Safety of Pediatric Bedside Tracheostomy in the Intensive Care Unit
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Background: Elective bedside pediatric tracheostomies in the intensive care unit have not been widely reported. Unlike in the adult population, this is not yet considered a safe or routine procedure in the pediatric population. We performed a preliminary study suggesting that bedside pediatric tracheostomies can be done safely and at reduced cost.

Design: Retrospective medical chart review.

Setting: Tertiary care referral center at a single university hospital.

Patients: Fifty-seven patients, ranging in age from 15 days to 8 years. Thirty operating room tracheostomies and 27 bedside tracheostomies were performed during a 6-year period. The mean age of the patients was 20.5 months, with no significant age difference between the 2 groups. The top 3 diagnoses necessitating tracheostomy were laryngotracheal disorders (18 patients [32%]), bronchopulmonary dysplasia (9 [16%]), and neurologic disorders (6 [11%]).

Interventions: Tracheostomy.

Main Outcome Measures: The initial 48-hour postoperative period was examined to compare complication rates between groups.

Results: Overall, the 2 groups had similar complication rates ($\chi^2=0.12; P=.73$). The operating room group had 3 complications (10%) related to bleeding, infection, and pneumothorax. The bedside group had 2 complications (7%), both involving pneumothorax. Each operating room tracheostomy incurred charges totaling $1693 vs $235 for each bedside tracheostomy.

Conclusions: Historically, pediatric tracheostomy has been viewed as a technically demanding procedure with a high complication rate, thus encouraging routine operating room use. We found that pediatric tracheostomy performed in the intensive care unit, with attention to prudent patient selection and adherence to consistent, sound techniques, was as safe as operating room tracheostomy.

PATIENTS AND METHODS

STUDY DESIGN

A chart review was undertaken of all pediatric tracheostomies performed by the Division of Otolaryngology at the University of Rochester Medical Center, Rochester, NY, between January 11, 1992, and November 25, 1998. Charts from 3 attending otolaryngologists were reviewed. Tracheostomies done on an emergent basis were excluded. Statistical analysis of complication rates by location of tracheostomy was performed with χ² techniques. Analyses of variance and χ² analyses were performed on each of the demographic and diagnostic variables with respect to the location of tracheostomy to ensure that there were no significant differences between groups on the basis of other factors.

PATIENTS

The upper age limit for inclusion in the study was 8 years. No exclusions occurred for prematurity. Each patient's medical record was reviewed for the diagnosis necessitating tracheostomy and the site of procedure: bedside ICU or OR. Those selected for a bedside tracheostomy met the following criteria: (1) low ventilatory requirements, ie, low positive end-expiratory pressure, peak airway pressure, and percentage of oxygen; (2) no anticipated need for additional diagnostic procedures, ie, bronchoscopy or direct laryngoscopy; and (3) easily palpable laryngeal anatomy and ability to be placed in flexion-extension position.

OUTCOME MEASURES

A postoperative window of 48 hours after tracheostomy was examined for incidence of complications. Only complications thought to be associated with the procedure itself were considered. Specifically, complications related to poor technique as a result of nonoptimal positioning, inadequate instrumentation or lighting, or poorly controlled patient factors, eg, excessive movement or high anesthetic risk, were of particular interest. Late complications such as tracheostomy tube displacement, wound infection, or bleeding after the 48-hour window were thought not to be attributable to the venue of the procedure.

Cost comparison was done in 1999 dollar amounts. Hospital charges were obtained from the pediatric ICU, anesthesia billing office, and hospital financial accounting departments. Physician fees and the cost of the actual tracheostomy tube were considered fixed costs and thus excluded from the analysis. Total time for the tracheostomy was estimated at 1 hour for both groups so that some comparison could be made. Comparison of actual times between the 2 groups was not possible because of inconsistent documentation of bedside procedure times and great variability in documentation of start and stop times for the OR procedure and anesthesia billing time. Cost difference (savings) was calculated.

TRACHEOSTOMY

All bedside tracheostomies were performed with the assistance of the pediatric or neonatal intensivist for sedation and paralysis. Every patient's airway was first controlled with an endotracheal tube. The patient was positioned with a shoulder roll in good neck extension. Individual surgeon headlights and supplemental overhead procedure lights were used routinely. Standard sterile preparation and draping were performed. No local anesthesia was used, to avoid distortion of the delicate landmarks.

