

Comparison of clinical methods to diagnose pediatric endobronchial intubation—A randomized controlled trial

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Abstract

Background and Aims: Diagnosing accurate placement of the tip of the endotracheal tube is crucial in pediatric practice. This study was conducted to find out the efficacy of five clinical methods to ascertain the tube position by a resident anesthesiologist.

Material and Methods: This was a randomized crossover study conducted in a research institute. Fifty pediatric patients were enrolled. All patients were randomly allocated to tracheal (group T) or bronchial group (group B). The five clinical methods which were evaluated include the auscultation, observation of chest movements, bag compliance, tube depth, and capnography. In group T, the tube was placed in the trachea and later positioned in bronchus (assisted by fiberoptic bronchoscopy). The vice versa was done in group B. In each position, a single test followed by all tests was performed and after the change of position, the same single test followed by all tests was performed. Correct and incorrect diagnoses by tests in detecting tube positions were made and their sensitivity and odds ratio were estimated.

Results: The tube depth and combination of all tests detected endobronchial intubation with a sensitivity of 88% and 97%, respectively, which is more than that of auscultation (70%) and observation (55%). Evaluation of the difference in agreement level of tube depth to detect tube-position showed the odds ratio of 2.28 (0.17–30.95) for detecting endobronchial intubation.

Conclusion: We observed that the tube-depth was better than the other individual tests in diagnosing endobronchial intubation in pediatric patients. However, its efficacy is lesser than that of performing all clinical tests together.

Keywords: Endobronchial intubation, intratracheal intubation, pediatric anesthesia

Introduction

Endotracheal intubation is a common procedure performed by an anesthesiologist. Correct placement of the tip of the endotracheal tube (ETT) is essential to avoid complications especially in pediatric anesthesia. The American Society of Anesthesiologists (ASA) Closed Claim analysis showed that the incidence of endobronchial intubation is higher in the pediatric population (4%) than in adults (2%).^[1] Even in the hands of an experienced anesthesiologist, the undiagnosed endobronchial intubation would result in

devastating complications such as hypoxemia, atelectasis, pneumothorax, and pulmonary edema.^[2-4] Although the ideal method to rule out the endobronchial intubation is fiberoptic bronchoscopy (FOB), it is not feasible in routine practice.

Several simple bedside clinical methods, as well as advanced diagnostic techniques like pleural ultrasound^[5] to rule out endobronchial intubation, have been reviewed in the literature. But, the literature lacks evidence regarding the efficacy of various clinical methods. Dronen *et al.* showed that even after employing many available clinical methods the incidence of endobronchial intubation was 25%.^[6] Hence,

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Access this article online	
Quick Response Code:	Website: www.joacp.org
	DOI: 10.4103/joacp.JOACP_272_19

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How to cite this article: Selvaraj S, Elakkumanan LB, Balachander H. Comparison of clinical methods to diagnose pediatric endobronchial intubation—A randomized controlled trial. *J Anaesthesiol Clin Pharmacol* 2021;37:430-5.

Submitted: 17-Aug-2019 Revised: 11-Dec-2019

Accepted: 24-Feb-2020 Published: 12-Oct-2021

this study has been designed to find out the effectiveness of various clinical methods to diagnose endobronchial intubation in the Indian pediatric population. The primary aim was to evaluate the efficacy of chest auscultation, observation of chest expansion, capnography changes, depth of insertion and, compliance of bag in diagnosing endobronchial intubation. The secondary aim was to evaluate the efficacy of the combination of all tests in diagnosing endobronchial intubation.

Material and Methods

This randomized controlled study was conducted in a tertiary institute after obtaining approval by the institutional research and ethics committee. Patients who underwent elective surgeries under general anesthesia with endotracheal intubation were enrolled for the study. Fifty ASA 1 and 2 patients of age 3 to 12 years were included in the study. Patients who had risk factors for gastric aspiration anticipated airway difficulties, and known airway abnormalities were excluded from the study.

Written informed consent was obtained from the parents/guardian. After preoperative evaluation, all patients were instructed to be nil per oral (6 h for solids and 2 h for clear liquids) and premedicated with midazolam 0.5 mg/kg orally 30 min before surgery. In the operating room, baseline heart rate, blood pressure, and peripheral oxygen saturation were noted.

