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Economic Evaluation of Pediatric Tracheostomy: A Cost of Illness Analysis

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Abstract

Objective. This study aimed to determine the direct costs of pediatric tracheostomy care within a health care system.

Study Design. Prospective analysis.

Setting. Academic children's hospital.

Methods. Costs associated with caring for pediatric tracheostomy patients under 18 years were analyzed between 2015 and 2021. Direct costs were calculated using the Medicare/Medicaid charges-to-costs ratio for various visit types. Costs were estimated using generalized linear equations, accounting for confounders.

Results. A total of 297 children underwent tracheostomy at a median age of 0.94 years. The median follow-up was 2.5 years, resulting in 13,966 visits (mean = 41). The total cost was $321 million. The initial admission accounted for 72% ($231 million) of costs while other inpatient admissions added 24% ($78 million). Emergency department, observation, and outpatient visits comprised 4% of costs. The length of stay (LOS) was the primary cost driver for inpatient visits. Each additional hospital day increased costs by roughly $1195, and each extra admission added about $130,223 after adjusting for confounders. Respiratory failure and infections were the primary reasons for 67% of subsequent admissions.

Conclusion. Pediatric tracheostomy care generated over $300 million in direct costs over 5 years. Inpatient stays constituted 96% of these costs, with the LOS being a major factor. To reduce direct health expenditures for these patients, the focus should be on minimizing admissions.

Keywords

cost of illness, economic analysis, pediatric tracheostomy

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Pediatric tracheostomy patients are among the highest utilizers of health care resources in the United States consuming 4% of costs despite representing less than 1% of inpatient admissions.[1] Hospitalizations necessitating a tracheostomy are long and include charges approaching $500,000 in many instances.[2,3] Tracheostomies are typically placed for severe illnesses that cause respiratory failure, airway obstruction, and poor pulmonary hygiene.[4] This results in prolonged tracheostomy dependence for children with anticipated decannulation often taking several years, if achievable.[5]

While a tracheostomy is in place, children may necessitate frequent hospital readmissions.[6-10] They also require health care services such as elective surgeries, speech and language therapy, physical and occupational therapy, and routine follow-up visits. Despite the high utilization, limited research has been performed on the economic cost of pediatric tracheostomy beyond the initial few years.[11] A more robust cost of illness analysis could inform decision makers regarding potential areas of cost savings and illustrate a more complete picture of the economic responsibility of pediatric tracheostomy care.

The Children's Health Airway Management Program (CHAMP) prospectively follows pediatric tracheostomy patients from initial placement until decannulation, death, or reaching 21 years of age, whichever occurs first.[12] CHAMP has previously published studies examining longitudinal outcomes, socioeconomic influences, and caregiver quality of life after pediatric tracheostomy.[5,13-16] Children are followed prospectively in this registry, which offers a valuable resource to study the cost of illness related to subsequent tracheostomy visits. The primary objective of this study was to calculate the direct cost of all visits and

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encounters among pediatric tracheostomy patients to a health care system. Secondary objectives identified how patient factors, types of encounters, and years after tracheostomy placement were associated with costs. We hypothesized that most costs are related to the index admission and that children requiring more frequent hospitalizations would have higher costs.

Methods

This study was approved by the UT Southwestern Medical Center Institutional Review Board (IRB #2019-1103). Beginning in 2015, pediatric tracheostomy patients were enrolled automatically at the time of placement into a registry within the electronic medical record. Once registered, all encounters with the institution are prospectively recorded. Children having their tracheostomy placed at an outside institution were excluded. The review and analysis of the data for this study was performed retrospectively.

All visits to Children's Health were included for patients who had their tracheostomy placed from January 2, 2015, to October 31, 2021. These visits include inpatient admissions, observation unit stays, emergency department (ED) visits, ambulatory surgeries, and "other" visits. Other visits include medical visits to physician offices, occupational, speech, or physical therapy encounters, and inpatient rehabilitation unit admissions. For this study, costs are determined from the institution's perspective. Encounter costs were calculated up to the first 5 years after tracheostomy placement.