Careful, light palpation of the larynx was performed, and a vertical skin incision approximately 2 cm long was made between the cricoid and sternal notch. A small amount of subcutaneous fat was typically excised to facilitate exposure. Careful, sharp dissection down to the level of the trachea was carried out with continual reaffirmation of the midline position. One of us (A.S.H.) preferred to palpate for the midline by means of a hemostat, as the entire wound was often smaller than the width of one's finger, making tactile discrimination very poor. Use of a clamp increased one's ability to discern soft tissue structures from the small pliable airway. The tubular trachea “rolled” underneath the clamp while the clamp was moved horizontally over the vertical trachea.

The thyroid was retracted superiorly and not sectioned if possible. Once the airway was judiciously skeletonized (very little inferior or lateral dissection was done), 2 laterally based 4-0 silk stay sutures were placed on either side of the tracheal midpoint. These were used to apply lateral traction on the airway as a midline vertical tracheal incision was made through 2 rings without cartilage excision. The tracheostomy tube was inserted and secured with skin sutures and neck ties. The stay sutures were left in place for 1 week in the event of accidental dislodgment. A postoperative chest x-ray film was routinely obtained.

RESULTS

PATIENTS

A total of 57 pediatric tracheostomies—27 bedside tracheostomies and 30 OR tracheostomies—were in-
includes. Aged ranges from 15 days to 8 years (Table 1). Overall mean age was 20.5 months, with a median age of 9 months. Approximately 75% percent of each group (23 [77%] in the OR group and 20 [74%] in the bedside group) was 2 years of age or younger. We performed all analyses involving age in 2 ways: First, we ran the analyses using child age as a continuous variable. Next, we ran the analyses with child age classified into 2 groups: (1) children younger than 12 months and (2) children 1 year or older. We performed the latter analyses to examine the possibility that there were differences between infant and child tracheostomies. An analysis of variance showed no significant relationship between age and location of tracheostomy (OR vs bedside) (F1,55 = 0.01; P = .92). Similarly, no significant differences were found between location of tracheostomy and child age (F1,55 = .33, P = .57). Similarly, no significant differences were found between location of tracheostomy and child age (F1,55 = .33, P = .57).

We categorized the children according to the major diagnosis leading to tracheostomy (Table 1). The most frequent diagnosis was laryngotracheal disorders, in 18 (32%) of all patients in whom tracheostomy consultation was requested. These included laryngeal web (2 patients), subglottic stenosis (8 patients), subglottic hemangioma (4 patients), laryngomalacia (2 patients), and vocal cord paralysis (unilateral or bilateral) (2 patients). Respiratory failure secondary to prolonged mechanical ventilation and the subsequent development of bronchopulmonary dysplasia was the second most common indication for tracheostomy, occurring in 9 (16%) of the sample. Forty-seven percent (29 of the 18 patients) either had a laryngeal anomaly or bronchopulmonary dysplasia (BPD) as the indication for tracheostomy. Neurologic disorders (secondary to anoxic birth injury and cerebral palsy) resulted in tracheostomy in 6 patients (11%). The remaining reasons for tracheostomy were distributed among Arnold-Chiari type II malformation with bilateral vocal fold immobility (4 patients), Down syndrome (4 patients), craniofacial anomalies (4 patients), and chromosomal defects (1). The craniofacial anomalies consisted of Robin sequence, Treacher Collins syndrome, Mobius syndrome, and Goldenhar syndrome (1 patient each). The remaining children had diagnoses that were solitary occurrences and were placed into a miscellaneous category. These included fibrodisproportion syndrome with hypoventilation, respiratory failure associated with liver failure, cystic hygroma, superior vena cava syndrome, obstructive sleep apnea, and severe arthrogryposis.

Ninety-eight percent of the total tracheostomies were done by the same fellowship-trained pediatric otolaryngologist (A.S.H.). Three tracheostomies, all taking place in the OR, were performed by 2 other otolaryngologists.

Analyses by χ² showed no significant relationships between location of tracheostomy (OR vs bedside) and the child's sex, attending physician, or diagnosis.

