A Study of Practice Behavior for Endotracheal Intubation Site for Children With Congenital Heart Disease Undergoing Surgery: Impact of Endotracheal Intubation Site on Perioperative Outcomes—An Analysis of the Society of Thoracic Surgeons Congenital Cardiac Anesthesia Society Database

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BACKGROUND: In adults undergoing cardiopulmonary bypass surgery, oral intubation is typically preferred over nasal intubation due to reduced risk of sinusitis and infection. In children, nasal intubation is more common and sometimes preferred due to perceived benefits of less postoperative sedation and a lower risk for accidental extubation. This study sought to describe the practice of nasal intubation in the pediatric population undergoing cardiopulmonary bypass surgery and assess the risks/benefits of a nasal route against an oral one.

METHODS: Patients <18 years of age in the Society of Thoracic Surgeons Congenital Heart Surgery Database between January 2010 and December 2015 were included. Patients with a preoperative endotracheal tube, tracheostomy, or known airway anomalies were excluded. Multivariable modeling was used to assess the association between route of tracheal intubation and a composite measure of infection risk (wound infection, mediastinitis, septicemia, pneumonia, and endocarditis). Covariates were included to adjust for important patient characteristics (eg, weight, age, comorbidities), case complexity, and center effects. Secondary outcomes included length of intubation, hospital length of stay, and airway complications including accidental extubations. We also performed a subanalysis in children <12 months of age in high-volume centers (>100 cases/y) examining how infection risk may change with age at the time of surgery.

RESULTS: Nasal intubation was used in 41% of operations in neonates, 38% in infants, 15% in school-aged children, and 2% in adolescents. Nasal intubation appeared protective for accidental extubation only in neonates (P = .02). Multivariable analysis in infants and neonates showed that the nasal route of intubation was not associated with the infection composite (relative risk [RR], 0.84; 95% CI, 0.59–1.18) or a shorter length of stay (RR, 0.992; 95% CI, 0.947–1.039), but was associated with a shorter intubation length (RR, 0.929; 95% CI, 0.869–0.992). Restricting to high-volume centers showed a significant interaction between age and intubation route with a risk change for infection occurring between approximately 6–12 months of age (P = .003).

CONCLUSIONS: While older children undergoing nasal intubation trend similar to the adult population with an increased risk of infection, nasal intubation in neonates and infants does not appear to carry a similar risk. Nasal intubation in neonates and infants may also be associated with a shorter intubation length but not a shorter length of stay. Prospective studies are required to better understand these complex associations. (Anesth Analg XXX;XXX:00–00)

KEY POINTS

- **Question:** In children with congenital heart disease undergoing cardiopulmonary bypass surgery, how often are they being nasally intubated and is this route of intubation associated with any outcome difference when compared to an oral one?
- **Findings:** While not used the majority of the time in any age group, the nasal (as opposed to oral) route of intubation was most often used in neonates and infants, for whom there may be an increased postoperative infection risk after 12 months of age.
- **Meaning:** A nasal (as opposed to oral) route of intubation may lead to decreased intubation length in neonates and infants undergoing cardiopulmonary bypass surgery and also may be associated with postoperative infection in all patients after the first year of life.

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Children undergoing surgery for congenital heart disease require endotracheal intubation. Many factors may influence the choice between oral intubation and nasal intubation.

The practice of oral versus nasal intubation seems to be institutionally based as practice varies widely based on perceived risks and benefits. Nasal intubation is thought to offer less likelihood of dislodgment intraoperatively during transesophageal echocardiography probe placement and manipulation, as well as more comfort postoperatively before extubation. Nasal intubation, however, carries an increased risk of epistaxis associated with traumatic intubation, particularly after systemic heparinization. It is also technically slightly more difficult, and it may be associated with nasal skin breakdown and pressure ischemia during hypothermia and low-flow states. There is additional concern that nasotracheal intubation may be associated with increased risk of sinusitis secondary to obstruction of the normal drainage of the maxillary sinuses.[1,2] Presence of particular pathogens in the nasal cavity also has been shown to be associated with surgical site infection in patients undergoing cardiac surgery.[3] However, oral intubation may potentially be associated with oral aversion in neonates intubated for prolonged periods, as well as oral and lingual injury.

We conducted a retrospective cohort study using data from the Society of Thoracic Surgeons Congenital Heart Surgery Database (STS-CHS) and the associated Congenital Cardiac Anesthesia Society (CCAS) module (STS-CCAS) to evaluate current patterns of airway management for pediatric patients undergoing cardiopulmonary bypass (CPB). We also explored potential associations between the route of intubation and the occurrence of infection (as well as how the presence of an endotracheal tube cuff may modify this association), the risk of accidental extubation, oral/nasal injury, postoperative intubation length, and postoperative length of hospital stay.

