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ORIGINAL ARTICLE

Early *versus* late tracheostomy in pediatric intensive care unit: does it matter? A 6-year experience

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ABSTRACT

BACKGROUND: The aim of this study is to examine the clinical data of children who underwent tracheostomy during their stay in Pediatric Intensive Care Unit (PICU), in order to describe the relationship between the timing of tracheostomy, the length of PICU stay and the occurrence of ventilator-associated pneumonia (VAP).

METHODS: This is a retrospective cohort study that collects all patients undergoing tracheostomy during their PICU stay over a six-year period. Data collection included PICU length of stay, days of intubation, days of mechanical ventilation, primary indication for tracheostomy, information about VAP and decannulations. The early tracheostomy group was defined as patients who had ten or fewer days of continuous ventilation, whereas the late tracheostomy group had more than ten days of continuous ventilation.

RESULTS: A significant decrease in the rate of VAP incidence was noticed in the early tracheostomy group *vs.* late group (P=0.004, OR=0.39, 95% CI: 0.18-0.85). No differences were observed about decannulation, need of long-term ventilation and death rate. Significant decreases of days of mechanical ventilation and PICU stay were found in subgroup of patients who underwent early tracheostomy and were decannulated within 18 months.

CONCLUSIONS: No standard timing for tracheostomy placement has been established in the pediatric population. Early tracheostomy can shorten the days of ventilation and hospitalization in PICU and reduce the incidence of VAP, but further studies are needed to identify patient categories in which it can be of benefit.

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Key words: Tracheostomy - Pediatric emergency medicine - Ventilator-associated pneumonia - Pediatric intensive care units.

Over the last 20 years, there has been an increase in the absolute number of tracheostomies performed in the pediatric intensive care units. Indications, timing and the profile of the tracheostomized patient evolved in the past years.[1-5] Until 30 years ago, tracheostomy was primarily performed as a lifesaving procedure for children with acute upper airway obstruction, while current vaccinations programs, mainly against *Corynebacterium diphteriae* and *Haemophilus influenzae*, have drastically reduced this type of indication. On the other hand, the evolution of neonatal and pediatric intensive care techniques resulted in an increase of technology-dependent children,[6] suffering from medical conditions (*i.e.*, bronchopulmonary dysplasia or neuromuscular diseases) requiring medical devices for hospi-

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tal discharge. In this group of patients, tracheostomy is often used to set a long-term ventilation (LTV), facilitating the returning home and allowing the growth and the neurobehavioral development.[7]

While the role of tracheostomy in adults has been endorsed in American and European guidelines,[8, 9] few studies had investigated its role in children, probably because of the wide variability of ages and diseases in the pediatric population. Common indications to tracheostomy in pediatric age include need of prolonged mechanical ventilation, failure of weaning, craniofacial surgery and chronic non-resolving respiratory failure.

In addition, there is a relative lack of data in pediatric population about the benefits and risks of performing tracheostomy within the first days from the start of invasive mechanical ventilation (early tracheostomy), especially regarding the possibility of shortening the length of PICU stay and decreasing the risk of ventilator-associated pneumonia (VAP).

The aim of this study is to examine the clinical data of children who underwent tracheostomy in a six-year period, in order to describe the relationship between the timing of tracheostomy, the length of PICU stay and the occurrence of VAP.

TABLE I.—*Categorized indications for tracheostomy in study population.*

Indications	Occurrence N. (%)
Cardiopulmonary	4 (5.7%)
Bronchopulmonary dysplasia	4 (5.7%)
Neoplasm	9 (12.9%)
Brain	8 (11.4%)
Neuroblastoma	1 (1.4%)
Neuromuscular	36 (51.4%)
Arnold-Chiari disease	1 (1.4%)
Hydrocephalus	2 (2.9%)
Seizure disorder	4 (5.7%)
Encephalopathy (*e.g.* infectious, hypoxic ischemic)	10 (14.3%)
Neuromuscular impairment (*e.g.* spinal muscular atrophy, muscular dystrophy, acquired hypotonia)	10 (14.3%)
Metabolic disease (*e.g.* glycogen storage disease)	4 (5.7%)
Cerebral hemorrhage	3 (4.3%)
Spinal dysraphism	2 (2.9%)
Injury	11 (15.7%)
Head and/or neck injury	11 (15.7%)
Upper airway obstruction/abnormality	5 (7.1%)
Tracheo-esophageal fistula	2 (2.9%)
Other airway diseases	3 (4.3%)
Craniofacial	5 (7.1%)
Crouzon	1 (1.4%)
Other polymalformative syndromes	4 (5.7%)
Overall	70 (100%)

