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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.**

☐ **Keywords—airway; endotracheal tube; intubation; pediatric**

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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

as intubation-related, it had to be: 1) attributed to the procedure in the ED physician's documentation or 2) documented as a new finding in the radiologist's final report of the immediate postintubation CXR in comparison to a preintubation CXR from the same encounter; if no previous CXR was performed, radiographic reports of pulmonary abnormalities were considered intubation-related only if the associated physical examination findings were specifically documented as absent on the preintubation examination.

We calculated the frequency of misplaced ETTs among all intubations as a percentage with 95% confidence intervals (CIs). Univariate analyses were used to compare patients with and without misplaced ETTs on demographic and procedural characteristics. We subcategorized misplaced ETTs as high or low and estimated a multivariable multinomial logistic regression with our primary outcome, ETT misplacement, as the dependent variable and selected patient and procedural features as the independent variables. We decided a priori to include age and sex in the multivariable model based on published data showing relationships between these patient characteristics and intubation performance (2–12,14). In addition, we included any patient or procedural features with a p value of < 0.1 in univariate testing as potential predictors. Odds ratios (ORs) from this multivariable model with accompanying 95% CIs are reported. To compare the proportion of complications across the 3 tube placement groups, we used Chi-square tests. We compared both overall complications and separate comparisons for any complications occurring at a rate of >5%. Bonferonni corrections were used to adjust for multiple comparisons. All tests were 2-tailed, and alpha was set at 0.05.

Our power and sample size estimates are based on a 2-sided 95% CI. Assuming an expected prevalence of misplaced ETTs of 30% in the ED setting, we would require 323 and 144 patients to estimate the prevalence with a level of precision equal to 5% and 7.5%, respectively. Given the expected number of patients to be intubated in the ED over the study period (40–60 patients annually for a period of 5 years), we determined we would have adequate power to estimate the prevalence of misplaced ETTs with at least 6.3% precision.

RESULTS

Two hundred and one patients underwent intubation in the pediatric ED during the study period. Characteristics of the study sample are summarized in Table 1. Our population had a median age of 5 years (interquartile range, 1–10) and was 50% female.

Attempted tracheal intubation resulted in a clinically undetected misplaced ETT in 77 of 201 patients (38% [95% CI, 31–45%]) as identified by CXR. Of these misplaced ETTs, 45 of 77 (58%) were identified as low and 32 (42%) as high. All attempts resulted in eventual successful tracheal intubation; there were no clinically unrecognized esophageal intubations. Providers adjusted tube position in 96% of patients who were reported to have misplaced tubes based on CXR. The median time between intubation and CXR was 19 minutes (interquartile range, 14–24 min). In univariate analyses comparing patients with misplaced and correctly placed ETTs, younger age and lower weight were associated with a higher frequency of a misplaced ETT, specifically low misplacement (Table 1). Neither the indication nor acuity of intubation affected the frequency of ETT misplacement. The occurrence of misplaced ETTs was also not associated with the training level of the proceduralist, the use of videolaryngoscopy, the type of ETT (i.e., cuffed or uncuffed), intubation during off-hours, or the number of attempts before successful tracheal intubation. The documented confirmation method (e.g., the detection of end-tidal carbon dioxide, the auscultation of bilateral breath sounds, or both) was not different for misplaced compared to correctly placed ETTs.

In the multivariate model, female sex (OR, 2.11 [95% CI, 1.02–4.34]) and younger age (OR, 1.18 [95% CI, 1.04–1.35] for each year decrease in age) were associated with an increased risk of an unrecognized low placed tube (Table 2). No patient or procedural factors were associated with an increased risk of high tube placement, although the presence of respiratory and cardiovascular comorbities was associated with a decreased risk of high placement.

Table 3 provides examples of the documentation necessary to classify a complication as intubation-related. Thirty-six of the 39 (92%) of the complications were specifically identified as intubation-related by a clinician or by change in radiographic findings pre- and postprocedure. The proportion of patients with a documented complication during intubation was higher for undetected low tubes (18/45; 40%) compared with correctly placed ETTs (18/124; 15%; $p = 0.001$; Table 4). There was no significant difference in complications between undetected high tubes and correctly placed tubes. Only atelectasis and hypoxemia occurred with a frequency of $\geq$5% in all 3 groups: when comparing the frequency of these complications individually, both occurred at significantly higher frequency among patients with undetected low tubes compared to those with correctly placed ETTs ($p = 0.001$ and $p = 0.011$, respectively).