All patients were then preoxygenated with 100% oxygen until the end-tidal oxygen was >0.9 . General anesthesia was induced by either the intravenous route (fentanyl and thiopentone) or inhalational route (sevoflurane). Muscle paralysis was achieved with atracurium. Then, ETT (cuffed or uncuffed from the same company) of appropriate size decided by attending anesthesiologist was inserted. Anesthesia was maintained with isoflurane in oxygen adjusted to maintain heart rate and blood pressure within 20% of the baseline.

After tracheal intubation, patients were randomized to either tracheal or bronchial group by computer-generated randomization number list. Allocation concealment was done by a serially numbered sealed opaque envelope which had instructions to both consultant and the resident. The consultant received instruction on whether the patient was in group T or group B and the resident was instructed regarding the first test to be performed.

The resident was given 30 s to perform the first test (among tests A to E) and 90 s for performing all tests (tests A to E). The patient and the monitors were covered appropriately to facilitate the blinding. In test A (auscultation of chest), both the patient and monitor were covered in such a way that only

the consultant could see the monitor. In test B (observation of equal chest expansion), only the monitor was covered and the patient's chest was exposed. In test C (Bag compliance) and test D (ETT length), both the patient and monitor were covered in such a way that only the consultant could see the monitor. In test E (capnography), the resident was allowed to see capnography in the monitor while the rest were covered for blinding.

In the group T, ETT was fixed 3–4 tracheal rings above the carina with the help of flexible fiberoptic laryngoscope by the consultant and the resident (R1) was asked to perform the test (among tests A to E) according to randomization followed by all tests (tests A to E) [Figure 1]. Then, the ETT was advanced into the right main bronchus under the fiberoptic guidance. Now, another resident (R2) who was blinded to ETT position and previous resident's (R1) result was asked to perform the same test (among tests A to E) followed by all tests (tests A to E). Later, at the end of the study, the ETT was positioned 3–4 tracheal rings above the carina. In group B, the ETT was positioned initially in the right main bronchus and later 3–4 tracheal rings above the carina by the consultant. The residents performed the tests similar to the group T. The residents were asked to participate in this study depending upon their availability and should have completed at least 1 year of residency. The R1 and R2 residents were always different to ensure avoiding the bias, whereas the residents (R1 or R2) for different patients could be different.

In the case of bradycardia, it was treated with an intravenous bolus of atropine. In the case of desaturation ($SPO_2 < 95\%$) at any point in time, the ETT was repositioned in the trachea and ventilated with 100% oxygen. This was noted and the further study procedure was abandoned. After the study period, all patients were monitored for any possible complications. The anesthesia was maintained by the attending anesthesiologist.

All patients were continuously monitored with pulse oximetry, electrocardiogram, heart rate, and blood pressure (every 2 min). The demographic parameters such as age, sex, weight, and height were noted. The responses given by residents (R1 and R2) after performing the first test (test 1) and all test (tests A to E) was noted.

The sample size (50 patients) was based on the duration of pediatric anesthesia postings of resident and consultant, no of patients requiring ETT intubation in 3–12 years and the availability of flexible FOB in our hospital. We had used the data from the previous year to estimate the sample size. The sensitivity of each test was calculated with a 95% confidence interval using SPSS version 21.0. Correct and incorrect diagnoses were calculated as proportions.