Patient encounters generate charges from the institution, which are submitted for reimbursement from the primary payer. Direct costs are estimated using the Medicare/Medicaid cost-to-charge ratio. This ratio is determined by the Centers for Medicare and Medicaid Services and is hospital-specific. Costs are further broken down by service type: pharmacy, medical supplies, laboratory, radiological, clinical, and other services (eg, nursing, food, ancillary, social services, discharge planning).

The primary outcome was the total cost of care in US dollars per patient from the time of tracheostomy placement (ie, the index admission) until tracheostomy decannulation, death, or the end of the study period in October 2021. Secondary outcomes included cost by encounter type and services provided (eg, imaging). There were no reported discount rates.

The following patient-specific data was also collected from the medical record: age at tracheostomy placement (years), age at specific encounter (years), sex (male or female), race (white, black, or African American, Asian, Pacific Islander, Native American, other/unknown), ethnicity (Hispanic or non-Hispanic), gestational age < 37 weeks (yes or no), neonatal ICU admission (yes or no), pediatric ICU admission (yes or no), and mechanical ventilation required at index discharge (yes or no). Additionally, the median household income based on the zip code of residence (US dollars), time since tracheostomy placement (years), and length of stay (LOS) in days were also recorded.

Principal encounter diagnosis based on the *International Classification of Diseases, 10th Revision-Clinical Modification* (ICD-10-CM) terminology was recorded. ICD-10-CM codes were grouped into system-based categories based on ICD-10 codes: congenital malformations (V13.6; Q00-Q99); respiratory distress syndrome of newborn (769; P22); sepsis (995.91; A40-A41); cardiac conditions (746.9, I00-I99); chronic respiratory disease (518.83; P27, J96.1); and unintentional injuries (800-999; V01-X59).

All statistics were performed with Stata (StataCorp 2021. *Stata Statistical Software: Release 17*; StataCorp LLC). Continuous data were presented as means with standard deviation or medians with interquartile ranges (IQRs). Categorical data were presented as counts with percentages. A mixed effect generalized linear regression model of costs (negative binomial family, log link) was performed to estimate the predicted mean cost of care for each patient during the study period. Mixed effect models accounted for intra- and interrelated variabilities among individual and groups of patients. Generalized linear models accounted for heteroskedasticity as well as cost data that is unlikely to exhibit negative values. A regression model was also used to estimate the mean cost per encounter type. A multiple mixed-effect regression model was developed to control for age, sex, race, ethnicity, principal diagnosis category, and LOS. As a sensitivity analysis, costs were estimated using time after tracheostomy as a continuous and a categorical variable and excluding the bottom 10th and top 10th deciles for cost. Statistical significance was set at $P < .05$. This study follows the Consolidated Health Economic Evaluation Reporting Standards guidelines for economic analyses.[17] Finally, the Pediatric Health Information System (PHIS) Database was queried for data confirmation of estimated cost. The PHIS database provides standardized cost based on the hospital's charges to cost ratio which allows for more direct comparisons between hospitals.

Results

Two-hundred ninety-seven (N = 297) children underwent tracheostomy during the study period. **Table 1** describes the characteristics of this group. The median (IQR) age in months at tracheostomy placement was 6.0 (3.5-33.9) months. The population was 52% male (N = 153), 56% white race (N = 166), and 30% self-identified as Hispanic ethnicity (N = 87). Tracheostomies were primarily indicated for respiratory failure (70%, N = 208) and 65% were discharged on mechanical ventilation (N = 195). Medicaid was the expected payer for most children (69%, N = 205). At latest follow up, N = 180 were alive with tracheostomy, N = 62 were decannulated, N = 41 were deceased, and N = 14 children were lost to follow-up.