**SAFETY OUTCOMES**

Five complications within 48 hours of tracheostomy were noted for the entire subject population, resulting in an overall complication rate of 9%. Two complications (both involving pneumothorax) occurred in the bedside group, giving a complication rate of 7.4%. Both patients were treated conservatively without chest tubes. The pneumothoraxes resolved within several days. Lighting, positioning, and technique were not thought to be factors in these complications. In addition, the patient was adequately paralyzed and sedated. The OR group had 3 complications, resulting in a complication rate of 10%. These included (1) postoperative bleeding controlled with packing; (2) immediate tracheostomy site infection, which resolved with local care; and (3) bilateral pneumothorax requiring bilateral chest tubes. This last complication was thought to be due to overzealous resection of fat. There were no cases of lost airway or deaths in either group. Although the OR group had a slightly higher rate of complication, comparison of the percentage complication rate between the 2 groups (3%) did not attain statistical significance (χ² = 0.12; P = .73) (Table 2).

### Table 1. Patient Demographics and Distribution

<table>
<thead>
<tr>
<th>Variable</th>
<th>Operating Room Group (n = 30)</th>
<th>Bedside Group (n = 27)</th>
<th>Overall Group (N = 57)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average, mo</td>
<td>20.1</td>
<td>20.8</td>
<td>20.5</td>
</tr>
<tr>
<td>Median, mo</td>
<td>11</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>&lt;2 y, No. (%)</td>
<td>23 (77)</td>
<td>20 (74)</td>
<td>43 (75)</td>
</tr>
<tr>
<td>Sex, No. (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>15 (50)</td>
<td>15 (56)</td>
<td>30 (53)</td>
</tr>
<tr>
<td>Female</td>
<td>15 (50)</td>
<td>12 (44)</td>
<td>27 (47)</td>
</tr>
</tbody>
</table>

### Table 2. Comparison of Safety and Cost Outcomes

<table>
<thead>
<tr>
<th>Variable</th>
<th>Operating Room Group</th>
<th>Bedside Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complications, No. (%)</td>
<td>3 (10)</td>
<td>2 (7)</td>
</tr>
<tr>
<td>Charges, $</td>
<td>Location</td>
<td>Supplies/instruments</td>
</tr>
<tr>
<td></td>
<td>750</td>
<td>130</td>
</tr>
<tr>
<td></td>
<td>Included in DRG</td>
<td>35</td>
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<tr>
<td></td>
<td>Anesthesia</td>
<td>210 (Anesthesiologist)</td>
</tr>
<tr>
<td></td>
<td>Total Charges</td>
<td>Total savings</td>
</tr>
<tr>
<td></td>
<td>1693</td>
<td>1458</td>
</tr>
</tbody>
</table>

*DRG indicates diagnosis related group; ICU, intensive care unit. †No significant difference between complication rates by group (χ² = 0.12).
COST ANALYSIS OUTCOMES

Hospital charges, rather than true costs, were measured in this study. Table 2 demonstrates the charge difference between the OR and bedside groups and illustrates the reduced costs of performing a bedside procedure. Charge for 1 hour of OR time was $750. This number includes hospital resources such as rental of OR space, lighting and energy, and personnel to run, stock, and clean the OR space. Anesthesiology fees were quoted at $525 for 1 hour of physician time and $288 for anesthetic and intravenous drugs and anesthesia-related equipment for 1 hour, for a total of $813. Billing for the anesthesiologist often began on interview of the patient in the preoperative holding area. Surgical supplies and instrument fees for a tracheostomy done in the OR were $130 per case. The total cost per tracheostomy done in the OR, assuming 1 hour of surgical time, was $1693.

Bedside charges were determined in an ICU setting and included the help of the pediatric or neonatal intensivist in all cases. Charges for the room, intravenous sedatives, and pain medications or paralytics are all included in an “ICU level of care.” Whether a child spent a day in the pediatric or neonatal ICU with or without addition of a tracheostomy did not affect hospital billing practices. No additional facility or procedural charges were added. The only additional charge incurred for the bedside group was a reusable sterile tracheostomy instrument tray from hospital supply ($35) and the additional time billed by the ICU physician for close monitoring of sedation and paralysis during the procedure ($200). Total charge for a bedside tracheostomy was $235.

The total charge difference (OR–bedside) per tracheostomy was $1458. This represents an 86% cost savings based on quoted charges by performing a pediatric tracheostomy at the bedside. We did not analyze the cost (charge) associated with management of the complications. We suspect that, since the number of pneumothoraxes was similar in the 2 groups, this would not greatly affect the charge comparison. Charges were obtained from the various hospital departments and do not represent reimbursement or true costs, which vary widely between third-party insurers.

