Auscultation of Bilateral Breath Sounds Does Not Rule Out Endobronchial Intubation in Children

Susan T. Verghese, MD*, Raafat S. Hannallah, MD*, Michael C. Slack, MD†, Russell R. Cross, MD†, and Kantilal M. Patel, PhD‡

Departments of *Anesthesiology, †Pediatric Cardiology, and ‡Pediatrics, Children's National Medical Center and George Washington University Medical Center, Washington, DC

We performed orotracheal intubation in 153 consecutive pediatric patients undergoing cardiac catheterization. Auscultation of bilateral breath sounds was confirmed. By fluoroscopy, the tip of the endotracheal tube (ETT) was seen in the right mainstem bronchus in 18 patients (11.8%) and in a low position, defined as within 1 cm above the carina, in 29 patients (19.0%). All of the 18 patients with right mainstem intubation were children <120 mo of age, and 7 were infants <12 mo of age (Fisher's exact test; $P = 0.013$). The age, weight, and ETT size for children who had endobronchial and low tracheal positions were significantly ($P < 0.001$) less than for those who had midtracheal positions. The failure to diagnose mainstem intubation by auscultation alone may be related to the use of the Murphy eye ETT, which reduces the reliability of chest auscultation in detecting endobronchial intubation. Suggested measures for preventing endobronchial intubation include maintaining increased awareness of the imperfection or lack of accuracy of the auscultatory method, assessing insertion depth by checking the length scale on the tube, and minimizing the patient's head and neck movement after intubation. When extreme flexion or extension of the neck is expected after ETT insertion, the resultant change in ETT final position must be anticipated and taken into consideration when deciding on the depth of ETT insertion. This approach resulted in a decrease in improper tube positioning from 20% when the study was initiated to 7.1% in the last 98 patients.

(Anesth Analg 2004;99:56–8)

Endotracheal intubation is a routine procedure in pediatric anesthesia. However, because of the differences in size and maturational anatomy between children and adults, the technique of laryngoscopy and the choice of endotracheal tube (ETT) size and length are dependent on the age and size of the individual child (1).

Confirmation of successful placement of the ETT in the midtracheal area can be accomplished in several ways. Auscultation of equal and bilateral breath sounds suggests the position of an ETT to be above the carina when both lungs are ventilated. Absolute confirmation of the tracheal tube position is possible by fiberoptic visualization or by fluoroscopy. The purpose of this study was to examine the incidence of endobronchial intubation by fluoroscopy in children undergoing cardiac catheterization in whom bilateral breath sounds had been documented by auscultation.

Accepted for publication January 5, 2004.

Address correspondence and reprint requests to Susan Verghese, MD, Department of Anesthesiology, Children's National Medical Center, 111 Michigan Ave., N.W., Washington, DC 20010. Address e-mail to sverghes@cnmc.org.

DOI: 10.1213/01.ANE.0000118104.23660.F3

Methods

This study was undertaken as a quality improvement project after a series of accidental endobronchial intubations were observed during fluoroscopy in children undergoing cardiac catheterization studies. IRB approval was obtained to collect these data. After the induction of general anesthesia and the administration of a nondepolarizing muscle relaxant, orotracheal intubation was performed in 153 consecutive pediatric patients undergoing cardiac catheterization. Laryngoscopy and intubation were performed by a CA-2, -3, or -4 resident under the direct supervision of an attending anesthesiologist. Visualization of the second marking of the ETT going through the cords was confirmed. The ETT was taped at a level appropriate to the child's age, i.e., age (years)/2 + 12 (2). Auscultation of bilateral breath sounds was confirmed by the attending anesthesiologist, and the level of the ETT at the incisors was recorded. The child was then positioned for the procedure with the arms extended over the shoulders parallel to the head. Auscultation of bilateral breath sounds was again confirmed and documented.

The cardiologist confirmed the position of the ETT by fluoroscopy, and the relationship of the tip of the ETT to

0003-2999/04

the carina was determined. If the tip of the ETT was endobronchial or very low in the trachea, defined as within 1 cm close to the carina, the tube was pulled back and retaped, and the correct position was reconfirmed.

The statistical analysis was performed by SAS (Version 6.12; 1997 SAS Institute Inc., Cary, NC). The study data are summarized by mean and SD, range, and minimum and maximum observations. The continuous data were analyzed by Student's *t*-test and the Kruskal-Wallis test; discrete, categorical, nominal, and/or ordinal data were analyzed by χ^2 and Fisher's exact tests. A P value <0.05 was considered significant at an $\alpha = 5\%$ level of significance.

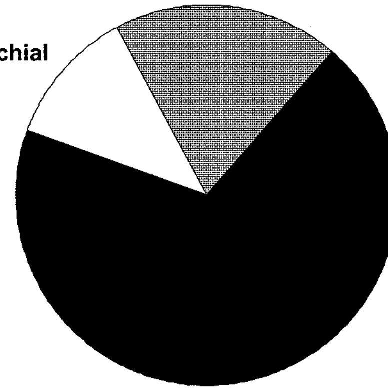

Figure 1. Endotracheal tube position by fluoroscopy.