There were 13,966 encounters over the study period (**Table 2**). This included 1695 inpatient stays,

Table 1. Characteristics of Children With a Tracheostomy, 2015 to 2021

Characteristic	Value
No. of children	297
Age at tracheostomy, mo	
Mean (SD)	38.4 (60)
Median (IQR)	6.2 (3.7-43.5)
Sex, n (%)	
Male	153 (52)
Female	144 (48)
Race, n (%)	
Asian	12 (4.0)
Black or African American	101 (34)
Other	18 (6.1)
White	166 (56)
Ethnicity, n (%)	
Non-Hispanic	207 (69)
Hispanic	87 (29)
Gestational age < 37 wk, n (%)	129 (43)
Mechanical ventilation at index discharge, n (%)	195 (66)
Median income by zip code, US dollars	
Mean (SD)	$43,778 ($18,094)

Abbreviation: IQR, interquartile range.

Table 2. Characteristics of Hospital Visits for Children With Tracheostomies, 2015 to 2021

Characteristic	Value
Total visits	13,966
No. of visits, mean (SD)	52.3 (44.7)
No. of visit types, n (%)	
Outpatient	11,071 (79)
Ambulatory surgery	518 (3.7)
Emergency room	682 (5.0)
Observation	280 (2.0)
Inpatient	1415 (10)
Primary diagnosis, n (%)	
Infectious (nonrespiratory)	111 (0.8)
Respiratory	2602 (19)
Gastrointestinal	959 (6.9)
Neoplasm, cancer	160 (1.2)
Musculoskeletal	180 (1.3)
Genital/urinary	222 (1.6)
Perinatal disorders	239 (1.7)
Congenital disorders	849 (6.1)
Trauma	316 (2.3)
NICU stay, n (%)	118 (0.8)
PICU stay, n (%)	654 (4.7)

Abbreviations: NICU, neonatal intensive care unit; PICU, pediatric intensive care unit.

518 ambulatory surgeries, 682 ED visits, and 11,071 outpatient encounters. Children with tracheostomies had a mean of 52 encounters (range = 1-318). The total cost of care for all encounters was $321 million, and inpatient costs accounted for 96% ($309 million) of the total. The median (IQR) for inpatient admissions was $53,000 ($21,000-$175,000). When limited to the index admission, the median (IQR) was $550,000 ($224,000-$1,100,000). The total cost of index admissions was $231 million, representing 72% of all costs (**Table 3**).

ED visit total costs were $1.2 million; ambulatory surgeries were $2.9 million, and outpatient encounters were $5.9 million. The median costs for these visits were: $1500 for ED visits, $4738 for ambulatory surgeries, $8270 for observation stays, and $154 for outpatient visits.

Total cost included $118 million for other services (eg, nursing, food, ancillary, social services, discharge planning), $19 million for pharmacy, $16 million for supplies, $11 million for laboratory services, $6.6 million for clinical services, and $5.4 million for imaging. The remaining costs were unspecified.

The regression model predicted LOS as the most critical determinant of costs for both the index admission and subsequent hospitalizations. The cost related to other visit types (eg, ED visit) had minimal impact. Other predictors of cost during inpatient admissions included: age at admission, intensive care unit (ICU) care, mechanical ventilation, extracorporeal membrane oxygenation (ECMO), total parenteral nutrition (TPN), infection diagnosis, and surgical complication of care. **Table 4** lists the predicted values while controlling for the age at admission and LOS. For example, a 35-month-old child with a 9-day hospital stay (median values for both variables) would generate $58K in costs if the visit included an ICU admission. Characteristics that did not impact the cost of care included sex, race/ethnicity, preferred language, socioeconomic status as gauged by the median income by zip code, time with the tracheostomy, and preterm birth.

Time after tracheostomy as a continuous and categorical variable showed a decrease in costs after the first year. The total cost per year was: $107 million in year 1, $66 million in year 2, $64 million in year 3, $42 million in year 4, and $43 million in year 5. The unadjusted mean costs per year per patient were: $104,000 for year 1 (index year); $53,000 for year 2; $38,000 for year 3; $32,000 for year 4; and $28,000 for year 5 after tracheostomy placement. See **Table 5** for an overview. When excluding the bottom decile for cost, the regression model was similar. However, when excluding the top decile, ECMO was no longer a significant predictor of total cost. We found no statistical interactions or effect modifiers.

