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Association of Patient Characteristics With Postoperative Mortality in Children Undergoing Tonsillectomy in 5 US States

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IMPORTANCE The rate of postoperative death in children undergoing tonsillectomy is uncertain. Mortality rates are not separately available for children at increased risk of complications, including young children (aged <3 y) and those with sleep-disordered breathing or complex chronic conditions.

OBJECTIVE To estimate postoperative mortality following tonsillectomy in US children, both overall and in relation to recognized risk factors for complications.

DESIGN, SETTING, AND PARTICIPANTS Retrospective cohort study based on longitudinal analysis of linked records in state ambulatory surgery, inpatient, and emergency department discharge data sets distributed by the Healthcare Cost and Utilization Project for 5 states covering 2005 to 2017. Participants included 504 262 persons younger than 21 years for whom discharge records were available to link outpatient or inpatient tonsillectomy with at least 90 days of follow-up.

EXPOSURES Tonsillectomy with or without adenoidectomy.

MAIN OUTCOME AND MEASURES Postoperative death within 30 days or during a surgical stay lasting more than 30 days. Modified Poisson regression with sample weighting was used to estimate postoperative mortality per 100 000 operations, both overall and in relation to age group, sleep-disordered breathing, and complex chronic conditions.

RESULTS The 504 262 children in the cohort underwent a total of 505 182 tonsillectomies (median [IQR] patient age, 7 [4-12] years; 50.6% females), of which 10.1% were performed in young children, 28.9% in those with sleep-disordered breathing, and 2.8% in those with complex chronic conditions. There were 36 linked postoperative deaths, which occurred a median (IQR) of 4.5 (2-20.5) days after surgical admission, and most of which (19/36 [53%]) occurred after surgical discharge. The unadjusted mortality rate was 7.04 (95% CI, 4.97-9.98) deaths per 100 000 operations. In multivariable models, neither age younger than 3 years nor sleep-disordered breathing was significantly associated with mortality, but children with complex chronic conditions had significantly higher mortality (16 deaths/14 299 operations) than children without these conditions (20 deaths/490 883 operations) (117.22 vs 3.87 deaths per 100 000 operations; adjusted rate difference, 113.55 [95% CI, 51.45-175.64] deaths per 100 000 operations; adjusted rate ratio, 29.39 [95% CI, 13.37-64.62]). Children with complex chronic conditions accounted for 2.8% of tonsillectomies but 44% of postoperative deaths. Most deaths associated with complex chronic conditions occurred in children with neurologic/neuromuscular or congenital/genetic disorders.

CONCLUSIONS AND RELEVANCE Among children undergoing tonsillectomy, the rate of postoperative death was 7 per 100 000 operations overall and 117 per 100 000 operations among children with complex chronic conditions. These findings may inform decision-making for pediatric tonsillectomy.

Editorial page 2292

Supplemental content

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Although pediatric tonsillectomies in the US accounted for more than 500 000 outpatient procedures in 2006[1] and the bulk of 377 000 outpatient tonsil and adenoid procedures in hospital-owned facilities alone in 2019,[2] information about associated mortality is sparse. The underlying postoperative mortality rate is uncertain and has been estimated to be between 1 and 10 deaths per 100 000 operations.[3-5] Population-based mortality rates are not separately available for subgroups of patients undergoing tonsillectomy with recognized risk factors for complications, such as young age (<3 years),[6,7] sleep-disordered breathing,[6,8] and chronic comorbid conditions[7] (including various neurological disorders,[9] cerebral palsy,[10] and Down syndrome[11]).

Although recent studies have evaluated postoperative mortality in large, nonselect cohorts of patients undergoing tonsillectomy,[4,5] the statistical stability of reported mortality rates is severely limited by small numbers of ascertained deaths. Additional information about tonsillectomy-associated deaths is available from studies of select patient populations,[9,12] clinician surveys,[8,13] and malpractice claims.[14] Although this information is not well suited for estimating mortality rates in the general population, it does suggest that children with obstructive sleep apnea[8] or neurological comorbidities[9,13] are at increased risk of postoperative mortality. Current clinical practice guidelines describe recurrent throat infections and obstructive sleep-disordered breathing as the leading indications for tonsillectomy in children and review evidence for corresponding surgical benefits (including a transient reduction in sore throats in select patients and short-term improvements in certain behavioral and sleep outcomes).[15] These guidelines also make specific recommendations for the preoperative evaluation and postoperative care of children at increased risk of complications.