DISCUSSION

Intubation is a critical and lifesaving procedure performed in the pediatric ED. Successful intubation

Table 1. Demographic and Clinical Characteristics

Demographic Characteristics	Total Sample (n = 201)	Correctly Placed ETT (n = 124)	Misplaced ETT		Omnibus *p* Value
			Low (n = 45)	High (n = 32)	
Age, years (range)	5 (1–10)	5 (1–13)*	2 (1–7)†	6 (2–15)	0.017
Female sex, n (%)	100 (50)	58 (47)	28 (62)	14 (44)	0.157
Average weight, kg (range)	18 (10–34)	18 (11–39)†	13 (6–28)	20 (12–47)	0.029
Clinical features					
No. of comorbid conditions‡ (range)	1 (0–2)	1 (0–3)†	1 (0–2)	0 (0–1)	0.031
Respiratory, n (%)	59 (29)	40 (32)†	16 (36)†	3 (9)	0.015
Cardiovascular, n (%)	22 (11)	15 (12)†	7 (16)†	0 (0)	0.045
Neurologic, n (%)	88 (44)	61 (49)	14 (31)	13 (41)	0.103
Syndromic/delayed, n (%)	56 (28)	39 (31)	10 (22)	7 (22)	0.354
Hemotologic/oncologic, n (%)	21 (10)	16 (13)	3 (7)	2 (6)	0.455
Known difficult airway, n (%)	22 (11)	13 (11)	7 (16)	2 (6)	0.442
Indications for intubation, n (%)					
Respiratory	138 (69)	89 (72)	32 (71)	17 (53)	0.118
Cardiovascular	6 (3)	6 (5)	0 (0)	0 (0)	0.276
Neurologic	117 (58)	71 (57)	24 (53)	22 (69)	0.378
Shock	21 (10)	13 (10)	3 (7)	5 (16)	0.481
Trauma	16 (8)	9 (7)	3 (7)	4 (13)	0.572
Equipment, n (%)					
Type of laryngoscope					0.161
Traditional	66 (34)	36 (30)	20 (45)	10 (31)	
Video	131 (67)	85 (70)	24 (55)	22 (69)	
Type of tube					0.787
Cuffed	4 (2)	2 (2)	1 (3)	1 (4)	
Uncuffed	167 (98)	104 (98)	37 (97)	26 (96)	
Procedural features, n (%)					
Acuity					0.914
Elective	7 (3)	5 (4)	2 (4)	0 (0)	
Urgent	160 (80)	98 (79)	35 (78)	27 (84)	
Emergent	34 (17)	21 (17)	8 (18)	5 (16)	
Physician training level					0.140
Resident	30 (15)	17 (14)	6 (14)	7 (22)	
Fellow	150 (75)	94 (76)	31 (70)	25 (78)	
Attending	19 (10)	12 (10)	7 (16)	0 (0)	
Rapid sequence intubation	114 (66)	71 (65)	26 (72)	17 (61)	0.592
No. of attempts (range)	1 (1–2)	1 (1–2)	1 (1–2)	1 (1–1)	0.135
Time of encounter, n (%)					
Off hours§	137 (69)	84 (68)	33 (73)	20 (63)	0.599
Confirmation method, n (%)					0.901
End-tidal CO_2	18 (10)	11 (10)	4 (11)	3 (12)	
Bilateral breath sounds	13 (7)	8 (7)	4 (11)	1 (4)	
Both	146 (82)	94 (83)	30 (79)	22 (85)	

ETT = endotracheal tube.
* $p < 0.05$ versus low.
† $p < 0.05$ versus high.
‡ Total number of comorbid conditions.
§ Weekdays from 5 PM to 6 AM or weekends.

requires not only insertion of the ETT into the trachea, but also placement of the ETT to the proper depth. Our analysis shows that the ETT depth is incorrect after standard clinical assessment in 38% of patients intubated in a pediatric ED. Female and younger patients are at higher risk of undetected ETT misplacement, specifically a low placed tube. In addition, there is an increased association of adverse events with low tube placement. To our knowledge, this study is the first detailed evaluation of depth of insertion among patients intubated in the ED with analysis of factors and outcomes associated with inappropriate depth of insertion.

