a safe procedure in experienced hands. Further larger studies are required to confirm the above findings.

Airway access in patients with cervical spine injury

Cervical injuries requiring stabilization may represent a significant challenge in airway management. If the patient needs early halo immobilization, easy access to the airway is prevented as a result of inability to extend the neck. Sims and Berger [44] conducted a retrospective chart review of 105 trauma patients with cervical spine injury who required halo fixation. The incidence of urgent intubation was 13% and a total of 17 tracheostomies were done, of which 8 were performed without a trial of extubation and the remainder were done after an emergent intubation following an extubation trial. Six patients died as a result of emergent intubation whereas none of the patients who underwent elective tracheostomy died. The authors recommended that early tracheostomy should be considered in patients with cervical spine injury requiring halo fixation, especially if they have a high injury severity score, have cardiac disease, are older than 60 years, or have a past history of difficult intubation, and are anticipated to require an artificial airway for more than one week.

An important concern in quadriplegic patients who require tracheostomy is the inability to extend the neck, which has been considered to be a relative contraindication for percutaneous tracheostomy [45], although percutaneous tracheostomy has been reported in this setting. Mayberry *et al*. [45] conducted a prospective study of 88 trauma patients receiving percutaneous tracheostomy. The procedure was performed without neck extension in the group of patients with the non-cleared cervical spine; the success rate was 96% for the non-cleared group compared to 100% in the cleared group and no patient had spinal cord injury caused by the procedure. The authors concluded that percutaneous tracheostomy is a safe procedure in trauma patients without cervical spine clearance. Another related issue is the delay of tracheostomy in patients who have undergone anterior surgical fixation of the spine until the surgical wound is healed [46]. Percutaneous tracheostomy minimizes injury to the adjacent neck structures and thus also the risk of stomal infection [46] and should be considered in patients who have undergone anterior fixation of the cervical spine and require prolonged ventilatory support [47,48].

Management of retained airway secretions and maintenance of patent airway

Trauma patients can lose the ability to clear retained secretions and maintain patent airway for several reasons. Head injury may result in airway compromise as a result of decreased mental status or absent airway protective reflexes (cough and gag reflexes). Such patients usually do not need mechanical ventilatory support and are intubated mainly for airway protection [49]. If tracheostomy is performed in these patients, they can be librated from mechanical ventilation rapidly and be transferred out of the ICU in a shorter time [5,8-10,20,49].

Koh *et al*. [6] conducted a retrospective study on 49 patients, 20 of which were victims of trauma, who required admission to the neurosurgical ICU. In this study, the reintubation rate was 22% despite meeting weaning criteria. Among the predictors of failed extubation were low Glasgow Coma Scale (GCS) and excessive tracheal secretions. The majority of patients who required reintubation were librated from mechanical ventilation within 48 hours of tracheostomy. This indicated that intubation was only required for the purpose of airway protection and, once the airway was secured via tracheostomy, patients were librated rapidly from ventilatory support. The authors concluded that if the patient is thought to have a poor long-term prognosis in terms of airway protection, early tracheostomy should be done to help in early transfer of the patients out of the ICU.

Boyd and Benzel [50] conducted a retrospective analysis of 116 tracheostomized neurosurgical patients, of whom 43% had head injury and 7% had cervical spine injury. The overall rate of complications related to tracheostomy was 6% and no deaths were attributable to the procedure. Thirty-two patients had evidence of pneumonia prior to tracheostomy, whereas eighteen patients developed pneumonia after tracheostomy. The low rate of complications related to tracheostomy in this study may be due to the short pre-tracheostomy period of endotracheal intubation (average of 5.8 days). The authors concluded that early tracheostomy is a beneficial and safe procedure in critically ill neurosurgical patients and that early tracheostomy can prevent many of the complications associated with prolonged translaryngeal intubation.

Airway access for prolonged mechanical ventilation

Critically ill trauma patients may require prolonged mechanical ventilatory support for a variety of reasons: severe chest trauma resulting in lung contusion, multiple rib fractures, flail chest or hemothorax can be associated with prolonged mechanical ventilation. Trauma patients are at risk of nosocomial pneumonia, which is associated with prolonged mechanical ventilation. The incidence of nosocomial pneumonia in trauma patients ranges from 20% to 40% [51]. Acute respiratory distress syndrome (ARDS) is another reason for prolonged mechanical ventilation in trauma patients. The incidence of ARDS in trauma patients is variable. In a study by Johnston *et al.* [52], 12% of trauma patients developed ARDS. In addition, trauma patients who sustain spinal cord injury usually need prolonged ventilatory support if this injury resulted in diaphragmatic paralysis.