In this retrospective cohort study, discharge data from 5 states were used to evaluate postoperative mortality rates in children undergoing tonsillectomy, both overall and in relation to recognized risk factors for complications.

Key Points

Question How common are postoperative deaths in children undergoing tonsillectomy, and what patient characteristics are associated with these deaths?

Findings In a retrospective cohort study of 504 262 children undergoing tonsillectomy, the rate of postoperative death was 7 per 100 000 operations overall. Among children with complex chronic conditions, the rate of postoperative death was 117 per 100 000 operations, representing 44% of overall deaths.

Meaning The study findings may inform decision-making for pediatric tonsillectomy.

Methods

Data Sources

The University of Wisconsin Health Sciences institutional review board waived review of this study. Study data were extracted from ambulatory surgery,[16] hospital inpatient,[17] and emergency department[18] discharge databases distributed by the Healthcare Cost and Utilization Project (HCUP), Agency for Healthcare Research and Quality, for the following states (and data years): California (2005-2011), Florida (2005-2017), Maryland (2013-2017), New York (2004-2016), and Wisconsin (2013-2017). Selection of study states and data years was based on 3 pragmatic considerations: availability of inpatient and outpatient discharge data sets, with which preoperative, surgical, and postoperative encounters could be linked at the person level; data acquisition costs; and a prespecified objective of assembling outcome data on at least 500 000 pediatric patients undergoing tonsillectomy (approximately equivalent to the number of US children who undergo tonsillectomy in a given year[1]). Based on an assumption that the underlying mortality rate is in the range of 5 to 10 deaths per 100 000 operations,[3,4] we expected to obtain information on 25 to 50 postoperative deaths.

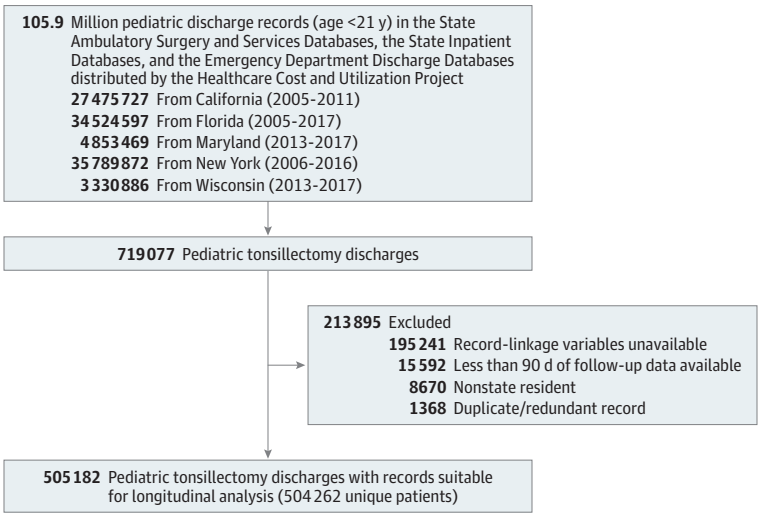
Definitions

Tonsillectomy was defined by procedure codes indicating surgical removal of the palatine tonsils, regardless of whether the tonsillar capsule or the adenoids were removed (eTable 1 in the Supplement). An *index tonsillectomy* (or *index stay* or *index surgery*) was defined as an outpatient or inpatient encounter associated with tonsillectomy. *Surgical facility* was defined by type of facility (inpatient or outpatient) that generated a discharge record indicating tonsillectomy. Inpatient discharge records associated with tonsillectomy were not interpreted to mean that an operation actually occurred in the inpatient setting, given the common practice of directly (and selectively) converting ambulatory surgery admissions to inpatient observational stays.[1,19] A surgical indication of *sleep-disordered breathing* was defined by adapting a validated set of *International Classification of Diseases, Ninth Revision* codes[20] and their approximate *International Classification of Diseases, Tenth Revision* equivalents. *Complex chronic conditions* were identified by diagnosis and procedure codes and subclassified into 12 domains indicating a chronic multisystem disorder or a single-system disorder severe enough to require specialty pediatric care and likely hospitalization in a tertiary care center.[21]

