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Endotracheal Tube Displacement during Cardiac Surgery in Infants: A Retrospective Cohort Study of Its Incidence and Predictors

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Abstract

Introduction: With the traction on the trachea and intrathoracic manipulation during cardiac surgery, the position of the endotracheal tube (ETT) might be changed as compared to before surgery. Migration of the ETT during pediatric cardiac surgery is particularly problematic in infants. **Methods:** In this retrospective cohort study, chest X-rays were taken in the operating room just before and after surgery. The position of the ETT among all infants under 1 year of age who underwent cardiac surgery between December 2017 to December 2019 was evaluated. The displacement of the ETT position was examined by measuring the position of the tube tip from the tracheal bifurcation on a chest X-ray, and the relationship between surgery-related factors (age, height, weight, sex, surgery time, cardiopulmonary bypass, tube size, use of tube cuff) was analyzed. **Results:** Eighty-eight of the 141 patients were enrolled. There was a significant proximal displacement of the ETT tip during cardiac surgery. The distance from the carina to the tube tip after surgery was long, on average 2.5 mm, compared to that before surgery (P = 0.013). Cephalad displacement of the ETT either ≥5 mm or ≥2.5 mm was found in 28 and in 38 out of 88 infants after surgery, respectively. After performing multivariate analysis, the use of un-cuffed ETT was the sole exploratory variable predictive of tube tip displacement (OR 0.34, 95% CI 0.10 - 0.93 if ≥5 mm; and OR 0.24, 95% CI 0.08 - 0.75 if ≥2.5 mm displacement; P = 0.04 and 0.01, respectively). **Conclusion:** Proximal displacement of the ETT during cardiac surgery occurs more frequently in infants with un-cuffed ETT.

Keywords

Endotracheal Tube Disposition, Pediatric Cardiac Surgery, Neonates, Infants, Risk Factor

1. Introduction

In pediatric anesthesia, unexpected displacement of the endotracheal tube (ETT) can cause serious complications, such as accidental extubation and endobronchial intubation. Displacement caused by changes in a head position [1] [2] [3] and by traction on the trachea by intrathoracic manipulation surgery has been described [4]. Additionally, the insertion and removal of the transesophageal echocardiography (TEE) probe used in pediatric cardiac surgery may cause abnormal positioning of the ETT. There are only a few reports about the ETT depth during open-heart surgery [5].

Migration of the ETT during pediatric cardiac surgery might be particularly problematic in infants and younger, where small changes in position may critically compromise the airway, posing a serious concern. As the trachea in an infant is so short and the safety margin is narrow [6] [7], even a slight deviation in the ETT position must be carefully considered. It is important to accurately place the ETT to a predetermined depth to ensure safety during operation [8]. While the effects on the ETT depth during cardiac surgery need to be investigated in detail, examining the simple influence of the operation just before and after surgery in the same surgical position is required.

The main aim of this study was to investigate the incidence and the extent of ETT displacement in neonates and infants during surgery performed for congenital heart disease. Our secondary goal was to explore factors associated with endotracheal tube displacement.

2. Materials and Methods

2.1. Study Design

This retrospective cohort study was approved by the ethics committee of Saitama International Medical Center (file No. 20-047), and was designed to investigate the incidence and risk factors of intraoperative malposition of ETT. This study was conducted in accordance with the amended Declaration of Helsinki.

At our hospital, chest X-rays are commonly taken in the operating room prior to incision, after shoulder-roll positioning for pediatric cardiac surgery, in order to confirm the appropriate placement of central venous catheters; and after skin closure, prior to removing the shoulder roll with the patient's head and neck in a neutral position, in order to check for misplaced material. The choice of ETT size and type (cuffed versus un-cuffed) is made by the attending anesthesiologists at the time of intubation. In our standard procedure for inserting ETT, the intubation depth mark was positioned at the level of the vocal cords using direct laryngoscopy. The ETT is taped to the right corner of the mouth and checked for air leakage at 15 mmHg peak airway pressure (cuff pressure is not monitored). After the induction of anesthesia, the anesthesiologist selected an appropriate TEE probe according to age and weight and inserted that in a protective manner. TEE probe with a shaft diameter of 4.5 mm for newborns, and 6.8 mm for 3 - 7 kg or less. A probe was inserted under vision using a laryngoscope to avoid crossing

the endotracheal tube, and the operation was performed while paying attention to the movement of the thorax, arterial pressure, pulse oximeter and capnograph.

