Tracheostomy for Infants Requiring Prolonged Mechanical Ventilation: 10 Years’ Experience

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KEY WORDS
traceoectomy, infant, bronchopulmonary dysplasia, ventilator, prematurity

ABBREVIATIONS
BPD—bronchopulmonary dysplasia
ELBW—extremely low birth weight
LTR—laryngotraheal reconstruction
PPV—positive pressure ventilation
VLBW—very low birth weight

Ms Overman completed the data collection, drafted the initial manuscript, and approved the final manuscript as submitted; Ms Liu carried out the statistical analyses, reviewed and revised the manuscript, and approved the final manuscript as submitted; Drs Kurachek, Shreve, Maynard, and Mammel conceptualized and helped design the study, edited the initial manuscript, and approved the final manuscript as submitted; and Dr Moore designed the data collection instruments, coordinated and supervised data collection, critically reviewed the manuscript, and approved the final manuscript as submitted.

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WHAT’S KNOWN ON THIS SUBJECT: Advances in the treatment of critically ill infants have increased survival of extremely low/very low birth weight and medically complex infants. Improved survival can result in prolonged mechanical ventilation and sometimes tracheostomy. Current tracheostomy rates for these infants are unknown.

WHAT THIS STUDY ADDS: This long-term review of infants discharged from a NICU with tracheostomies is the first to describe tracheostomy rates specifically in extremely low/very low birth weight infants. It focuses on long-term clinical outcomes and comorbidities rather than surgical complications.

BACKGROUND: Despite advances in care of critically ill neonates, extended mechanical ventilation and tracheostomy are sometimes required. Few studies focus on complications and clinical outcomes. Our aim was to provide long-term outcomes for a cohort of infants who required tracheostomy.

METHODS: This study is a retrospective review of 165 infants born between January 1, 2000 and December 31, 2010 who required tracheostomy and ventilator support. Children with complex congenital heart disease were excluded.

RESULTS: Median gestational age was 27 weeks (range 22–43), and birth weight was 820 g (range 360–4860). The number of male (53.9%) and female (46.1%) infants was similar (P = .312). Infants were divided into 2 groups based on birth weight ≤1000 g (A) and >1000 g (B). Group A: 87 (57.6%) infants; group B 64 (42.4%). Overall tracheostomy rate was 6.9% (87/1345) for group A versus 0.9% (64/6818) for B (P < .001). Group A had a longer time from intubation to positive pressure ventilation independence, 505 days (range 62–1287) vs 372 days (range 15–1270, P = .011). Infants who had >1 reason for tracheostomy comprised 78.8% of the sample; 69.1% of infants were discharged on ventilators. Birth weight did not affect time from tracheostomy to decannulation (P = .233). More group A infants were decannulated (P = .023). Laryngotraheal reconstruction rate was 35.8%. Five-year survival was 89%. Group B had higher mortality (P = .033). 64.2% of infants had developmental delays; 74.2% had ≥2 comorbidities.

CONCLUSIONS: Tracheostomy rates were higher for extremely low birth weight infants than previously reported rates for all infants. Decannulation rates and laryngotraheal reconstruction rates were consistent with previous studies. Survival rates were high, but developmental delay and comorbidities were frequent. Pediatrics 2013;131:1–6
Despite early surfactant therapy, optimizing ventilator strategies, and increased use of noninvasive positive pressure ventilation, bronchopulmonary dysplasia (BPD) continues to be a complication of premature births. Survival of extremely low birth weight (ELBW) and very low birth weight (VLBW) infants has increased, contributing to an increased incidence of BPD. Moreover, the care of critically ill infants born at term with congenital anomalies has also improved. Many of these infants require mechanical ventilation for extended periods. Some ultimately require tracheostomy placement for prolonged ventilation. Others require tracheostomy placement due to congenital airway anomalies but have minimal ventilatory needs.

Studies have shown that early tracheostomy reduces the incidence of subglottic and tracheal stenosis in children who are intubated for long periods. In addition, tracheostomy results in improved comfort, decreased need for sedation, decreased systemic corticosteroid exposure (which is associated with poorer neurodevelopmental outcomes), improved nutrition and growth, improved ability to attempt oral feeds, and, once established, vocalization with a speaking valve. Overall tracheostomy rates range from 0.55% to 2.7%.