Studies comparing early versus late tracheostomy in trauma patients

Timing of tracheostomy has been a subject of debate. Several studies examined the effect of early tracheostomy on the duration of mechanical ventilation, ICU and hospital length of stay, compared to that of late tracheostomy.

There are some limitations in these studies, including the retrospective design of some studies, the use of quasi randomization methods in some of the randomized trials, the variable definition of early versus late tracheostomy, and the absence of blinding. Keeping these limitations in mind, the studies that compare early versus late tracheostomy are reviewed below. Table 5 summarizes the findings of these studies.

Dunham and La Monica [3] prospectively randomized 74 trauma patients to early tracheostomy (3 to 4 days post intubation, $n = 34$) and late tracheostomy (>4 days, $n = 40$). They did not find any significant difference between the two groups regarding laryngotracheal pathology or respiratory infection. However, the number included in this study was too small to draw any meaningful conclusion, and only 65% of patients underwent laryngoscopic examination to detect airway injury.

Rodriquez *et al.* [5] studied 106 mechanically ventilated trauma patients in a prospective randomized controlled study. They randomized 51 patients to early tracheostomy (within 7 days of intubation) and 55 patients to late tracheostomy (>7 days). They were able to demonstrate a significant decrease in the duration of mechanical ventilation, and ICU and hospital length of stay in patients randomized to early tracheostomy. They found that the incidence of pneumonia was significantly reduced only in those who had tracheostomy done earlier than three days post-intubation. This study did not describe the weaning protocol used. In addition, patients who were assigned to the late tracheostomy group who had been weaned successfully before undergoing the procedure were not included in data analysis, which may result in a bias as this favors a shorter duration of care to the early tracheostomy group.

Lesnik and coworkers [8] retrospectively studied 101 patients with blunt multiple trauma of which 32 were tracheostomized within 4 days of intubation. Early tracheostomy resulted in reduction of mechanical ventilation duration as well as in the incidence of nosocomial pneumonia. The length of ICU stay and the duration of hospitalization were not reported. The limitations of this study include that the technique of tracheostomy and the selection criteria for the procedure were not described, in addition to its retrospective design. Armstrong and colleagues [9] performed a retrospective chart review of 157 blunt trauma patients who were divided into an early tracheostomy group (≤6 days of intubation, $n = 62$) and late tracheostomy group (>6 days, $n = 95$). They found that early tracheostomy was associated with a decrease in the ICU and hospital length of stay.

D'Amelio *et al.* [10] studied 43 trauma patients retrospectively, 31 of whom underwent tracheostomy. Patients who had tracheostomy done within the first 7 days of intubation had lower mechanical ventilation duration as well as ICU and hospital length of stay.

Table 5

Timing of tracheostomy

Design	Patient population	Number of patients	Group/patient number	Results in early tracheostomy group: ICU LOS	Hospital LOS	Duration of MV	% pneumonia	Reference
Prospective randomized	Trauma	74	E = 3-4 (34) L = 14 (40)	N/A	N/A	N/A	↔	[3]
Prospective randomized	Trauma	106	E ≤ 7 (51) L > 7 (55)	↓	↓	↓	↓	[5]
Retrospective observational	Trauma	101	E ≤ 4 (32) L > 4 (69)	N/A	N/A	↓	↓	[8]
Retrospective observational	Trauma	157	E ≤ 6 (62) L > 6 (95)	↓	↓	N/A	↓[a]	[9]
Retrospective observational	Trauma	31	E ≤ 7 (21) L > 7 (10)	↓	↓	↓	N/A	[10]
Prospective observational	Trauma	653	E ≤ 7 (29) L => 7 (107)	↓	↔	↓	N/A	[20]
Prospective observational	Trauma	62	E = 5-6 (31) L => 6 (31)	N/A	N/A	↓	↔	[21]
Prospective randomized multicenter	Trauma (139) Non-trauma (18)	157	E = 3-5 (127) L = 10-14 (28)	↔	N/A	N/A	↔	[52]

[a]Statistically not significant. Vertical down arrows indicate significant reduction. Horizontal arrows indicate no difference. E, early tracheostomy; ICU, intensive care unit; L, late tracheostomy; LOS, length of stay; MV, mechanical ventilation; NA, data not available.