METHODS

Data Source

The STS-CHS Database with anesthesia elements (STS-CCAS) was used for this study. The Congenital Heart Surgery Database (STS-CHSD) includes data on >390,000 surgeries conducted at 133 centers in North America. The database currently collects data from approximately 96% of all US centers performing CHS, including approximately 98% of all operations.[4] Fifty-four centers participate in the CCAS component of this database and submit additional data directly related to the anesthetic administered during pediatric and CHS, including information related to airway management and complications. Preoperative, operative, and outcomes data are collected on all patients undergoing pediatric and CHS at participating centers. Coding for this database is accomplished by clinicians and ancillary support staff using the International Pediatric and Congenital Cardiac Code and is entered into the contemporary version of the STS-CCAS data collection form.[5] The Duke Clinical Research Institute serves as the data warehouse and analysis center for all of the STS National Databases. Evaluation of data quality includes the intrinsic verification of data, along with a formal process of in-person site visits and data audits conducted by a panel of independent data quality personnel and pediatric cardiac surgeons at approximately 10% of participating institutions each year.[4,6,7] This study was approved by the STS-CHSD Access and Publications Committee and the Duke University Institutional Review Board and was not considered human subjects research by the Duke University Institutional Review Boards in accordance with the Common Rule (45 CFR 46.102(f)).

Study Population

All cardiovascular operations performed with CPB in patients <18 years of age and included in the STS-CCAS from January 2010 to December 2015 were potentially eligible for inclusion (n = 36,919 procedures from 53 centers). We excluded cases in patients <2.5 kg undergoing isolated surgical closure of patent ductus arteriosus (n = 3), patients with preexisting tracheostomy or endotracheal tube or children with other known airway anomalies (n = 4931), procedures from centers with 10% or more missingness on outcomes in a given harvest (n = 4968), procedures missing key covariate or outcome information (n = 213), or procedures with data points that were extreme outliers for intubation length (>10 standard deviations from mean) and postoperative length of stay (>365 days; n = 43), or not possible (postoperative length of intubation longer than postoperative length of stay; n = 34). We did not exclude patients if they underwent >1 procedure in the time period. The final study population included 26,754 procedures representing 24,631 patients in 50 centers representing 144 surgeons.

Data Collection and Definitions

Data collection included demographic information, baseline characteristics, preoperative risk factors as defined in the STS-CHS Database, operative variables, and outcomes data. All data collected from the database came from discrete predefined values rather than searching through any open text entry data. Age groups were defined as neonates (0–30 days), infants (1–12 months), toddlers (1–3 years), school aged (4–11 years), and adolescents (12–17 years). Center characteristics were also collected including average annualized CPB case volume. Center case volumes were calculated using only index CPB or non-CPB operations classifiable by the Society of Thoracic Surgeons-European Association for Cardio-Thoracic Surgery—also referred to as STAT (STS-EACTS) mortality categories, which offers a classification of every congenital heart disease surgery into 1 of 5 categories based on mortality risk.[8]

Outcomes

We examined the occurrence of a composite infection outcome (deep sternal wound infection, mediastinitis,

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pneumonia, sepsis, or endocarditis) and secondary outcomes of hospital length of stay, duration of postoperative intubation, and other perioperative airway complications found in a combination of the surgical and anesthesia adverse events lists in the STS-CCAS database.