2.2. Patients

From December 2017 to December 2019, neonates and infants who underwent pediatric cardiac surgery at our hospital were included. Exclusion criteria were cases already intubated before entering the operating room, with posture change during surgery, and in which the tip of the tracheal tube or tracheal bifurcation was unclear on each chest X-ray, especially if the findings of two or more anesthesiologists were not in agreement with each other about the measured values (**Figure 1**).

2.3. Measurements

The electronic medical records were manually screened to identify who met the inclusion criteria. Age, height, weight on admission, sex, diagnosis and type of surgery, ETT size and type, surgery duration and use of cardiopulmonary bypass were collected as possible predictors of ETT displacement based on previous

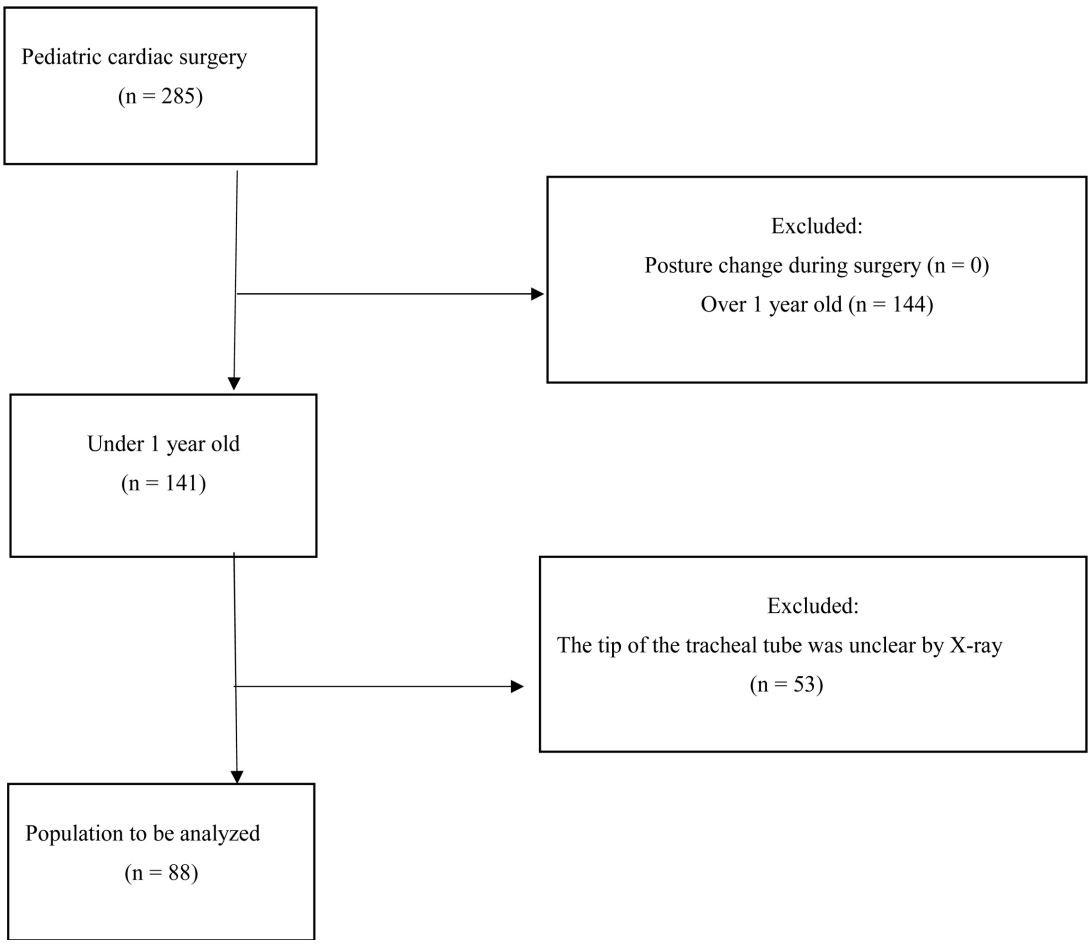

Figure 1. Patient flowchart of the study. In total, 88 cases were included in the study.

reports [9] [10] [11]. ETT tip-to-carina distance was measured independently from chest X-rays pre- and post-surgery in one decimal place in millimeters on a high-performance monitor by two anesthesiologists (Figure 2). If the findings of two anesthesiologists were not in agreement with each other about the measured values, a third party determined or excluded whether the values were appropriate.

2.4. Data Analysis