Study Cohort

The selection process for the study cohort is summarized in **Figure 1.** Inclusion criteria were outpatient or inpatient discharge record indicating tonsillectomy and age younger than 21 years at surgical admission. Exclusion criteria were encrypted record-linkage identifier missing in the discharge record, discharge during the last calendar quarter of the last available data year, out-of-state resident, or duplicate or redundant discharge record (eg, cancelled operation or follow-up encounter). Tonsillectomy discharges were linked at the state and person level to preoperative and postoperative discharges using encrypted record linkage and anonymized time-to-event variables supplied by HCUP. Information about race and ethnicity was included because of reported associations between these factors, certain comorbidities (obesity, asthma), and tonsillectomy complications. This information is subject to state-by-state differences in how data were gathered and reported

Figure 1. Selection of Study Cohort in a Study of the Association of Patient Characteristics With Postoperative Mortality in Children Undergoing Tonsillectomy



The subtotal of excluded discharge records is greater than the total number of records because some records met multiple exclusion criteria.

to HCUP. To evaluate temporal trends in mortality, the study period was divided into 2 surgical eras (2005-2010 and 2011-2017). Information about surgical indication and overlapping surgical procedures was obtained by reviewing diagnosis and procedure codes recorded at index stays.

For the purpose of calculating time intervals between encounters, admission day was derived by subtracting length of stay from discharge day. Day of operation was treated as day of surgical admission, either by definition (for direct ambulatory surgery discharges) or by default (for inpatient surgery encounters). As a result, the calculated interval from day of surgical admission to death may, in some cases, have overestimated the interval from the operation itself to death. Information about discharge disposition was commonly missing in records from freestanding surgical facilities and was imputed to be routine (nonfatal) based on assumptions that on-site deaths without transfer are very rare at ambulatory surgery facilities[1] and that any related deaths would be ascertained in linked emergency department and inpatient records.

Outcomes and Measures

The primary outcome was postoperative mortality, which was defined as any death within 30 days of surgical admission or during a prolonged index surgical stay lasting more than 30 days and was measured as deaths per 100 000 operations. This outcome measure was selected to capture information about any late (in-hospital) deaths in children with tonsillectomy-associated anoxic brain injury[11,13] and to address more general concerns about the appropriateness of short-term surgical mortality measures for patients with serious comorbidity.[22,23]

Statistical Analysis

The study cohort included a small number of children who underwent repeat tonsillectomy procedures; accordingly, the unit of analysis was tonsillectomy (not child). We used simple imputation to set length of stay at 0 days for all discharges from ambulatory surgery centers for 2 reasons: length-of-stay data are frequently missing in HCUP ambulatory surgery databases because of state- and year-specific differences in reporting and because reported (nonmissing) length of stay was 0 in 100% of discharge records from freestanding surgery centers and in more than 99% of discharge records from hospital-owned centers. Tabular information about tonsillectomies was displayed using raw numbers in the sample; corresponding percentages, rates, and risk measures were sample-weighted. Inverse probability sample weights were derived from state-specific logistic regression models with the following covariates: age group (5 levels), race and ethnicity, primary payer, type of surgical facility, type of tonsillectomy procedure (with or without adenoidectomy), and year. Raw counts of less than or equal to 10 observations were suppressed in the text and tables, in accordance with HCUP requirements. Weighted mortality rates and risk measures were estimated with modified Poisson regression models using generalized estimating equations to adjust for any model misspecification and for patient-level clustering.[24] Preliminary analysis confirmed that conditional mortality means and variances were approximately equal, that observed and Poisson-predicted counts (deaths) were similar, and that the counts were not overdispersed (based on a comparison of results from a negative binomial model). Cumulative residuals were formally assessed to confirm model fit.[25] Based on power considerations, we limited covariates in multivariable models to the primary (prespecified) exposures of interest: age group (5 levels), sleep-disordered breathing, and complex chronic conditions (2 levels). Follow-up time was imputed to be the difference (in days) between the mid-point of the calendar quarter in which tonsillectomy occurred and the mid-point of the last quarter of the last year for which state discharge data were available. Cumulative incidence of postoperative mortality in children with and without complex chronic conditions was compared using a model that treated postdischarge deaths beyond 30 days

as competing events. All analyses were carried out with SAS, version 9.4 (SAS Institute). Reported *P* values were based on 2-sided tests, with $P < .05$ considered to be statistically significant.