Analytic Approach

We first examined associations with our outcomes of interest by performing unadjusted analyses of the overall cohort according to route of endotracheal tube using Wilcoxon Mann-Whitney tests and χ^2 tests for continuous and categorical data, respectively. We also repeated this analysis in separate cohorts stratified by age groups (neonates, infants, toddlers, school aged, and adolescents). Given trends observed in unadjusted analyses, we then performed a targeted adjusted analysis in neonates and infants to examine the association of route of tracheal intubation and our specific outcomes of interest. We elected to focus a multivariable analysis on neonates and infants as these age groups seemed to be relatively evenly split in terms of intubation practices. We generated these adjusted models by using the covariates in the STS-CHS Mortality Risk Model,[8] which takes into account primary procedure performed, age, weight among infants and neonates, prior cardiothoracic operation, any noncardiac congenital anatomic abnormality (except "other"), any chromosomal abnormality or syndrome (except "other"), prematurity, preoperative/preprocedural mechanical circulatory support, shock persistent at the time of the operation, preoperative renal dysfunction or renal failure requiring dialysis (or both), preoperative mechanical ventilation to treat cardiorespiratory failure, preoperative neurological deficit, any other preoperative factor, and procedural risk category (STS-EACTS Mortality Category)[8] for each outcome of interest. We did not perform an adjusted analysis for airway complications as we did not believe there were any relevant confounders to adjust for (factors associated both with route of tracheal intubation and specific airway complications). For our primary infection composite outcome, we used generalized estimating equations with an independent working correlation structure to account for the clustering of patients within hospitals. Such an approach yields a robust covariance matrix estimates for inference to calculate adjusted odds ratios comparing the odds of having the outcome in those with a nasal route of tracheal intubation versus those with an oral route while accounting for variation across centers. For our secondary outcomes (length of stay and duration of postoperative intubation), we also used a robust Poisson regression model with generalized estimating equation to account for hospital-level variation and generate relative risks associated with nasal tracheal intubation. We limited our secondary analyses to survivors only but still included patients who died postoperatively in a separate supplemental analysis. We also performed an additional subgroup analysis in neonates in the highest mortality category (STAT 5) examining the impact of tracheal intubation route and the presence of an endotracheal tube cuff using standard *t* tests. Finally, we performed a sensitivity analysis looking at the predicted risk of infection for tracheal intubation route across age from 0 to 71 months of age (representing the spectrum from 0 to 5 years of age) using a locally weighted scatterplot smoothed and unsmoothed approach. In this analysis, we specifically limited our analysis to high-volume centers (average cases per year >100) to increase the precision of our estimate and not include centers that uniformly chose 1 method of intubation over another. As incidence data on our primary outcome has not been previously reported, we used summary data made available to us before the study to provide a power estimate. We determined that our primary outcome occurred in approximately 5.1% of infants and neonates. We also determined that these patients were nasally intubated 36% less often than orally intubated. Defining a clinically significant difference of 20% and assuming an acceptable α of .05, we calculated that we would need approximately 5467 patients and 8541 patients in our nasal intubation and oral intubation groups, respectively, to achieve a power of 80%. Given an initial population of 16,200 procedures and estimating a 10% decrease because of additional planned exclusion criteria, we believed our sample size to be sufficient. All calculations were done using SAS 9.4 (SAS, Cary, NC).

RESULTS

Cohort Characteristics

Table 1 summarizes baseline characteristics for the study cohort stratified by age at operation and route of tracheal intubation. Nasal intubation was used in 29% of all operations (n = 7635) but was more often used in neonates (41% of operations) and infants (38%) than in school-aged children (15%) and adolescents (1.6%). In unadjusted analysis, we observed statistically significant associations between a nasal route of tracheal intubation and several patient factors. Nasal tracheal intubation was associated with younger age, history of prematurity, lower weight for age *z* score, presence of syndromes, chromosomal and genetic abnormalities, and greater procedure complexity level. Patients with nasal tracheal intubation had a slightly shorter surgical time and were also less likely to have a cuffed endotracheal tube. Looking across age groups, these association patterns were slightly different from each other, but nasal tracheal intubation was still generally used in patients with an increased likelihood of comorbidities. In general, we saw an attenuation of surgical characteristic differences when stratifying by age group (as compared to an examination of the entire cohort). Additional differences are summarized in Supplemental Digital Content 1, Table 1, http://links.lww.com/AA/C482.

Unadjusted Outcomes

We found significant associations between a nasal route of endotracheal intubation and unadjusted outcomes, including increased postoperative length of stay, intubation length, and decreased likelihood of extubation in the operating room. The degree and statistical significance of these associations varied depending on the age category (Table 2). The data also indicated varying relationships across age groups when examining surgical characteristics and infection outcomes. Finally, we observed a pattern of increasing risk of infection associated with nasal intubation in older patients (Table 2).

In examining the effects of a nasal route of endotracheal intubation on airway complications, we saw some interesting patterns (Figure 1). In neonates specifically, no accidental or transesophageal echocardiography (TEE)–related

Table 1. Baseline Characteristics and Intraoperative Events

	Neonates (0–30 d)			Infants (1–12 mo)		
Baseline Characteristics	**Oral (n = 2162)**	**Nasal (n = 1519)**	***P* Value**	**Oral (n = 6115)**	**Nasal (n = 3782)**	***P* Value**
Weight at surgery[a] (kg)	3.2 [2.8–3.5]	3.2 [2.8–3.5]	.8003	5.8 [4.8–6.9]	5.6 [4.6–6.7]	<.0001
Age at surgery[a] (d)	7.0 [5.0–10.0]	6.0 [4.0–9.0]	<.0001	161 [114–217]	146 [100–199]	<.0001
Gender			.5011			.0975
Male	879 (41%)	634 (42%)		3183 (52%)	2047 (54%)	
Female	1283 (59%)	884 (58%)		2929 (48%)	1733 (46%)	
Unassigned	0 (0%)	0 (0%)		1 (<1%)	0 (0%)	
History of prematurity (<37 wk completed gestation)	271 (12.7%)	172 (11.8%)	.4093	1351 (22.9%)	671 (18.7%)	<.0001
STS-EACTS complexity level			.1125			.0096
1	42 (2%)	18 (1%)		2094 (34%)	1275 (34%)	
2	114 (5%)	105 (7%)		2045 (34%)	1259 (33%)	
3	390 (18%)	272 (18%)		1041 (17%)	659 (18%)	
4	1057 (49%)	725 (48%)		789 (13%)	532 (14%)	
5	558 (26%)	398 (26%)		127 (2%)	45 (1%)	
Intraoperative events						
Endotracheal tube cuff	1692 (78.5%)	1036 (68.4%)	<.0001	5213 (85.6%)	2934 (77.8%)	<.0001
Length of surgery (min)[a]	396.0 [331.0–467.0]	363.0 [272.0–470.0]	<.0001	327.0 [270.0–424.0]	309.0 [248.0–397.0]	<.0001
Extubated in OR	55 (2.6%)	39 (2.6%)	.9525	1052 (17.3%)	507 (13.6%)	<.0001

