Hypoxemia in Young Children Undergoing One-lung Ventilation: A Retrospective Cohort Study

Wes Templeton MD FASA

Associate Professor of Anesthesiology

Wake Forest University School of Medicine

Methods for Single-Lung Ventilation in Pediatric Patients

Gregory B. Hammer, MD*†, Brett G. Fitzmaurice, MD*, and Jay B. Brodsky, MD*

Departments of *Anesthesia and †Pediatrics, Stanford University Medical Center, Stanford, California

Because many children are too small for double-lumen tubes (DLTs), other techniques are often required for single-lung ventilation (SLV) in pediatric patients. This article offers tube selection guidelines for SLV in children.

Methods

We reviewed published values for airway measurements in children (Table 1) (1,2). Data from the first study was derived by analyzing fresh autopsy specimens of intact tracheo-bronchial trees from 160 children between the ages of 6 mo and 16 yr (1). Thin cross-sections of the airways were made at various levels and photographed on color slides. By using a metric rule photographed with the specimen, measurements were read from the projected slides. The second set of data was obtained from chest computed tomographic examinations of 130 children from 1–21 yr of age (2).

The trachea is elliptical in shape, with the frontal diameter exceeding the sagittal diameter. Because the sagittal dimension is the "limiting" diameter and determines the largest tube that will fit, the sagittal measurement was used as our value for tracheal diameter.

bronchial blockers (Tables 2–5), recommendations for SLV are given in Table 6.