Sensitivity Analysis

We carried out a preplanned analysis to compare the primary outcome measure with a set of alternative measures defined by length of follow-up (7, 30, and 90 days) and whether late (in-hospital) deaths were also included. For each measure, we calculated the following: total deaths, mortality rate, percentage of total deaths that were associated with complex chronic conditions, and agreement (sensitivity, specificity, and area under the curve) with a consensus-based criterion standard on whether death was tonsillectomy-related. The reference standard was developed in 2 steps. First, 2 raters (M.B.E. and D.O.F.) independently reviewed key information (length of stay, time intervals between encounters, diagnosis and procedure codes, discharge status) in all discharge records for decedents, classified cases on a 3-point scale indicating the likelihood (likely, uncertain, unlikely) that death was tonsillectomy-related, and resolved differences by consensus. Second, the same raters independently reevaluated cases in which death had been classified as being of "uncertain" relationship to tonsillectomy, carried out a ("forced") reclassification of these cases to a 2-point scale (likely, unlikely), and resolved differences by consensus.

Results

Characteristics of the Study Cohort

A total of 719 077 inpatient and outpatient pediatric tonsillectomy discharges were identified in discharge records from 5 states; 505 182 of these discharges (in 504 262 unique individuals) met selection criteria for the study cohort (Figure 1). Information on length of stay was missing (and imputed to be "0") in 11.6% of records from hospital-owned ambulatory surgery centers and in 32.9% of records from freestanding centers. Median (IQR) follow-up time was 1963 (1050-3059) days; by design, at least 90 days of follow-up data were available for all cases. **Table 1** summarizes key characteristics of the study cohort. Median (IQR) age at surgical admission was 7 (4-12) years; 10.1% of tonsillectomies were performed in children younger than 3 years. Surgical discharge records specifically indicated sleep-disordered breathing in 28.9% of cases. Most tonsillectomies were conducted in ostensibly healthy children, but 2.8% of surgical discharge records indicated a complex chronic condition. Most tonsillectomies (95.4%) were associated with direct discharge from an outpatient surgical facility. Direct outpatient discharge was less common in the following subgroups: those younger than 3 years (37 031/44 957 [82.4%]), with sleep-disordered breathing (126 344/143 699 [87.9%]), with complex chronic conditions (9174/14 299 [64.2%]), and patients with all 3 characteristics (666/1766 [37.7%]).

Cases With a Fatal Outcome

A total of 36 deaths met criteria for the primary outcome of death within 30 days of surgical admission or during an index surgical stay lasting more than 30 days. Decedents had a

Table 1. Characteristics of the Study Cohort in a Study of Children Undergoing Tonsillectomy

Characteristic	No. (%)[a] Tonsillectomy discharges (n = 505 182[b])
Data source	
California (2005-2011)[c]	87 291 (24.0)
Florida (2005-2017)	173 324 (37.4)
Maryland (2013-2017)[c]	12 447 (1.9)
New York (2004-2016)	192 622 (30.7)
Wisconsin (2013-2017)	39 498 (6.0)
Surgical era	
2005-2010	267 451 (53.6)
2011-2017	237 731 (46.4)
Surgical facility	
Ambulatory	480 788 (95.4)
Hospital inpatient[d]	243 94 (4.6)
Surgical type	
With adenoidectomy	413 456 (83.0)
Without adenoidectomy	91 726 (17.0)
Age group, y	
<3	44 957 (10.1)
3-4	101 809 (20.1)
5-9	198 833 (39.7)
10-14	69 371 (13.9)
15-20	90 212 (16.3)
Sex	
Female	250 088/489 338 (50.6)
Male	239 250/489 338 (49.4)
Race and ethnicity[e]	
Black	49 473 (8.9)
Hispanic	88 312 (19.0)
White	28 4182 (53.2)
Other[f]	83215 (18.9)
Surgical indication	
Sleep-disordered breathing only	112 371 (22.8)
Infection only	187 980 (36.5)
Sleep-disordered breathing and infection	31 328 (6.1)
Neither sleep-disordered breathing nor infection[g]	173 503 (34.6)
Total complex chronic conditions	
0	490 883 (97.2)
1	11 883 (2.3)
2	1782 (0.4)
≥3	634 (0.1)
Complex chronic conditions	
No condition	490 883 (97.2)
Other congenital/genetic defect	5009 (1.0)
Hematologic/immunologic	2559 (0.5)
Neurologic/neuromuscular	2152 (0.4)

(continued)

Table 1. Characteristics of the Study Cohort in a Study of Children Undergoing Tonsillectomy (continued)

Characteristic	No. (%)[a] Tonsillectomy discharges (n = 505 182[b])
Cardiovascular	2078 (0.4)
Technology dependence	2023 (0.4)
Gastrointestinal	1661 (0.3)
Respiratory	1629 (0.3)
Metabolic	1195 (0.2)
Renal	571 (0.1)
Malignancy	462 (0.1)
Transplant	345 (0.1)
Neonatal	216 (0.0)

[a] Percentages are sample-weighted. Totals may not equal 100% because of rounding. Subtotal for complex chronic conditions is greater than 100% because some patients had multiple conditions.