The median and interquartile range (IQR) of continuous data and the number and percentage of categorical data were calculated. The significance of the change in tip-to-carina distance pre- and post-surgery was assessed by paired comparisons using the Wilcoxon Rank Sum test. If there was a significant difference, further analysis was performed with reference to that value. In this study, the median proximal displacement of the ETT after surgery occurred in 2.5 mm. Variables associated with a change in distance (≥2.5 mm or ≥5 mm) were explored using a multivariate logistic regression analysis of the above factors. The discrimination ability of the logistic regression model was assessed using the C-statistics. Tests were two-tailed and a p-value < 0.05 was considered statistically significant. Statistical analyses were performed using the SAS ver. 9.4 (SAS Institute Inc., Cary, NC, USA).

3. Results

Within the period, 285 patients who underwent pediatric cardiac surgery and 141 patients of them in neonates and infants at our hospital were included. There was no case with posture change during surgery, and 53 cases were excluded by the mismatch of two measurements. As a result, 88 patients were available in the registry database (Figure 1).

Characteristics of the selected patient characteristics and type of surgery are shown in Table 1 and Table 2. TEE was used during anesthesia in all patients.

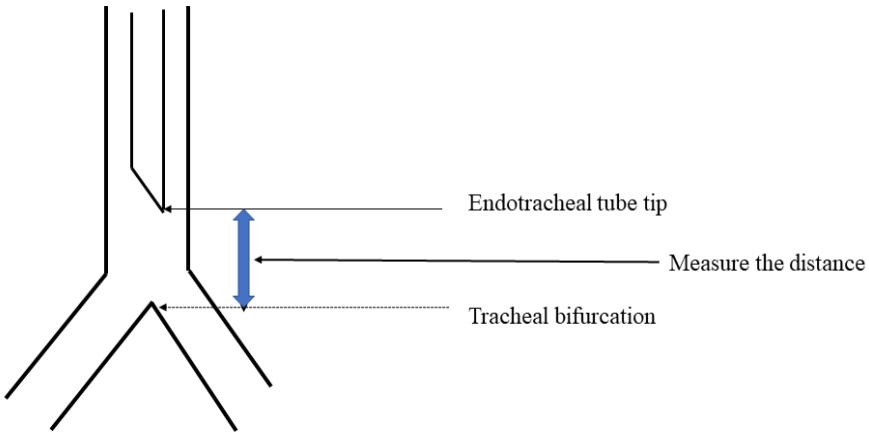

Figure 2. The tracheal tube placement position was examined by measuring the position of the tube tip from the tracheal bifurcation with a chest X-ray.