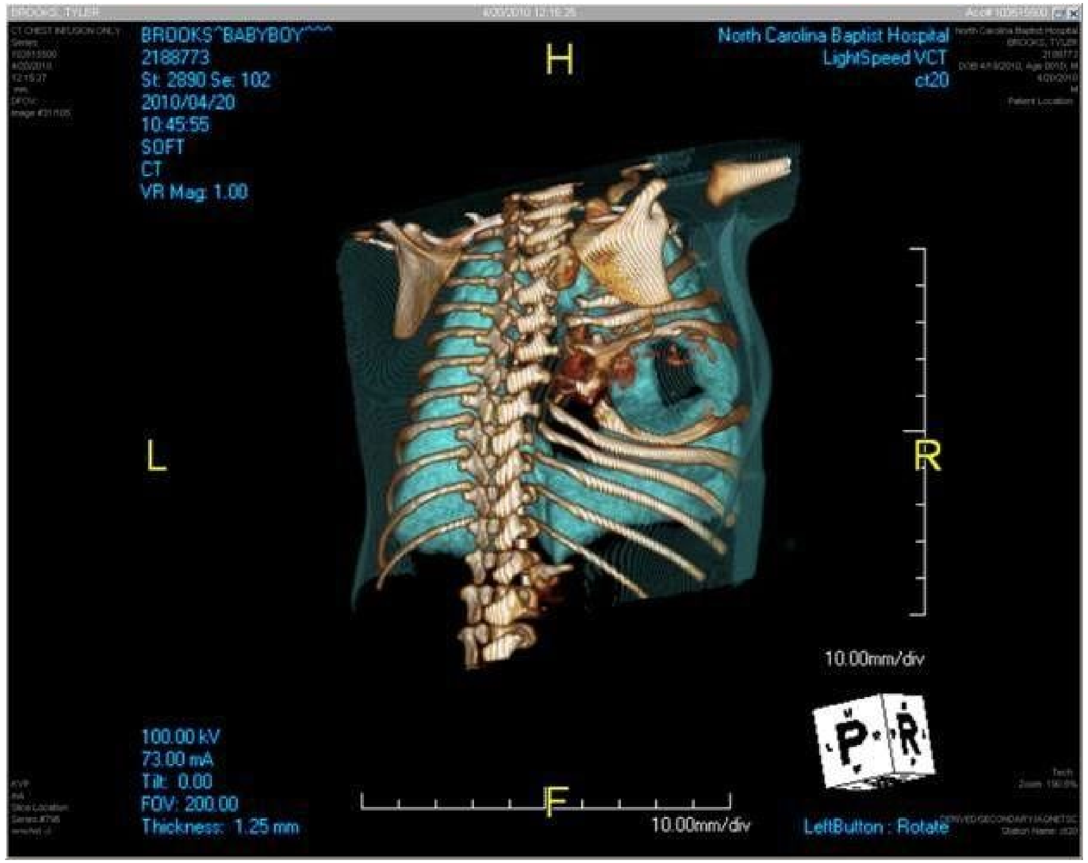
Discussion

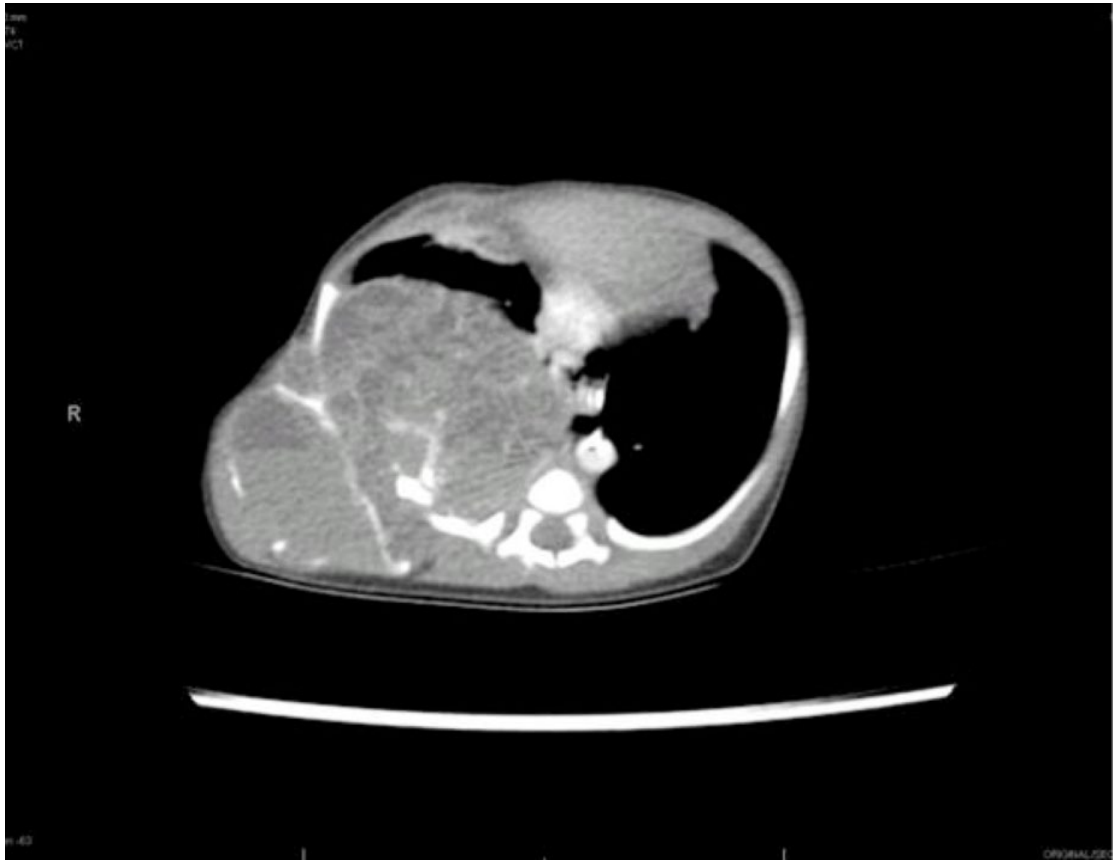
The different SLV techniques that can be used in children are briefly reviewed.

