

Tracheostomy in the critically ill: indications, timing and techniques

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Purpose of review

Tracheostomy is one of the most common procedures performed in the intensive care unit. Indications, risks, benefits, timing and technique of the procedure, however, remain controversial. The decision of when and how to perform a tracheostomy is often subjective, but must be individualized to the patient. The following review gives an update on recent literature related to tracheostomy in the critically ill.

Recent findings

Surprisingly, few data are available on the current practice of tracheostomy in the intensive care unit setting. Very few trials address this issue in a prospective, randomized fashion (randomized controlled trial). Most reports include small numbers representing a heterogeneous population, describing contrary results and precluding any definite conclusions. Evidence seems to suggest that early tracheostomy, however, might be preferable in selected patients.

Summary

Due to increased experience and advanced techniques, percutaneous tracheostomy has become a popular, relatively safe procedure in the intensive care unit. The question of appropriate timing, however, has not been definitely answered with a randomized controlled trial. Instead, a number of retrospective studies and a single prospective study have shed some light on this issue. Most reports favor the performance of tracheostomy within 10 days of respiratory failure.

Keywords

ICU, intensive care, mechanical ventilation, percutaneous, respiratory failure, tracheostomy

Abbreviations

BMI	body mass index
GCS	Glasgow Coma Score
ICU	intensive care unit
LOS	length of stay
NIMV	noninvasive mechanical ventilation
PDT	percutaneous dilatational tracheostomy

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Introduction

Advances and improvements in treating critically ill patients have resulted in more patients requiring prolonged airway and respiratory support [1]. Noninvasive mechanical ventilation (NIMV) without an artificial airway is often successful in the management of respiratory failure due to exacerbation of chronic obstructive pulmonary disease (COPD) or congestive heart failure (CHF), thus avoiding the need for invasive airway support [2]. NIMV is well tolerated and carries a lower mortality than invasive ventilation in selected patients [3]. Despite the advances of NIMV, however, most patients with respiratory failure will require intubation and the question of whether, when and how to perform tracheostomy will need to be addressed. Although this topic has been discussed for over two decades it still remains a controversy. The reason for this dilemma is the lack of adequately sized, randomized, prospective controlled studies. Therefore, most recommendations are based on consensus opinions of clinical experts [4–6].

Furthermore, the reader should be aware that almost all studies are carried out retrospectively, and that they include different patient populations, small sample sizes and very different definitions of early (varying between 2 and over 28 days) or late tracheostomy.

Indications for tracheostomy in the critically ill

The decision to perform a tracheostomy in critically patients should be adapted to each patient and pathology – balancing the patient's wishes, expected recovery course, risk of continued translaryngeal intubation and surgical risks of the procedure [7•]. Medical indications for tracheostomy include failure of extubation, upper airway obstruction, airway protection and airway access for secretion removal, avoidance of serious oropharyngeal and laryngeal injury from prolonged translaryngeal intubation

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[8[•]]. Expected prolonged mechanical ventilation is one of the major indications for tracheostomy. In 1989, the American College of Chest Physicians (ACCP) Consensus Conference on Artificial Airways in Patients Receiving Mechanical Ventilation issued the statement that tracheostomy is preferred (over continued translaryngeal intubation) if the need for an artificial airway is anticipated to be greater than 21 days [9]. A similar recommendation followed the European consensus in 1998 [10]. For mechanical ventilation that was anticipated to last between 10 and 21 days, the decision was left to the attending physician, and daily assessment was recommended as to the need for continued intubation. Recent ACCP guidelines suggest that tracheostomy should be considered after an initial period of stabilization on the ventilator (generally, within 3–7 days), when it becomes apparent that the patient will require prolonged ventilator assistance [4].

Proposed beneficial effects of tracheostomy include improved patient comfort through allowance of speech, oral nutrition, and easier nursing care [11]. The need for less sedation and analgesia requirements [12^{••}] and the reduced airway resistance are thought to facilitate the weaning process [13]. Ventilator-associated pneumonia may also be reduced by substituting a tracheostomy for translaryngeal intubation.