Results

A total of 153 patients (age range, 0.1–216 mo) were studied. An interim analysis was performed on the first 55 patients, and the results were presented previously (3). The study was continued with the remaining 98 patients. Forty-two patients underwent interventional cardiac catheterization for device closures of atrial septal defects. One-hundred-eleven of the remaining patients underwent diagnostic cardiac catheterization for complex cardiac diseases. One-hundred-one (66.0%) were younger than 120 mo, and 25 (16.3%) were infants less than 12 mo of age. A cuffed tube was used in 91 patients, and an uncuffed tube was used in 62 patients. By fluoroscopy, the tip of the ETT was seen in the right mainstem bronchus in 18 patients (11.8%) and in a low position in 29 patients (19.0%) (Fig. 1). All 18 patients with right mainstem intubation were children <120 mo of age, and 7 were infants <12 mo of age (Fisher's exact test; $P = 0.013$ versus older children). The age, weight, and ETT size of children who had endobronchial and low tracheal positions were significantly ($P < 0.001$) less than those who had midtracheal positions: 49.7 ± 51.6 mo (range, 0.1–180.0 mo) versus 97.9 ± 67.5 mo (range, 0.1–216 mo), 17.8 ± 15.1 kg (range, 2.6–65.0 kg) versus 32.4 ± 23.5 kg (range, 3.0–109.0 kg), and 4.76 ± 0.97 mm (range, 3.0–7.0 mm) versus 5.70 ± 1.23 mm (range, 3.0–8.0 mm), respectively. There was no association between the experience of the anesthesia trainee and the incidence of right mainstem intubation. When data collection was initiated, the incidence of mainstem intubation was 20% (11 of 55). After an initial analysis for an abstract presentation (3), which resulted in increased awareness and more attention to the movement of the head during arm positioning, this incidence was reduced to 7.1% (7 of 98 patients; $P = 0.034$).

Discussion

Achieving appropriate ETT positioning in children is not always easy because the tracheal length of a child is shorter than that of an adult. Moreover, the position of the ETT is easily altered by rotatory movements, flexion, and extension of the head. Therefore, it is customary to reassess bilateral lung ventilation by auscultation after changes in patient position from supine to prone or lateral, as well as changes in position of the operating room (OR) table. However, this method of assessment alone may not be sufficient to confirm correct tube positioning in children. In one study, ETT malposition rates observed in intensive care unit (ICU) postintubation chest radiographs were 39.1% after positioning guided by clinical assessment alone (4).

The length of the trachea (vocal cords to carina) in neonates and children up to one year of age varies from 5 to 9 cm. Wheeler et al. (2) suggest that an ETT is properly positioned when the distal indicator mark at the alveolar ridge (or the incisors, when present) is 10 cm in most infants three months to one year of age, 11 cm for a one-year-old child, and 12 cm for a two-year-old child. After these ages, the correct length for insertion for oral intubation (in centimeters) may be approximated by a formula as follows: age in years/2 + 12. The tip of the ETT should be advanced under direct vision not more than 2.5 cm in newborn infants, because the distance between the glottis and the carina is only approximately 5 cm. In older children, a cuffed ETT is advanced just enough for the upper end of the cuff to disappear beyond the glottis (5). However, variations in normal airway lengths are too great to allow reliance on any predetermined reference scale. After an ETT is inserted, it is common practice to observe for symmetry of chest expansion and auscultate for equality of breath sounds. In our experience, the necessary hyperextension of the arms above the shoulders to clear the chest wall for radiological equipment during cardiac catheterization procedures lifts the thorax and unavoidably results in neck flexion.

Tracheally intubated patients may have the tip of the ETT move up within the trachea with head extension or move down closer to the carina when the neck is flexed (6,7). A recent study of pediatric ICU patients who needed mechanical ventilation in the prone position with head extension showed that the ETT tended to move up in the trachea in that position. The cephalad movement of the ETT ranged from 10% to 57% of the thoracic tracheal length, with a mean of 34%, which is equivalent to 1.9 cm (range, 0.5–3.5 cm) (8). The wide range of tube movement found with extension and flexion of the neck is due to inconsistent effects of changes in soft tissue geometry on the ETT. Additional tube movement may be due to the fact that the lung root is a mobile structure. The level of the carina, therefore, may be elevated or depressed by intermittent positive pressure ventilation, OR table tilts down or up, or other manipulations that may alter the intraabdominal pressure. The mechanism of ETT movement with changes of head position in the neonate has been studied by obtaining serial radiographs in term newborn cadavers. The skull is thought to act as a lever arm from the anterior end of the maxilla to the first cervical vertebra; the upper cervical spine acts as the fulcrum for the movement. The movement of the ETT is directed by the maxillocervical lever arm when the skull and upper cervical spine are flexed, extended, or rotated (9).