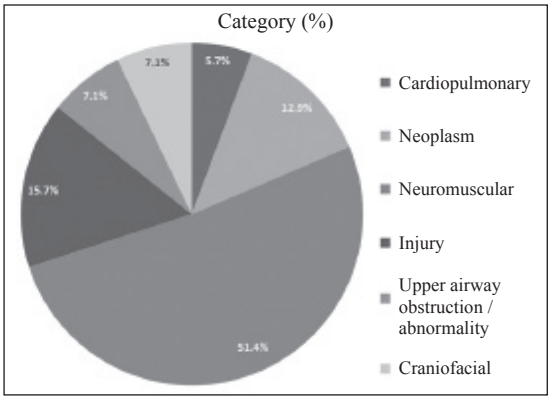

Figure 1.—Distribution of patients.

Materials and methods

This is a retrospective cohort study that was conducted in all consecutive patients (from the first day of life to 17 years) admitted to our academic PICU for various medical conditions over a six-year period (from 1st June 2008 to 31st May 2014) who underwent tracheostomy. Our PICU is an 8-bed critical care unit which serves as tertiary referral trauma center and admitting also infants and children after major neurosurgical procedures. All the tracheostomies were performed in surgical technique, performed by the same surgical team of reference for our PICU. In our PICU all tracheostomies are routinely performed in surgical technique, also due to young age of our patients. Patients were excluded from data analysis if tracheostomy was scheduled prior to PICU admission. Patient personal and clinical data were extracted from medical records. A standardized data extraction form was utilized. Data collection included age at admission, gender, pediatric index of mortality 3 (PIM 3), PICU length of stay, time from

TABLE II.—*Subgroup demographic data.*

Variables	Cardiopulmonary	Neoplasm	Neuro-muscular	Injury
N. (%)	4 (5.7%)	9 (12.9%)	36 (51.4%)	11 (15.7%)
Median PIM3 score (IR)	2.3 (0.9-12.6)	1.0 (0.6-3.3)	6.1 (1.5-11.2)	4.0 (1.2-70.9)
Median age at tracheostomy (IR)	0.2 (0.0-1.0)	13.4 (1.6-15.7)	4.8 (0.2-9.9)	13.5 (8.5-15.0)
Male gender (%)	4 (100%)	3 (33.3%)	19 (52.8%)	7 (63.6%)
Median days in PICU (IR)	56.5 (36.0-81.5)	18.0 (11.5-32.5)	29.0 (16.3-48.0)	38.0 (17.0-49.0)
Median ventilation days (IR)	26.0 (22.8-33.0)	16.0 (7.0-26.5)	19.5 (11.0-35.5)	11.0 (8.0-19.0)
Median PICU days before tracheostomy (IR)	22.0 (13.8-31.8)	9.0 (3.5-17.5)	13.5 (10.0-24.3)	8.0 (6.0-14.0)
Median ventilation days before tracheostomy (IR)	20.0 (5.5-27.8)	8.0 (2.5-17.5)	11.5 (5.0-17.0)	8.0 (6.0-14.0)
Early tracheostomy (%)	1 (25.0%)	5 (55.6%)	18 (50.0%)	6 (54.5%)
VAP (%)	1 (25.0%)	6 (75.0%)	15 (45.5%)	2 (18.2%)
Decannulation (%)	1 (25.0%)	5 (55.6%)	15 (41.7%)	7 (63.6%)
LTV (%)	2 (50.0%)	2 (22.2%)	14 (38.9%)	0 (0%)
Dead in PICU (%)	0 (0%)	0 (0%)	4 (11.1%)	1 (9.1%)

VAP: ventilation-associated pneumonia; LTV: long-term ventilation.

admission to tracheostomy, days of intubation, days of mechanical ventilation (which are divided in pre- and post-tracheostomy), main diagnosis, requirement of long-term respiratory support, overall mortality during the PICU stay, VAP incidence and decannulation (in a follow-up period of 18 months).

