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Pediatric Tracheostomy Outcomes After Development of a Multidisciplinary Airway Team: A Quality Improvement Initiative

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Abstract

Objectives. To analyze a multidisciplinary tracheostomy team's effect on length of stay and cost.

Methods. An airway management program using a balanced scorecard was created to track key performance measures. Interventions included weekly rounding, standardized placement, postoperative care, and caregiver education. Process measures included time to first education, speech-language pathology consultation rates, and pretracheostomy consultations. Outcome measures focused on the total length of stay, 30-day revisit rates after discharge, accidental decannulation rate, and standardized cost. Regression analysis was used to predict the program's effect on length of stay and total cost.

Results. In total, 239 children met inclusion. The mean time to first education class was reduced from 13.7 to 1.9 days ($P < .001$). The speech-language pathology consultation rate increased from 68% to 95% ($P < .001$), and the presurgical consultation rate with the tracheostomy team increased from 14% to 93% ($P < .001$). The length of stay decreased from 133 to 96 days ($P = .006$). Total costs were lower for short admissions but higher for prolonged admissions. Revisits within 30 days remained stable over time (18%).

Discussion. Establishing a multidisciplinary tracheostomy team results in improvements in quality metrics when caring for children with tracheostomies. Controlling for associated factors showed the mean length of stay decreased significantly in the first full year of program implementation. Cost analysis estimated significant reductions for tracheostomy patients spending less time in the hospital.

Implications for Practice. A airway management program can positively affect tracheostomy processes and outcomes.

Keywords

pediatric tracheostomy, quality improvement initiative, multidisciplinary team

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Children requiring tracheostomy placement are among the most medically complex patients in the health care system. Although tracheostomies occur in less than 1% of pediatric admissions, they account for up to 4% of total pediatric hospital costs.[1] Hospitalizations for tracheostomy can exceed 30 days in length and include charges approaching $500,000 in many admissions.[2,3] Inpatient complication rates can reach 30% with a mortality rate of 8% during the index hospitalization and greater than 15% overall.[4-8] Tracheostomy patients are a heterogenous population commonly having multiple comorbidities, including sepsis, respiratory failure, congenital malformations, or cardiac defects.[6,9]

Reducing health care utilization and cost remains a challenging aspect of tracheostomy care. Pediatric tracheostomies are typically placed for severity of illness and rarely for elective needs, which makes standardized care difficult. That is, the variable nature and severity of an individual child's illness challenge an ability to target specific cost-reducing interventions. Quality improvement initiatives that have been shown to improve outcomes include early tracheostomy placement, dedicated tracheostomy care teams, and standardized tracheostomy education.[10-13] Pediatric initiatives typically involve the latter two since early tracheostomy is not consistently performed in young children. Despite evidence that dedicated teams and standardized processes can reduce tracheostomy utilization and costs in adults,[12] there have been

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very few studies to examine this strategy in pediatric patients.[10,14,15] Economic investigations that include sensitivity analyses have also been limited. Demonstrating that a multidisciplinary tracheostomy team (MDT) and standardized processes can improve utilization and costs would be beneficial to health care systems, providers, and families who care for these complex children.

The Children's Health Airway Management Program (CHAMP) was designed as an MDT dedicated to the holistic management of children with tracheostomies. The team was officially formed in mid-2018 in response to the growing need to improve patient safety and institutional quality outcomes, specifically length of stay and total costs. Holistic management reflects an involvement in all critical tracheostomy-related decisions: preplacement counseling, perioperative care, caregiver and staff training, and outpatient management. The team is also responsible for developing standard operating procedures for the care of the child with a tracheostomy from placement until decannulation, death, or aging out of pediatric care at 21 years old. To align performance measures and ensure quality, the team used a ''Balanced Scorecard.''[16] The Balanced Scorecard links performance to outcomes by tracking 4 perspectives: clinical excellence, operational excellence, exceptional experience, and financial strength. Continuous monitoring and adjustments in response to these perspectives allows the team to potentially reduce length of stay, reduce variance with hospital costs, and improve the child's overall well-being.

The principal rationale for this study is to report the results of a series of tracheostomy patients before and after the creation of an airway management program. Creation of a dedicated tracheostomy team and objective metric analysis was hypothesized to reduce the index hospital length of stay and total standardized costs. Secondary objectives looked at morbidity, influence of services involved in the admission, readmissions, and family quality of life during the evolution of this program.