Previous studies have revealed significant rates of unrecognized misplaced ETTs, with the incidence varying depending on the setting of the attempted intubation. Data for the pediatric ED setting are derived from 2 studies designed to evaluate the use of rapid sequence intubation in the pediatric ED. These studies of 156 and 114 patients, respectively, reported rates of mainstem intubation of 7% and 30% (10,13). Unrecognized esophageal intubation was uncommon, with only 1 reported case between the 2 studies. Among patients intubated and subsequently transported to a pediatric intensive care unit (PICU), similarly high rates of undetected mainstem intubations have been

Table 2. Multivariable Model Predicting Placement

Predictor, odds ratio (95% CI)	Misplaced Low vs. Correctly Placed (Referent)	Misplaced High vs. Correctly Placed (Referent)
Sex (female)	2.11 (1.02–4.34)	0.94 (0.41–2.15)
Decreasing age (in years)*	1.18 (1.04–1.35)	1.06 (0.96–1.17)
Weight	1.03 (0.99–1.07)	1.03 (0.99–1.05)
No. of comorbidities†	1.30 (0.76–2.23)	0.23 (0.07–0.74)

CI = confidence interval.
* Change in odds associated with a 1-year decrease in age.
† Respiratory and cardiovascular.

documented. In a study of 250 children, 40% of whom were intubated in the pediatric ED before transfer and the remainder of whom were intubated at outside facilities, 16% had mainstem intubations at the time of arrival to the ICU (15). While some of these were detected clinically, 10% of patients who had a postintubation CXR had an unrecognized mainstem intubation. There is not a distinction in these studies if the ETT was thought to be misplaced at the time of intubation or if it may have moved during transport. More recently, another study of 253 patients intubated before transfer from an outside hospital to a tertiary PICU found 13% of patients with mainstem intubations upon arrival (11). Interestingly, in the limited studies describing patients intubated in the PICU, the rates of mainstem bronchial intubation are reported to be much lower, closer to 3% (16,17).

While no studies have specifically evaluated factors associated with tube position, there has been research into factors associated with failure to successfully intubate the trachea. In the pediatric ED setting, both first attempt and initial intubator success have been shown to be higher among adolescent patients than among infants, toddlers, and preschool aged children (13). The level of training of the intubator has also been shown by both Sagarin et al. and Kerrey et al. to affect first attempt success (10,13). However, data suggest that malposition can occur frequently even when performed by experts in airway management: in a study of 257 pediatric patients intubated in the operating room by anesthesiologists, malposition of the ETT occurred in 18% of cases, with an even higher incidence (35%) among patients <1 year of age (12).

Our finding of a higher rate of ETT unrecognized misplacement among females has been reported elsewhere, although not in the pediatric literature. Earlier studies by Brunel et al. and Schwartz et al. found endobronchial intubation to be more common among female adults (2,14). They hypothesized that this was because of the shorter distance between the lips and carina in adult women compared to men. Previous studies of pediatric airways using computed tomography have shown that, while the length of the trachea increases with increasing height, there is no difference between sexes (18,19). However, there have been differences reported in the supraglottic pharyngeal airway length related to sex (20). While this relationship is not consistent in prepubertal and pubertal children, it may suggest potential differences in lip to carina distances between the sexes despite the lack of variation in tracheal length. In addition, recent studies by Brown et al. and Pallin et al. have shown significantly greater first-attempt failure in the ED setting in both adult women and girls, respectively, compared to their male counterparts (21,22). These sex-related differences in intubation performance metrics are of interest and merit further investigation to explore the underlying mechanism.

Our study is novel in that it was designed primarily to evaluate positioning of the ETT within the tracheobronchial tree after initial clinical assessment by auscultation and capnography and to explore the factors associated with unrecognized improper positioning. While previous studies have focused on mainstem intubations, they have not reported on the frequency of ETTs that were placed too high. We found that 16% of patients intubated in the ED had ETTs that were misplaced too high in the trachea. This more inclusive definition explains why we found a higher prevlance of misplaced ETTs than previous studies (10,13,15). In addition, these studies have not explicitly looked at patient or provider characteristics that may contribute to misplaced ETTs. We identified that factors associated with unrecognized misplaced ETTs were patient-specific, namely sex and age. Training level of the proceduralist did not affect the rate of misplacement, although the high proportion of intubations performed by pediatric emergency fellows in our study (>75%) may make comparisons to residents or attendings difficult. Interestingly, the use of videolaryngoscopy, which has become more widely available in pediatric EDs over the past several years, also did not reduce the incidence of ETT misplacement. Although videolaryngoscopy may provide improved glottic visualization and, in some cases, improved intubation success rates, it has not been shown to offer an advantage in recognizing insertion depth (23–26).