Single Lumen Endotracheal Tube (ETT)

The simplest method is to intentionally intubate a mainstem bronchus with a conventional single-lumen ETT (4,5). The ETT is advanced into the bronchus until breath sounds over the contralateral (operative) lung disappear. A fiberoptic bronchoscope (FOB) can be passed through or alongside the ETT to confirm or guide placement. When a cuffed ETT is used, the distance from the tip of the tube to the proximal edge of the cuff must be shorter than the length of the mainstem bronchus to insure that the cuff is entirely in the bronchus (6).

This technique requires no special equipment other than a FOB. Problems include failure to achieve an adequate seal of the bronchus, especially if an uncuffed ETT is used. This may prevent the operated lung from collapsing completely or fail to protect the healthy, ventilated lung from contamination. One is





9 Day Old with a Cystic Hemartoma

Video of 9 day old

A Few Questions About One-Lung Ventilation in Children

What is the risk of hypoxemia?

What is the risk of hypercarbia?

Does it matter how we execute OLV?

Does the side of surgery matter?

Could MPOG offer a novel approach to begin to answering questions like these for such a rare case?

Design: Retrospective Observational

Initially query generated around 350-500 cases

- Most series 15-50 patients

15 institutions – First Multicenter Study on Pediatric OLV

Inclusion Criteria

- 2 mos – 3 years Inclusive
- Non cardiac procedures
- Required Documentation of OLV
- CPT codes - 32601, 32661, 32662, 32663, 32652, 32650, 32666, 32667, and 32100

Outcomes-Determined by Committee

Hypoxemia

- $SpO_2 < 90\%$ for ≥ 3 minutes

Severe Hypoxemia

- $SpO_2 < 90\%$ for ≥ 5 minutes

Hypercarbia

- $ETCO_2 > 60$ mmHg ≥ 5 minutes
- $PaCO_2 > 60$ mmHg

Execution Challenges

Number of cases was still small

Determining OLV start and stop times

Not all covariates on all patients could be extracted electronically

CPT codes not specific enough to build appropriate filter

Solution to many of these issues was manual review…

Individual Solutions

- Type and Number of cases – Posting had to be reviewed
- OLV Start and Stop Time – Ventilator data had to be manually reviewed, couldn't develop adequate logic…always forced to exclude too many

  - Tidal Volume
  - FiO2
  - ETCO2

} OLV Start and OLV Stop Time

ANESTHESIOLOGY

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T. Wesley Templeton, M.D., Scott A. Miller, M.D., Lisa K. Lee, M.D., M.S., Sachin Kheterpal, M.D., M.B.A., Michael R. Mathis, M.D., Eduardo J. Goenaga-Díaz, M.D., Leah B. Templeton, M.D., Amit K. Saha, Ph.D.; for the Multicenter Perioperative Outcomes Group Investigators*

Anesthesiology 2021; XXX:00–00

ABSTRACT

Background: One-lung ventilation in children remains a specialized practice with low case numbers even at tertiary centers, preventing an assessment of best practices. The authors hypothesized that certain case factors may be associated with a higher risk of intraprocedural hypoxemia in children undergoing thoracic surgery and one-lung ventilation.

Methods: The Multicenter Perioperative Outcomes database and a local quality improvement database were queried for documentation of one-lung ventilation in children 2 months to 3 yr of age inclusive between 2010 and 2020. Patients undergoing vascular or other cardiac procedures were excluded. All records were reviewed electronically for the presence of hypoxemia, oxygen saturation measured by pulse oximetry (Spo_2) less than 90% for 3 min or more continuously, and severe hypoxemia, Spo_2 less than 90% for 5 min or more continuously during one-lung ventilation. Records were also assessed for hypercarbia, end-tidal CO_2 greater than 60 mmHg for 5 min or more or a $Paco_2$ greater than 60 on arterial blood gas. Covariates assessed for association with these outcomes included age, weight, American Society of Anesthesiologists (Schaumburg, Illinois) Physical Status 3 or greater, duration of one-lung ventilation, preoperative Spo_2 less than 98%, bronchial blocker *versus* endobronchial intubation, left operative side, video-assisted thoracoscopic surgery, lower tidal volume ventilation (tidal volume less than or equal to 6 ml/kg plus positive end expiratory pressure greater than or equal to 4 cm H_2O for more than 80% of the duration of one-lung ventilation), and type of procedure.