The early tracheostomy group was defined as patients who had ten or less days of continuous ventilation before the procedure, whereas the late tracheostomy group had more than ten days of continuous ventilation. The threshold of ten days corresponds to that chosen by the Cochrane Database System Review in the latest review on this topic.[10]

We identified VAP as defined by the USA Centers for Disease Control and Prevention.[11] Later, we have distinguished, according to date of onset, the cases of VAP that occurred before tracheostomy by subsequent cases.

The primary indication for tracheostomy was designated from the following six categories: 1) cardiopulmonary; 2) CNS neoplasm; 3) neuromuscular; 4) injury; 5) upper airway; and 6) craniofacial abnormalities. The goal was to distinguish patients who would most likely need a permanent tracheostomy or LTV (specifically, patients in categories 1 and 3) from those in which the need for tracheostomy was due to maxillofacial and laryngotracheal injuries with reparable anatomic disruption (categories 5 and 6). For patients in categories 3 and 4, the tracheostomy was usually justified by either an inability of the

TABLE III.—*Outcome measures based on the timing of tracheostomy.*

	Early tracheostomy (N.=37)	Late tracheostomy (N.=33)	P value	OR (95% CI)
Median age, years (IR)	6.2 (1.1-11.4)	1.4 (0.0-13.6)	0.209	
Male gender (%)	23 (62.2%)	18 (54.5%)	0.628	
Median PIM 3 (IR)	3.7 (0.8-11.2)	4.0 (1.2-10.2)	0.922	
Median days on ventilation (IR)	9.0 (5.5-15.0)	27.0 (18.0-35.5)	<0.001	
Median ventilation days before tracheostomy (IR)	5.0 (1.0-8.0)	17.0 (14.0-23.0)	<0.001	
Median days in PICU (IR)	17.0 (11.5-29.0)	37.0 (27.0-50.5)	<0.001	
Median PICU days before tracheostomy (IR)	7.0 (3.5-10.0)	18.0 (14.0-28.0)	<0.001	
VAP (%)	9 (27.3%)	18 (54.5%)	0.044	0.31 (0.11-0.90)
Decannulation (%)	19 (51.4%)	17 (51.5%)	0.989	
Long-term ventilation (%)	10 (27.0%)	9 (27.3%)	0.982	
Dead in PICU (%)	3 (8.1%)	3 (9.1%)	0.883	

Early ≤10 days; late >10 days.

Upper airway obstruction	Cranio-facial abnormalities	Age			All patients
		<1 year	1-5 years	>5 years	
5 (7.1%)	5 (7.1%)	19 (27.1%)	18 (25.7%)	33 (47.1%)	70 (100%)
3.3 (0.8-9.0)	0.5 (0.3-6.5)	12.3 (17.0)	9.1 (22.5)	11.4 (21.0)	3.8 (1.1-10.9)
1.0 (0.6-6.5)	0.1 (0.0-2.3)		2.3 (1.5)	12.3 (3.7)	4.8 (0.3-12.6)
5 (100%)	3 (60.0%)	13 (68.4%)	13 (72.2%)	15 (45.5%)	41 (58.6%)
16.0 (12.5-22.0)	32.0 (4.5-62.0)	47.6 (29.8)	28.8 (22.6)	34.1 (48.1)	26.0 (16.0-43.5)
7.0 (6.0-13.0)	23.0 (3.5-37.0)	33.6 (24.2)	19.1 (15.2)	20.2 (34.5)	17.0 (8.0-27.3)
6.0 (3.0-12.5)	5.0 (2.0-31.0)	20.3 (14.6)	12.7 (7.8)	13.5 (14.8)	13.0 (6.0-18.3)
6.0 (2.5-12.0)	5.0 (2.0-23.5)	17.2 (13.3)	10.9 (8.0)	9.0 (6.2)	10.5 (5.0-16.3)
4 (80.0%)	3 (60.0%)	6 (31.6%)	12 (66.7%)	19 (57.6%)	37 (52.9%)
1 (20.0%)	2 (40.0%)	11 (57.9%)	5 (29.4%)	11 (36.7%)	27 (40.9%)
4 (80.0%)	4 (80.0%)	11 (57.9%)	7 (38.9%)	18 (54.5%)	36 (51.4%)
0 (0%)	1 (20.0%)	8 (42.1%)	6 (33.3%)	5 (15.2%)	19 (27.1%)
0 (0%)	1 (20.0%)	3 (15.8%)	0 (0%)	3 (9.1%)	6 (8.6%)