Previous studies have reported mainstem intubation as an adverse event, but none have explored clinical complications that may be associated with incorrect ETT placement. We found an association between intubation-related complications and improperly positioned ETTs, with a significantly higher frequency of complications associated with low tube placement. Specifically, we found an increased rate of hypoxemia and atelectasis in patients with undetected low ETTs. While these are not unexpected complications of low tube

Table 3. Documentation to Identify Intubation-Related Complications

Method	Examples				
	Complication	Preintubation Examination	Preintubation CXR	EP Documentation	Postintubation CXR
EP documentation (n = 18)	Hypoxemia and aspiration (no. 138)	"Breath sounds are equal. Symmetric chest wall expansion. Poor inspiratory effort, scattered rhonchi"	None	"Intubation attempted…near-immediate desaturation to the 70s and difficulty rerecruiting with bagging…copious bilious fluids seen pooled in the hypopharynx…concern for possible aspiration"	"Right midlung and left lower lobe opacities. These could be related to aspiration, consolidation, and/or atelectasis"
EP and radiologist documentation (n = 7)	Atelectasis, hypoxemia (no. 192)	"Lungs are clear to auscultation. irregular agonal respirations, RR 28, significant retractions and occasional upper airway stridor/stertor"	None	"Difficulty passing tube through cords…patient was not ventilating and was having desaturations…ETT pulled…patient bagged with desaturation to 20s and poor air entry"; after successful intubation: "decreased aeration on the left hemithorax so ETT pulled back…CXR obtained with likely R mainstem intubation and left hemithorax opacification"	"Right mainstem bronchus intubation with collapse of the left lung"
Radiologist documentation: pre- and post-CXR comparison (n = 9)	Atelectasis (no. 180)	"Coarse breath sounds, no increased work of breathing. Slightly shallow [sic] respiration"	"Pulmonary congestion and mild interstitial edema"	None	"New right upper lobe and left midlung atelectasis"
Radiologist documentation: pre-examination and post-CXR comparison (n = 3)	Atelectasis (no. 73)	"Lungs clear to auscultation"	None	None	"ETT terminates in the right mainstem bronchus…there is resulting hypoinflation of the left lung"

CXR = chest radiograph; ED = emergency department; EP = emergency physician; ETT = endotracheal tube; RR = respiratory rate.

Table 4. Complications of Intubation

Complication	Correctly Placed ETT (n = 124)	Misplaced ETT		Fisher Exact Test Omnibus *p* Value
		Low (n = 45)	High (n = 32)	
Overall	18 (15)*	18 (40)	6 (19)	0.002
Hypoxemia	9 (7)*	10 (22)	2 (6)	0.023
Atelectesis	6 (5)*	11 (24)	4 (13)	0.001
Difficult ventilation	1 (1)	1 (2)	0 (0)	0.621
Pneumothorax	1 (1)	0 (0)	0 (0)	1.00
Pneumomediastinum	0 (0)	0 (0)	0 (0)	N/A
Aspiration	4 (3)	1 (2)	1 (3)	1.00
Other	3 (2)	1 (2)	0 (0)	1.00

ETT = endotracheal tube; N/A = not available.
* Statistically significant vs. low placement group by Fisher exact test after Bonferroni correction for multiple comparisons.

placement, we believe this study is the first to show that these complications occur at a higher frequency within the time between intubation and radiographic assessment of tube placement. We found that these complications also occurred among patients with high tubes, but at rates that did not statistically differ from those with correctly placed tubes. Of greatest concern with a high tube would be the risk of inadvertent extubation. We did not follow the post-ED course for our study population and so cannot report on the frequency of this sequelae compared to properly placed ETTs.

We compared complications associated with unrecognized misplaced ETTs to those associated with ETT that were correctly placed at the end of clinical assessment. This latter group includes ETTs that may have been initially misplaced but were repositioned based on auscultation or capnography. As such, we likely underreport the risk of complications with any misplaced ETT. On the other hand, the time that elapses between intubation and confirmatory CXR is more time for the potential development of sequelae related to misplacement. In addition, adverse events associated with unrecognized misplaced ETTs may be modifiable or minimized with measures to ensure more prompt recognition and adjustment. For example, an increased rate of atelectasis may not be clinically significant in the short-term, but uncorrected it has been shown to progress to important clinical complications, such as prolonged hypoxia or the development of pneumonia (27). For these reasons, we felt that reporting the frequency of adverse events associated with misplaced ETTs that initially go undetected was important.