[b] The study cohort consisted of 504 262 unique patients, including those who underwent more than 1 tonsillectomy procedure. The unit of analysis was tonsillectomies (n = 505 182).

[c] Discharges from freestanding ambulatory surgery centers were incompletely reported in California data sets and unavailable in Maryland data sets.

[d] Includes ambulatory surgery encounters directly converted into inpatient stays.

[e] Categories were based on uniform coding in discharge data sets distributed by the Healthcare and Cost Utilization Project.

[f] Category includes Asian or Pacific Islander, Native American, other/multiple races, and unknown/missing.

[g] Includes 170 964 discharge records for which diagnosis codes indicated tonsillar and/or adenoidal hypertrophy without a specific code indicating sleep-disordered breathing or infection.

median (IQR) age of 8.5 (3.5-15) years. The number of decedents younger than 3 years was less than or equal to 10 (exact number suppressed). The most commonly listed surgical indication for decedents was sleep-disordered breathing (n = 13). Most decedents (32 of 36 [88%]) underwent tonsillectomy as the sole procedure or in association only with a low-risk (usually otologic) procedure. The median (IQR) interval from surgical admission to death was 4.5 (2-20.5) days (range, 0-307 days). Nineteen deaths (53%) were associated with an emergency department or inpatient readmission; these terminal readmissions typically occurred soon after surgical discharge (median [IQR] interval, 4 [1-8] days) and were typically associated with prompt death (median [IQR] length of stay, 1 [0-2] days). Most deaths (28 of 36 [78%]) were associated with a diagnosis code indicating a life-threatening respiratory problem (eg, respiratory failure, pulmonary edema, pneumonia, aspiration) or otherwise unexplained cardiac arrest. Very few deaths (exact number suppressed) were associated with a diagnosis or procedure code indicating bleeding. Sixteen postoperative deaths (44%) occurred in children who had at least 1 complex chronic condition. Children with a neurologic/neuromuscular or congenital/genetic disorder accounted for 12 of 16 deaths (75%) associated with complex chronic conditions. The median (IQR) interval from surgical admission to death was significantly longer in children with a complex chronic condition than in those without one of these conditions (19.5 [3.5-55.5] days vs 3 [1.5-8] days; Kruskal-Wallis test $P = .006$).

Mortality Rates and Rate Ratios

The overall unadjusted (sample-weighted) 30-day plus in-hospital mortality rate was 7.04 (95% CI, 4.97-9.98) deaths per 100 000 operations. In bivariable comparisons (**Table 2**), mortality was significantly higher in children younger than 3 years (and in those aged 15-20 years) and in children with complex chronic conditions, but not in those with sleep-disordered breathing. Mortality rates increased stepwise in relation to the number of complex chronic conditions, reaching 1010.50 (95% CI, 476.71-2141.99) deaths per 100 000 operations in children with 3 or more conditions. There was no significant change in mortality across surgical eras. In a multivariable Poisson model (for which a test of cumulative residuals indicated excellent fit; $P = .92$), results showed that mortality was not significantly associated with young age or sleep-disordered breathing, but was significantly higher in children with complex chronic conditions than in those without these conditions (117.2 vs 3.9 deaths per 100 000 operations; adjusted rate difference, 113.55 [95% CI, 51.45-175.64] deaths per 100 000 operations; adjusted mortality rate ratio, 29.4 [95% CI, 13.4-64.6]) (**Table 3**). The cumulative incidence of postoperative mortality was significantly higher in children with complex chronic conditions (Grey test $P < .001$) (**Figure 2**).

Sensitivity Analyses

The primary outcome measure and the alternative 30- and 90-day mortality measures closely agreed with the consensus-based criterion standard that death was tonsillectomy-related (area under the curve range, 0.85-0.91) (eTable 2 in the Supplement). Regardless of mortality measure, the percentage of deaths associated with complex chronic conditions was high (range, 31.0%-47.5%) (eTable 3 in the Supplement).