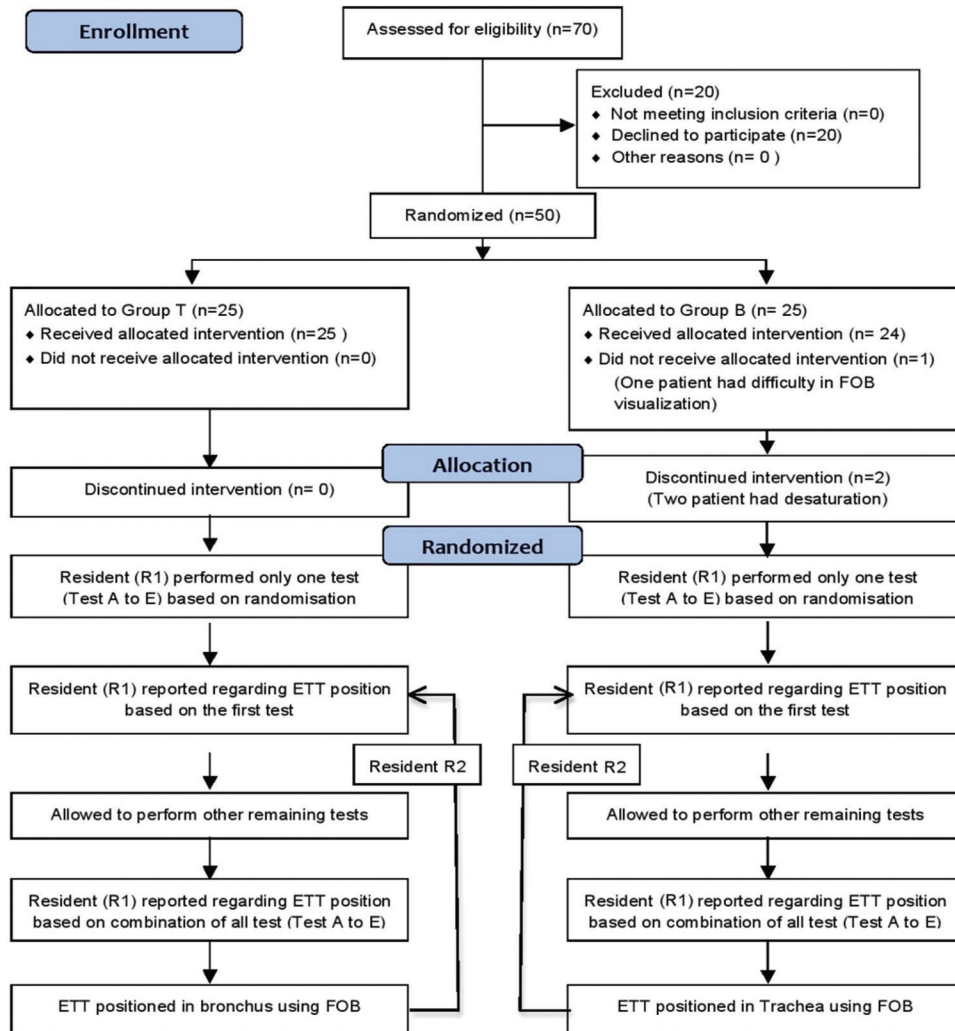


Figure 1: CONSORT flow diagram

Demographic parameters (age, weight, height, or length) were expressed as mean \pm SD. Descriptive and inferential statistical analysis was carried out in the present study. Results on continuous measurements were presented as mean \pm SD. Significance was assessed at a 5% level of significance. It was assumed that the dependent variables were normally distributed and samples drawn from the population were random. Chi-square/Fisher's exact test has been used to find the significance of study parameters on the categorical scale between two or more groups. Diagnostic statistics such as sensitivity and odds ratio (OR) was also computed

Results

70 patients were enrolled and 20 patients were not willing to participate in the study. Only 50 patients were randomized into two groups. After allocation into group B, three patients (two patients had desaturation and poor visualization

of FOB was present in one patient) were excluded from further study. Hence, 47 patients had completed the study and were included in the final analysis. The demographic parameters are shown in the table [Table 1].

Sensitivity to diagnose endobronchial intubation was highest when all clinical tests were performed in combination (97%) than when the tests were performed individually. Among the individual tests performed, ETT depth (test D) had the highest sensitivity (88%). The compliance of bag (test C) had a sensitivity of 40% which was significantly less when compared to all the other tests. The sensitivity of the two commonly performed tests such as auscultation (test A) and observation (test B) was found to be 70% and 55%, respectively. Whereas, the capnography (test E), when performed alone, had a sensitivity of 50%. In one patient, the combination of all clinical tests had failed to diagnose the endobronchial intubation [Table 2]. The sensitivity for the combination of all tests was similar to detect both tracheal and bronchial position (97%).

The OR of diagnosing endobronchial intubation obtained by comparing with the outcomes of the same test in diagnosing the tracheal position showed us that OR was high for the depth of ETT and a combination of all tests. While the OR for all other individual tests is less.