Abbreviations: OR, operating room; STS-EACTS, Society of Thoracic Surgeons-European Association for Cardio-Thoracic Surgery.
[a]Median [interquartile range].

Table 2. Surgical Characteristics and Infection Outcomes

	Neonates (0–30 d)			Infants (1–12 mo)			Toddlers (1–3 y)		
Surgery Characteristics	**Oral (n = 2162)**	**Nasal (n = 1519)**	***P* Value**	**Oral (n = 6115)**	**Nasal (n = 3782)**	***P* Value**	**Oral (n = 3806)**	**Nasal (n = 1542)**	***P* Value**
Postoperative length of stay[a] (d)	16.0 [10.0–33.0]	16.0 [10.0–30.0]	.4910	6.0 [4.0–11.0]	7.0 [5.0–12.0]	<.0001	5.0 [3.0–9.0]	6.0 [4.0–10.0]	<.0001
Intubation length[a] (h)	96.3 [50.4–167.7]	79.4 [44.6–148.3]	.0004	20.7 [8.1–41.5]	22.8 [8.0–47.9]	.3883	7.9 [4.9–17.6]	9.2 [4.5–25.3]	.0123
Infection Outcomes	**Oral**	**Nasal**	***P* Value**	**Oral**	**Nasal**	***P* Value**	**Oral**	**Nasal**	***P* Value**
Wound infection: deep	18 (0.8%)	13 (0.9%)	.9394	16 (0.3%)	5 (0.1%)	.1739	6 (0.2%)	2 (0.1%)	.8107
Wound infection: mediastinitis	16 (0.7%)	22 (1.5%)	.0364	23 (0.4%)	24 (0.6%)	.0692	21 (0.6%)	4 (0.3%)	.1557
Septicemia	82 (3.8%)	44 (2.9%)	.141	113 (1.9%)	45 (1.2%)	.0112	28 (0.7%)	26 (1.7%)	.0016
Pneumonia	16 (0.7%)	8 (0.5%)	.4284	60 (1.0%)	28 (0.7%)	.2149	21 (0.6%)	10 (0.7%)	.6729
Wound infection	27 (1.3%)	13 (0.9%)	.2576	18 (0.3%)	9 (0.2%)	.6013	13 (0.3%)	5 (0.3%)	.9211
All wound infections	114 (5.3%)	79 (5.2%)	.923	92 (1.5%)	68 (1.8%)	.2606	62 (1.6%)	19 (1.2%)	.2818
Pneumonia									
Septicemia									
Deep wound infection	116 (5.4%)	80 (5.3%)	.8955	184 (3.0%)	91 (2.4%)	.0762	73 (1.9%)	35 (2.3%)	.4075
Mediastinitis and endocarditis									

[a]Median [interquartile range].

extubations were observed with nasal endotracheal tubes as compared to 0.37% with oral endotracheal tubes (*P* = .018). No other differences observed in airway complication rates were statistically significant.

Multivariable-Adjusted Analysis

In the multivariable analysis examining neonates and infants as a limited cohort (Table 3), we observed that a nasal route of intubation was associated with shorter intubation length (relative risk, 0.929; 95% CI, 0.869–0.992) but not hospital length of stay (relative risk, 0.992; 95% CI, 0.947–1.039). Nasal route of intubation was not significantly associated with our infection composite (odds ratio, 0.84; 95% CI, 0.59–1.18). Additional analyses, including patients who died, are included in Supplemental Digital Content 2, Table 2, http://links.lww.com/AA/C483.

