INTRODUCTION

Endotracheal intubation remains a standard procedure in the delivery room and the neonatal intensive care unit (NICU). However, the precise positioning of the endotracheal tube (ETT) is essential to reduce the incidence of complications, including atelectasis, barotrauma, pneumothorax, tracheal damage, unplanned extubation or postextubation stridor. The particularly short length of the neonatal trachea with at times less than 3 cm in preterm infants provides an extremely limited range for ETT placement. Not surprisingly, the incidence of ETT malposition after intubation of neonates and children is significant and ranges from 15% to 30%. Previous studies have demonstrated that 30% of intubations in the pediatric emergency department and 13%
of intubations in the pediatric intensive care unit resulted in improper ETT placement.6

Methods to confirm the ETT position like end-tidal carbon dioxide monitoring and ultrasonographic technique can reliably detect esophageal intubation but cannot verify the position of the ETT within the tracheobronchial tree.7,8 Therefore, the current gold standard to confirm the correct ETT position is chest radiography.9 However, radiographic imaging should be limited in neonates because of radiation exposure.10

Several studies have demonstrated the influence of demographic and clinical parameters such as the physician’s experience or the age and weight of the patient on the likelihood to achieve accurate ETT position.11,12 However, these surveys did not evaluate the predictive value of the combination of multiple variables, and neonates, especially preterm infants, were rarely included.

The purpose of this investigation was to evaluate the likelihood of accurate ETT position in neonates and small infants according to demographic and clinical parameters.

2 | METHODS

2.1 | Study design and subjects

This was a prospective single-center study. Our population consisted of term and preterm neonates and small infants who underwent endotracheal intubation either in the delivery room or in the NICU at our tertiary perinatal center between January 2018 and November 2019.

Patients were nasally intubated with an uncuffed endotracheal tube (Vygon) via direct laryngoscopy (Dahlhausen) with a size 0 or 1 Miller blade (Dahlhausen) and a Magill forceps (Sohngen) to guide the tube through the vocal cords. There is an institutional consent in our department that the ideal ETT placement in neonates is a mid-tracheal tip position. An adhesive tape (BSN Medical) was used for nasal ETT fixation. After intubation and ETT fixation, the physician who had performed the intubation completed the first part of a data collecting form prior to the radiographic control. Patient demographics recorded were gender, weight at intubation, and postnatal age, and the presence of malformations. Further information retrieved included acuteness of intubation (elective/urgent/emergency), whether the patient was previously intubated and, if applicable, the last ETT position, experience of the physician (numbers of neonatal intubations performed <10/10-50/50-100/>100), view obtained by laryngoscopy (Cormack-Lehane 1/2/3/4), number of intubation attempts (1/2-3/>3), postintubation auscultation (bilateral equal/not bilaterally equal/uncertain), ETT insertion depth before radiographic imaging, physicians estimation of correctness of ETT position before radiographic imaging (very certain/certain/uncertain/very uncertain). After obtaining the postintubation radiographic imaging of the tube position, the physician completed the last two items of the data collection form evaluation of ETT position via radiographic imaging (accurate/low/high) and adjustment of ETT position (cm).

What is already known about the topic

- Precise positioning of the endotracheal tube (ETT) is essential to reduce the incidence of ventilation-associated complications in neonates. So far, radiographic imaging is the only technique that can reliably confirm accurate ETT position.

What new information this study adds

- Various analyzed demographic and clinical parameters were not reliable to predict correct ETT position in neonates and small infants.
- Male sex was the only variable that significantly correlated with an accurate ETT position.

If more than one physician attempted intubation, the data collecting form was filled in only by the physician who performed the final intubation. Intubation was conducted according to the clinic standard. Emergency intubations in the delivery room were predominantly conducted without preprocedural medication, whereas premedication with midazolam (0.1 mg/kg), remifentanil (1 µg/kg), and rocuronium (0.5 mg/kg) was applied for urgent and elective intubations.