Discussion

This prospective cohort study showed that the total cost of care for pediatric tracheostomy patients at a single

Table 3. Estimated Cost in Dollars by Encounter Type

Encounter type	N (%)	Total costs (%) (millions)	Mean (SD) (thousands)	Median (IQR) (thousands)
Inpatient	1415 (10)	$309 (96)	$218 (474)	$53.2 (21.0-17.5)
ED visit	682 (4.9)	$1.19 (0.4)	$1.76 (1.15)	$1.55 (0.88-2.38)
Ambulatory surgery	518 (3.7)	$2.90 (0.9)	$5.61 (3.50)	$4.74 (3.85-6.30)
Observation	280 (2.0)	$2.74 (0.9)	$9.79 (6.56)	$8.26 (5.95-11.8)
Outpatient	11,071 (79)	$5.86 (1.8)	$0.53 (1.56)	$0.15 (0.05-0.44)
All encounters[a]	13,966 (100)	$321 (100)	$23.0 (16.5)	$0.267 (0.067-1.2)

Abbreviations: ED, emergency department; IQR, interquartile range.
[a]All encounters include additive amounts for total encounters and costs, along with the mean and median costs of a single encounter.

Table 4. Predicted Margins Based on Generalized Linear Model of Total Cost by Patient

	Margin	Standard error	z	*P* value	95% confidence interval
Inpatient	130,224	14,880	8.75	<.001	101,059-159,388
ED visit	6471	918	7.05	<.001	4672-8271
Ambulatory surgery	23,446	3381	6.93	<.001	16,820-30,073
Observation	37,074	5576	6.65	<.001	26,145-48,003
Other	1284	174	7.36	<.001	942-1626
LOS[a]	1195	188	6.36	<.001	827-1564
Time with tracheostomy[a]	−4108	1985	−2.07	.04	−8000 to −216

[a]Value reflect a 1-unit increase. Predictive margins represent the predicted values of the dependent variable for specific values of the independent variables, averaged over all observations in the dataset.

Table 5. Predicted Margins Based on Generalized Linear Model of Total Cost by Patient Per Year of Tracheostomy Status

	Margin	Standard error	z	*P* value	95% confidence interval
Year 1	104,019	17,000	6.24	<.001	71,346-136,691
Year 2	53,445	9920	5.39	<.001	34,002-72,888
Year 3	38,022	7663	4.96	<.001	23,004-53,040
Year 4	31,708	7557	4.20	<.001	16,895-46,520
Year 5	27,586	6141	4.49	<.001	15,550-9622

Note: Predictive margins represent the predicted values of the dependent variable for specific values of the independent variables, averaged over all observations in the dataset.

institution was $321 million between January 2015 and October 2021. Most of the costs (96%) were related to inpatient admissions, and close to two-thirds were from the index admission when the tracheostomy was placed. This data also determined that LOS and subsequent inpatient admissions are the primary drivers of tracheostomy cost.

LOS was shown to be the most important factor in determining costs for both the index and subsequent inpatient admissions. This is likely a result of hospitalizations being associated with complications and patient complexity that require more medical resources, such as medications, nursing care, and equipment.[18,19] In this cohort, other predictors of inpatient cost included age at admission, ICU care, mechanical ventilation, ECMO, TPN, infection diagnosis, and surgical complications. This is consistent with past studies that have found young children with a tracheostomy, particularly neonates, requiring longer hospitalizations.[2,3] Patients with comorbidities such as heart disease, bronchopulmonary dysplasia, subglottic stenosis, gastroesophageal reflux disease (GERD), and short gestational age have also been predisposed to developing tracheostomy-related complications requiring longer hospital stays.[20] Those with chronic health conditions risk acute complications that require individualized care plans to reduce severity and corresponding costs.[21] Socioeconomic disadvantage impacts pediatric tracheostomy outcomes in which children from disadvantaged communities have longer total LOS and increased risk of prolonged hospitalizations even when controlling for comorbidities.[15] Further, longer stays can create additional complications which require medical intervention, such as infections and pressure ulcers, further increasing the costs. Preventative strategies targeting iatrogenic disease, such as nursing interventions and multidisciplinary consults, can be implemented as to not increase the cost burden of hospital stays.[12,22]