Discussion

Among children undergoing tonsillectomy, the rate of postoperative death was 7 per 100 000 operations overall and 117 per 100 000 operations among children with complex chronic conditions. These mortality estimates were based on information about more deaths in a larger cohort than previous population-based studies of postoperative mortality in large, nonselect cohorts of patients undergoing tonsillectomy.[4,5,26-28] This made it possible to quantify postoperative mortality with greater precision than was possible in recent studies from Taiwan,[26] Sweden,[4] and Canada.[5] The overall mortality rate in the study cohort appears to be higher than the aggregated rate of 2.7 deaths per 100 000 individuals for the 10 most common pediatric surgeries in Ontario, Canada, during 2002 to 2013.[5] To our knowledge, this is the first study to quantify postoperative mortality in relation to complex chronic conditions in a general population of children undergoing tonsillectomy. Study findings were consistent with previous observations about deaths following tonsillectomy in children with a variety of comorbidities and, in particular, chronic neurologi-

Table 2. Unadjusted Postoperative Mortality Rates and Risk Measures in a Study of Children Undergoing Tonsillectomy

Characteristic	No.		Postoperative deaths per 100 000 operations (95% CI)		
	Deaths	Operations	Rate[a]	Absolute rate difference[a]	Rate ratio[a]
All tonsillectomies	36	505 182	7.04 (4.97 to 9.98)		
Surgical era					
2005-2010	21	267 451	7.02 (4.53 to 10.88)	Reference	1 [Reference]
2011-2017	15	237 731	7.08 (4.07 to 12.31)	−0.05 (−5.15 to 5.06)	1.01 (0.50 to 2.04)
Age group, y					
<3	≤10[b]	44 957	14.06 (6.43 to 30.75)	10.89 (−0.95 to 22.73)	3.46 (1.24 to 9.67)
3-4	≤10[b]	101 809	7.07 (2.69 to 18.63)	3.24 (−4.13 to 10.60)	1.74 (0.54 to 5.64)
5-9	≤10[b]	198 833	4.06 (2.09 to 7.88)	Reference	1 [Reference]
10-14	≤10[b]	69 371	5.14 (1.91 to 13.79)	1.51 (−4.42 to 7.45)	1.27 (0.38 to 4.16)
15-20	11	90 212	11.58 (6.38 to 21.04)	8.27 (0.56 to 15.99)	2.85 (1.17 to 6.97)
Sex[c]					
Female	21	250 088	8.10 (5.15 to 12.72)	1.88 (−3.20 to 6.95)	1.30 (0.63 to 2.68)
Male	14	239 250	6.22 (3.54 to 10.94)	Reference	1 [Reference]
Race and ethnicity[d]					
Black	≤10[b]	49 473	15.08 (7.51 to 30.24)	7.54 (−3.51 to 18.58)	1.99 (0.86 to 4.59)
Hispanic	≤10[b]	88 312	5.06 (1.70 to 15.03)	−2.48 (−8.15 to 4.02)	0.67 (0.20 to 2.18)
White	21	284 182	7.54 (4.77 to 11.91)	Reference	1 [Reference]
Other[e]	≤10[b]	83 215	3.80 (1.20 to 12.00)	−3.90 (−10.15 to 2.24)	0.50 (0.14 to 1.73)
Sleep-disordered breathing					
Yes	13	143 699	10.14 (5.62 to 18.31)	3.73 (−2.85 to 10.31)	1.75 (0.85 to 3.63)
No	23	361 483	5.78 (3.79 to 8.82)	Reference	1 [Reference]
Any complex chronic condition					
Yes	16	14 299	117.22 (69.12 to 198.80)	114.64 (52.02 to 177.25)	30.32 (15.03 to 61.13)
No	20	490 883	3.87 (2.44 to 6.13)	Reference	1 [Reference]
Total complex chronic conditions					
0	20	490 883	3.87 (2.44 to 6.13)	Reference	1 [Reference]
1	≤10[b]	11 883	40.95 (16.13 to 103.92)	37.63 (−1.03 to 76.30)	10.59 (3.75 to 29.94)
2	≤10[b]	1782	294.98 (100.38 to 866.77)	291.46 (−26.84 to 609.76)	76.28 (23.62 to 246.39)
≥3	≤10[b]	634	1010.50 (476.71 to 2141.99)	1006.66 (247.48 to 1765.84)	261.33 (108.22 to 631.05)

[a] Rates, differences, and ratios are sample-weighted. The unit of analysis was tonsillectomies.