A postintubation chest radiograph was performed in all infants in the course of the clinical routine. Radiographs were taken with the mobile radiograph device Practix 300 (Philips) upgraded to digital by adding computed radiography cassettes(IP Cassette type CC, Fuji). Radiographs were conducted in anterior-posterior position, with the infant’s chest and head placed plane on the cassettes, and with the face in a midline position. Accurate ETT insertion depth was defined as the tip of the ETT positioned in the middle third of the trachea between the clavicles and the carina or approximately on the level of the second thoracic vertebral body.14 The accuracy of the ETT position was evaluated by the physician who performed intubation.

The study protocol was approved by the ethics committee of the local medical chamber of Hamburg.

2.2 | Statistical analysis

Statistical analysis was performed using SPSS Version 26 software (IBM). Data on neonatal demographics were expressed as median and range for continuous variables and as counts and percentages for categorical variables.

Relationships between the accurateness of ETT position and examined categorical variables, as well as among categorical variables, were examined using χ² and Fisher’s exact tests. Results are presented as odds ratios (OR) with 95% confidence interval (CI). Two-tailed P-values <.05 were considered significant. Relationships between independent variables and outcomes were examined by
mixed-effects logistic regression (SPSS routine GENLINMIXED) to account for cluster effects, considering fixed effects of the respective independent variables and random intercepts for individual patients.

3 | RESULTS

3.1 | Demographic characteristics

During the observation period, 168 nasal intubations conducted in 139 patients were included. Not all endotracheal intubations performed at our NICU during the study period were included (ie exclusion of intubate-surfactant-extubate (INSURE) cases in the delivery room, in whom no radiographic imaging for verification of ETT position was obtained). The median weight at intubation was 1318 g (range: 390-5000), and the median postnatal age was 0 days (range: 0-187).

An accurate tube position was attained in 71.4% of the intubations. The ETT was high in 8.3% and low in 20.2%, and in the mainstem in 3% of the cases. ETT adjustment was ≤5 mm in 83% of inaccurate placements without significant differences between the various birth weight groups (Figure 1). No esophageal intubation was detected by radiographic imaging.

The influence of demographic patient and intubation characteristics on ETT tip position accuracy is summarized in Table 1. Bivariate analysis identified male gender as the only clinical variable that significantly correlated with a precise ETT position (OR 2.5; 95% CI: 1.3, 5.0; P = .010). Further analysis revealed several associations between the different parameters. Physicians with a higher level of experience (>50 intubations) were more likely to be "very certain" compared to less experienced colleagues (OR 3.8; 95% CI: 1.9, 7.8; P < .001). The number of attempts needed for intubation was significantly associated with the view with 43.2% requiring only one attempt at CL 1 (Cormack and Lehane 1) vs 16.0% at CL 2-4 (OR 4.0; 95% CI: 1.7, 9.3; P < .001). Moreover, a better view of the glottis also led to a more frequent indication of being "very certain" regarding a precise ETT position (OR 3.2; 95% CI: 1.7, 6.5; P < .001). Also, CL1 visibility was significantly more often attained in neonates >1500 g compared to <1500 g (OR 3.0; 95% CI: 1.5, 5.7; P < .001).

4 | DISCUSSION

While several studies have investigated formula to calculate accurate ETT depth and imaging techniques to verify the ETT position, there has been little research aiming to identify parameters that correlate with a precise ETT position in neonates. In this prospective study, an accurate tube position was attained in 71.4% of the intubations. This observation is consistent with other studies reporting an incidence of ETT malposition among patients <1 year of 35%.7,15 As expected, experienced physicians were more likely to intubate neonates <1500 g compared to less experienced colleagues (OR 4.1; 95% CI: 2.0, 8.2; P < .001). However, even when adjusted for the weight of the infant, intubation experience remained non-correlated with the accurate ETT position, which is consistent with previous studies demonstrating that training of the proceduralist is not associated with tube misplacement.12 Nevertheless, physicians with a lower level of experience (<50 intubations) were less likely to be "very certain" regarding the estimation of precise ETT position compared to more experienced colleagues (OR 3.8; 95% CI: 1.9, 7.8; P < .001). Consistent with previous studies, the acuteness of intubation was not associated with an accurate ETT position.12

![FIGURE 1](Endotracheal tube position according to birth weight)
Surprisingly, in previously intubated patients, knowledge of the previous tube location did not influence the precision of the present ETT position. This finding might be explained by the partially significant growth of the children between two intubations. Among the 29 cases of reintubation in this study, the average evolution of age and weight between two events of intubation was 12 days and 162 g (15%), respectively.