COMMENT

Pediatric tracheostomy has traditionally been performed in the OR. As we find ourselves faced with the cost-containment pressures of modern medicine, many minimally invasive procedures once done in a formal OR setting—eg, adult tracheostomy, inferior vena cava filter placement, and percutaneous endoscopic gastrostomies—are now being completed at the patient’s bedside with substantial cost savings, but without an increase in complication rates.24,12,13 Despite these good results in the adult population and the recent improvements in the outcomes for children undergoing tracheotomy,14 most surgeons continue to solicit the setting of an OR.15 Wetmore et al16 recently reported on a large series of pediatric tracheostomies, showing that tracheostomy-related mortality was a low 0.5%; however, all tracheostomies in that study were performed in the OR. We have extended the improved results of OR pediatric tracheostomy to a bedside procedure with continued good results and considerable cost savings.

This study was not randomized, and therefore more complicated cases or those deemed to have “difficult anatomy” preferentially went to the OR. Those evaluated as “routine” were logical bedside candidates. Of the 17 medical charts that did clearly document reasons for OR tracheostomy, the overwhelming majority (15) were for concomitant procedures, mostly diagnostic airway procedures. This was mostly for the convenience of having a large amount of specialized equipment (carbon dioxide laser, variable laryngoscopes and bronchoscopes, and light sources) readily available to perform more definitive examination or treatment if necessary. Unclear or incomplete medical chart documentation (13 cases) made it difficult to ascertain whether tracheostomy was planned in the preoperative stages or whether the decision to perform tracheostomy was made after diagnostic laryngoscopy or bronchoscopy was performed in the OR group.

Despite an obvious bias for children who needed additional OR procedures, the patients were fairly well matched according to age and sex between the 2 groups. With respect to age, approximately 75% of each group was 2 years or younger. When we considered the case outcomes of children younger than 12 months with those of patients older than 1 year, we noted no significant differences in diagnosis, location of tracheostomy, or complication rate. Older children and teenagers, although perhaps still considered to be in a pediatric population, approach adultlike anatomy, and the risks of tracheotomy decrease when compared with those seen in the adult population. Our study limited the upper age to 8 years in an attempt to more accurately assess tracheostomy in this younger age group, where morbidity and mortality have historically been higher. Future studies may be more meaningful if larger data pools are analyzed by weight categories rather than by age.

The category of laryngotracheal disorders encompasses a wide range of disorders and was the most common indication for tracheostomy (32%). There were about 3 times as many patients with laryngeal anomalies in the OR group as in the bedside group, likely because of the need to perform concomitant diagnostic studies, ie, laryngoscopy and bronchoscopy. Bronchopulmonary dysplasia (16%) and neurologic (11%) categories were the next most frequent indications for tracheostomy and comprised a higher percentage of the bedside group than did laryngotracheal disorders. This is understandable because these patients were less likely to have a need for further examination of the airway and required an uncomplicated tracheostomy amenable to the bedside setting.

There are 7500 new cases of BPD per year in the United States, and it is the most common form of chronic lung disease.10 It is well known that the incidence and severity of BPD increase with decreasing gestational age, and, therefore, we are likely to see BPD as an increasing indication for tracheostomy as we are able to support earlier and earlier life. Wetmore et al17 also reported a rising proportion (doubling) of tracheostomies done for BPD when compared with the previous decade at the same in-
tion. No tracheostomies in our study were done for group, tracheitis, or epiglottitis, which is similar to Wetmore and coworkers’ results showing a trend away from this practice as well. Improved antibiotics, new vaccines, and more sophisticated ICUs make medical management of airway compromise secondary to infectious causes a more prudent approach.

The main focus of this study was to examine the technical safety of performing a tracheostomy outside the usual OR arena. We had no deaths from tracheostomy, which is in line with data reported by Crysdale et al for OR-only tracheostomies. The complication rates for both the OR (10%) and bedside (7%) groups were low. We looked specifically at a 48-hour postoperative window to identify complications thought to be associated with the procedure itself and to exclude complications inherent to all tracheostomies regardless of site of procedure. Many of the previous studies grouped acute (pneumomediastinum, pneumothorax, and bleeding) and subacute (obstruction, granulation tissue, granuloma, and decannulation) into 1 early complication category. This makes comparison with our narrow 48-hour complication window difficult. Crysdale et al reported an “early” complication rate similar to ours (9%) in a much larger population of strictly OR tracheostomies. However, they looked at a postoperative window of 7 days and included such complications as granuloma formation, accidental decannulation, tracheostomy tube obstruction, and tracheoesophageal fistula. Wetmore et al also reported on “early” complications as being within 7 days of the procedure and had a higher complication rate (19%), but they included more subacute processes, eg, obstruction and decannulation. Gaudet et al, however, categorized their immediate complications as occurring within 72 hours of tracheostomy and also reported a slightly higher complication rate of 12%, but they included such occurrences as aspiration, accidental decannulation, and cardiorespiratory arrest.