Materials and Methods

CHAMP was developed between 2016 and 2017 after creation of a tracheostomy quality and improvement committee. The committee consisted of stakeholders involved in the care of children with tracheostomies: pediatric otolaryngology, pulmonology, critical care, neonatology, nursing, respiratory therapy, and speech therapy. A series of quarterly meetings ending in early 2018 was used to further engage stakeholders to determine key metrics for improvement. This included performing a detailed financial analysis of tracheostomy-related inpatients stays, identifying members of the team, and developing a formal proposal that was presented to hospital leadership. The institution agreed to financially support a dedicated team that would coordinate care for children with tracheostomies. The team included a medical director, otolaryngologist, pulmonologist, 2 dedicated nurses, a dedicated respiratory therapist, a dedicated speech-language pathologist, a dedicated surgery scheduler, and business manager. The program was developed as a quality improvement initiative, and therefore institutional review board (IRB) approval was not needed for prospective data collection. Subsequent review of the data and presentation for this report was done retrospectively and approved by the University of Texas Southwestern Medical Center IRB (#2019-113).

CHAMP developed an operational plan that used a Balanced Scorecard. The 4 perspectives were operational and clinical excellence, exceptional experience, and financial strength. The operational metrics were (1) time to first tracheostomy education, (2) 30-day follow-up after discharge, (3) speech-language pathology evaluation for feeding and communication, and (4) presurgical consultations with the tracheostomy team nurse. The clinical excellence measures were (1) total length of stay, (2) 30-day emergency department (ED) revisit rates, (3) screening bundle fulfillment rate, and (4) accidental decannulation rates. The screening bundle rate was the percentage of patients who had complete documentation of speech-language pathology consults, billing, and 1-way speaking valve evaluation. The financial strength measures included mean standardized cost-per-index admission. Exceptional experience metrics were (1) patient satisfaction and (2) CHAMP team member satisfaction.

The program developed standardized processes for children who underwent tracheostomy. These included (1) pretracheostomy consultations with families and care teams to discuss tracheostomy utility, timing, immediate postsurgical care, and typical hospital course and disposition; (2) standardization of the tracheostomy placement, for example, placing the same type of tracheostomy tube, performing laryngoscopy at the time of placement, and first tracheostomy change 5 days after placement; (3) weekly multidisciplinary team rounding on all tracheostomy patients until discharged; (4) speech-language pathology consultation for feeding and communication strategies, including early 1-valve usage, if eligible; and (5) tracheostomy caregiver education classes.

All children who underwent tracheostomy were automatically enrolled in a tracheostomy registry. The registry used the Epic (Epic Systems Corporation) ''episodes of care'' functionality, allowing the team to build a reporting dashboard and track key metrics of the balanced scorecard. This dashboard, updated daily, was reviewed monthly by the team with appropriate adjustments when necessary (eg, improving availability of first tracheostomy education classes if progressive delays were noted). The anticipated time to assess institutional improvement was the end of calendar year 2019. Although other long-term metrics were measured by the team, the key assumptions of this initiative were that CHAMP could reduce the length of index admissions and consequentially the total associated admission costs.

The following demographic information was collected from the electronic medical record: age at tracheostomy placement, sex (male or female), race (American Indian, Asian, black, white, multiple races, unknown/not reported), ethnicity (Hispanic, non-Hispanic), gestational age in weeks, birthweight in kilograms, primary payer (Medicaid, other), complications of birth/delivery (yes/no), and area deprivation index (ADI)[17] of primary residence ZIP code. Race and

ethnicity are self-selected by the family or caregivers. These are considered separate categories, so Hispanic could include black or white patients. Race and ethnicity are presented to help determine the generalizability of the study population. The ADI is a validated measure of socioeconomic advantage scored 0 to 10 for state-level comparisons. Higher numbers represent more community socioeconomic disadvantage. The ADI is presented to provide a measure of socioeconomic status.[18]

We determined if the following health conditions were present on admission or developed during the admission based on reviewing the medical record for *International Classification of Diseases, 10th Revision* (*ICD-10*) codes: short gestation (ICD10-P07), newborn complications (ICD10-P02), bacterial sepsis of newborn (P36), respiratory distress syndrome (P22), sepsis (A40-1), cardiac conditions (Q20), chronic respiratory conditions (P27), and trauma (V01-X59). These items were chosen because they are among the leading causes of pediatric mortality and serious illness likely encountered in children with a tracheostomy. Patients were characterized as complex if they were diagnosed with sepsis, underwent major cardiac surgery, or needed total parental nutrition (TPN).[19]