Subsequent inpatient admissions were the second highest driver of total health care costs associated with tracheostomies and were frequently related to respiratory conditions. In pediatric patients with tracheostomies, the respiratory tract is more vulnerable to infection as the nasal and oral airways are no longer able to provide a protective barrier. Primary prevention of respiratory infection may be an important area of focus to reduce subsequent inpatient admissions. A concomitant diagnosis of GERD and cerebral palsy has also been associated with higher respiratory infection risk.[23] Ventilator-dependent patients younger than 1 year old with at least for complex chronic conditions are also especially vulnerable.[24] Future protocols should specifically address these risk factors through specialized care plans and prevention strategies. Interventions that have been used at other institutions include patient positioning and oral care, use of nocturnal heated humidification, and respiratory secretion clearance strategies. There is also potential benefit to using prophylactic inhaled antibiotics as part of posttracheostomy care.[25] One of the more efficacious approaches consisted of a care bundle that included a standardized regimen for tracheostomy tube cuff pressure, head elevation, oral care, and ventilator circuit changes.[26] However, this still exists a paucity of data for providing evidence-based recommendations to reduce tracheostomy-associated respiratory infections, with many studies being retrospective and ineffective for gathering causal relationships. Common inpatient revisits are also a result of device and prosthesis adjustments.[27] This could be addressed through improvements in discharge planning and follow-ups. In general, studies have shown patients receiving care coordination and continuity across care settings have fewer preventable hospitalizations.[28] For more complex patients, this can involve a complex care medical home program that focuses on bridging the gap between hospital and home through expanded care access and caregiver knowledge.[29]

While outpatient visits accounted for 79% of all health care encounters, the total cost of these visits only amounted to $5.9 million. This further emphasizes the high cost burden associated with inpatient admissions for high medical acuity. Conversely, ED visits and ambulatory surgeries totaled at $1.2 million and $2.9 million, despite accounting for only less than 5% and 4% of health care encounters, respectively. These visits cost nearly 10-fold (ED) and 25-fold (ambulatory surgeries) greater than outpatient costs. This is likely associated with emergent cases requiring more complex, expensive care and surgeries utilizing more health care resources than outpatient office visits. However, these costs were still significantly less than that of inpatient encounters and suggests that proper utilization of outpatient care may help divert from high-cost inpatient care, particularly for patients with complex needs. This could be done through tertiary care-primary care partnerships. One such model at Children's Hospital of Wisconsin partnered families with primary care providers in a seamless inpatient-outpatient transition and found statistically significant decreases in hospitalizations, length of hospital stays, and tertiary care center costs.[30]

The predicted total cost by patient based on years with tracheostomy showed significance only between the first and second year. Years 3 to 5 generated approximately the same costs in this series. This suggests that the first year is most critical for predicting total cost, likely due to complications and additional care arising in the year that a tracheostomy is placed. This reiterates the importance of prevention strategies in patient care plans. Caregivers also play an essential role as they provide medical care at home and are a critical link between the pediatric patient and the health care system. With better caregiver education and empowerment, outcomes can be improved for not only patients, but also caregivers, who experience increased psychological burden in their roles.[31,32]

Several limitations exist within this study. First, the cohort reflects a single academic children's hospital, which may be unique to other patient populations based on institutional practices. Second there is not a direct assessment of the child's caregiver's economic resources which may have a bearing on hospital utilization.[33] Third, there may be direct costs that were generated outside of this particular health system, which may have been missed and underestimates the total costs during that time period. Fourth, there are potentially a large number of indirect costs to pediatric tracheosotmy care including costs to caregivers, the community, and other nonhospital services. Specifically, the costs for home nursing were unable to be captured by our registry. These costs may represent a large amount especially for children necessitating nursing care 24 hours a day. Measuring the financial impact of home care nursing would be valuable to analyze in subsequent research. These are much more challenging to capture but necessitate future analyses to capture. Finally, the relationship between vaccination against childhood respiratory diseases and hospitalizations was beyond the scope of this project. This represents an important area for future exploration in vulnerable pediatric populations.