Contraindications

Absolute contraindications for tracheostomy, such as soft tissue infections of the neck or anatomic aberrations, are rare. Severe respiratory distress with refractory hypoxemia and hypercapnia may be considered as relative contraindications. Hematologic and coagulation disorders are often considered as contraindications for tracheostomy, although previous studies have shown that this procedure can be safely performed in patients with severe neutropenia or thrombocytopenia [14,15].

Timing of tracheostomy in the critically ill

Optimal timing for tracheostomy (early versus late) remains a subject of debate and continued investigation. There is no consensus in the literature about the definition of what duration of intubation is considered 'early' tracheostomy. Tracheostomy in the 1980s was considered 'early' if it was performed before 21 days of orotracheal intubation [7[•]]. Timing of tracheostomy, however, has changed over the last few years. Furthermore, tracheostomy performed within 2–10 days has been recommended in the otorhinolaryngologic literature to prevent laryngeal injury for many years [16,17].

Some authors suggest consideration of objective predictors of prolonged mechanical ventilation (>14 days), such as an alveolar-arterial oxygen gradient of 175 mmHg or higher (without COPD) and a Glasgow Coma Score

(GCS) less than 9 at 48 h of admission (positive predictive value of 91% and negative predictive value of 96%) be used to determine tracheostomy timing [18]. Two admitting characteristics have been identified in patients with traumatic brain injury for prolonged intubation (>7 days): a GCS of 8 or below and an injury severity score of 25 or higher [19]. In patients with blunt head injury a GCS under 7 and Simplified Acute Physiologic Score (SAPS) over 15, on intensive care unit (ICU) day 4, have been recommended as criteria for early tracheostomy [20].

Optimal timing of tracheostomy should also include considerations of the risks of the procedure itself and the expected benefits including shortened duration of mechanical ventilation, shortened length of stay (LOS) in the ICU and hospital, decreased morbidity and mortality, and improved utilization of ICU resources and reduced costs. Table 1 [11,24[•],25,26] is a summary of reported series of patients receiving either 'early' or 'late' tracheostomy. Different definitions of early and late tracheostomy and morbidity make comparisons between studies difficult.

Duration of mechanical ventilation

One of the major purported advantages of tracheostomy is facilitated weaning from mechanical ventilation [27]. The proposed mechanisms are believed to be a lower resistance in the breathing system, less dead space, better removal of secretions, improved patient comfort, and need for less sedation [13]. Interestingly, Nathan *et al.* [28] found an increased work of breathing following extubation (1.04 J/l) compared with spontaneously breathing through an orotracheal tube attached to a t-piece (0.74 J/l). The mechanical factors describing breathing through a shorter tracheostomy tube compared with the longer orotracheal tube that may reduce the work of breathing and facilitate weaning were analyzed in detail in a recent publication in *Respiratory Care* [29]. In summary, these mechanical advantages are unlikely to explain why patients appear to wean faster following tracheostomy. Large prospective randomized studies testing this hypothesis are sparse, however, and no definitive conclusion can be stated.

Rumbak *et al.* [11] studied 120 patients in a prospective, randomized trial comparing early (within 48 h) versus delayed tracheostomy (14–16 days). They achieved a significantly decreased time on mechanical ventilation in the early tracheostomy group (7.6 ± 4.0 versus 17.4 ± 5.3 days). Flaatten *et al.* [21^{••}] showed a decreased median number of days on the ventilator after early tracheostomy (4.7 versus 14.7 days) in their retrospective analysis of 461 patients receiving tracheostomy during their ICU stay. This is in agreement with the results of another retrospective study comparing early versus late tracheostomy in 185 surgical ICU patients [23[•]]. The

Table 1 Summary of studies reporting important outcomes from early versus late tracheostomy