The following index hospitalization data were recorded: discharge primary service (neonatal intensive care, pediatric intensive care, cardiac intensive care, pulmonary/respiratory medicine), age at tracheostomy, weight at tracheostomy, time to first education class, rate of formal pretracheostomy consultation, speech-language pathology consultation rate, rate of speaking valve trials, audiometric assessments, accidental decannulations, tracheostomy-related complication (based on *ICD-10* classifications J95.0-J95.09), total length of admission, need for mechanical ventilation at discharge, disposition (home, short-care nursing facility, in-hospital death, transfer to outside hospital), 30-day readmission rate, readmission cause (tracheostomy related—yes or no), and time to first follow-up appointment in days. The current status of each patient is reported as of December 31, 2020: alive with tracheostomy, deceased, decannulated, or lost to follow-up. Lost to follow-up is defined as any patient not seen within the Children's Health in the previous 2 years. The level of neurocognitive disability at the end of the study period was indicated as normal, mild/moderate, or severe. The definition of neurocognitive disability has been previously characterized with severe neurocognitive disability generally referring to children with global development delay.[8,20] Starting in late 2018, families were asked to fill out the PedsQL Family Impact module during their index stay after the tracheostomy was placed. The PedsQL Family Impact Module is a validated global quality-of-life instrument that measures the impact of a chronic condition like tracheostomy on the family.[21] The instrument is scored 0 to 100, with higher scores indicating better quality of life. Families with healthy children score in the low to mid-80s, and total scores are reported.

A detailed financial analysis for each hospital stay was performed semiannually with data provided by institutional financial accountants. These data were comprehensive, but for the purposes of this study, we used total cost analysis based on the hospital's ratio of cost to charges (RCC). Total cost (RCC based) estimates cost of services that are based on billing data and the hospital's cost-to-charge ratio supplied by the Centers for Medicare & Medicaid Services. Total costs are based on actual expenses from services provided by the hospital (including clinical, imaging, laboratory, pharmacy, and supplies) but exclude physician fees.

Patients were divided by the year the tracheostomy was placed (2015, 2016, 2017, 2018, and 2019), with 2015 considered the baseline year and 2019 as the first full year of program operation. To determine if differences existed by study year, a univariate analysis was performed with analysis of variance (ANOVA) for continuous variables and the Pearson χ^2 test for categorical variables.

To evaluate the 2 primary outcomes of the program, a regression analysis was used since these models can control for confounding variables. The length of stay was predicted using a mixed-effect parametric survivor regression with Weibull distribution. The event in the model was discharge or death. A forward stepwise regression model approach determined which variables influenced length of stay. Variables with a P value $<.20$ were kept in the model, and variables that showed statistical significance between the study years in the univariate analysis were added. Variables that subsequently exhibited P values $>.05$ were removed until a final model for length of stay was formed. The mixed-effect model was checked against the standard fixed-effect regression model with the likelihood ratio test.

Generalized linear models (Gaussian family and log link with robust standard errors) were used to model total cost (RCC based) applying the same forward stepwise approach. Generalized linear models can be used to model health care cost since it accounts for heteroskedasticity, allows for values that do not include zero, and does not need retransformation (ie, log-transformations).[22] The models for length of stay and total cost were applied for each study year. The hypothesis was that the average length of stay and mean total costs per stay would be significantly different between 2019 and 2015.

The Pediatric Health Information System (PHIS) was used for additional data validation: total cost (RCC based), readmissions, and complex patient designation. All statistics were performed with Stata Statistical Software (Release 16; StataCorp LLC). Statistical significance was set at $P < .05$. Data were managed using REDCap (Research Electronic Data Capture) tools hosted at the University of Texas Southwestern Medical Center.[23] This study adheres to the Standards for Quality Improvement Reporting Excellence (SQUIRE 2.0).[24]

Results

Demographics

In total, 239 children underwent tracheostomy between 2015 and 2019 who were subsequently discharged or deceased by December 31, 2020. The median age at tracheostomy was 0.55 (interquartile range [IQR], 3.5) years, and median

Table 1. Demographics of Pediatric Tracheostomy Patients by Study Year.[a]