airway control or a critical reduction of the respiratory drive.

Statistical analysis

Data were collected using a Microsoft Excel 1997-2003 spreadsheet (Microsoft Corporation, Redmond, WA, USA) and analyzed in SPSS v. 20.0 (IBM Corp., Armonk, NY, USA). Median and interquartile range (IR) are given for normally distributed metric variables, frequencies and percentages are given for non-metric variables. The *t*-test or Mann-Whitney U-test were performed to compare the means for all time-related outcome measures, while Fisher's exact test or Pearson's chi square were applied to observe associations for qualitative variables. A P value of <0.05 was considered statistically as significant. Consensus to data analysis was obtained from legal representatives. No patient did not have a tracheostomy for ethical reasons or refusal.

TABLE IV.—*Outcome data based on tracheostomy decannulation (yes/no) and on the need for long-term ventilation.*

Variable	Early tracheostomy (N.=37)	Late tracheostomy (N.=33)	P value	OR (95% CI)
Tracheostomy decannulation: yes (N.=36)				
Median MV days (IR)	7.0 (4.0-11.0)	27.0 (17.5-37.0)	<0.001	
Median PICU LOS (IR)	13.0 (9.0-24.0)	39.0 (30.5-74.0)	<0.001	
VAP (%)	3 (18.8)	12 (70.6)	0.003	0.10 (0.02-0.50)
Tracheostomy decannulation: no (N.=34)				
Median MV days (IR)	11.0 (8.0-17.8)	26.5 (18.3-35.8)	0.001	
Median PICU LOS (IR)	21.0 (15.0-50.3)	35.5 (25.3-44.5)	0.281	
VAP (%)	6 (35.3)	6 (37.5)	1.000	0.91 (0.22-3.76)
No LTV (N.=51)				
Median MV days (IR)	8.0 (5.0-11.0)	27.0 (17.3-34.8)	<0.001	
Median PICU LOS (IR)	18.0 (11.0-26.0)	36.5 (25.8-45.0)	<0.001	
VAP (%)	5 (20.0)	11 (45.8)	0.07	0.30 (0.08-1.05)
LTV (N.=19)				
Median MV days (IR)	13.5 (6.5-31.3)	26.0 (21.0-55.5)	0.055	
Median PICU LOS (IR)	16.0 (11.3-69.5)	39.0 (28.0-57.0)	0.06	
VAP (%)	4 (50.0)	7 (77.8)	0.335	0.29 (0.04-2.32)

In the long-term ventilation group a statistically significant difference has been observed in age (6.7 *vs*. 0.5, P=0.001)
MV days: days of mechanical ventilation; PICU LOS: mean length of stay in Pediatric Intensive Care Unit; VAP: ventilation-associated pneumonia.

Results

Of the 3610 admissions to the PICU during the period of observation, 70 underwent tracheostomy, an overall occurrence rate of 1.94% (19.4 of 1000). There were no intraoperative complications and we did not report early and/or late complications (occlusion, displacement, major bleeding, tracheal stenosis or granuloma). The various diagnoses, following the six already described categories, are shown in Table I. Of the 70 patients, 4 (5.7%) had cardiopulmonary disease, 9 (12.9%) had CNS neoplasms, 36 (51.4%) had neuromuscular impairment, 11 (15.7%) had traumatic injury, 5 (7.1%) had an upper airway obstruction or abnormality and 5 (7.1%) had a craniofacial malformation (Figure 1). As shown in Table II, for all children undergoing a tracheostomy, the mean PICU stay was 36.4 days (median 26.0 days) and the mean PICU stay before tracheostomy was 15.2 days (median 13.0 days). Mean ventilation time was of 23.6 days (median 17.0 days). For 5 categories, patients were ventilated mostly before tracheostomy, suggesting that this procedure may be helpful to allow weaning from mechanical ventilation. Instead, patients belonging to the category "neuromuscular" were mostly ventilated after tracheostomy: it is likely that, for this type of patients, the tracheostomy is a step aimed to set a long-term medical care, as suggested by the large number of patients who, in this group, were not decannulated (58.3%) and underwent long-term ventilation (38.9%). Of all patients, 34 (48.6%) did not have decannulation and 19 (27.1) were discharged on long-term ventilation. 6 patients (8.6%) died during their PICU stay.