Sensitivity in diagnosing endotracheal position of the ETT was highest with a combination of all three tests (97%, OR: 0.3263), and lowest for capnography (66%, OR: 0.0977). Auscultation, when performed alone, had a sensitivity of 80% with OR of 0.161. Both ETT depth (test D) and observation (test B) were equally sensitive in detecting the tracheal position of ETT (77%, OR: 0.157). The bag compliance (test C) had a sensitivity of 70% with OR of 0.102 in detecting the tracheal position of ETT. In one patient, all tests had failed to detect the tracheal position of ETT [Table 2].

In 15 out of 18 observations, while performing the ETT depth test, the overall ETT position was diagnosed correctly with a sensitivity of 83% and OR of 0.1197 ($P = 0.022$). While auscultation detected ETT position correctly in 15 out of 20 observations with a sensitivity of 75% and OR of 0.069 ($P = 0.047$). In detecting ETT position observation (test B), sensitivity and OR were 66% and 0.052 ($P = 0.019$), respectively. While the evaluation of capnography changes and bag compliance showed the sensitivity to be 61% and 55%, respectively. If all tests were performed in combination in 94 observations only two observations were incorrect resulting in a sensitivity of 97% with OR of 0.196 in detecting ETT position correctly ($P = 0.497$).

Table 1: Demographic parameters

Parameter	Mean ± SD
Age (year)	7.54 ± 2.67
Weight (kg)	18.18 ± 4.67
Height (cm)	111.70 ± 12.54

Table 2: Various tests for bronchial position correct detection, incorrect detection, sensitivity and odds ratio

Test	Bronchial Position of ETT			Tracheal position of ETT			Overall position		
	Correct/ incorrect	#Sensitivity (%)	#Odds ratio	Correct/ incorrect	#Sensitivity (%)	#Odds ratio	Correct detection/ incorrect detection (bronchial position)	Correct detection/ incorrect detection (tracheal position)	Odds ratio
Auscultation (n=10)	7/3	70 (34-93)	0.102	8/2	80 (44-97)	0.161	7/3	8/2	0.58
Observation (n=9)	5/4	55 (21-86)	0.064	7/2	77 (39-97)	0.157	5/4	7/2	0.43
Compliance of bag (n=10)	4/6	40 (12-73)	0.033	7/3	70 (34-93)	0.102	4/6	7/3	0.28
Tube depth (n=9)	8/1	88 (51-99)	0.298	7/2	77 (39-97)	0.157	8/1	7/2	2.28
Capnography (n=9)	5/4	55 (21-86)	0.064	6/3	66 (29-92)	0.097	5/4	6/3	0.63
Combination of all tests (n=47)	46/1	97 (88-99)	0.326	46/1	97 (88-99)	0.326	46/1	46/1	1.00

n: total number of observations. #Sensitivity and odds ratio are calculated using Fisher's exact test with 95% CI

Discussion

The accurate placement of an ETT at the mid-tracheal position in the pediatric patient is always challenging as the tracheal length varies between 5 and 9 cm.^[7] In our study, we found the sensitivity of ETT depth in detecting endobronchial intubation was highest (88%) than the other individual tests, which is similar to a previous study (88%).^[8]

In detecting the overall ETT position (tracheal or bronchial), the ETT depth served as a better predictor than the other individual tests with a sensitivity of 83% which is comparable to previous studies (75–89%).^[7,9-11] We had also evaluated the difference in agreement level of ETT depth to detect tracheal and bronchial position which showed the OR was 2.28 for detecting endobronchial intubation.

In the literature, the sensitivity of auscultation in detecting overall ETT position was found to be 92.5%, while in detecting endobronchial intubation it was found to be 65%.^[8,12] The reduced sensitivity for diagnosing endobronchial intubation could be because of the varying length of ETT in the bronchus (2.6–3.2 cm).^[13,14] Additionally, the bronchial diameter also varies, resulting in a leak around the ETT which reduces the sensitivity of auscultation.^[15] Sitzwohl *et al.* had shown that the failure rate would be as high as 55% with inexperienced anesthetists.^[8] All these reasons could have resulted in lower sensitivity of auscultation in diagnosing the tracheal position (80%) and the bronchial position (70%).

Observation of chest movement had a sensitivity of 55% and 77% in detecting endobronchial intubation and tracheal position, respectively. This low accuracy could be due to the leak around the proximal end of ETT. After an extensive literature search, we could not find any trial to suggest the length of the ETT that has to be kept in the bronchus for producing apparent changes in chest expansion.