Variable	2015	2016	2017	2018	2019	Total	*P* value
Patients	65 (27)	40 (17)	44 (18)	47 (20)	43 (18)	239 (100)	
Age, median (IQR), mo	5.0 (20)	10 (117)	5.5 (37)	8.4 (44)	7.8 (44)	6.6 (42)	.02
Weight, median (IQR), kg	5.40 (5.79)	8.35 (22.69)	5.50 (11.03)	8.05 (11.15)	6.90 (12.79)	6.20 (11.05)	.05
Male	29 (45)	16 (40)	26 (64)	22 (47)	25 (58)	120 (50)	.14
Asian	2 (3.1)	2 (5.0)	1 (2.3)	2 (4.3)	1 (2.3)	8 (3.3)	.94
Black	24 (37)	11 (28)	14 (32)	17 (36)	16 (37)	82 (34)	.85
Hispanic	21 (32)	8 (20)	12 (27)	15 (32)	14 (33)	70 (29)	.52
White	48 (74)	20 (50)	30 (68)	34 (72)	32 (74)	164 (69)	.08
Other race	8 (12)	5 (13)	8 (18)	8 (17)	4 (9.3)	33 (14)	.73
Gestational age, median (IQR), wk	37 (8.5)	36 (13)	34 (14)	37 (10)	36 (9.2)	36 (11)	.61
Birthweight, median (IQR), g	2.38 (1.86)	2.42 (2.12)	1.82 (2.36)	2.42 (1.98)	2.52 (2.21)	2.41 (2.05)	.84
Birth complications	43 (66)	26 (65)	24 (57)	25 (57)	30 (70)	148 (63)	.78
Medicaid coverage	60 (92)	27 (70)	37 (84)	36 (77)	29 (67)	190 (80)	.03
ADI, mean (SD)[b]	6.5 (2.5)	4.6 (3.1)	6.2 (2.9)	5.8 (2.9)	4.8 (2.7)	5.7 (2.9)	.003

Abbreviations: ADI, area deprivation index; IQR, interquartile range.
[a]Values are presented as number (%) unless otherwise indicated.
[b]State area deprivation index.

gestational age was 36 (IQR, 9.3) weeks. The population had an equal distribution of males (n = 120) and females (n = 119), with race and ethnicity characteristics consisting of 54% white (131/239), 34% black or African American (81/239), 3.4% Asian (8/239), 7.9% other (Native American, unknown, multiple races) (19/239), and 29% Hispanic (70/239) children. The primary language was not English for 12% (28/239) of families. Most children (80%, 190/239) relied on Medicaid as the primary payer. The median state rank for the ADI was 6.0. The mean (SD) parental quality of life was 69.2 (20.9).

There were significant demographic differences between the baseline year (2015) and subsequent years. The 2016 population was older compared to 2015 (4.8 vs 2.5 years, P = .03), although the other years were statistically similar. The percentage of children on Medicaid and the community ADI decreased over time. In 2019, the Medicaid percentage was 67% (29/43) compared to 92% (60/65) in 2015. The ADI rank also decreased (better socioeconomic status) from 2015 to 2019 (4.8 vs. 6.5, P = .003). See **Table 1** for additional details.

Associated conditions and diagnoses were similar across the study years. As expected, respiratory failure was the most common associated diagnosis (71%, 170/230). Short gestation and history of newborn complications were the second and third most common conditions, each at 48%. The most frequent indication for tracheostomy was respiratory failure (69%, 162/239), followed by airway obstruction (23%, 55/239). The primary service lines also changed slightly from year to year, but most patients were managed by the pulmonary service prior to discharge. See **Table 2** for other details.

Interventions

CHAMP was able to successfully implement weekly tracheostomy rounds, standardized tracheostomy placement, and caregiver education classes. The following significant changes emerged when comparing 2019 to 2015: pretracheostomy consultations increased from 14.1% (9/65) to 93% (40/43), mean time to first education class was reduced to 1.9 days from 13.7 days (mean difference, −12 days; 95% CI, −14 to −8.9 days; $P < .001$), and speech-language pathology consultation rates increased from 68% to 95% ($P < .001$). Consequently, 1-way speaking valve utilization increased from 22% (14/65) to 51% (22/43) (P = .002). Despite these changes, the tracheostomy-related complication rate remained stable, at a mean of 18% over all years (43/239) (see **Table 3**).

Discharge and Follow-up

The mean (SD) length of stay (LOS) after tracheostomy was 66.4 (74) days, and the mean (SD) total LOS was 122 (102) days. Most patients were discharged to an acute care rehabilitation facility (49%, 116/239). There were 12 (5.0%) in-hospital deaths during the index stay. The median total cost was $515,000 and remained statistically similar over time (P = .19). The time to first follow-up appointment decreased significantly from 115 days in 2015 to 39 days in 2019 (mean difference, −76 days; 95% CI, −117 to −35; $P < .001$). Most patients were discharged on at least partial daily mechanical ventilation (80%, 191/239). The readmission rate remained stable for an annual mean of 18%. The status of patients as of December 31, 2020, included 56% (134/239) alive with tracheostomy in place, 24% (57/239) decannulated, 16% (37/239) deceased, and 4.6% (11/239) lost to follow-up. The percentage of those with severe neurocognitive disability was 64% (151/239).