Sixty-five patients of 70 (92.9%) were ventilated for more than 48 hours, and they were examined for the occurrence of VAP. Early and late tracheostomy groups did not significantly differ in terms of age, sex and PIM 3 (Table III). Patients were examined for PICU length of stay, days from admission to tracheostomy, total days of mechanical ventilation and days of ventilation before tracheostomy. In the early tracheostomy group, there was a significant reduction in days of ventilation (17.2 *vs.* 30.6, P<0.001) and in the stay in PICU (30.6 *vs.* 43.0, P<0.001).

A significant decrease in the rate of VAP incidence was seen in the early tracheostomy group as compared with the late group (P=0.044, OR=0.31, 95% CI: 0.11-0.90), while no significant differences were observed about decannulation, need of LTV and death rate.

Furthermore, data about PICU length of stay, days of mechanical ventilation and occurrence of VAP were evaluated referring to decannulation and to the need of LTV (Table IV). Significant decreases of days of mechanical ventilation and PICU stay were found in subgroup of patients who underwent early tracheostomy and were later decannulated, while, in the subset of not decannulated patients, there was a difference only in terms of days of mechanical ventilation between early and late tracheostomy. Otherwise, early tracheostomy was associated with a significant reduction of days of mechanical ventilation and days of PICU stay in the subgroup of no-LTV patients. Finally, no differences between early and late tracheostomy were observed in patients needing LTV.

Discussion

The results of this study are consistent with the present literature on tracheostomy practice in a PICU setting.[12, 13] Similarly to the studies that have focused on indications of tracheostomy in the pediatric population,[13, 14] it has been noticed that main indication is represented by chronic/degenerative diseases, both cardiopulmonary and neurological (57.1%). In almost 50% of children requiring a tracheostomy a long-term use is intended and, in 56% of them, the tracheostomy allows to carry out a long-term ventilation, which is fundamental to sustain the vital functions of the patient. In this cluster, while the subgroup of patients with a neuromuscular disease (*e.g.*, SMA) remains relevant, we expect that the number of children with bronchopulmonary dysplasia who will face long-term ventilation will increase significantly, suggesting

the need for further studies to evaluate the time course and the possible complications of these patients' population.

A not small number of patients with CNS neoplasm required a permanent tracheostomy (44.4%). None of these died during their PICU stay, but many (75.0%) developed a VAP. In addition, an important number of tracheostomies refers to common conditions in our PICU, such as major traumatic injuries (15.7%), upper airway malformations (7.1%) and craniofacial abnormalities requiring surgery (7.1%). Our data slighty differ from those provided by Funamura *et al.*,[13] since in our review a higher incidence of tracheostomies performed after trauma and a lower incidence of tracheostomies for upper airway malformations were found. This observation may be explained by the large number of injured children referring to our PICU, since it is a regional referral center for pediatric trauma. In our injured patients, tracheostomy was mostly performed in a temporary way, in order to facilitate the weaning and to avoid the consequences of a prolonged intubation, while just four patients required a permanent tracheostomy, because of a poor post-trauma neurological impairment. In children with craniofacial abnormalities (*e.g.*, Crouzon's Syndrome), tracheostomy often represent the first time of a surgical procedure, whereas in one of our cases it was functional to long-term ventilation. Five tracheostomies were performed in order to protect the airway in children with tracheoesophageal fistulae or affected by other airway abnormalities. In these latter two categories, early tracheostomy often represents the standard of care, as these patients usually have an anatomy that does not ensure airway protection and they often undergo multiple surgical procedures.