We did not specifically measure depth of insertion, making it difficult to know if ETT misplacement was related to inadherance to accepted age- or weight-based guidelines or formulaic approaches (e.g., 3 times the tube size), or to lack of precision of these approaches for estimating proper tube depth. However, strategies to minimize misplacement could be used to address each of these potential contributors. To increase adherance to existing guidelines for depth of insertion, premarking the ETT can provide visual cues for depth insertion during the procedure. Alternatively, including a specific assessment of postintubation depth marking as part of an intubation checklist would allow for detection of inadvertent discordance with planned insertion depth before securing the ETT. Concurrently, evaluation of the perfomance of the various approaches for estimating ideal tube depth might help determine if the issue is lack of accuracy of the accepted guidelines or formulae, particularly with changing anthropomorphic patterns in the pediatric population and increasing use of cuffed ETTs. In the interim, efforts to achieve more rapid radiographs, or to use new bedside approaches, such as point-of-care ultrasound, could be valuable to promptly assess appropriate depth of insertion. In our study, we report a median time to confirmatory CXR of 19 minutes. Previous studies have also documented significant delays between intubation and radiographic confirmation. Galicinao et al. reported a 14-minute delay between the time a CXR was ordered and when it was obtained, and Kerrey et al. found it took 8 minutes longer for CXR results to be communicated to the physician in charge compared to the newer method of using bedside ultrasound to assess for correct ETT placement (28,29). Improving time to radiographic assessment or adoption of newer, more quickly assessable confirmation methods might minimize or eliminate some of the potentially time-dependent complications, such as atelectasis.

Limitations

Our study has several limitations. As a retrospective review, some data were missing from the medical record or may have been unavailable to providers at the time of documentation. By reviewing both the QA database and the EMR, we were able to minimize missing data to 4% of collected information overall. In addition, the QA database is a voluntary reporting database and some intubations performed during the study period may have been missed. However, there are internal methodologies to ensure capture of all intubations performed in the ED in the QA database. These include case review of ICU admissions and review of billing and procedural coding information. Another limitation is that we used a radiographic definition to judge proper ETT position. This could be problematic for 2 reasons. First, there is an opportunity for tube movement before being secured, or tip movement resulting from neck flexion or extension between the time of intubation and the time of the radiograph, which in a young child, can be the difference

between proper and improper placement. Second, clinically effective oxygenation and ventilation may have been occurring despite the radiographic finding of a misplaced tube. However, radiographic determination of tube position is standard of care and clearly valued by clinicians, because >95% of providers adjusted the tube position when a radiograph was read as ETT misplacement by the radiologist. An additional limitation is that several of our reported complications (i.e., atelectesis, pneumothorax, and pneumomediastinum) could have been present before intubation. However, we only included complications reported by providers who believed them to be related to the intubation procedure and were confirmed by review of preintubation examination findings and radiographs. In addition, we have no reason to believe there would be a difference in reporting complications by providers based on tube position. Therefore the identified difference in rate between those with misplaced tubes and those with correctly placed tubes should not be affected. Finally, this study was perfomed at a single-site tertiary care facility and the majority of intubations were performed by pediatric emergency medicine fellows, which may limit generalizability.

CONCLUSIONS

Unrecognized misplaced ETTs occur in more than one-third of patients intubated in the pediatric ED despite clinical assessment, with younger and female patients being at higher risk. Other factors, such as the urgency of intubation, level of training of the proceduralist, and the equipment used are not associated with tube misplacement. Tube misplacement is clinically significant, because there is an associated increased risk of complications associated with ETT misplacement, specifically tubes that are placed too low. Prompt radiographic evaluation is essential, particularly for young patients at greatest risk for low misplaced ETTs, in order to minimize resultant adverse events. Further investigation into how to mitigate this risk is warranted.

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ARTICLE SUMMARY

1. Why is this topic important?

Endotracheal intubation with insertion of the endotracheal tube (ETT) to the appropriate depth can be technically challenging in pediatrics, and improper placement may be poorly tolerated in critically ill patients. Little is known about how often patients intubated in the pediatric emergency department (ED) have misplaced ETTs that escape clinical detection.

2. What does this study attempt to show?

This study evaluates how frequently misplaced ETTs escape clinical detection, allowing for identification of risk factors for improper depth of insertion and exploration of associations between tube position and intubation-related complications.

3. What are the key findings?

Clinically undetected misplaced ETTs occur in 38% of patients intubated in the pediatric ED. Female sex and young age are risk factors for low misplacement, which is associated with an increased risk of intubation-related complications.

4. How is patient care impacted?

The high frequency of unrecognized ETT misplacement and the associated increased risk of complications with improper placement argues for measures to improve detection of incorrect positioning, such as prompt radiographic evaluation, particularly for young patients at greatest risk.