Main Outcomes

The multiple parametric survival analysis showed that the predicted total LOS decreased significantly from 143 days in

Table 2. Admission Data, Associated Conditions, and Interventions of Pediatric Tracheostomy Patients by Study Year.[a]

Variable	2015	2016	2017	2018	2019	Total	*P* value
Patients	65 (27)	40 (17)	44 (18)	47 (20)	43 (18)	239 (100)	
Newborn complication	34 (52)	20 (50)	23 (52)	16 (34)	22 (51)	115 (48)	.32
Short gestation	27 (42)	21 (53)	24 (55)	19 (40)	24 (56)	115 (48)	.37
RDS	16 (25)	14 (35)	8 (18)	14 (30)	8 (19)	60 (25)	.32
Sepsis	5 (7.7)	1 (2.5)	3 (6.8)	2 (4.3)	3 (7.0)	14 (5.9)	.81
Cardiac condition	37 (56.9)	12 (30.0)	19 (43.2)	20 (42.6)	21 (48.8)	109 (45.6)	.10
Chronic respiratory failure	49 (75.4)	24 (60.0)	36 (81.8)	31 (66.0)	30 (69.8)	170 (71.1)	.19
Trauma	1 (1.5)	7 (17.5)	3 (6.8)	4 (8.5)	3 (7.0)	18 (7.5)	.06
Complex patient	32 (49.2)	17 (42.5)	22 (50.0)	27 (57.4)	23 (53.5)	121 (50.6)	.71
Respiratory failure	38 (59)	28 (70)	28 (64)	36 (77)	32 (74)	162 (69)	.61
Time to education class, mean (SD), d	13.7 (9.7)	7.0 (10.5)	3.3 (5.2)	3.1 (4.7)	1.9 (3.9)	6.3 (8.7)	< .001
Tracheostomy team consultations	9 (14.1)	21 (52.5)	31 (70.5)	42 (89.4)	40 (93.0)	143 (60)	< .001
Speech-language pathology evaluations	44 (67.7)	35 (87.5)	39 (88.6)	45 (95.7)	41 (95.3)	204 (85.4)	< .001
Audiometric examination	0 (0.0)	0 (0.0)	14 (87.5)	21 (77.8)	24 (82.8)	59 (81.9)	.72
Speaking valve trials	14 (21.5)	23 (57.5)	20 (45.5)	18 (38.3)	22 (51.2)	97 (40.6)	.002
QOL				60 (28)	72 (18)	69 (21)	.27

Abbreviations: QOL, quality of life, PedsQL scores; RDS, respiratory distress syndrome.
[a]Values are presented as number (%) unless otherwise indicated.

Table 3. Discharge and Follow-up Data of Pediatric Tracheostomy by Study Year.[a]

Variable	2015	2016	2017	2018	2019	Total	*P* value
Patients	65 (27)	40 (17)	44 (18)	47 (20)	43 (18)	239 (100)	
LOS, mean (SD), d	126.6 (127.7)	115.4 (103.7)	134.4 (108.9)	125.4 (75.1)	103.8 (70.1)	121.8 (101.7)	.67
Cost, mean (SD), $[b]	490 (421)	420 (375)	507 (509)	623 (424)	524 (384)	514 (425)	.31
Tracheostomy-related complication	18 (28)	13 (33)	12 (27)	11 (23)	11 (26)	65 (27)	.91
Accidental decannulation	10 (15.4)	4 (10.0)	4 (9.1)	6 (12.8)	4 (9.3)	28 (11.7)	0.82
Disposition							
Home	27 (41.5)	16 (40.0)	17 (38.6)	13 (27.7)	11 (25.6)	84 (35.1)	
Short-term rehabilitation facility	26 (40.0)	17 (42.5)	25 (56.8)	26 (55.3)	22 (51.2)	116 (48.5)	
Outside hospital	11 (16.9)	5 (12.5)	1 (2.3)	6 (12.8)	4 (9.3)	27 (11.3)	
Deceased	1 (1.5)	2 (5.0)	1 (2.3)	2 (4.3)	6 (14.0)	12 (5.0)	.07
Mechanical ventilation	49 (75.4)	32 (80.0)	34 (77.3)	40 (85.1)	36 (83.7)	191 (79.9)	.70
Readmissions	10 (15.4)	9 (22.5)	12 (27.3)	5 (10.6)	6 (14.0)	42 (17.6)	.22
Time to follow-up, median (IQR), d	115.4 (124.4)	68.1 (81.6)	74.9 (119.5)	81.0 (73.4)	38.9 (28.5)	80.7 (99.3)	.007
Status							
Alive with tracheostomy	26 (40)	17 (43)	24 (55)	35 (75)	32 (74)	134 (56)	
Decannulated	23 (35)	15 (38)	11 (25)	5 (11)	3 (7.0)	57 (24)	
Deceased	14 (21.5)	7 (17.5)	5 (11.4)	4 (8.5)	7 (16.3)	37 (15.5)	
Lost to follow-up	2 (3.1)	1 (2.5)	4 (9.1)	3 (6.4)	1 (2.3)	11 (4.6)	<.001

