

Original
Contributions



FACTORS ASSOCIATED WITH MISPLACED ENDOTRACHEAL TUBES DURING INTUBATION IN PEDIATRIC PATIENTS

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Abstract—Background: Correct positioning of the endotracheal tube (ETT) during emergent pediatric intubations can be challenging, and incorrect placement may be associated with higher rates of complications. **Objectives:** The aims of this study are to: 1) assess the prevalence of clinically undetected misplaced ETTs after intubation in the pediatric emergency department; 2) identify predictors of ETT misplacement; and 3) evaluate for any association between intubation-related complications and ETT position. **Methods:** In this retrospective cross-sectional study, the primary outcome was rate of unrecognized low or high ETTs detected on confirmatory chest radiographs. The secondary outcome was frequency of complications (i.e., hypoxemia, difficult ventilation, atelectasis, pneumothorax, pneumomediastinum, and aspiration) associated with misplaced ETTs. Multivariable analyses were used to evaluate the associations between patient and procedural characteristics and misplaced ETTs and between ETT position and complications. **Results:** Seventy-seven of 201 (38.3%) intubations performed in the emergency department resulted in clinically unrecognized misplaced ETTs. Of the misplaced tubes, 45 of 77 (58%) were identified as low and 32 (42%) were high. In multivariable analyses, female sex and decreasing age were associated with increased risk of low tube placement (odds ratio for female sex, 2.4 [95% confidence interval, 1.1-5.1]; odds ratio of decreasing age, 1.16 [95% confidence interval, 1.0-1.3]). Low tube misplacement was associated with an increased risk of intubation-related complications compared to both correct and high tube

placement ($p < 0.05$, Chi-square). **Conclusion:** Clinically unrecognized ETT misplacement occurs frequently in the pediatric emergency department, with low placement being most common, particularly in girls and younger children. Measures to improve clinical or radiographic recognition of incorrect tube position should be considered. © 2016 Elsevier Inc. All rights reserved.

Keywords—airway; endotracheal tube; intubation; pediatric

INTRODUCTION

Endotracheal intubation is a technically complex procedure in pediatrics. One important component is the insertion of the endotracheal tube (ETT) to the appropriate depth. Proper placement should locate the distal tip of the ETT between the thoracic inlet and the carina. This can be particularly challenging in children in whom shorter tracheal length increases the risk of misplacement.

Age- and length-based formulas exist to help estimate optimal tube insertion depth, as does a standard set of approaches for confirmation of the ETT, including auscultation, capnography, and chest radiography (CXR). However the clinical signs used to confirm proper placement, such as auscultation of bilateral breath sounds and visualization of equal chest rise, are imprecise (1–5).

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End-tidal carbon dioxide monitoring has proven to be a reliable means of identifying esophageal intubations, but it does not identify tube misplacement within the tracheobronchial tree. Direct visualization with flexible fiberoptic bronchoscopy may be reliable for those with adequate experience, but it is not widely available or used in pediatric emergency departments (EDs). As such, immediately available methods of assessing correct placement can be insufficient.

Up to 25% of adult patients intubated outside of the operating room have misplaced ETTs on CXR (6–9). Pediatric data similarly demonstrate high rates of misplaced ETTs outside the operating room. For example, 30% of intubations in the pediatric ED and 13% of intubations in the pediatric intensive care unit resulted in improper ETT placement (10,11). However, these estimates are extrapolated from studies that were not primarily aimed at evaluating ETT position.

Misplaced ETTs may result in hypoxemia, aspiration, difficult or inadequate ventilation, atelectasis, barotrauma, and pneumothorax. These complications may be poorly tolerated in a critically ill patient, particularly when the misplacement is not recognized on the initial clinical assessment and detection is delayed until a confirmatory CXR is performed. Therefore, efforts to identify the risk factors for unrecognized misplaced ETTs and associated complications are warranted. Recognition of these risk factors can facilitate future targeted interventions to improve the quality of pediatric emergent intubation.

The goals of this study were to evaluate the frequency of misplaced ETTs that were undetected by clinical examination or capnography, to identify risk factors for improper depth of insertion, and to evaluate for any association between intubation-related complications and ETT position.

METHODS

We performed a retrospective study of patients intubated in the ED at a tertiary children's hospital. The ED is a level 1 trauma center with approximately 60,000 visits per year. Cases were identified from an internal quality assurance (QA) database of all patients intubated in the ED. All patients presenting between January 2009 and July 2013 who were intubated in the ED were included; those intubated in the prehospital setting were excluded. The study was approved by the hospital's institutional review board.

Data contained in the QA database included: date of birth, date of intubation, sex, indication for intubation, premedications used, need for cervical spine precautions, known difficult airway, number of attempts, training level of intubator, and type of laryngoscope used. These data

were transferred directly from the QA database to a separate study database and was confirmed for accuracy by the primary investigator (K.M.), who cross-checked it against the electronic medical record (EMR). The primary investigator also reviewed the EMR to provide any missing values and to extract data on additional variables, including time of day the intubation occurred, weight, height, history of previous intubations, number of admissions in the past 12 months, comorbidities, acuity of intubation, ETT size, presence of ETT cuff, method of confirmation, depth of insertion, time of CXR, tube position by CXR, need for readjustment, and occurrence of intubation-related complications. The senior investigator (J.N.) reviewed the data from the QA database and the EMR for 10% ($n = 20$) of the patients and inter-rater agreement was calculated: inter-rater agreement was 86% to 100%, with kappa values ranging from 0.66 to 1.0 on primary and secondary outcomes.

Patients were deemed to have a "known" difficult airway if noted in the physician documentation from the ED visit or in anesthesia records available to the treating physician at the time of intubation. Acuity was defined as "emergent" if such phrasing was included in the physician documentation of the intubation, if a patient's clinical status required calling an "anesthesia STAT" or "airway STAT," or if cardiopulmonary resuscitation was ongoing; the intubation was considered "elective" only if documented as such in the physician note. All other intubations were classified as "urgent." Rapid sequence intubation was defined as the administration of both sedative and neuromuscular blockade in rapid succession. Time of encounter was classified as occurring during regular hours if the intubation occurred on a weekday between 6 AM and 5 PM, because these are the times when the most staff and support are available at the studied institution. Intubations occurring overnight, during the weekend, or on holidays were considered "off hours."

The primary outcome was rate of clinically unrecognized misplaced ETTs identified by portable CXR report. We defined an appropriately placed ETT as one whose tip was distal to the thoracic inlet and proximal to the carina. Misplaced tubes were subcategorized as low placement (i.e., at or below the carina) or high placement (i.e., at or above the thoracic inlet) in order to explore whether these 2 groups were associated with different risk factors and complications. CXRs were manually reviewed by the primary and senior investigators in indeterminate cases of ETT position. We calculated the time from the intubation procedure to the time of postprocedure confirmatory CXR using time stamps extracted from the EMR.

A secondary outcome was the occurrence of intubation-related complications, including hypoxemia, difficult ventilation, atelectasis, pneumothorax, pneumomediastinum, and aspiration. For an event to be classified

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