Limited Cohort Subanalyses

In a subset of 957 neonates undergoing procedures in the STAT 5 mortality category, we observed lower

Table 1. Continued

Toddlers (1–3 y)			School Aged (4–11 y)			Adolescents (12–17 y)			Overall		
Oral (n = 3806)	Nasal (n = 1542)	*P* Value	Oral (n = 4232)	Nasal (n = 746)	*P* Value	Oral (n = 2804)	Nasal (n = 46)	*P* Value	Oral (n = 19,119)	Nasal (n = 7635)	*P* Value
12.0 [9.9–14.0]	11.7 [9.7–13.8]	.0496	21.3 [17.1–29.3]	18.25 [15.9–22.9]	<.0001	55.8 [46.5–68.1]	48.9 [38.3–60.0]	.0012	10.7 [5.5–22.0]	6.0 [4.0–10.0]	<.0001
884 [587–1165]	822 [552–1129]	.0004	2512 [1877–3420]	2053 [1704–2649]	<.0001	5455 [4942–5968]	5104 [4538–5511]	.0004	706 [148–2628]	165 [66–577]	<.0001
		.7885			.8919			.3005			.6539
1982 (52%)	796 (52%)		2246 (53%)	394 (53%)		1677 (60%)	31 (67%)		10,371 (54%)	4152 (54%)	
1823 (48%)	744 (48%)		1985 (47%)	352 (47%)		1125 (40%)	15 (33%)		8741 (46%)	3478 (46%)	
1 (<1%)	0 (0%)		0 (0%)	0 (0%)		0 (0%)	0		2 (<1%)	0 (0%)	
627 (18.2%)	204 (14.3%)	.001	562 (15.9%)	105 (16.3%)	.8171	249 (11.5%)	4 (12.1%)	.9057	3060 (17.8%)	1156 (16.2%)	.0018
		<.0001			.0023			.6444			<.0001
1634 (43%)	564 (37%)		1801 (43%)	264 (36%)		982 (36%)	19 (42%)		6553 (35%)	2140 (28%)	
1468 (39%)	597 (39%)		1420 (34%)	299 (41%)		985 (36%)	17 (38%)		6032 (32%)	2277 (30%)	
306 (8%)	148 (10%)		468 (11%)	79 (11%)		308 (11%)	2 (4%)		2513 (13%)	1160 (15%)	
346 (9%)	200 (13%)		483 (12%)	94 (13%)		470 (17%)	7 (16%)		3145 (17%)	1558 (21%)	
21 (1%)	15 (1%)		9 (<1%)	2 (<1%)		3 (<1%)	0 (0%)		718 (4%)	460 (6%)	
3468 (91.5%)	1179 (76.7%)	<.0001	4068 (96.5%)	614 (82.5%)	<.0001	2750 (98.3%)	42 (93.3%)	.0116	17,191 (90.3%)	5805 (76.3%)	<.0001
320.0 [251.0–418.0]	304.0 [228.0–405.0]	<.0001	322.0 [251.0–425.0]	300.0 [226.0–404.0]	<.0001	367.0 [282.0–464.0]	325.0 [201.0–458.0]	.0541	339.0 [268.0–440.0]	317.0 [244.0–416.0]	<.0001
1299 (34.2%)	395 (26.3%)	<.0001	1447 (34.3%)	217 (30.5%)	.0444	884 (31.7%)	12 (30.8%)	.8969	4737 (24.9%)	1170 (15.7%)	<.0001

Table 2. Continued

School Aged (4–11 y)			Adolescents (12–17 y)			Overall		
Oral (n = 4232)	Nasal (n = 746)	*P* Value	Oral (n = 2804)	Nasal (n = 46)	*P* Value	Oral (n = 19,119)	Nasal (n = 7635)	*P* Value
4.0 [3.0–7.0]	5.0 [4.0–9.0]	<.0001	5.0 [4.0–7.0]	5.0 [3.0–7.0]	.7851	6.0 [4.0–11.0]	8.0 [5.0–15.0]	<.0001
7.5 [4.8–14.7]	7.5 [4.2–17.5]	.3496	9.0 [5.6–18.3]	8.4 [4.4–22.4]	.7018	12.4 [5.8–30.6]	22.9 [6.9–54.9]	<.0001
Oral	**Nasal**	***P* Value**	**Oral**	**Nasal**	***P* Value**	**Oral**	**Nasal**	***P* Value**
5 (0.1%)	0 (0.0%)	.3476	3 (0.1%)	0 (0.0%)	.8244	48 (0.3%)	20 (0.3%)	.873
9 (0.2%)	6 (0.8%)	.0066	1 (0.0%)	0 (0.0%)	.8981	70 (0.4%)	56 (0.7%)	<.0001
17 (0.4%)	10 (1.3%)	.0013	7 (0.3%)	0 (0.0%)	.7344	247 (1.3%)	125 (1.6%)	.0294
18 (0.4%)	5 (0.7%)	.3631	12 (0.4%)	0 (0.0%)	.6566	127 (0.7%)	51 (0.7%)	.9731
1 (0.0%)	1 (0.1%)	.1653	5 (0.2%)	0 (0.0%)	.7744	64 (0.3%)	28 (0.4%)	.6865
27 (0.6%)	10 (1.3%)	.0394	18 (0.6%)	0 (0.0%)	.5857	313 (1.6%)	176 (2.3%)	.0002
46 (1.1%)	18 (2.4%)	.003	25 (0.9%)	0 (0.0%)	.5201	444 (2.3%)	224 (2.9%)	.0038