[b] Data are suppressed for cells with ≤10 observations, in accordance with Healthcare and Cost Utilization Project data use agreement.

[c] Information on sex missing for 15 844 tonsillectomy discharges.

[d] Categories based on uniform coding in discharge data sets distributed by the Healthcare and Cost Utilization Project.

[e] Category includes Asian or Pacific Islander, Native American, other/multiple races, and unknown/missing.

cal conditions.[9,11,13] Study findings were also consistent with previous observations about posttonsillectomy deaths related to sudden out-of-hospital events[8,13] and life-threatening respiratory compromise.[8,13,14] Although age younger than 3 years and severe obstructive sleep apnea are each considered to be risk factors for tonsillectomy complications[6,29] and to be indications for routine, overnight, posttonsillectomy observation,[15] there were no statistically significant, multivariable associations between these factors and postoperative mortality. However, the absolute number of deaths in the youngest age group was small, and it remains uncertain whether young age is an independent risk factor for postoperative death after tonsillectomy.

One potential application of study findings is to enhance risk communication about pediatric tonsillectomy[30] and to counteract a general tendency to overconfidently interpret sparse data

Table 3. Multivariable Analysis of Postoperative Mortality in a Study of Children Undergoing Tonsillectomy

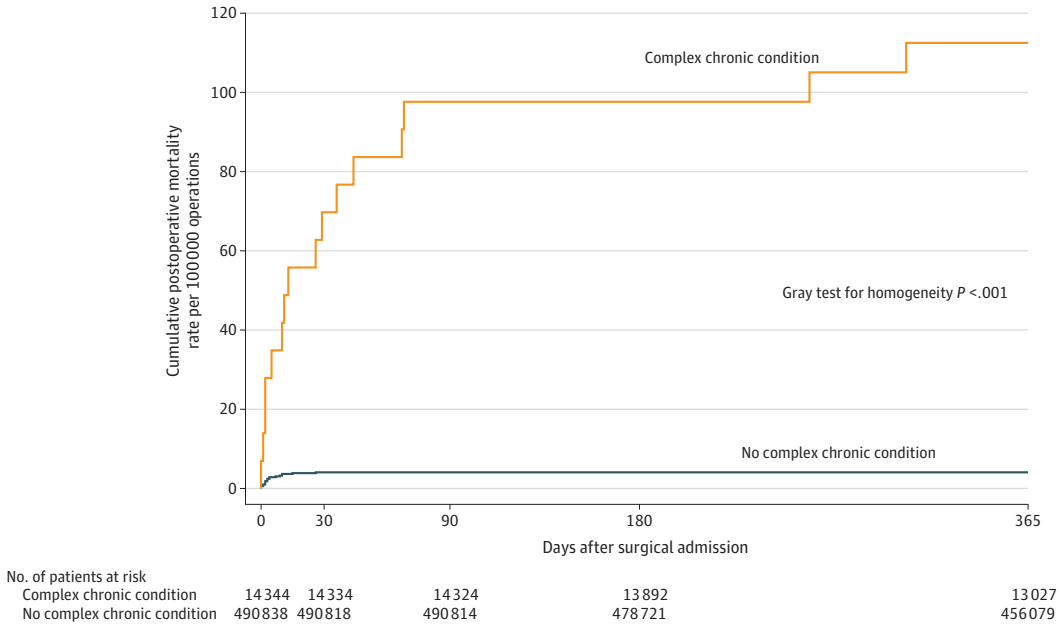
Characteristic	No.		Postoperative deaths per 100 000 operations (95% CI)			
	Deaths (n = 36)	Operations (n = 505 182)	Rate[a]	Adjusted absolute rate difference[b]	Rate ratio[a]	
					Unadjusted	Adjusted[b]
Age group, y						
<3	≤10[c]	44 957	14.06 (6.43 to 30.75)	−0.19 (−4.28 to 3.90)	3.46 (1.24 to 9.67)	2.30 (0.80 to 6.62)
3-4	≤10[c]	101 809	7.07 (2.69 to 18.63)	1.97 (−2.91 to 6.86)	1.74 (0.54 to 5.64)	1.49 (0.46 to 4.81)
5-9	≤10[c]	198 833	4.06 (2.09 to 7.88)	Reference	1 [Reference]	1 [Reference]
10-14	≤10[c]	69 371	5.14 (1.91 to 13.79)	1.91 (−3.22 to 7.04)	1.27 (0.38 to 4.16)	1.16 (0.35 to 3.85)
15-20	11	90 212	11.58 (6.38 to 21.04)	5.97 (−0.28 to 12.23)	2.85 (1.17 to 6.97)	3.12 (1.24 to 7.87)
Sleep-disordered breathing						
Yes	13	143 699	10.14 (5.62 to 18.31)	1.06 (−2.6 to 4.72)	1.75 (0.85 to 3.63)	1.06 (0.43 to 2.62)
No	23	361 483	5.78 (3.79 to 8.82)	Reference	1 [Reference]	1 [Reference]
Complex chronic condition						
Yes	16	14 344	117.22 (69.12 to 198.80)	113.55 (51.45 to 175.64)	30.32 (15.03 to 61.13)	29.39 (13.37 to 64.62)
No	20	490 883	3.87 (2.44 to 6.13)	Reference	1 [Reference]	1 [Reference]