Study	Sample size early/late	Timing (days) early/late	Duration of mechanical ventilation (days) early/late	LOS (days) ICU early/late	LOS (days) Hospital early/late	Morbidity (%) (pneumonia) early/late	Mortality (%) ICU early/late	Mortality (%) Hospital early/late
Flaatten [21••] retrospective	230/231	<6/>6	4.7/14.7 (median)* 6.7/16.0 (mean)	6.8/12.7 (median)* 9.0/20.6 (mean)			7/14.7*	22.2/32.5*
Barquist [22••] prospective, randomized	29/31	<8/>28	21.5/21.2 NS	25.0/24.7 NS		96.5/90.3 NS	6.9/16.1 NS	
Moller [23•] retrospective	81/104	<7/>7	12.2±0.9/21.9±1.3*	16.7±1.0/26.0±1.3*	23.8±1.2/33.4±1.7*	27.2/42.3*		
Rumbak [11] prospective, randomized	60/60	<2/14–16	7.6±2.0/17.4±5.3*	4.8±1.4/16.2±3.8*		5/25*		31.7/61.7*
Hsu [24•] retrospective	163 total	<21/>21	19.0/44.3*	10.8/14.2*		43.6/60.4 NS	14.5/28.3*	44.5/54.7 NS
Arabi [25] prospective, database	29/107	<7/>7	9.6±1.2/18.7±1.3*	10.9±1.2/21.0±1.3*	101±19/105±7 NS		3/1 NS	17/14 NS
Sugerman [26] prospective, randomized	127/28	3–5/10–14		20±2/24±2 NS		49/57 NS		24/18 NS

Most used different definitions for important variables (i.e., 'early' and 'late') including morbidities. LOS, length of stay; ICU, intensive care unit; NS, not significant.

* Statistically significant.

authors found a significant reduction in days of mechanical ventilation in the early tracheostomy group (12.2 ± 0.9 versus 21.9 ± 1.3 days). This analysis not only suffered from a small study population, however, but also from an inhomogeneous distribution of patient diagnosis between the two groups (more cardiac and less trauma patients, as well as lower APACHE II scores in the early tracheostomy group).

Hsu *et al.* [24•] analyzed 163 medical ICU patients retrospectively and divided the patients into two groups: successful weaning and failed weaning. Regarding the relationship of timing of tracheostomy to successful weaning, an intubation period in excess of 21 days was associated with decreased rate of eventual successful weaning (31.5 versus 56%). Patients who underwent early tracheostomy had shorter weaning periods (19.0 versus 44.3 days).

Length of stay in intensive care unit and hospital

Rumbak *et al.* [11] demonstrated a significantly decreased LOS in the ICU after early tracheostomy in medical patients (4.8 ± 1.4 versus 16.2 ± 3.8 days), although some patients were sent to a step-down unit while still on mechanical ventilation. In keeping with this, Flaatten *et al.* [21••] found a marked decrease in the median ICU LOS in patients who received early tracheostomy (<6 days) compared with late tracheostomy (6.8 versus 12.7 days), although this study was retrospective and patients were not randomized. The previously cited study by Moller *et al.* [23•] (with its limitations) was also able to demonstrate a significantly shortened ICU LOS after early tracheostomy (16.7 ± 1.0 versus 26.0 ± 1.3 days) as well as shortened hospital LOS (22.8 ± 1.2 versus 33.4 ± 1.7 days). Hsu *et al.* [24•] found shorter posttracheostomy ICU stays after early tracheostomy (<21 days) (10.8 versus 14.2 days), retrospectively. Similarly, Arabi *et al.* [25] found a decreased ICU LOS (10.9 ± 1.2 versus 21.0 ± 1.3 days) but no difference in overall hospital LOS (101 ± 19 versus 105 ± 7) following earlier tracheostomy. The authors attributed the latter to the very limited number of rehabilitation facilities patients could be transferred to, thus staying in the hospital for a prolonged time.

Morbidity

Whereas Sugerman *et al.* [26] did not find a significant decrease in incidence of pneumonia in trauma patients receiving early tracheostomy, Rumbak *et al.* [11] were able to show a remarkable 80% fewer pneumonias in patients receiving early tracheostomy. Sugerman *et al.* noted, however, a bias toward enrollment of patients with a poorer prognosis in the tracheostomy group. Moller *et al.* [23•] found a significantly decreased rate in ventilator associated pneumonia after early tracheostomy (27 versus 42%). Interestingly, Hsu *et al.* [24•] were not able to demonstrate a decreased occurrence of nosocomial

pneumonia during the weaning period after early tracheostomy (<21 days) (43.6 versus 60.4%). Again, one has to keep in mind that this study was retrospective with a small inhomogeneous study population. Although Boudierka *et al.* [30] did not find a difference in pneumonia rate between early tracheostomy (day 5–6) and continued orotracheal intubation (58 versus 61%), they did find a delay in occurrence of pneumonia (day 6.7 ± 1.8 versus 9.2 ± 2.3) and a faster recovery from ventilatory support (6 ± 4.7 versus 11.7 ± 6.7) in the tracheostomy group.