It had been documented that the airway pressure consistently rises with endobronchial intubation by $26 \pm 17\%$.^[16] Mahajan *et al.* have shown that compliance falls early than the airway pressure changes by spirometry during endobronchial intubation.^[12] The changes in the compliance could be appreciated during manual ventilation with a reservoir bag, hence, this test was included in our study. But, extensive literature search did not fetch any comparison or correlation between airway pressure changes and bag compliance. There could also be an observer bias in interpreting the changes in bag compliance. Since the introduction of advanced anesthesia workstations in our day-to-day practice, the manual ventilation of patients has come down to a greater extent. Sitzwohl *et al.* had shown that experience makes an impact in clinical test interpretation which was quantified and found failure rates as high as 55% for inexperienced residents.^[8] Perhaps the bag compliance could have been served as a better indicator for the experienced anesthesiologist. In our study also all the participants were residents with 1 year of anesthesia experience which could be one of the causes for least sensitivity (40% for endobronchial and 45% for the tracheal position) of the test.

The accuracy of capnography in detecting ETT position ranged from 55% to 66% in our study. Similar to other tests, the leak around the ETT could have resulted in decreased sensitivity of capnography. The combination of all tests was found to have the highest sensitivity in diagnosing endobronchial intubation (97%). But, in two patients in whom even after performing a combination of all tests, the actual ETT position could not be diagnosed. In the first patient, the endobronchial position of ETT could not be diagnosed. As this patient was in the bronchial group, we had to perform endobronchial intubation initially. At the end of the study after placing the ETT in the trachea, we had observed a significant leak around the ETT that necessitated the change of the ETT. Even though the ETT was appropriate with the age, it was relatively much smaller than the tracheal lumen leading to the leak. This interindividual variation in tracheal and bronchial diameter has been observed by Chunder *et al.* who concluded that the difference exists in the mean diameter of trachea and bronchus of the same age group in the Indian population.^[15] In the second patient, the combination of all tests failed to detect the tracheal position of ETT for which we could not reason out any logical explanation.

The study was conducted inside the operating room in a calm environment under a controlled setting in spite of that there was a considerable failure by individual clinical methods to diagnose endobronchial intubation. So, in an emergency scenario like cardiac arrest where the clinician's mind would

be preoccupied with the patient's problem, their performance might be affected resulting in more unreliable results after performing the individual tests. Hence, it is always better to perform all clinical tests to diagnose rule out endobronchial intubation rather than simply relying upon one test.

All the observers were residents who had more experience with adults than the pediatric endotracheal intubation. While comparing adult and pediatric endobronchial intubation, only a small portion of ETT will be visible outside the angle of mouth in pediatric patients due to the shorter pediatric ETT. This observer bias could have resulted in a higher sensitivity of ETT depth in diagnosing endobronchial intubation.

Another limitation is that the area to be auscultated was also not standardized in our study. Also, this result may not correlate with a different population. There are various formulas available to predict the appropriate ETT length which utilizes various parameters like age, weight, height, foot length, and incisor to manubriosternal joint distance. Because of the wide variation in these parameters, our study results may not be helpful in other populations.

The order of the performance of the combination of all tests was not randomized. Hence, the possibility of one test influencing the other tests could not be ruled out. A possible limitation of the study was that we did not standardize the formula for ETT length determination. As the sample size was smaller in our study, future trials could be planned with more sample size.

The study was designed in such a way clinical tests were performed after keeping the ETT in either bronchial or tracheal position. This was designed because of the fact the clinician performs these tests with the ETT in one position after intubation to rule out endobronchial intubation. But tests such as auscultation, airway pressure, bag compliance, and capnography could have had higher sensitivity if they were performed to compare the tracheal and bronchial position.

Conclusion

We have noted that the combination of all clinical tests is superior in diagnosing pediatric endobronchial intubation than the individual tests alone. We have also observed that the ETT length was better among the individual tests in diagnosing pediatric endobronchial intubation. We recommend that all anesthesiologists should perform an assessment of the depth of ETT, observation of chest movement, bilateral auscultation of the chest, capnography, and bag compliance in combination to rule out the endobronchial intubation in pediatric patients.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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