Several studies focus on the surgical indications, complications, and techniques used for pediatric tracheostomy. Few studies focus on the complications and long-term clinical outcomes for infants that require tracheostomy placement and prolonged mechanical ventilation. Most of the available literature was published or conducted before 2004, when many of the new ventilator modalities and techniques had not yet become incorporated into clinical practice for the treatment of respiratory failure. These advances in respiratory care and the treatment of infants in NICUs have significantly improved the outlook for critically ill newborns over the past 20 years.

Children's Hospitals and Clinics of Minnesota is a pediatric health care system with 2 full-service pediatric hospitals. At these institutions, pediatric pulmonologists are consulted annually on ≥50 patients (6.13% of all NICU patients annually) for recommendations about management of infants with prolonged mechanical ventilation requirements and those with congenital airway anomalies that require tracheostomy with minimal ventilatory needs. Of those infants, 15 to 20 will ultimately have a tracheostomy placed. Upon discharge, the patients are managed by a single pediatric pulmonary practice. Before discharge from the hospital the family receives extensive training in tracheostomy care with manikins (including changing the tracheostomy tube). Once manikin training is complete the family is required to change the tracheostomy on their child, complete a skill checklist, and ultimately manage all cares for the child for at least one 24-hour shift before discharge. On an outpatient basis suitable candidates are weaned from ventilator support and decannulated (Fig 1). The purpose of this study is to provide a descriptive report of long-term outcomes for a cohort of patients discharged from Children's Hospitals and Clinics of Minnesota.

1. If PEEP is ≥6 cm, wean PEEP as tolerated to 5 cm. Before discharge to home, the pressure support (PS) should have been weaned to 10–15.

2. If ventilator rate is ≥26, wean rate by 1–2 breaths per week until rate is reduced to 25 breaths/min.

3. Begin continuous positive airway pressure (CPAP) + PS trials: 15 minutes twice daily.

4. Advance CPAP + PS trials by 15 minutes twice daily each week to capture time from 8 a.m. to 8 p.m.

5. When patient is on full daytime CPAP + PS, begin trach collar/nose time, 15 minutes twice daily.

6. Advance trach collar/nose time by 15 minutes twice daily each week to capture time from 8 a.m. to 8 p.m.

7. When tolerating trach collar/nose during daylight hours, wean night vent rate by 1–2 breaths per week until a rate of 5 is tolerated for 1 week.

8. Remove from ventilator 24/7.

**FIGURE 1**

Pressure control ventilation home weaning protocol: used to wean patients from mechanical ventilation at home, without readmission to the hospital. CBG, capillary blood gas; PEEP, positive end expiratory pressure; VBG, venous blood gas.

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**Weaning tolerance:**

1. Oxygen saturation is ≥92% on an FiO2 <0.30
2. Resting respiratory rate is 5–60
3. Retractions are absent to mild and not increasing
4. Unlabored respirations:
   - no diaphoresis
   - activity maintained
   - affect/behavior stable
   - no irritability
   - resting heart rate is at preweaning rate
5. End-tidal CO2 readings ≤50 mm Hg
6. In-home CBG or VBG if weaning tolerance is uncertain
Hospitals and Clinics of Minnesota after tracheostomy placement.

METHODS

This study involved a retrospective chart review of 184 tracheostomized NICU patients followed by a single pediatric pulmonary practice. Inclusion criteria included birth between January 1, 2000 and December 31, 2010. To better understand outcomes in patients with pulmonary disease, upper airway anomalies, and congenital lung abnormalities, patients with complex congenital heart disease (cyanotic heart lesions and/or single ventricle physiology) were excluded. Our center’s experience is that children who require tracheostomy and ventilation for cyanotic heart lesions have a higher rate of complications, more prolonged ventilatory needs, and a greater incidence of morbidity and mortality. To allow for comparison with previous studies and gain a better understanding of the outcomes for ELBW and VLBW infants, the remaining 165 eligible patients were subdivided into 2 groups: patients who weighed <1000 g at birth (Group A) and those who weighed ≥1000 g at birth (Group B). Data were obtained from each patient’s inpatient and outpatient medical record. The study was approved by the Institutional Review Board at Children’s Hospitals and Clinics of Minnesota. Informed consent was not required because it was a retrospective study that did not affect patient care.