Abbreviations: IQR, interquartile range; LOS, length of stay.
[a]Values are presented as number (%) unless otherwise indicated.
[b]Cost is rounded to 100,000, so 420 = 420,000.

2015 to 102 days in 2019 (mean difference, −41 days; 95% CI, −70 to −13 days; $P = .005$). The model also showed the following variables associated with increasing length of stay: cardiac defects, trauma, low weight at tracheostomy, tracheostomy indication, speech consult, and mechanical ventilation at discharge. A mixed-effect model tested whether the primary discharge service or the need for mechanical ventilation at discharge was superior to a fixed model. That is, the variation inherent in service-line practices and ventilatory setting/needs should be accounted for when analyzing the length of stay. See **Table 4** for details. **Figure 1** shows the model rate in graphic form.

Table 4. Multilevel Mixed-Effect Parametric Survival Analysis of Length of Stay of Pediatric Tracheostomy Patients by Study Year.[a]

	Univariable analysis		Multivariable analysis[b]	
Year	HR (95% CI)[c]	*P* value	HR (95% CI)	*P* value
2015	Reference			
2016	1.05 (0.70-1.57)	.81	0.95 (0.62-1.44)	.82
2017	0.87 (0.58-1.30)	.51	0.91 (0.60-1.38)	.67
2018	1.03 (0.69-1.53)	.89	1.24 (0.82-1.88)	.31
2019	1.30 (0.87-1.96)	.20	1.82 (1.18-2.81)	.007

Abbreviations: HR, hazard ratio.
[a]Service line and mechanical ventilation were random-effects variables. Likelihood ratio test = 13.25, *P* = .004 for random-effects model.
[b]Adjusted for weight, complex patient, trauma, tracheostomy indication, speech, and mechanical ventilation discharge.
[c]HR <1.0 indicates longer stays; HR >1.0 indicates shorter stays.

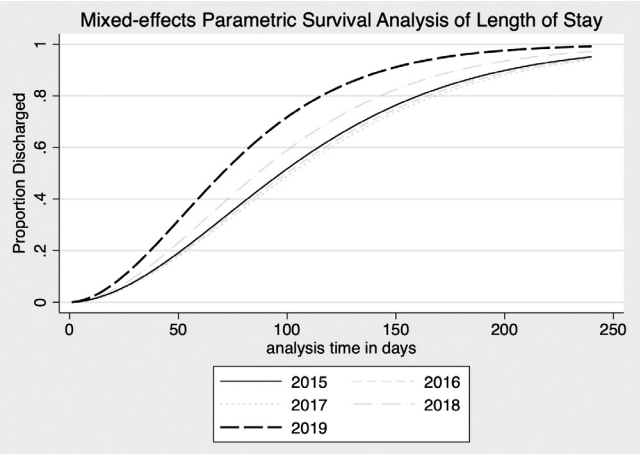

Figure 1. Parametric survival regression analysis of length of stay.

The mean total costs per year are shown in **Table 3**. The mean cost remained similar on univariate analysis (*P* = .31). The predicted mean total cost was associated with LOS, study year, and complex patient classification, and there was an interaction between study year and LOS. That is, the cost curve started to bend, either flattening or growing further, depending on the length of stay and study year. To help illustrate, **Table 5** shows the mean cost per day at days 30, 90, and 180 for each study year. The table shows that the mean cost was significantly lower in 2019 compared to 2015 for shorter admissions (up to 90 days), while longer admissions cost more in 2019 compared to 2015. As such, a 30-day admission cost $203,188 less in 2019 compared to 2015 (95% CI, –$298,701 to –$107,675; *P* < .001), and a 180-day admission cost $173,082 more (95% CI, $33,231 to $312,932; *P* = .02). **Figure 2** shows these results in graphic form.