unadjusted rates of our infection composite in the nasal route group (9.5% vs 7.8%), regardless of whether an endotracheal tube cuff was used, but these results were not statistically significant (Figure 2). In a separate adjusted subanalysis modeling the risk of infection across age in months up to 6 years of age, we found a significant interaction between endotracheal tube route and age in months (P = .003). To further examine such an interaction, we plotted the predicted risk of composite infection against time using the locally weighted scatterplot smoothing technique with a less flexible (Figure 3A) and a finer (Figure 3B) smoothing parameter. Visual inspection of the predicted risk of infection curves suggests a similar risk of our composite infection outcome and a nasal tracheal intubation route, which then becomes comparatively higher risk in patients >12 months of age (Figure 3B). Using a less flexible smoothing parameter shows a similar result with observed risks of composite infection to be similar (Figure 3A).

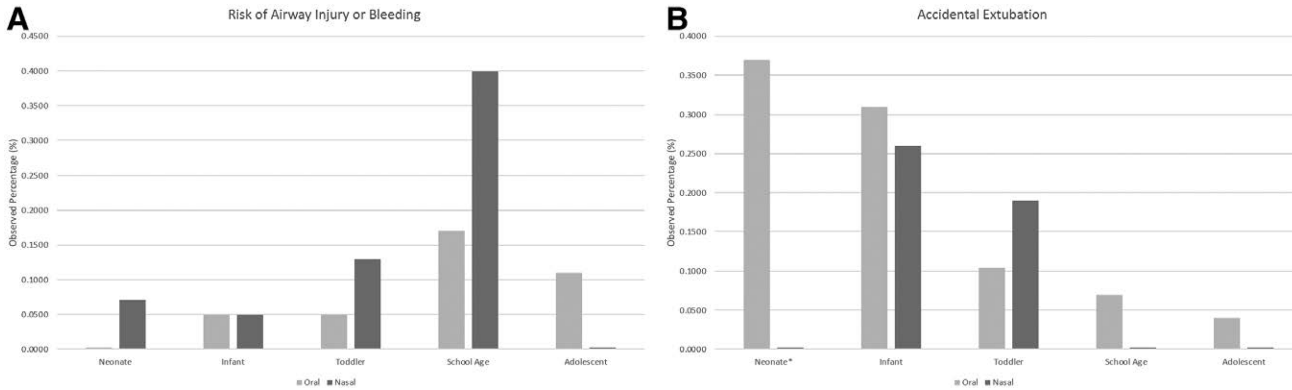

Figure 1. A, Airway injury and bleeding by age group and route of endotracheal intubation. B, Accidental extubation by age group and route of endotracheal intubation, *$P < .05$.

Table 3. Neonates and Infants Analysis

	Oral (n = 8256)	Nasal (n = 5284)	*P* Value
Surgery characteristics			
Postoperative length of stay (d)	8.0 [5.0, 16.0]	9.0 [6.0, 17.0]	<.0001
Intubation length (h)	27.3 [10.5, 78.2]	28.5 [11.4, 78.4]	.5603
Infection outcomes			
Wound infection, deep	34 (0.4%)	18 (0.3%)	.51
Wound infection, mediastinitis	39 (0.5%)	46 (0.9%)	.004
Septicemia	194 (2.4%)	89 (1.7%)	.008
Pneumonia	76 (0.9%)	36 (0.7%)	.13
Wound infection	45 (0.6%)	21 (0.4%)	.23
All wound infections	205 (2.5%)	146 (2.8%)	.32
Pneumonia, septicemia, deep wound infection, mediastinitis, and endocarditis	299 (3.6%)	171 (3.2%)	.23
Multivariable Model Analysis			
Composite Infection	**Odds Ratio**	**95% CI**	***P* Value**
Nasal ETT	0.84	0.59–1.19	.32
Oral ETT	Ref.		
Hospital LOS (d)[a]	**Relative Risk**	**95% CI**	***P* Value**
Nasal ETT	0.992	0.947–1.039	.7326
Oral ETT	Ref.		
Intubation Length (h)[a]	**Relative Risk**	**95% CI**	***P* Value**
Nasal ETT	0.929	0.869–0.992	.0285
Oral ETT	Ref.		
Survivors only[a]			

Abbreviations: CI, confidence interval; ETT, endotracheal tube; LOS, length of stay.

DISCUSSION

This study demonstrates an interaction between age at surgery and the association between route of tracheal intubation and postoperative infection in children undergoing CPB surgery. While a nasal route may not confer an increased risk of postoperative infection in neonates and infants, there appears to be a growing risk of postoperative infection after infancy. There was also a clear benefit for a nasal route in neonates in relation to the observed risk of accidental extubation. While there were statistically significant associations between a nasal route of extubation and intubation length, it is unclear whether there is a clear clinical significance of this measured association (7% shorter duration would equate to a difference between 13 and 14 hours of postoperative intubation).