A tendency to delay tracheostomy in children younger than one year may be assumed, whereas in this age early tracheostomy is not common (31.6%). Nevertheless, the incidence of VAP in these children, compared to the other ages, is almost doubled (57.9% *vs.* 33.3%), suggesting that an optimal timing for tracheostomy could actually reduce this complication and perhaps shorten the length of stay in PICU.

Tracheostomized patients have high probability to experience a prolonged PICU course.[12] The long hospital stays were more likely due to the underlying diseases that gave rise to the need of tracheostomy, rather than to the tracheostomy itself. Anyway, tracheostomy practice seems to be a safe practice and does not involve additional risks. Tracheostomy is rather a reliable way to prevent death due to respiratory failure: actually, no patient died because of a respiratory condition, while lots of children, by tracheostomy, received a chance of life, in the way they can be weaned from the ventilator or be discharged to home ventilation.

Relative to continued translaryngeal intubation, in adults tracheostomy was associated with less sedation use and more patient comfort,[15, 16] leading to possibly faster ventilator weaning, earlier mobility and PICU discharge. It is reasonable to think that the prolonged intubation can play an important role in the pathogenesis of VAP. In fact, the endotracheal tube allows the passage of contaminated secretions from the oropharynx to the lungs [17] and facilitates the formation of biofilm, which constitutes a reservoir for bacterial infections.[18] On the other hand, the tracheostomy offers the possibility of a better suctioning of secretions, which represent a source of infection, and above all allows to shorten the duration of invasive mechanical ventilation, which is an independent risk factor for the onset of VAP.

Actually, by looking at the results of our study, we found that the performing of a tracheostomy before 10 days of invasive mechanical ventilation reduces the days of mechanical ventilation and it is associated with a lower risk of VAP. These observations support the current ideas about the possible benefits of early tracheostomy.[19] On the other hand, the reduction of the PICU length of stay and the difference in mortality were not statistically significant. We must conclude that it is not possible to say whether and how the benefits of early tracheostomy outweigh the risks of this procedure to the point to make this procedure advantageous.

Following the analysis by subgroups, we

found that the early placement of tracheostomy can be a convenient choice regardless of the length of the tracheostomy itself and the need to LTV. In fact, all of these groups of patients, when subjected to early tracheostomy, experience a shorter PICU stay, fewer days of ventilation and, in relation to patients in LTV, a lower incidence of VAP. For patients who are predicted to quickly decannulate, tracheostomy may often represent an essential measure to take in order to resolve the current pathology of the patient; this is not demonstrated for patients suffering from chronic-degenerative diseases (*e.g.*, those belonging to the categories 1, 2, and 3). This could be a limitation of the study because these patients, through a tracheostomy, may be more rapidly moved out of the PICU and may more easily start a long-term care program. The challenge is to identify in the first days of hospitalization the features of the patients to whom the early placement of a tracheostomy can produce a significant improvement, decreasing their stay in PICU and the risks associated with it.

Limitations of the study

The current study is limited by its retrospective nature. Although the analysis of demographics characteristics did not show any statistically significant differences, it is not possible to exclude bias in favor to the early tracheostomy group. The timing of the tracheostomy is usually at the discretion of the attending physician, suggesting the need to identify selection criteria for early tracheostomy placement. In addition, we have not investigated about the presence of complications related to tracheostomy placement. A prospective randomized trial is needed to obtain consistent objective data.

Conclusions

No standard timing for tracheostomy placement has been established in the pediatric population, although many children experience this procedure every year. Early tracheostomy can shorten the days of ventilation and hospitalization in PICU and reduce the incidence of VAP, but further studies are needed to identify patient categories in which it can actually be of benefit.

Key messages

— To date, there are no shared guidelines regarding the timing of tracheostomy in patients admitted in the pediatric ICU.

— Timing of tracheostomy in pediatric population varies and can be influenced by the age of the patient and the underlying disease.

— Our study shows that, independently from the underlying cause, a tracheostomy within ten days of intubation may decrease the incidence of VAP and the duration of ventilation and reduces ICU length of stay.

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Conflicts of interest.—The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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