Discussion

Establishing an MDT results in measured improvements in process and quality metrics when caring for children with a tracheostomy. The primary outcomes of admission length and cost appeared similar on univariate analysis. Controlling for associated factors with multiple regression modeling showed the mean length of stay decreased significantly in the first full year of program implementation. Cost analysis findings were more nuanced but estimated significant reductions for tracheostomy patients spending less time in the hospital. This suggests that earlier tracheostomy placement may result in the greatest economic impact of an MDT. The study also reaffirms that most pediatric tracheostomy patients are under 1 year of age with a history of prematurity and chronic respiratory disease.

Despite the potential benefits of a multidisciplinary tracheostomy program, objective outcome assessments remain limited. Hartnick et al[10] studied a group of neonates who underwent tracheostomy before and after implementation of a tracheostomy team.[14] They reduced the length of stay, estimated a potential cost savings, and showed quality-of-life improvement after implementation. Notably, these studies were limited to a small sample of children electively admitted for tracheostomy, and total costs of the hospital stays were unexplored.

McKeon et al[25] performed a prospective study of inpatient tracheostomy patients to determine if an MDT could reduce adverse events. Their program, which is similar in scope to CHAMP, was able to reduce tracheostomy-related adverse events (TRAEs). Although a specific definition for TRAE was not defined in the study, it did appear to be any event that was reported in an adverse event registry. These mostly likely included accidental decannulation or tracheostomy malfunctions like mucus plugging. That group did not examine length of stay or costs associated with tracheostomy admissions.

Petitgout[15] presented the results of a 15-year study looking at a hospital-based coordination plan and determined that care coordination significantly reduced mean length of stay and charges per patient after implementation. The results estimated a reduction of nearly $300,000 in annual charges. However, the findings were limited to examining charges that do not necessarily reflect total cost. There also was no regression analysis to test the strength of their findings.

Several studies have looked at comparable initiatives for adult tracheostomy patients. These have shown improvements in outcome metrics like length of stay, adverse events, and safe discharges with an MDT.[11,12,25-27] Although cost

Table 5. Predicted Total Standardized Costs in Dollars for Pediatric Tracheostomy Patients by Study Year and Length of Stay.[a]

Length of stay	Study year 2015	Study year 2019	Mean difference	95% CI	*P* value
30 days	457,270	254,082	−203,188	−298,701 to −107,675	<.001
90 days	488,054	383,523	−104,531	−201,750 to −7313	.04
180 days	538,160	711,241	173,081	33,231 to 312,931	.02
Mean	514,178	1,098,622	584,443	−1984 to 1,170,871	.05

[a]Based on generalized linear models of total cost, adjusting for length of stay and complex patient type.

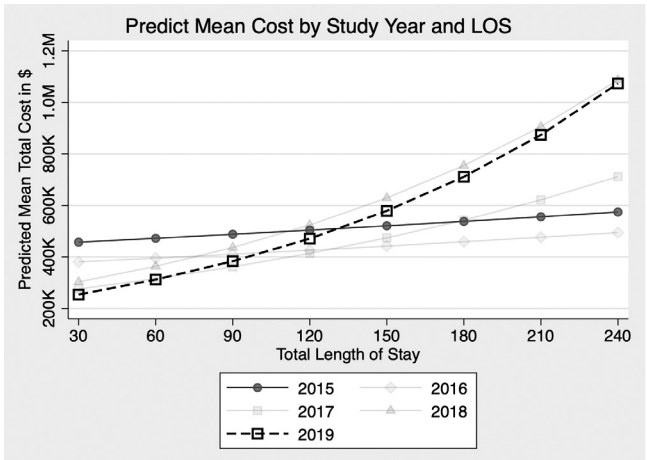

Figure 2. Predicted cost by study year and length of stay. K, thousands; LOS, length of stay; M, millions.

analyses have been limited, early tracheostomy has been shown as a potential target for cost reduction.

Consistent with other programs, CHAMP successfully implemented standard processes around placement of a tracheostomy. These steps reliably led to optimal outcomes. An increase in pretracheostomy consultations, standardized placement techniques, and regimented postoperative practices was essential to this process. Resultant metrics that CHAMP monitored included time to caregiver education, speech-language pathology consultation, speaking valve utilization, and hearing assessments.