[a] Rates, difference, and ratios are sample-weighted. The unit of analysis was tonsillectomies.

[b] Estimates are adjusted for all other displayed covariates.

[c] Data are suppressed for cells with ≤10 observations, in accordance with Healthcare and Cost Utilization Project data use agreement.

Figure 2. Cumulative Postoperative Mortality in Relation to Complex Chronic Conditions in Children Undergoing Tonsillectomy



Comparison of cumulative incidence functions based on a competing-risk analysis, in which the primary study outcome (death within 30 days or during an extended surgical stay) was the event of interest and any other death was treated as a competing event.

about the frequency of rare adverse events.[31,32] Study results make it possible to describe postoperative mortality following tonsillectomy in children without complex chronic conditions as rare and, at the same time, to indicate that this risk is quantifiably nonzero. For children with complex chronic conditions, the risk is much higher and may be higher still in those with multiple complex chronic conditions. This higher risk needs to be considered in light of high-quality evidence for improvements in behavior and sleep after tonsillectomy in children with obstructive sleep apnea.[33,34] However, in some high-risk children, it may be particularly difficult to achieve these benefits.[10,35] Study findings also suggest that the traditional measure of surgical mortality, death within 30 days, may not be an ideal measure for pediatric tonsillectomy. Consistent with studies of surgical mortality rates in medically fragile adults[22,23] and observations about delayed deaths in children with tonsillectomy-related neurologic injury,[8,13] it may be better to use an episode of care measure that captures deaths over a longer fol-

low-up period (eg, 90 days) or, at least, includes late deaths in continuously hospitalized patients. Future research is needed to explore whether the observed association between complex chronic conditions and postoperative mortality is specific to tonsillectomy or might also apply to other common pediatric operations (eg, myringotomy with tube insertion, hernia repair, operative circumcision).

Limitations

This study has several limitations. First, the small absolute number of ascertained deaths precluded a statistical analysis of potential interactions between the covariates of primary interest on mortality risk. Second, reverse-causality bias could have arisen if identified complex chronic conditions represented disorders that developed only in the wake of surgical complications. However, based on case-by-case review of fatal cases almost all identified complex chronic conditions represented congenital or perinatal conditions (eg, cerebral palsy, Down syndrome, congenital heart disease) or conditions recorded during presurgical or (uncomplicated) ambulatory surgery encounters. Third, administrative data provided no information about the severity of sleep-disordered breathing, which precluded evaluation of any possible association of severity with mortality. Fourth, administrative data were insufficient to fully assess surgical indication or cause(s) of death; in some cases, the relative contributions of preexisting comorbidity, surgical indication, and surgical complications were unclear. Fifth, reported postoperative mortality rates were based entirely on administrative data that would not have included information on any out-of-hospital deaths (eg, in children found dead in bed) not associated with transport to an emergency department. Sixth, this study was limited to tonsillectomies performed before 2018, although there was no evidence that mortality rates were increasing or decreasing during the study period.

Conclusions

Among children undergoing tonsillectomy, the rate of postoperative death was 7 per 100 000 operations overall and 117 per 100 000 operations among children with complex chronic conditions. These findings may inform decision-making for pediatric tonsillectomy.

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Acquisition, analysis, or interpretation of data: All authors.
Drafting of the manuscript: Edmonson, Francis, Coller.
Critical revision of the manuscript for important intellectual content: All authors.
Statistical analysis: Edmonson, Zhao, Francis, Kelly.
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