A shortcoming of such a limited follow-up period is missing late sequelae of poor technique, such as infection, tracheomalacia, or tracheal stenosis, although their detection was not the purpose of this study. If anything, one might have expected to see more morbidity with the bedside group because of more variable or poor surgical conditions. We did not find this in our study. The complication rate in our study was 3% less in the bedside group than in the OR group, although these results did not attain statistical significance and do not represent a notable effect size. The pneumothorax that did occur at the bedside were not thought to be secondary to poor setup or the lack of general anesthesia. Given the proper setup, bedside procedures were easily accomplished with equipment equivalent to that available in the OR suite.

Our secondary objective was to elucidate the cost savings, as the current managed care environment demands improved efficiency and cost-effectiveness. While this is not a cost-effectiveness study in the truest sense, we did find that the bedside procedure was associated with reduced cost. Charges, not costs, were measured, and one should recognize the limitation of using these numbers in this analysis. Charges were used as a proxy for costs. Nevertheless, we have shown a significant charge reduction (86%) from that for performing OR tracheostomies. No breakdown of procedure-specific OR times, ie, the time spent performing a tracheostomy alone minus that of prior diagnostic procedures, and few of the bedside operating times were available. We chose a tracheostomy procedure time of 1 hour to enable us to compare the 2 groups, although admittedly this is a weaker method than if actual times had been readily available. Theoretically, the charge difference could be smaller if bedside tracheostomy took substantially longer, but this seems unlikely on the basis of our experience. If anything, the children who went to the OR may have taken longer because of difficult anatomy or complicated medical conditions. This selection bias exists but is not analyzed in this study because of a lack of procedure-specific OR times. There is no additional charge for performing a tracheostomy in the ICU apart from additional hours billed by the pediatric intensivist. However, from a theoretical standpoint, additional resources have certainly been consumed with respect to staffing and materials to perform such a procedure in the ICU, but measuring these in our current hospital system is not possible. Finally, several unmeasured benefits of a bedside procedure include improved utilization of OR time and avoidance of the numerous delays in treatment because of the added flexibility of being able to perform a bedside procedure easily.

We cannot emphasize enough the importance of careful patient selection and adherence to consistent setup and technique in making bedside tracheostomy a safe procedure. A key technical point worth repeating is the use of a small mosquito clamp to palpate and “roll” the small pliable trachea. In our opinion, this technique for palpation of the midline is far more sensitive than digital palpation. In addition, the assistance of the pediatric intensivist with anesthesia reduces the incidence of complications at the bedside while also reducing associated costs of the OR. However, this study should be considered a preliminary report, as the small sample size and relatively low incidence of tracheostomy complications in the population may not necessarily allow for the statistical power to detect a difference in the complication rates between groups. We again point out that this study was not randomized and that selection bias in this analysis is a factor all readers must recognize when considering our comparison of the 2 groups’ safety record. Given these promising preliminary findings, however, we hope to encourage others to consider the viability and cost benefit of performing pediatric tracheostomy at the bedside.

Historically, pediatric tracheostomy has been accomplished in an OR setting because of its increased technical difficulty and high associated morbidity and mortality. We report herein an excellent safety record in performing pediatric bedside tracheostomies, with no deaths and a complication rate of 7%, which is at or be-
low the currently published norms for operative series. While our primary goal was to examine the safety of the bedside procedure, we have also shown substantial cost savings (86%) by performing tracheostomies in the ICU. However, this analysis was limited to charges only, and a more rigorous cost-effectiveness analysis is required in future studies. We attribute our success to careful patient selection, advances in patient monitoring, and adherence to sound, consistent technique. Larger prospective, randomized studies examining procedure-related complication rates according to strict age or weight categories would be helpful in confirming our initial results on this topic.

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REFERENCES