Data collected included gestational age and birth weight, number of days intubated before tracheostomy, weight at tracheostomy, home ventilation requirements, time to positive pressure independence (PPV), time to decannulation, rate of laryngotraheal reconstruction (LTR), neurologic outcomes, comorbidities, presence of recurrent wheezing, chronic nebulizer use, and survival.

Descriptive statistics were calculated for frequency of categorical data (gender), mean (SD), median (range), and continuous variables (gestational age, birth weight, time to decannulation). Two-sample t tests were used to compare the time to PPV independence and decannulation. The rates of complications between patients were compared by $\chi^2$ analysis. A Kaplan-Meier curve was used to estimate survival, and log-rank test results were used to compare the survival rates between groups. A two-sided $P$ value of <.05 was considered significant. All statistical analyses were conducted with the SPSS version 15.0 software (IBM SPSS Statistics, IBM Corporation, Armonk, NY).

RESULTS

Table 1 describes the patient characteristics. Median gestational age was 27 weeks (range 22–43). Median birth weight was 820 g (range 360–4860). The number of male and female infants was similar (53.9% vs 46.1%, $P = .312$; Table 1). There were 87 infants (57.6%) in Group A and 64 (42.4%) in Group B (Table 1). The overall tracheostomy rate was 1.8% (Group A 6.9% (87/1345); Group B 0.9% (64/6818; $P < .001$).

Table 2 describes the reasons for tracheostomy and compares reasons for tracheostomy based on birth weight. One hundred thirty infants (78.8%) had >1 reason for a tracheostomy. Compared with Group B patients, Group A patients were more likely to require tracheostomy because of BPD (95.4% vs 17.2%, $P < .001$) and/or noncomplicated congenital heart disease (70.1% vs 45.3%, $P = .002$).

Table 3 reports the length of hospital stay, days intubated before tracheostomy, time to PPV independence, and time to decannulation based on birth weight. Of 165 patients, 114 (69.1%) were discharged from the hospital on mechanical ventilation (Group A: 69 [79.3%]; Group B: 39 [60.9%], $P = .013$).

Four patients required mechanical ventilation for <5 days after tracheostomy placement. All had upper airway anomalies that resulted in the need for tracheostomy (including obstructing pharyngolaryngomalacia and subglottic stenosis). Group A

<table>
<thead>
<tr>
<th>TABLE 1</th>
<th>Patient Characteristics ($n = 165$)</th>
<th>Median (range)</th>
<th>$n$ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gestational age (wk)</td>
<td>27 (22–43)</td>
<td>151</td>
<td></td>
</tr>
<tr>
<td>Birth wt (g)</td>
<td>820 (560–4860)</td>
<td>151</td>
<td></td>
</tr>
<tr>
<td>Age at admission (d)</td>
<td>1 (0–851)</td>
<td>164</td>
<td></td>
</tr>
<tr>
<td>Total length-of-hospital stay (d)</td>
<td>159 (13–585)</td>
<td>163*</td>
<td></td>
</tr>
<tr>
<td>Length-of-stay in ICU (days)</td>
<td>86 (0–546)</td>
<td>133, from initial admission</td>
<td></td>
</tr>
<tr>
<td>Mean no. of days intubated before tracheostomy</td>
<td>94 (1–591)</td>
<td>154</td>
<td></td>
</tr>
<tr>
<td>Mean wt at tracheostomy (kg)</td>
<td>3.4 (0.8–11.8)</td>
<td>153</td>
<td></td>
</tr>
<tr>
<td>Mean no. of failed extubations before tracheostomy</td>
<td>1 (0–6)</td>
<td>147</td>
<td></td>
</tr>
<tr>
<td>Average gestational age at tracheostomy (wk)</td>
<td>27 (22, 43)</td>
<td>151</td>
<td></td>
</tr>
<tr>
<td>Percent of infants with betamethasone treated mothers</td>
<td>50.7% (77)</td>
<td>152</td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>76 (46.1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>89 (53.9)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Birth wt$^a$</td>
<td></td>
<td>151</td>
<td></td>
</tr>
<tr>
<td>≤1000 g</td>
<td>87 (57.6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;1000 g</td>
<td>64 (42.4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gestational age$^c$</td>
<td>164</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;25 wk</td>
<td>46 (28)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥25 wk</td>
<td>118 (72)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$^a$ One patient was excluded due to transfer to another institution after tracheostomy placement.