Endotracheal intubation, excluding tracheostomy, can be attained by 1 of 2 routes, either orally or nasally. Nasal intubation has historically been associated with bacteremia, which may expose the patient to further complications.[9] However, the presence of the endotracheal tube in the nares is commonly thought to be more secure, particularly when there is a need to share the airway, such as during head and neck surgery and during endoscopic procedures, including TEE. We conducted this study to determine whether there was a standard in the airway management of children with congenital heart disease undergoing CPB. Furthermore, we wanted to determine whether differences in airway management techniques were associated with postoperative outcome differences.

Common Practices

This study demonstrates that in the United States (as reflected in the STS-CCAS database), there is no standardized approach to airway management in children undergoing heart surgery. There is a tendency to nasally intubate neonates and infants, but most patients are intubated orally by school age and beyond. This is perhaps not difficult to understand. In adults, nasoendotracheal intubation has been associated with sinusitis, and there are subsequent concerns over the potential for bacteremia.[2,10,11] The presence of a nasal endotracheal tube may potentially decrease drainage from the sinuses, leading to stagnation of fluids and infection and contribute to ventilator-associated pneumonia. In children, however, although incidental sinusitis has been reported, it is not thought to be dependent on tube location. The sinus cavities are known to epithelize and cavitate later in life (beginning around age 2 and continuing to grow in size through adolescence).

The presence or absence of sinuses alone, however, is not the only factor in the inducement of bacteremia. The nasal cavities are quickly colonized after birth depending on many factors, including route of delivery (vaginal versus cesarean section). Trauma to the nasal mucosa during nasal intubation may result in bacteremia, and transfer of nasal flora into the trachea via the endotracheal tube passage may potentially seed the lungs and serve as a nidus

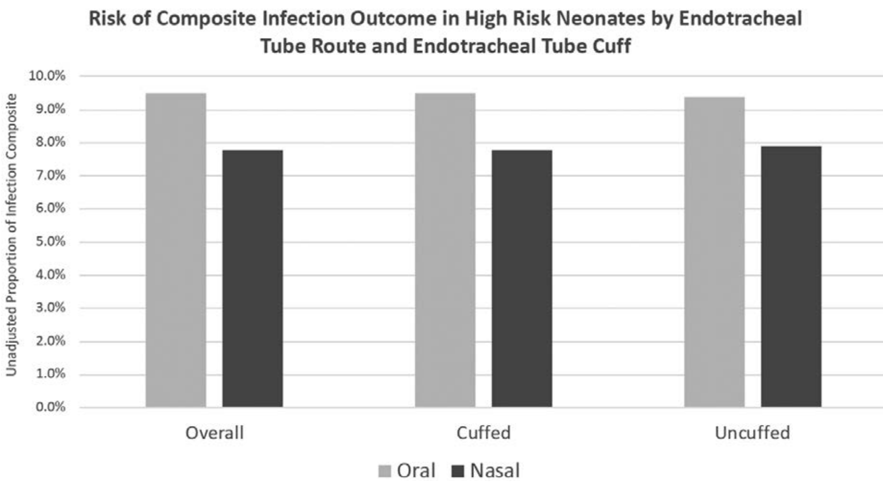

Figure 2. Proportion of infection outcome in high-risk neonates by route of endotracheal intubation and presence of endotracheal tube cuff.