Due to an insufficient number of patients Rumbak *et al.* [11] were unable to observe a significant difference in the in-hospital and 10-week postintubation evaluation of the trachea between the early and late tracheostomy groups. The incidence of laryngotracheal injury following intubation or tracheostomy in ICU patients was studied by a Spanish group [8•] who found the length of orotracheal intubation was the most important factor in the development of laryngotracheal injury. A comparison of patients undergoing prolonged intubation with those receiving tracheostomy may provide insight into the contributions of each of these to morbidity. Two studies addressing this are summarized in Table 2 [30,31].

Prolonged orotracheal intubation followed by tracheostomy seems to negatively influence the development of injury. In general, patients who spend many days in the ICU and need prolonged mechanical ventilation are usually in poor general condition (e.g. experience low tissue perfusion and suffer hypoxia due to anemia, hypotension and cardiac, kidney or hepatic failure) and present more serious upper airway injury [32–34]. Therefore, performing tracheostomy especially in these patients in a timely manner seems to be advantageous.

Mortality

Rumbak *et al.* [11] found a 50% reduction in mortality rate after early tracheostomy compared with delayed tracheostomy (19 versus 37%). More patients died of ventilator-associated pneumonia in the delayed tracheostomy group than in the early tracheostomy group (nine versus two). This confirms the findings of Kollef *et al.* [31] with mortality rates of 13.7 versus 26.4%. In a retrospective analysis by Flaatten *et al.* [21••] the overall ICU, hospital and 1-year survival rates were lower in patients receiving early tracheostomy compared with patients receiving mechanical ventilation for more than 24 h without a tracheostomy. Both groups had a similar severity score (SAPS around 47) with an estimated hospital mortality of about 42%. The standardized mortality ratio calculated from the expected mortality was 0.69 versus 0.93.

Although Hsu *et al.* [24•] found a lower ICU mortality (14.5 versus 28.3%) between early and late tracheostomy,

Table 2 Summary of prospective studies reporting important outcomes from tracheostomy versus continued, prolonged intubation

Study	Sample size T/I	Timing of tracheostomy (days)	Duration of mechanical ventilation (days) T/I	LOS (days)	ICU T/I	LOS (days)	Hospital T/I	Morbidity (%) (pneumonia) T/I	Mortality (%) ICU T/I	Mortality (%) Hospital T/I
Boudierka [30] prospective, randomized	31/31	6	$14.5 \pm 7.3/17.5 \pm 10.6^*$					18/19 NS	12/7 NS	
Kollef [31] prospective	51/470	9.7 ± 6.4	$19.5 \pm 15.7/4.1 \pm 5.3^*$	$18.8 \pm 15.5/5.7 \pm 6.7^*$	$30.9 \pm 18.1/12.8 \pm 10.1^*$			33.3/7.5*		13.7/26.4*

End-points are different between the two. LOS, length of stay; ICU, intensive care unit; T, tracheostomy; I, translaryngeal intubation; NS, not significant.
* Statistically significant.

the authors did not find a significant difference in hospital mortality rate (44.5 versus 54.7%). Arabi *et al.* [25] neither found a difference in ICU (3 versus 1%) nor in overall hospital mortality (17 versus 14%) between the two groups.

Costs

Although not all studies were able to show an overall mortality benefit from early tracheostomy, the majority of studies did show a shortened ICU LOS and decreased morbidity. This includes shortened time on mechanical ventilation with need for less sedation. Earlier transfer of the patient to a less care-intensive unit or even to the regular ward positively affects the nurse:patient ratio. This facilitates improved utilization of ICU resources and costs. Studies on this topic are lacking, however.

Barquist *et al.* [22**] had to abort their prospective, randomized, intention-to-treat study after an interim analysis did not show any significant differences between length of ventilation, pneumonia rate, or death between early (before day 8) and late tracheostomy (after day 28). Again, study design plays an important role when interpreting and comparing different studies. Since the authors conducted an intention-to-treat study all randomized patients were included even if the actual tracheostomy procedure took place after day 8 (in the early group) or before day 28 (in the late group) or if patients did not receive a tracheostomy at all but were assigned to a specific group.