Our study has several strengths that enhance its validity and relevance in the realm of pediatric tracheostomy care. Primarily, the prospective nature of our cohort ensures a systematic and comprehensive capture of all encounters within the health care system, minimizing potential biases associated with retrospective analyses. Additionally, the extended timeframe spanning from January 2015 to October 2021, provides a robust representation of evolving clinical practices and health care economics. The diverse patient demographics within our cohort, encompassing a range of ages, races, and comorbidities, further bolster the generalizability of our findings to broader pediatric populations. While our study is centered on a single academic children's hospital, the consistency of our results with existing literature suggests that our observations may be extrapolated to similar institutions, offering valuable insights for clinicians, policymakers, and researchers.

Cost of illness studies are important given their role in helping shape clinical decision-making.[34] They allow for clinicians and policymakers to effectively allocate health care resources. This includes optimizing medical outcomes but also addressing the socioeconomic context of provision of medical care. Previous studies have included the cost impacts of pediatric anxiety disorders and childhood obesity, with conclusions on cost-saving measures, future research directions, and health policy potential.[35,36] As mentioned, this study is among the first to follow children with tracheostomies prospectively.[37] The data shows that virtually all costs within the first few years is related to inpatient admissions. The cost of admissions is primarily driven by LOS, although the patients' other comorbidities play an important role. As such, health systems should aim to decrease patient cost burden by reducing the risk for inpatient stays by involving multidisciplinary care teams, coordinating specific care to higher-risk patients, and other preventative strategies to reduce complications and promote care continuity in the community. The substantial costs associated with inpatient admissions, particularly during the index admission, underscore the financial strain placed on health care systems and payers. This, in turn, can influence insurance premiums, public health funding allocations, and even family out-of-pocket expenses. Furthermore, the prolonged hospital stays, and frequent readmissions represent not just direct medical costs but also allude to the indirect burdens shouldered by families. These can encompass lost wages, travel expenses, and the profound emotional toll of extended hospitalizations. As such, it becomes imperative to equip caregivers with the proper education and resources, enabling them to provide high-quality medical care at home. This not only helps in averting further costly medical interventions but also ensures that they receive the necessary support, such as home nursing care. Such provisions aim to optimize the quality of life for both caregivers and their tracheostomy-dependent children.

Conclusion

The total cost associated with care for pediatric tracheostomy patients over a 5-year period at a single institution was $321 million. While the index admission represented the largest percentage of costs, LOS and inpatient admissions were strong drivers of cost in the years after placement. For children with a tracheostomy, initiatives designed to reduce hospital admissions represents the best opportunity to decrease direct health expenditures.

Authors Contributions

Jinghan Zhang, interpretation of data, drafting the article, final approval of the version to be published, and agreement to be accountable for all aspects of the work; **Palmila Liu**, interpretation of data, drafting the article, final approval of the version to be published, and agreement to be accountable for all aspects of the work; **Ajay M. Narayanan**, interpretation of data, drafting the article, final approval of the version to be published, and agreement to be accountable for all aspects of the work; **Stephen R. Chorney**, interpretation of data, drafting the article, final approval of the version to be published, and agreement to be accountable for all aspects of the work; **Yann-Fuu Kou**, interpretation of data, drafting the article, final approval of the version to be published, and agreement to be accountable for all aspects of the work; **Romaine F. Johnson**, conception and design, acquisition of data, analysis and interpretation of data, drafting the article, final approval of the version to be published, and agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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