The newborns were 10 of 88 cases. The closure of ventricular septal defect was the most common procedure in 36 cases. The distances from the tracheal bifurcation to the ETT tip measured immediately before and after surgery were 16.1 ± 7.6 mm and 18.6 ± 8.4 mm, respectively. Of all the subjects in this study, the one with the largest tube position movement was 24.5 mm, which was shallower. The median proximal displacement of the ETT after surgery was 2.5 mm ($p = 0.013$). Cephalad displacement of the ETT either ≥5 mm or ≥2.5 mm was found in 28 and in 38 out of 88 infants after surgery, respectively. By using multivariate logistic regression about each factor, the use of uncuffed endotracheal tube was the sole exploratory variable predictive of tube tip displacement (OR 0.34, 95% CI 0.10 - 0.93 if ≥5 mm; and OR 0.24, 95% CI 0.08 - 0.75 if ≥2.5 mm displacement; $p = 0.04$ and 0.01, respectively) (Table 3 and Table 4). Each other factor of the age, height, weight gender, operation time, use of the cardiopulmonary bypass and tracheal tube diameter was not statistically significant in the displacement of the ETT tip (Table 3 and Table 4).

4. Discussion

This single-center retrospective cohort study is the first to investigate the incidence and risk factors of ETT displacement during infant cardiac surgery. Open heart surgery might change the position of ETT by traction on the trachea by intrathoracic manipulation and the use of TEE. Our main finding was that proximal displacement of the ETT often occurs after cardiac surgery, especially with the use of uncuffed ETT.

The 2.5 or 5 mm malposition might be evaluated as not very large, however, the tracheal length of newborns and infants is about 3 to 4 cm [5] [6], and the ETT can slip out or enter the bronchi with slight deviations [12]. In our study, there was a case where the tube became shallower up to 24.5 mm. As the safety margin of the tracheal tube placement position is further narrowed, we believe

Table 1. Patients and surgical characteristics.

Variable	Median (IQR)
Age, months	3 (2 - 6)
Height, cm	59 (53.5 - 64.75)
Weight, kg	4.7 (3.6 - 6.2)
Gender, male, n (%)	56 (65.2)
Operation time, min	261 (170 - 350)
Use of CPB, n (%)	68 (77.3)
ETT diameter, mm	3.5 (3 - 4.5)
Cuff available, n (%)	48 (55.8)

Values are presented as n (%) or median (IQR: interquartile range). CPB, cardiopulmonary bypass.

Table 2. Distribution of procedures.

Procedure	n
VSD closure	36
TOF repair	13
PA banding	6
PDA clipping	6
AVSD repair	5
myocardial electrode implantation	4
arterial switch	3
ventricle-pulmonary artery conduit	2
systemic-pulmonary artery shunt	2
TAPVR repair	2
LVAD implantation	2
surgical repair for aortic coarctation	1
interrupted aortic arch repair	1
on pump central shunt	1
pulmonary valve stenosis repair	1
directional cavopulmonary shunt	1
aortic valve commissurotomy	1
pulmonary artery repair	1

VSD: Ventricular Septal Defect; TOF: Tetralogy of Fallot; PA: Pulmonary Artery; PDA: Patent Ductus Arteriosus; AVSD: Atrioventricular Septal Defect; TAPVR: Total Anomalous Pulmonary Venous Return; LVAD: Left Ventricular Assist Device.

Table 3. Odds ratio and 95% CIs for ≥5 mm displacement of tube position in multivariate analysis.

Factors	Adjusted OR (95% CI)	P value
Age	0.96 (0.77 - 1.2)	0.71
Height	0.95 (0.80 - 1.12)	0.51
Weight	1.84 (0.92 - 3.69)	0.08
Gender	0.57 (0.19 - 1.52)	0.24
Operation time	0.99 (0.99 - 1.01)	0.76
Use of CPB	0.82 (0.27 - 2.8)	0.82
Tracheal tube diameter	0.58 (0.11 - 2.13)	0.33
Use of uncuffed tube	0.31 (0.10 - 0.93)	0.04

OR: Odds Ratio. The C-statistics of the multivariate logistic model is 0.67 (95% CI: 0.55 - 0.78).