Unilateral breath sounds were observed in eight neonates after intubation. Among these, three children presented with a diaphragmatic hernia, one with pulmonary hypoplasia, two with pneumothorax, and one with a deep ETT position. On the other hand, in the five patients with right mainstem intubation in this study, bilaterally equal auscultation of breath sounds was reported in four patients and uncertain auscultation in one neonate. These cases confirm that bilateral breath sounds auscultation as a criterion for accurate ETT position is not only false-negative under certain circumstances but is also unsuitable for detecting high ETT position and does not exclude mainstem intubation.16

Several formulae have been proposed to achieve accurate ETT placement.4,17,18 However, the incidence of malposition with most methods remains 15% to 30%.4,16 This conforms with our study, where the application of the “7-8-9 rule”17 did not increase the likelihood of an accurate ETT position. This fact is most likely because one single formula cannot account for the wide range of weight categories and because standardized formulas do not factor for individual variations intracheal length and facial characteristics. In addition, inaccurate estimation of the neonate’s weight in the delivery room can lead to misleading calculations.

Foglia et al19 found that video laryngoscope and muscle relaxation were independently associated with reduced odds of adverse tracheal intubation-associated events in a cohort of 2607 intubations in neonates. In our study, we did not evaluate the use of a...
video laryngoscope. However, one of the significant strengths of this technique is the potential to improve vocal cord view.20 Yet, good visibility did not prove to correlate with precise ETT depth in our analysis. Similarly, we did not explicitly investigate the correlation of the application of muscle relaxation with accurate ETT placement. However, in clinical routine, emergency intubations were performed without sedation medication and muscle relaxation, whereas elective intubations were conducted after application of midazolam, remifentanil, and rocuronium. And, as stated above, we detected no difference between the two groups.

Of the 10 analyzed factors, male sex was the only variable that significantly correlated with the accurate ETT position (OR 2.5; 95% CI: 1.3, 5.0; P = .010). Among male patients, the ETT position was high in 6.2% and low in 14.4% of the cases, whereas in female patients, ETT misplacement was 12.7% and 26.8%, respectively. This surprising correlation is in line with a study that analyzed risk factors associated with misplaced ETT in 201 children aged from 1 to 10 years and identified female sex as a risk factor for low misplacement.12 The shorter distance between lips and carina in women compared to men was hypothesized to be the reason for more common endobronchial intubation among female adults in earlier studies.21,22 But previous studies of pediatric airways using computed tomography have revealed no difference in the length of the trachea between boys and girls of equal height.23 Thus, these sex-related differences in neonates and children merit further investigation to explore the underlying mechanism.

In conclusion, this study substantiates the inalienability of postintubation imaging for the verification of ETT placement in neonates and small infants. To diminish ionizing radiation applied by radiographic imaging, several studies have evaluated the diagnostic value of ultrasonography for the assessment of endotracheal tube placement both in adults and in children.24 However, although bedside ultrasonography can accurately distinguish esophageal from tracheal intubation, it provides limited ability to verify the accurate depth of ETT insertion.7,25

There were several limitations to our study. This study was a single-center analysis, intubation procedure, and definition of appropriate ETT position may differ elsewhere. We did not report end-tidal carbon dioxide monitoring as this method has proven high sensitivity and specificity of detecting esophageal intubations, but it is incapable of identifying tube misplacement within the tracheobronchial tree.8 ETT position might have unintentionally been altered during fixation prior to radiographic control; this was observed in two cases.

5 | CONCLUSION

Analyzed demographic and clinical parameters such as the size of the infant, acuteness of intubation, knowledge of previous ETT position, and experience of the physician demonstrated no correlation with an accurate ETT position and are therefore unsuitable for the estimation of an accurate ETT position in neonates. These findings emphasize the indispensability of postintubation imaging in neonates and small infants.

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CONFLICT OF INTEREST
No conflict of interest.

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