Techniques of tracheostomy in the critically ill

Numerous studies on different techniques of tracheostomy have been published over the last two decades although alternative techniques to the traditional surgical procedure were attempted as early as 1955, but abandoned because of a high complication rate [35]. Percutaneous dilatational tracheostomy (PDT) was reintroduced with Ciaglia's technique in 1985 [36], and became increasingly popular in the 1990s [37].

Various devices have been developed to minimize identified risks and improve the simplicity of the procedure [38*]. A modern percutaneous tracheostomy device was developed by Toye and Weinstein in 1969 and its use in 100 trauma patients reported in 1986 [39,40]. The wire-guided percutaneous technique was developed and reported in the same year by the American surgeon Ciaglia, who combined the Seldinger wire nephrostomy tube multiple dilator placement technique with a special, low profile tracheostomy tube [36]. Several variants on the percutaneous tracheostomy technique have been developed including a wire-guided sharp forceps (Griggs' technique) [41], performance of the procedure under fiberoptic control, using a single, tapered dilator (Blue Rhino; Cook Critical Care, Bloomington, Indiana, USA)

[42], passing the dilator from inside the trachea to the outside (Fantoni's technique) [43], and using a screw-like device to open the tracheal wall (PercuTwist; R sch GmbH, Kernen, Germany) [44]. Each of these variations came about as an attempt to improve some aspects of another technique. Durbin's review on these techniques gives a very detailed and illustrated overview [38*].

Complications

The overall rate of complications associated with tracheostomy is relatively low [45,46]. Reported complications range from stomal infections, pneumothorax, subcutaneous emphysema, hemorrhage, tracheal stenosis, tracheomalacia and granulation tissue to (rarely) death [47–50].

Those complications have to be weighted against the identified risks of long term orotracheal intubation, including edema, inflammation, oral-labial ulcerations, vocal fold granulomas, arytenoid injury, and alterations of laryngeal motility due to laryngeal or tracheal stenosis, fibrosis or necrosis.

The most serious (but rare) complications are most often reported in anecdotal case reports and small series. Serious bleeding can occur with either surgical tracheostomy or PDT but appears to be less frequent with PDT [51]. One of the more serious concerns is posterior tracheal wall injury [52]. This is more likely with PDT but is also reported with surgical tracheostomy. Pneumothorax is infrequent with PDT but may occur in 1–3% of surgical tracheostomy. Routine chest radiograph is no longer recommended following tracheostomy placement, unless there are signs of unexpected compromise of air exchange [53,54]. Airway loss with the inability to replace it is a problem with tracheostomy in general.

A large number of uncontrolled case series and a few prospectively collected comparative studies report complications with PDT. A meta-analysis of five prospective, randomized comparisons of the classic Ciaglia PDT and surgical tracheostomy (in the operating room) found similar and infrequent acute complications for the two techniques [55–60]. Another meta-analysis which included cases series as well as prospective studies suggested a lower incidence for stomal wound infection and tracheal stenosis with PDT but a higher mortality [45]. Comparison of surgical tracheostomy (21 trials, 3512 patients) and PDT (27 trials, 1817 patients) demonstrated that perioperative complications are more frequent with PDT (10 versus 3%), whereas postoperative complications were more frequent following surgical tracheostomy (10 versus 7%). Most of the differences were in minor complications, except perioperative death

(0.44 versus 0.03%) and serious cardiorespiratory events (0.33 versus 0.06%), which were higher with PDT. Due to the inclusion of nonrandomized patients, however, this meta-analysis should be viewed cautiously. Overreporting of fatal complications is likely to influence the analysis. Minor complications, such as bleeding not requiring interventions, transient desaturation, and the need to convert to open procedure from PDT were reported rarely.

One of the more informative controlled, randomized, prospective comparisons of the complications of PDT and surgical tracheostomy was reported by Massick *et al.* [61]. Fifty patients were either randomized to PDT or surgical tracheostomy, 64 patients were included in a separate group (surgical tracheostomy performed in the operating room) if they met the exclusion criteria. Overall, there was no difference in acute complications between the study (ICU) groups (four in PDT, one in surgical tracheostomy, but 13 in surgical tracheostomy in the operating room). The late complications included one death after failing to reinsert the tracheostomy tube and failed orotracheal intubation after accidentally misplaced tracheostomy tube (PDT) following elective tube change on day 7. Besides confirming a low acute complication rate for PDT and surgical tracheostomy performed in the ICU, this study highlighted the high rate of complications of surgical tracheostomy performed in the operating room.