The failure to diagnose mainstem intubation by auscultation alone may be related to the use of the Murphy eye ETT. The Murphy eye was designed to allow ventilation of the lung when the bevel of the ETT is occluded. The eye of the Murphy tube allows bilateral breath sound auscultation even with bronchial intubation (Fig. 2) and thus reduces the reliability of chest auscultation in detecting endobronchial intubation (10).

Our study results showed that low tracheal position and right mainstem intubation were more frequent in children <10 years of age, especially in younger children with lower weight. When extreme flexion or extension of the neck is expected after ETT insertion, the resultant change in the ETT final position must be anticipated when deciding on the depth of ETT insertion. This explains the decreased incidence of endobronchial intubations in the latter part of our study. A limitation of our findings, however, is that only a specific group of patients who underwent cardiac catheterization was studied. In addition, the exact centimeter change in tube position within the trachea was not measured.

In conclusion, although it is useful to consider formulas based on population means in determining ETT tube position, the result in the individual patient is unpredictable. When extreme flexion or extension of the neck is expected after ETT insertion, the resultant change in ETT final position must be anticipated when deciding on the depth of ETT insertion.

The authors thank Deirdre Savoy, Graphics Presentation Specialist, Department of Anesthesiology, and Children's National Medical Center for technical assistance.

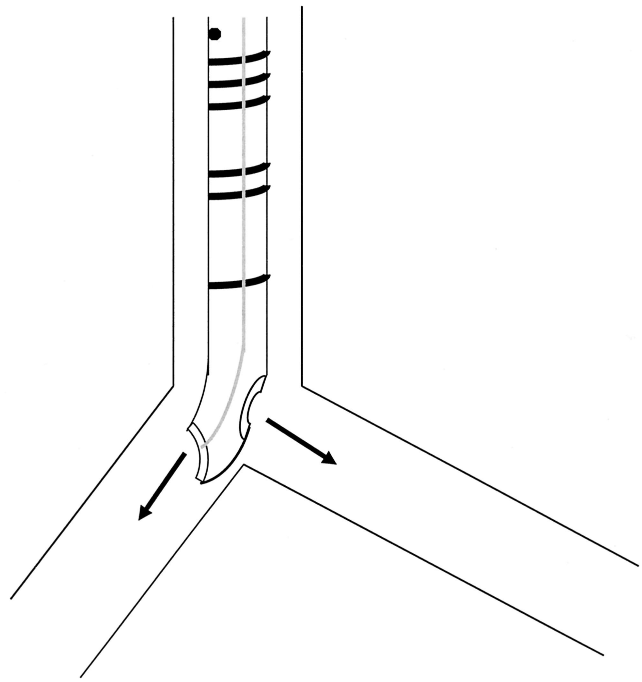

Figure 2. The use of the Murphy eye endotracheal tube allows auscultation of bilateral breath sounds even with endobronchial intubation.

References

1. Eckenhoff JE. Some anatomic considerations of the infant larynx influencing endotracheal anesthesia. Anesthesiology 1951;12:401–10.
2. Wheeler M, Coté CJ, Todres ID. Pediatric airway. In: Coté CJ, Todres ID, Ryan JF, Goudsouzian GN, eds. A practice of anesthesia for infants and children. 3rd ed. Philadelphia: Saunders, 2001: 70–120.
3. Verghese ST, Hannallah RS, Cross RR, et al. Auscultation of bilateral breath sounds does not rule out endobronchial intubation in children [abstract]. Anesth Analg 2002;96:S220.
4. Hauser GJ, Muir E, Kline LM, et al. Prospective evaluation of a nonradiographic device for determination of endotracheal tube position in children. Crit Care Med 1990;18:760–3.
5. Fearon B, Whalen JS. Tracheal dimensions in the living infant. Ann Otol Rhinol Laryngol 1967;76:965–74.
6. Yap SJ, Morris RW, Pybus DA. Alterations in endotracheal tube position during general anaesthesia. Anaesth Intensive Care 1994;22:586–8.
7. Sun KO. Alterations in endobronchial tube position with head and neck movement. Anaesth Intensive Care 1995;23:403–4.
8. Marcano BV, Silver P, Sagy M. Cephalad movement of endotracheal tubes caused by prone postioning in pediatric patients with acute respiratory distress syndrome. Pediatr Crit Care Med 2003;4:186–9.
9. Donn SM, Kuhns LR. Mechanisms of endotracheal tube movement with change of head position in the neonate. Pediatr Radiol 1980;9:37–40.
10. Sugiyama K, Yokoyama K, Satoh K, et al. Does the Murphy eye reduce the reliability of chest auscultation in detecting endobronchial intubation? Anesth Analg 1999;88:1380–3.