This study included a large, diverse population of pediatric tracheostomy patients. In addition, the primary goal at onset was to reduce the total length of stay and consequently the total cost of admission. After controlling for other variables that affect the length of the stay, it appeared that a significant decrease in the total length of stay could be attained within the first full year of the program.

Total cost was strongly associated with length of stay and patient complexity (sepsis, TPN, or major cardiac surgery). The relationship between cost and length of stay was not linear and exhibited an interaction between year and LOS. That is, costs were significantly lower in 2019 for shorter stays, but the advantage was lost with longer stays. The interpretation is that CHAMP was able to get the ''average'' tracheostomy patient discharged faster after full implementation of the program, but sicker tracheostomy patients were less affected. Perhaps an increased cost of care over time due to health care cost inflation or resource utilization contributed to this finding. While other studies might exclude complex patients as outliers, these are intentionally included here since they represent the challenge of tracheostomy care. These children are often among the sickest in the hospital, resulting in very long hospital stays. This analysis reinforces the work of others that a tracheostomy team works best on elective and early tracheostomies as cost savings appeared with shorter stays.

Process improvement leads to quality improvement. CHAMP's processes focused on standardization of tracheostomy practices, including pretracheostomy consultations, time to caregiver education, speech-language pathology evaluations, and 1-way valve utilization. Other potentially impactful processes implemented that were not presented here were surgical technique standardization and developing a caregiver education rubric. The team maintains that these steps resulted in small, incremental changes that affected length of stay and total cost. For example, pretracheostomy consultations allowed the team to set expectations for families. This education prior to placement allowed families to make necessary changes in their personal lives to safely receive the child. Unnecessary discharge delays due to caregiver obstacles could therefore be mitigated. Tracheostomy team consultations may have also reduced the number of surgeries in children with little chance of meaningful recovery. Ensuring short time to first tracheostomy class helped achieve caregiver competency—one of the most important barriers to a safe discharge. The increased involvement of speech-language pathologists and audiometric assessments emphasizes a commitment to feeding and communication in this vulnerable population. One-way speaking valve trials increased during the years studied, which highlights a recognition that vocalization is a crucial aspect of this process. An active area of program investigation is determining how these devices affect dysphagia and secretion control.

Notable findings remained stable throughout the study period. Tracheostomy-related complications occurred at a steady rate of 20%. Most of these complications resulted in minimal harm (eg, skin breakdown requiring local wound care), but 2 accidental decannulations resulted in significant neurologic injury. Current program focus is on understanding these events and preventing severe harm from accidental decannulations as well as measuring decannulation per 100 tracheostomy days. The all-cause readmission rate also remained the stable. Although not presented here, it appears

that most readmissions were not tracheostomy complication related but due to other causes like gastrostomy tube dislodgement or acute respiratory failure. There may be a role for combining tracheostomy care/gastrostomy tube training to help reduce some revisits. In addition, ongoing CHAMP studies are prospectively examining predictors of frequent revisits.

CHAMP started collecting quality-of-life scores from families in 2018. The PedsQL survey scores were typically in the low to mid-60s. Estimated PedsQL scores for families with healthy children fall in the 80s. As expected, having a hospitalized child with a level of illness necessitating tracheostomy significantly reduces caregiver quality of life. The program is currently studying whether this impact remains after discharge and with longer follow-up.

This study is limited by the single-institution data gathered over a 5-year span. Therefore, the generalizability of the results to other centers may be difficult depending on the patient population. Second, there is no control group in this study but rather a baseline year of 2015. The cost of establishing an MDT was not specifically calculated and may be a limitation for institutions with insufficient funding. The statistical modeling for length of stay and total cost was performed using parametric survival analysis and generalized linear models. These models have many advantages since they can account for confounding variables, but other options are available, including simple hypothesis testing. In addition, analysis of cost is nuanced and open to interpretation and model building. Outside influences like patient complexity and institutional goals for expedited discharges may have equally resulted in longer or shorter stays independent of the MDT. Future studies should continue to characterize length of stay and cost impact with creating similar programs.

Implications for Practice

The establishment of an MDT designed to improve the care of children with a tracheostomy was able to reduce hospital length of stay and total costs among shorter stays. The airway management program was also able to implement numerous process improvements and show sustained change over several years. Creating a team that systematically manages many aspects of this complex group of pediatric patients can reduce associated costs. Institutions designing quality improvement initiatives related to pediatric tracheostomy can reflect upon the findings shown here as a rationale to create and support similar MDT programs.

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