Neonatal tracheostomies provide life-sustaining airway support for children with acute or chronic airway obstruction, neurologic impairment, and pulmonary insufficiency, thereby circumventing anatomical and physiologic obstruction to ventilation.\(^1\) Tracheostomy in the newborn is a complex procedure but is performed with moderate frequency at tertiary care centers. A review of recent literature suggests that about half of all pediatric patients who receive a tracheostomy are younger than 1 year.\(^2\) Morbidity and mortality in this population are greater than in adult patients, with hazards related to anesthesia, the procedure itself, and care of the appliance.\(^3\) In an earlier study, Pereira et al\(^4\) described the indications for and outcomes of tracheostomy in a population of preterm infants. That work highlighted the severity of pulmonary disease as the most significant factor associated with the need for tracheostomy in this group. In the population studied, the incidence of procedure-related complications was about 18%, although no mortality was recorded, and significant complications were not present during longitudinal follow-up.

Tracheostomy facilitates survival for many critically ill preterm neonates despite the associated risks. A study on airway management in neonates\(^5\) suggests that the reduced incidence of subglottic stenosis owing to improved management of long-term endotracheal intubation has resulted in severity of lung disease being the principal indication for neonatal tracheostomy. Pereira et al\(^4\) also described an increase in tracheostomy-related complications in infants weighing less than 1000 g. Tracheostomies in infants represent a challenge owing to the potential for increased complications and intellectual and physical impairments as a result of long-term dependence.\(^6\) A combination of preterm and very low-birth-weight (VLBW) status intensifies these risks.

**IMPORTANCE** The indications for neonatal tracheostomy may have changed with current noninvasive respiratory therapies compared with previous decades.

**OBJECTIVES** To study the current trends in neonatal tracheostomy and identify the primary indication for the procedure and risk factors for failed extubation.

**DESIGN, SETTING, AND PARTICIPANTS** This retrospective medical record review included 47 neonates who underwent tracheostomy from January 1, 2009, to December 31, 2013, at the University of Maryland Children’s Hospital. Group 1 included infants undergoing tracheostomy for the primary indication of upper airway obstruction; group 2, infants with primary pulmonary disease. Data on weight, gestational age, comorbid conditions, congenital abnormalities, complications, outcomes, and indications for tracheostomy were compared statistically between groups.

**MAIN OUTCOMES AND MEASURES** Differences in gestational age, birth weight, and age at tracheostomy.

**RESULTS** Among the 47 infants included in the study (30 boys; 17 girls, mean [SD] age, 113 [73] days, 31 (66%) demonstrated anatomical causes of airway obstruction, and 16 (34%) had significant pulmonary disease. Among infants with anatomical causes, subglottic stenosis represented the largest group (11 of 31 [35%]). The mean age at the time of tracheostomy was significantly lower in the group with airway obstruction (98.9 vs 146.9 days; difference, 48 [95% CI, 4.8-91.2] days; \(P = .04\)). No procedure-related morbidity or mortality was encountered.

**CONCLUSIONS AND RELEVANCE** Anatomical upper airway obstruction may be returning as the most common indication for a neonatal tracheostomy, thereby supporting the belief that current respiratory therapies have lowered the burden of chronic lung disease and the need for prolonged ventilatory care.

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Respiratory distress syndrome (RDS) is the most common pulmonary disease in premature infants and is caused by the lack of pulmonary surfactant that interferes with normal gas exchange. More high-risk, preterm, low-birth-weight infants are surviving RDS with the combination of surfactant therapy and improved ventilation techniques, thereby reducing the need for tracheostomy in this population.

Upper airway obstruction is another primary indication for neonatal tracheostomy. Obstruction encompasses numerous pathophysiologic processes that compromise the airway by mechanical impediment to air flow. Proximal lesions at the level of nasal and oral cavities include Pierre Robin sequence and other craniofacial abnormalities, whereas those that affect the larynx directly include subglottic stenosis, laryngomalacia, and vocal fold paralysis. Other pathologic mechanisms include cysts, hemangiomas, and lymphangiomas. Airway obstruction could also be caused by damage to the airway owing to infection or trauma and neurologic deficits that interfere with pulmonary toilet, including the patient’s ability to breathe, swallow, cough, or otherwise protect the airway.

Our study aims to identify the factors currently associated with failed extubation in the neonatal intensive care unit (NICU), to determine whether any differences are found in the groups with anatomical obstruction vs pulmonary insufficiency, and to ascertain whether outcomes have changed during the last 5 years. Identifying these factors may help health care professionals make an earlier determination regarding the need for intervention and may shorten the NICU stay.

Methods

We reviewed the medical records of all infants who underwent tracheostomy at University of Maryland Children’s Hospital from January 1, 2009, to December 31, 2013. This retrospective study was approved by the institutional review board of the University of Maryland, which waived the need for informed consent.