$^b$ Birth weight is unknown for 14 patients.

$^c$ Gestational age is unknown for 1 patient who transferred from an outside facility, and it was not documented in the medical record.
patients had a longer time from intubation to PPV independence than Group B ($P = .011$). Birth weight did not affect time from tracheostomy placement to decannulation ($P = .008$). However, more Group A infants were decannulated (88.5% vs 71.4%, $P = .088$).

The overall rate of LTR was 35.8% (Group A 47.1%, Group B 25%, $P = .006$). The reasons for the need for LTR are shown in Table 4. Fifteen patients with tracheomalacia had an anterior tracheal reconstruction using a costochondral cartilage graft. One patient with tracheomalacia had an anterior and posterior tracheal reconstruction using costochondral cartilage grafts.

The rate of comorbidities is shown in Table 5. 74.2% had ≥2 comorbidities, and 64.2% of patients presented had some degree of developmental delay. Sixty-two infants (37.8%) were diagnosed with recurrent wheezing, and 133 infants (80.6%) were on chronic nebulizer therapy with budesonide.

The average survival rates for patients living to 1, 3, and 5 years of life were 96%, 91%, and 90%, respectively. Group B had a higher mortality rate than Group A ($P = .033$). Ninety-four percent of Group A patients survived to a minimum of 5 years compared with 85% of Group B patients ($P = .195$).

**DISCUSSION**

This study provides a descriptive report of long-term outcomes for a cohort of infants discharged from a single pediatri c health care facility after tracheostomy for prolonged mechanical ventilation. To our knowledge this study is the longest review and largest cohort of infants with tracheostomy. The information collected was complete and comprehensive.

Overall tracheostomy rates in our study were comparable to the highest rates reported in the literature. However, tracheostomy rates in Group A were nearly 4 times higher than the overall rate. Heroy reported at 2.7% overall incidence of tracheostomy for patients admitted to a NICU. More recent studies, with smaller numbers of patients than were included in our study, have shown a decline in tracheostomy for airway obstruction but an increase for prolonged ventilation. Most of the available literature focuses on complications from tracheostomies. Few report on overall tracheostomy rates. None of the currently available literature analyzes tracheostomy rates based on birth weight. The studies that report tracheostomy rates have small sample sizes, and thus caution ought to be used in generalization. The high rate found in our study for Group A infants is likely reflective of the need for prolonged need for mechanical ventilation in ELBW and VLBW infants.

Group A patients had a longer time from intubation to tracheostomy placement
and intubation to decannulation than Group B. This is not surprising because the standard of care at our institution is to wait until the patient is near a corrected gestational age of 40 weeks before placing a tracheostomy. Multiple attempts to wean PPV and noninvasive positive pressure ventilation are made before tracheostomy placement is recommended.

LTR rates were comparable to that reported by Sidman et al when they reviewed tracheostomy and decannulation rates at the same institution from 1991 through 2002. Thus despite the high rate of tracheostomy in Group A, there has been no significant change in the rate of surgical procedures required to achieve decannulation. Five-year survival was high, with higher mortality rates in Group B, likely related to the severity of their comorbid conditions and prevalence of chromosomal abnormalities. Although survival rates were high, a significant number of patients had some degree of developmental delay. Unfortunately, because this was a retrospective study and different developmental screening evaluations were used, to a variable degree, we were unable to subdivide patients on the basis of the severity of their delays.

This study has several limitations. It is a retrospective study that relied heavily on chart review. Three individuals who were trained in data collection completed the chart review. Weekly meetings were held to review progress and answer questions to ensure that all persons were abstracting data similarly. The data are from a single pediatric facility and outpatient practice. The ability to generalize to other practices may, therefore, be limited. That being said, nearly all our findings were similar to that reported in the literature.

Despite the limitations of this study, it has several strengths. It adds up-to-date information about current tracheostomy rates. It is the first to describe tracheostomy rates in ELBW and VLBW infants. Moreover, the study focuses on long-term clinical outcomes and comorbidities of infants who require tracheostomies rather than purely focusing on surgical complications. Future prospective studies should determine the appropriate timing of tracheostomy placement in ELBW and VLBW infants and seek to determine if early tracheostomy results in improved developmental outcomes, decreased systemic steroid exposure, and improved lung function later in life.

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