Arabi and coworkers [20] examined the impact of early versus late tracheostomy on the outcome of trauma patients. They studied 653 trauma patients, of whom 136 (21%) underwent tracheostomy: 29 patients had early tracheostomy (≤7 days of mechanical ventilation) and the remainder had late tracheostomy (>7 days). They found that the duration of mechanical ventilation and ICU length of stay were significantly shorter in the early tracheostomy group. Mortality rates were similar in both groups.

Bouderka *et al.* [21] prospectively studied 62 trauma patients with isolated head injury. They randomized them in two groups: an early tracheostomy group (5th to 6th day, $n = 31$); and a late tracheostomy group (after 6th day). The investigators found that the mechanical ventilation duration was shorter in the early tracheostomy group. There was no difference in the frequency of pneumonia or mortality between the two groups.

Surgerman *et al.* [53] conducted a prospective, randomized multicenter study of 157 patients. All patients were victims of trauma (head and non-head injury), apart from 18 who were non-trauma patients. The 157 eligible patients were randomized on days 3 to 5 to receive tracheostomy or to continue with translaryngeal intubation. Patients who remained intubated were randomized again on days 10 to 14. They found that ICU length of stay and the frequency of pneumonia did not differ between the two groups. The study had several limitations, however: of five participating centers, only one completed the study. In addition, of 157 eligible patients, only 112 completed the study because of physicians' bias and incomplete information.

Maziak *et al.* [22] performed a systematic review concerning the timing of tracheostomy. Their meta-analysis consisted of five studies, three of which were done on trauma patients [3,5,8]. The authors concluded that there was insufficient evidence to support that early tracheostomy could result in shorter mechanical ventilation or lower airway injury in critically ill patients. There are many limitations to this systematic review, however, including the mixed population of patients (trauma and non-trauma) and two studies being retrospective chart reviews, in addition to the significant limitations of the randomized controlled trials.

A more recent meta-analysis that included five randomized trials with mixed patient populations (trauma, medical, surgical, and burn) concluded that early tracheostomy reduced the duration of mechanical ventilation and length of ICU stay significantly but did not significantly change mortality or risk of pneumonia [54].

Performing tracheostomy during early stages of severe brain damage may raise concerns about the effect of the procedure on intracranial pressure. Stocchetti *et al.* [55] studied prospectively the effect of early tracheostomy on intracranial pressure (ICP), cerebral perfusion pressure (CPP), and jugular oxygen saturation on 20 neurosurgical patients with a GCS

Table 6

Predictors for prolonged mechanical ventilation

Factors	References	Comments
Older age	[3]	Age >40 associated with prolonged mechanical ventilation but only in conjunction with other factors
Low GCS	[3,6,48,56,57]	GCS ≤7-8 on admission is highly predictive of prolonged mechanical ventilation Mean GCS ≤6 on day 3
Oxygenation	[3,54]	Measured either as A-a O2 gradient or PaO2/FiO2 ratio, low oxygenation associated with prolonged mechanical ventilation (A-a O2 ≥100 or PaO2/FiO2 ≤250)
Injury Severity Score	[48,54]	>25 associated with prolonged mechanical ventilation
Nosocomial pneumonia/ witness aspiration	[6,55]	Increased risk of prolonged mechanical ventilation
Reintubation	[55]	Increased risk of prolonged mechanical ventilation by 2.21 times
Hemodynamic/fluid balance	[54]	Use of Swan Ganz Catheter and positive fluid balance were associated with prolonged mechanical ventilation
SAPS	[56]	SAPS ≥16 on day 4 of ICU

A-a O2, alveolar–arterial oxygen gradient; FiO2, fraction of inspired oxygen; GCS, Glasgow Coma Score; ICU, intensive care unit; PaO2, partial pressure of oxygen; SAPS, simplified acute physiology score.

less than 8. All patients were selected with an ICP of <20 mmHg during the 24 hours preceding inclusion in the study. The interval between the initial injury and tracheostomy ranged from 2 to 12 days with a mean of 5 ± 2.46 days. The authors found that tracheostomy did not lead to significant changes in ICP or CPP in the majority of cases. Only in some cases, brief episodes of intracranial hypertension occurred with an increase in the ICP above 20 mmHg. They concluded that early tracheostomy (≤12 days) is well tolerated in the majority of cases and did not lead to a persistent rise in ICP. They recommended proper patient selection, however, with avoidance of those with unstable ICP, in addition to close monitoring of ICP during tracheostomy.