Table 4. Odds ratio and 95% CIs for ≥2.5 mm displacement of tube position in multivariate analysis.

Factors	Adjusted OR (95% CI)	P value
Age	0.92 (0.73 - 1.17)	0.50
Height	0.95 (0.79 - 1.14)	0.58
Weight	1.53 (0.74 - 3.15)	0.24
Gender	0.78 (0.26 - 2.34)	0.65
Operation time	0.99 (0.99 - 1.01)	0.81
Use of CPB	1.12 (0.33 - 3.78)	0.85
Tracheal tube diameter	0.89 (0.19 - 4.06)	0.88
Use of uncuffed tube	0.24 (0.08 - 0.75)	0.01

OR, Odds Ratio; CI, Confidence Interval; CPB, Cardiopulmonary Bypass. The C-statistic showed good discrimination in the multivariate logistic model (C = 0.70, 95% CI: 0.59 - 0.82).

that sufficient attention should be paid to this significant change [13]. For example, repositioning the patient's head after the ETT has been secured can significantly alter the position of the distal tip of the tube [14] [15]. The head and neck might be slightly flexed or extended in the surgical department or intensive care unit. It might be possible that only slight misalignment cause serious situation; extubation or one-lung ventilation, etc.

The significant differences in misalignment were observed with and without cuffing of the tracheal tube. Those showed that the use of the cuffed tracheal tubes had a relation with tracheal fixation. It might be possible that the cuffing help to fix the tube in the tracheal wall and prevent it for slippage. However, opinions remain disagreeable regarding the presence or absence of endotracheal tube cuffs in children [16] [17]. It should always be considered that excessive cuff pressure causes local edema [18]. In this study, the intracuff volume was not strictly controlled by a cuff pressure gauge, and the cuff was adjusted according to the presence or absence of leaks; thus, the cuff pressure may not have been appropriate enough to fix the depth of the tracheal tube. It might be important to see if the monitoring of cuff pressure may contribute to the fixation of the tube without ischemia and edema. The use of cuffed ETT under monitored cuff pressure might improve safety in pediatric cardiac surgery.

While lung ultrasound [19], fiberoptic bronchoscopy [20] and fluoroscopy [21] may be used to assess ETT placement, many methods have been suggested to ascertain ETT placement; posteroanterior chest radiographs provide unambiguous evidence about the location of the tip. While chest films have not been routinely used in operating rooms in general, those are taken not only just after surgery but also just before surgery to confirm the indwelling position of a central venous catheter at our hospital. As the head and neck were fixed and X-rays were taken in the same posture in this study, each chest radiograph under general anesthesia might be correctly confirmed to perform after the patient has been

properly positioned for the surgical procedure. Moreover, all the chest radiographs were reviewed independently by two anesthesiologists.

There were several limitations to this study. First, due to the retrospective nature of the study and its single-center design with a small sample size nature, future prospective studies should confirm these results. Second, the correct position of the ETT was unclear in 53 cases on the chest radiographs, especially the ones taken after the operation due to the uncertain resolution of the radiograph. All the chest radiographs were independently reviewed by two anesthesiologists. We excluded the cases if the findings of both anesthesiologists were not consistent, though these exclusion criteria might be too stringent. However, this is the result of our desire to find accurate facts in the order of a few millimeters. Third, the performed surgical procedures were not uniform for all cases; hence, the effect on the trachea and intrathoracic structures vary. More useful results might be obtained if the surgical technique is taken into consideration for each factor [7]. In addition, it is necessary to examine the results in more detail, especially around TEE procedures and surgical techniques.

5. Conclusion

The ETT position changed and became proximal displacement after the cardiac surgery. While using a cuffed ETT, there might be a possibility of preventing the misalignment in the endotracheal tube position. Careful consideration is required for perioperative infant cardiac patients.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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