We included all patients younger than 1 year who underwent a tracheostomy for the indications of anatomical airway obstruction leading to prolonged endotracheal intubation or primary pulmonary insufficiency requiring long-term mechanical ventilation. When both factors were present, the indication identified at the time of surgery was deemed to be the principal reason. We identified 47 infants who received a tracheostomy during this period. The infants were divided into groups based on the indication for tracheostomy. Group I included patients undergoing tracheostomy for an airway obstruction, whether congenital or acquired. Airway obstruction included subglottic stenosis, tracheomalacia, and retrognathia, severe obstructive sleep apnea, and Pierre Robin sequence (n = 31). Group II included patients requiring tracheostomy for pulmonary-related ventilator dependence (n = 16). These patients had RDS, bronchopulmonary dysplasia (BPD), and other lung diseases. Data on weight, gestational age, comorbid conditions, congenital abnormalities, complications, outcomes, and indications for tracheostomy were recorded.

A review of each patient’s medical record collated the following information: (1) gestational age in weeks; (2) birth weight in grams; (3) age at tracheostomy in days; (4) principal causes for extubation failure; and (5) complications related to the procedure. All data were collected in a spreadsheet format and exported to MatLab (version 2011a; MathWorks). Descriptive statistics were first calculated, followed by statistical tests of significance using analysis of variance. A result was deemed to be significant if the probability of incorrect rejection of a null hypothesis was less than .05. Unless otherwise indicated, data are expressed as mean (SD).

Results

Descriptive Statistics

Forty-seven infants (30 boys and 17 girls) received a tracheostomy at a mean age of 113 (73) days. The mean birth weight was 1993 (1022) g. The mean gestational age was 32 (1) weeks. Four infants were younger than 1 month at the time of the procedure, and 43 were 30 days or older. Four infants (9%) were VLBW (<1500 g), and 15 infants (32%) were of low birth weight (<2500 g). The largest group consisted of infants with a birth weight that was appropriate for their gestational age (17 [36%]; ≥2500 g). Eleven infants (23%) had a birth weight less than 1000 g (extremely low birth weight [ELBW]).

Anatomical obstruction accounted for 31 tracheostomies (66%), whereas ventilator support accounted for the other 16 (34%) (difference, 32%; 95% CI, 11.7%–48.7%). Among the anatomical causes, subglottic stenosis accounted for the largest proportion of tracheostomies (11 of 31 [35%]). The anatomical abnormalities observed included Pierre Robin sequence, velocardiofacial syndrome, oculoauriculovertebral syndrome, and arthrogryposis. The numbers and proportions of patients with each specific anomaly are listed in the Table. Although obstructive and pulmonary causes contributed to respiratory failure that resulted in a tracheostomy in 9 infants (19%), the indication for a tracheostomy was attributed to the primary clinical condition that necessitated the procedure at the time of surgery.

Statistical Comparisons

To determine whether the differences were significant between both groups, we used analysis of variance for
univariate and multivariate comparisons. Comparison of the mean gestational age between groups (anatomical obstruction [group 1] and pulmonary insufficiency [group 2]) showed no significant difference (32.9 [5.3] and 30.4 [5.7] weeks, respectively; difference, 2.5 weeks; 95% CI, −0.87 to 5.87 weeks; \( P = .14 \)) (Figure, A). Group 2 tended to have lower mean birth weights compared with group 1 (1663 [1006] vs 2176 [998] g; difference, 513 g; 95% CI, −107.4 to 1133.4 g; \( P = .10 \)) (Figure, B). However, infants received a tracheostomy at a younger age in group 1 (mean age at tracheostomy, 98.9 [69.8] days) compared with those in group 2 (146.9 [69.6] days), with a difference of 48 (95% CI, 4.8-91.2; \( P = .04 \)) days (Figure, C).

### Discussion

The indications for neonatal tracheostomies have changed during the last 3 decades, reflecting improved endotracheal tube management, advances in ventilation strategies, the development of novel pulmonary surfactants, and better family and parent education. Most reviews of the literature examining these trends have largely described data from the pediatric population as opposed to infants, in whom the rate of complications is expected to be higher and the consequences on development are more profound. In the 1990s, the routine use of tracheostomy to establish airway access had begun to lose favor with improvements in the use of endotracheal intubation. During this time, investigators reported an increase in the proportion of infants and children requiring long-term mechanical ventilation. The rate of immediate procedure-related complications approached 20% to 30%, even in large-volume centers. More recent data have shown that the most common indication for tracheostomy in the combined neonatal and pediatric population has been for ventilator dependence secondary to BPD or RDS. Major complications, which were still higher in neonates compared with older children, appeared to decline (<10%). Extremely low-birth-weight infants with significant pulmonary insufficiency owing to immaturity formed nearly 75% of those receiving a tracheostomy from pooled data obtained from 2 major children's hospitals.