What is the optimum time for performing tracheostomy in critically ill trauma patients? The best answer to this question requires one to weigh the benefits and risks of tracheostomy. The complications associated with prolonged translaryngeal intubation and the advantages of tracheostomy have been discussed earlier in this review. One must stress that the decision should be individualized. In our center, we perform early tracheostomy (<7 days) on patients with severe brain injury (GCS ≤8), those expected to be ventilated for more than 10 days, patients who are judged to be unable to protect their airways and in the absence of spontaneous cough. We tend to delay tracheostomy to give an extubation trial for patients who have a GCS higher than 8, those who are showing rapid recovery and those with spontaneous cough. We should emphasize that selection criteria for early versus late tracheostomy have not been validated in randomized controlled trials, although there are certain variables that can help the intensivist in predicting who is likely to need prolonged mechanical ventilation and possibly tracheostomy.

Who is likely to require tracheostomy?

The decision to perform early tracheostomy can be guided if the patient is predicted to require prolonged mechanical ventilation. Table 6 summarizes the studies examining predictors for prolonged mechanical ventilation in trauma patients.

Ross and colleagues [4] examined the ability of injury severity measures, oxygenation, and mental status to predict the need for prolonged ventilatory support in trauma patients. A total of 212 trauma patients were studied. They found that age >40 years, GCS ≤7 and alveolar-arterial oxygen gradient (A-a O2) ≥100 to 150 were predictors of prolonged mechanical ventilatory support.

Similarly, Koh and coworkers [6] found that neurosurgical patients with poor GCS and nosocomial pneumonia were at higher risk of extubation failure. Elective tracheostomy in this high-risk group resulted in significantly lower ICU length of stay and shorter duration of mechanical ventilation.

Gurkin *et al.* [49] examined the factors that can predict tracheostomy in patients with traumatic brain injury. All traumatic brain injury patients who required intubation and survived longer than 7 days were included; 246 patients with head injury were identified, of whom 35 required tracheostomy. They found that a GCS ≤8 on presentation and Injury Severity Score ≥25 are highly predictive of tracheostomy.

Velmahos and coworkers [56] reviewed 125 patients who required mechanical ventilation for >48 hours. In this study, prolonged mechanical ventilation was defined as the need for mechanical ventilatory support for >7 days. The use of a Swan Ganz catheter, injury severity score, PaO2/FiO2 ratio at 48 hours, and positive fluid balance at 48 hours were most predictive of prolonged mechanical ventilation.

Kollef *et al.* [57] prospectively studied 521 patients requiring mechanical ventilation for more than 12 hours. The patient population included both trauma and non-trauma patients. They found that nosocomial pneumonia, aerosol treatment, witnessed aspiration and reintubation were independently associated with patients having prolonged ventilatory support and tracheostomy.

Major and coworkers [58] conducted a retrospective chart review study of patients with blunt head trauma. Patients were divided into two groups, those who were extubated and those who required tracheostomy. The author found that the GCS on hospital day 3 and simplified acute physiology score were significantly different in the two groups. They concluded that using these two scores may be useful in predicting the need for prolonged airway protection in patients with blunt head injury.

Lanza *et al.* [59] retrospectively reviewed head injury patients to examine the predictive value of the GCS for tracheostomy in these patients. Of 47 patients divided according to their GCS rating, 34 had a GCS ≤7 and 13 had GCS >7. They found that the likelihood of tracheostomy is significantly greater in patients with GCS ≤7. They recommended performing early tracheostomy in those patients to optimize resource utilization. Further studies are required to identify clearly the factors that can predict the need for prolonged endotracheal intubation and mechanical ventilatory support in trauma patients. By adopting a standardized method for selecting patients who will require early tracheostomy, prolonged ICU and hospital stay will be avoided and this will be certainly associated with better resource utilization.

Conclusions

The timing of tracheostomy in trauma patients is still a subject of debate and often influenced by practice preferences. However, numerous retrospective studies and a few randomized controlled studies have demonstrated the benefits of early tracheostomy in trauma patients in terms of ICU and hospital length of stay and mechanical ventilation duration. Large prospective randomized studies are required to define the proper timing of tracheostomy. In addition, predictors of prolonged ventilatory support in trauma need to be validated in large studies. Such predictors are likely to help in selecting patients who will benefit from early tracheostomy.

Nevertheless, the existing data suggest that tracheostomy should be strongly considered if a trauma patient needs more than 7 to 10 days of endotracheal intubation. This general conclusion should be modified on an individual basis, however, taking into account the anticipated duration of mechanical ventilation and the ability to protect the airways.

Competing interests

The author(s) declare that they have no competing interests.

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