Delaney *et al.* [62**] conducted a meta-analysis including 17 randomized controlled trials with a total of 1212 study participants. Comparing PDT with surgical tracheostomy they demonstrated a reduced incidence of wound infection, and an overall decreased risk of death when using PDT.

While PDT appears equivalent to surgical tracheostomy for the overall incidence of clinically relevant bleeding, major periprocedural and long-term complications, subgroup analysis has revealed that, again, PDT was superior to surgical tracheostomy when the surgical tracheostomy was performed in the operating room.

Until a registry using standard reporting conventions is established, however, individualized patient decisions and clinical judgment are necessary to choose a tracheostomy technique [63*].

Considerations in subgroups: the morbidly obese patient

Since the introduction of PDT by Ciaglia and colleagues in 1985, obesity has remained a relative contraindication to this procedure. Obesity is a 'growing' problem, however, whose wave is washing beyond the borders of the United States, not only to western European countries. Approximately 127 million adults in the US are over-

weight (body mass index (BMI) ≥ 25), 60 million obese (BMI ≥ 30), and 9 million severely obese (BMI ≥ 40). All medical specialties – including intensive care medicine – are affected by this issue. Furthermore, obese patients are at higher risk for medical complications; for example, they are more likely to become and remain intubated, and have longer ICU stays with a higher mortality risk [64].

Obese patients experience a higher complication rate with either surgical tracheostomy or PTD although useful information from the literature in this special subgroup of patients is very scarce. Heyrosa *et al.* [65*] reported data on tracheostomies from 2000 to 2004 in their institution. Tracheostomy was performed on 1062 patients, of whom 142 had a BMI > 35 (ranging from 35 to 105, mean 42). Of these 142 patients, 89 received PDT (67 bedside, 22 operating room) and 53 received surgical tracheostomy (all in the operating room). Primary endpoints (PEPs), based on standardized definitions for reporting and characterizing acute tracheostomy complications [63*] (PDT converted to open procedure, re-operation, loss of airway control, bleeding requiring surgical airway control), as well as secondary endpoints (SEPs) (dislodgement of tube, cuff leak, bleeding more than 24 h post procedure), were similar in both groups (PEP PDT 5.6%, surgical tracheostomy 5.6%; SEP PDT 1.1%, surgical tracheostomy 5.6%). The authors compare their remarkably low complication rate with that reported by Byhahn *et al.* [66*] who report 43.8% in the obese group ($n = 73$, mean BMI 29.1) and 18.2% in the nonobese group ($n = 401$; mean BMI 24.5). They explain this strikingly improved outcome (lower complication rate with higher BMI and larger sample size) by performing only one PDT technique instead of four, thus having greater experience. The authors conclude that (in experienced hands) performing PDT in morbidly obese patients is a safe procedure (remember, however, this is a retrospective, nonrandomized report with a small sample size).

Conclusion

There remain many important questions to be answered regarding the use of artificial airways in the critically ill. What predicts the duration of mechanical ventilation in critically ill patients? When should a tracheostomy be performed? Are certain types of patients (trauma versus medical) more likely to benefit from the procedure? Do the expected benefits clearly outweigh the associated risks? Which technique should be used?

Although these questions have been asked for more than two decades and continue to be asked now, the literature does not provide definite answers. Evidence seems to support early tracheostomy, however. Gain in experience, improved percutaneous techniques, and the use of fiber-optic guidance have made tracheostomies safer and

more readily available to the critically ill patient in recent years.

Although this is clearly only opinion and not based on multiple prospective randomized controlled studies, the hesitance of many clinicians to perform a tracheostomy early in the ICU course is not based on sound research either.

References and recommended reading

Papers of particular interest, published within the annual period of review, have been highlighted as:

- of special interest
- of outstanding interest

Additional references related to this topic can also be found in the Current World Literature section in this issue (pp. 100–101).

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