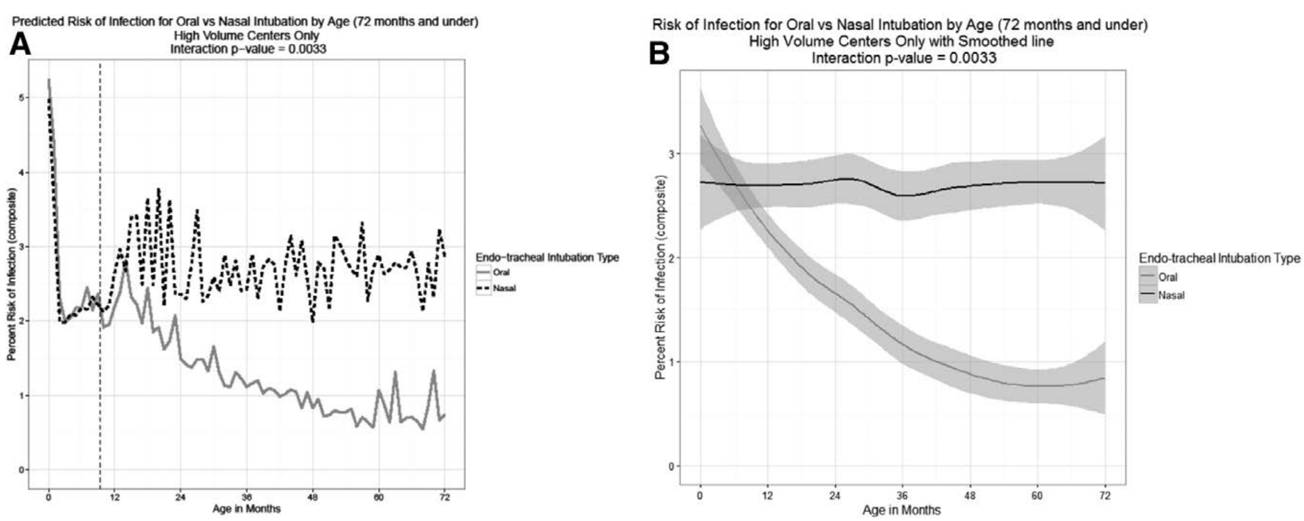

Figure 3. A, Actual predicted risk of composite infection outcome by age in months and route of endotracheal intubation. B, Smoothed predicted risk of composite infection outcome by age in months and route of endotracheal intubation.

for subsequent pneumonia. In addition, a 2000 Cochrane review, examining nasal versus oral intubation for mechanical ventilation of newborn infants, concluded that postextubation atelectasis is more frequent after nasal intubation.[12]

Does this translate to an obvious increase in all infection rates in children nasally intubated during CPB?

Infection Risk

In our study, we observed noticeable differences in the proportion of patients by intubation type for mediastinitis, septicemia, and all wound infections. For the full cohort of patients receiving nasal intubation, there were slightly higher percentages with mediastinitis (0.7% vs 0.4%), septicemia (1.6% vs 1.3%), and all wound infections (2.3% vs 1.6%) compared to patients receiving oral intubation. Additionally, the composite outcome was also more likely in the nasal intubation group overall compared to the oral intubation group overall (2.9% vs 2.3%).

However, within each age group, findings were not consistent across age ranges. We found that infants receiving oral intubation were more likely to have septicemia than those receiving nasal intubation (1.8% vs 1.2%). In school-age children, we noted that nasal tubes were associated with a higher risk of composite infection. However, this was not the case in younger patients, and further interpretation was required. A multivariable analysis examining the risk that a nasal tube poses for infection, after adjusting for known confounders, noted no significant association between a nasal route of intubation when neonates and infants were considered together as a population. It should also be noted that we observed no difference in infection outcome based on the presence of an endotracheal tube cuff in nasal or oral tubes.

Accidental Extubation

TEE is routinely utilized for procedures involving CPB in children for both pre- and postoperative assessment of cardiac function and anatomic evaluation. This means the airway must be shared with an endoscope that is manipulated by cardiologists, frequently out of direct observation by the anesthesia team due to surgical drapes and positioning. The risk of accidental endotracheal extubation in these circumstances may potentially be increased with oral intubation over nasal.

We did, in fact, note that neonates who received oral intubation were more likely to have accidental extubation or TEE-related extubation than those receiving nasal intubation (0.4% vs 0.0%; *P* value .0177). However, this should be interpreted with care as the number of events is extremely low, and we failed to identify any events within the nasal group. There are otherwise no statistically significant differences between oral and nasal in relation to airway complications.

Postoperative Intubation Length and Length of Stay

We had hypothesized that a child nasally intubated required less sedation and therefore a shorter stay in intensive care. Of note, we found the duration of postoperative intubation was 7% less with nasal intubation compared to oral, after excluding for confounding factors. The clinical benefit of this observation may be clinically significant but is not clear without further study. Length of hospital stay was not significantly different with either route.

This study does have limitations that should be considered when interpreting the results. While we attempted to adjust for potential confounding, this adjustment may be incomplete or insufficient as there may be other confounders left unaccounted for in the analysis. Although this study presents 6 years worth of data from 50 individual centers, we are left with a lack of power with regard to some associations. For example, our examination of infection risk in high-risk neonates suggests a relative risk increase of 20% in patients intubated orally, but we lack the sample size to call this a statistically significant increase. In this analysis, we also did not exclude procedures if a particular patient had >1 procedure in the relevant timeframe. Because we believe that most of the risk has to do with procedure-based factors (route of tracheal intubation, type of surgery, age at surgery) rather than unchanging patient-based factors (gender, race/ethnicity), we assume that the inclusion of these additional procedures did not influence our results. We should also note that more patients were excluded than initially planned with regard to our power analysis. We calculate that instead of achieving 80% power, we achieved closer to 78%.

CONCLUSIONS

In summary, we found no consistent standard practice with regard to airway management with the exception that oral intubation is preferred in the older age group. This is endorsed by a decrease in composite infection as compared to nasally intubated children. However, in neonates, while there may be no difference in composite infection with nasal (as compared to oral) endotracheal intubation, there may be a benefit in terms of decreased risk of accidental extubation and a shorter length of intubation.

DISCLOSURES

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