Advances in preterm respiratory care appear to have increased the overall survival of VLBW and ELBW neonates admitted to the NICU. The most prominent advance has been the development of noninvasive ventilation, which includes methods that reduce the adverse effects associated with intubation and mechanical ventilation, such as BPD, sepsis, and trauma to the upper airways. Current neonatal respiratory research indicates that combining less invasive care strategies that avoid excessive oxygen and ventilation, decrease postnatal infections, and optimize nutrition may decrease the incidence and severity of BPD. Noninvasive ventilation has gained much popularity via the intubation, surfactant, and extubation (INSURE) protocol, which results in less severe RDS, reduction in the incidence of sepsis and pneumothorax, lower mortality, and a significantly shortened NICU stay. Investigators have sought to determine whether nasal continuous positive airway pressure (CPAP) and intermittent positive pressure ventilation could be viable alternatives to endotracheal intubation. The first of these observational studies showed that comorbidities present in ELBW infants deter the success of nasal CPAP, and a later randomized clinical trial agreed that this therapy alone may not be beneficial in obviating the need for endotracheal intubation. The most recent trial that studied outcomes in 1316 infants concluded that the use of CPAP resulted in less dependence on mechanical ventilation and improved 7-day survival and reduction in NICU stay. Use of surfactant therapy in spontaneously breathing infants undergoing tracheostomy for upper airway obstruction (n = 31); group 2, infants with primary pulmonary disease (n = 16). The central line in each notched boxplot represents the median; the edges of the box, the 25th to 75th interquartile range. The whiskers extend to the most extreme points within the distribution.

### Table. Causes of Anatomical Obstruction

<table>
<thead>
<tr>
<th>Cause</th>
<th>No. (%) of Infants*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subglottic stenosis</td>
<td>11 (35)</td>
</tr>
<tr>
<td>Pierre Robin sequence</td>
<td>5 (16)</td>
</tr>
<tr>
<td>Tracheomalacia</td>
<td>4 (13)</td>
</tr>
<tr>
<td>Vocal cord paralysis</td>
<td>4 (13)</td>
</tr>
<tr>
<td>Glottic edema</td>
<td>1 (3)</td>
</tr>
<tr>
<td>Tongue atonia</td>
<td>1 (3)</td>
</tr>
<tr>
<td>Retrognathia</td>
<td>1 (3)</td>
</tr>
<tr>
<td>Arthrogryposis</td>
<td>1 (3)</td>
</tr>
<tr>
<td>Velo-cardio-facial syndrome</td>
<td>1 (3)</td>
</tr>
<tr>
<td>Oculo-airculovertebral syndrome</td>
<td>1 (3)</td>
</tr>
<tr>
<td>Severe sleep apnea with vocal cord paralysis</td>
<td>1 (3)</td>
</tr>
<tr>
<td>All</td>
<td>31 (100)</td>
</tr>
</tbody>
</table>

* Percentages have been rounded and may not total 100.
infants receiving CPAP therapy also resulted in a significant reduction in the need for mechanical ventilation.22 With this paradigm shift in NICU respiratory therapies, the number of infants dependent on mechanical ventilation has been reduced overall, resulting in a secondary reduction of tracheostomies performed in this age group.

Our study suggests that the trend may be heading toward airway obstruction as the most frequent indication for placement of a tracheostomy in preterm infants. The cohort of patients did not differ significantly between the groups other than the principal reason for a tracheostomy. Infants with primary pulmonary insufficiency tended to have lower birth weights and gestational ages. As expected, infants with known anatomical airway obstruction were deemed to be earlier candidates for a tracheostomy. The general trend toward an earlier age at which a tracheostomy was performed in this group is potentially owing to the expectation that noninvasive ventilation strategies may not play a role in avoiding a tracheostomy. The shift in indication for the procedure is likely owing to the recent advances in therapies and improved management of RDS and BPD in neonates. These advances can explain the reduced need for tracheostomy for primary pulmonary pathologic mechanisms. These trends have been driven by novel research in the use of surfactant therapy23 and by emergence of clear indications for the use of nasal positive airway pressure therapy.24 Research has consolidated both nasal CPAP and intermittent positive pressure ventilation in their position as the primary tools for respiratory support.25 These therapies may be specifically useful in the first 72 hours after extubation and may have other roles in the care of ELBW infants to prevent BPD, neurodevelopmental impairment, and death.26

Our results are in concordance with those of a recent study from a major Canadian children’s hospital,27 which also noted that the overall tracheostomy rate has declined during the last 3 decades. Most of the airway obstruction in our study was secondary to subglottic stenosis, followed by Pierre Robin sequence and tracheomalacia. The data presented herein differ from those obtained from a pooled cohort of infants who underwent tracheostomy from 2 different NICUs, as previously reported in 2003.2 Overall, the burden of pulmonary disease appeared to be higher in that study, with about 75% of the infants needing a tracheostomy for BPD. We did not perform a power analysis in our study.

Conclusions

The indication for tracheostomy showed a reversal toward obstructive pathologic mechanisms. These findings suggest and support the perception that advancements in NICU care for infants with lung disease are continuing to succeed by reducing morbidity and are changing the primary indication for the procedure.