Results: Three hundred six cases from 15 institutions were included for analysis. Hypoxemia and severe hypoxemia occurred in 81 of 306 (26%) patients and 56 of 306 (18%), respectively. Hypercarbia occurred in 153 of 306 (50%). Factors associated with lower risk of hypoxemia in multivariable analysis included left operative side (odds ratio, 0.45 [95% CI, 0.251 to 0.78]) and bronchial blocker use (odds ratio, 0.351 [95% CI, 0.177 to 0.67]). Additionally, use of a bronchial blocker was associated with a reduced risk of severe hypoxemia (odds ratio, 0.290 [95% CI, 0.125 to 0.62]).

Conclusions: Use of a bronchial blocker was associated with a lower risk of hypoxemia in young children undergoing one-lung ventilation.

(*Anesthesiology* 2021; XXX:00–00)

EDITOR'S PERSPECTIVE

What We Already Know about This Topic

- Current approaches to one-lung ventilation in children involve selective endobronchial intubation or use of a bronchial blocker

What This Article Tells Us That Is New

- In a retrospective multisite cohort study in children aged 2 months to 3 yr having one-lung ventilation for thoracic surgery, hypoxemia was common
- Bronchial blocker use as well as left-sided surgeries were associated with a lower risk of hypoxemia during one-lung ventilation

One-lung ventilation in children undergoing noncardiac surgery presents unique challenges that frequently require specialized equipment and creative solutions to achieve success. At this time, the infrequency of these cases at any one institution has limited our ability to perform prospective trials to compare the efficacy and risks of different devices and approaches. As a result, most of the primary literature on this topic is based on individual experience and single-center case series.[1–4] Further, there are little, if any, multicenter data to guide clinicians in terms of best practices.

Current approaches to one-lung ventilation in this age group involve endobronchial intubation or use of a bronchial blocker.[5,6] Currently, there exist almost no data to support the use of one approach or the other in terms of reducing the risk of hypoxemia or other long-term outcomes. In most cases, the approach to one-lung ventilation is based on local preference or technical expertise rather than a choice based on an assessment of the risks and benefits of

Supplemental Digital Content is available for this article. Direct URL citations appear in the printed text and are available in both the HTML and PDF versions of this article. Links to the digital files are provided in the HTML text of this article on the Journal's Web site (www.anesthesiology.org).

Submitted for publication February 2, 2021. Accepted for publication August 10, 2021. From the Department of Anesthesiology, Wake Forest School of Medicine, Winston-Salem, North Carolina (T.W.T., S.A.M., E.J.G.-D., L.B.T., A.K.S.); the Department of Anesthesiology, University of California, Los Angeles, Los Angeles, California (L.K.L.); and the Department

A Few Results

(n=306 Patients)

- Endobronchial intubation was preferred almost 2-1
- Risk of hypoxemia 26%
- Risk of severe hypoxemia 18%
- Risk of hypercarbia 50%

Risk Factors for Hypoxemia

Table 2. Multivariable Least Absolute Shrinkage and Selection Operator Regression Analysis of Risk Factors for Hypoxemia (Spo_2 Less than 90% for 3 Min or More Continuously) in Young Children Undergoing Thoracic Surgery and One-lung Ventilation

	Odds Ratio	95% CI	*P* Value
Age, yr	0.78	0.49–1.21	0.278
ASA Physical Status III or IV	*	—	
Left-sided cases	0.45	0.251–0.[illegible]8	0.005
One-lung ventilation duration, h	1.17	0.98–1.41	[illegible]
Bronchial blocker	0.351	0.177–0.[illegible]7	0.002
Preoperative Spo_2 < 98	1.78	0.81–3.85	[illegible]
Lower tidal volume ventilation	1.91	0.96–3.78	0.062
Video-assisted thoracoscopic surgery	0.68	0.358–1.32	0.249
Type of surgery			
1	2.23	0.80–7.3	0.148
2	*	—	—
3	0.295	0.064–0.97	0.986
4	0.45	0.137–1.25	0.986

Type of surgery: 1, lung wedge or lobe resection; 2, pleurodesis or decortication; 3, mediastinal surgery; 4, other. The optimal lambda value was determined to be $\lambda = 0.0167$ with an alpha value of 1.

*Covariate beta coefficient reduced to 0 by least absolute shrinkage and selection operator regression method.

ASA, American Society of Anesthesiologists; Spo_2, oxygen saturation measured by pulse oximetry.

Endobronchial Intubation vs Blocker

Table 3. Direct Comparison between Endobronchial Intubation and Bronchial Blocker in Children Undergoing Thoracic Surgery and One-lung Ventilation

	Endobronchial Intubation, n = 199	Bronchial Blocker, n = 107	*P* Value
Age, yr, median [interquartile range]	0.67 [0.50–1.33]	0.75 [0.46–1.67]	0.447
Weight, kg, median [interquartile range]	8.9 [7.4–11.2]	8.8 [7.3–11.3]	0.757
ASA Physical Status III or IV, n (%)	68 (34.2)	57 (53.3)	0.002
Left-sided surgeries, n (%)	99 (49.7)	50 (46.7)	0.701
One-lung ventilation duration, h, median [interquartile range]	2.99 [2.03–4.09]	2.65 [1.64–3.69]	0.039
Preoperative Spo_2, median [interquartile range]	100 [98–100]	99 [98–100]	0.022
Preoperative $Spo_2 < 98\%$, n (%)	27 (13.6)	21 (19.6)	0.221
Lower tidal volume ventilation, n (%)	36 (18.1)	23 (21.5)	0.570
Video-assisted thoracoscopic surgery, n (%)	158 (79.4)	62 (57.9)	< 0.001
Type of surgery, n (%)			
1	161 (80.9)	75 (70.1)	
2	2 (1.0)	1 (0.9)	
3	15 (7.5)	16 (15.0)	
4	21 (10.6)	15 (14.0)	
Institutional identifier, n (% of cases at institution)			
10	4 (2.0)	14 (13.1)	
13	5 (2.5)	0 (0.0)	
15	4 (2.0)	3 (2.8)	
16	1 (0.5)	0 (0.0)	
18	25 (12.6)	1 (0.9)	
19	45 (22.6)	31 (29.0)	
27	7 (3.5)	31 (29.0)	
39	21 (10.6)	1 (0.9)	
42	10 (5.0)	0 (0.0)	
46	8 (4.0)	0 (0.0)	
47	1 (0.5)	0 (0.0)	
48	14 (7.0)	23 (21.5)	
5	4 (2.0)	0 (0.0)	
53	48 (24.1)	0 (0.0)	
7	2 (1.0)	3 (2.8)	
Outcomes, n (%)			
Hypoxemia	64 (32.2)	17 (15.9)	0.003
Severe hypoxemia	46 (23.1)	10 (9.3)	0.005
Hypercarbia	99 (49.7)	54 (50.5)	0.932

Comparisons made using chi-square or Mann–Whitney U test.
ASA, American Society of Anesthesiologists; Spo_2, oxygen saturation measured by pulse oximetry.

Final Thoughts

A new direction for MPOG

MPOG may have the power in many cases to provide insights to rare cases and rare events…MH, Anterior Mediastinal Masses, Difficult Airway

Validation? – approaches in the future especially for large data sets where things have been extracted electronically.

Prediction vs Inference?