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Detection of Endotracheal Intubation by Insertion Depth of Endotracheal Tube, Bilateral Chest Auscultation, and Observation of Bilateral Chest Movement during Emergency Intubation: Prospective Observational Study

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Abstract

Introduction: Endotracheal intubation, a routine lifesaving procedure in Emergency Medicine practice, can cause serious life threat to the intubated patient if the position of the tube is not confirmed appropriately. We did a prospective observational study on 289 patients to determine whether a bedside method of correct placement of the endotracheal tube can be obtained. *Methodology:* The operators recorded their findings of insertion depth of endotracheal tube, chest auscultation, observation of symmetrical chest movement and finally their impression regarding position of endotracheal tube in a sequentially numbered form. The principal investigator compared the findings of the operator, with the post intubation chest radiograph, which was taken as the gold standard. *Results:* We found a very high sensitivity of 99%, 100% and 100% for chest auscultation, chest movement and combination of all three methods (chest auscultation, chest movement and depth of the E.T. tube). However, the specificity was low at 49% for chest auscultation, 40% in chest movement and 51 % for combination of three methods. We calculated that, in subjects of Indian ethnicity, the safe depth of E.T. tube was 22cm in male and 21cm in females ($p<0.001$) to reduce the chances of endobronchial intubation. *Conclusion:* We conclude that a single test is not confirmatory to ascertain tube position and it is better to combine all findings together to give a better sensitivity and specificity. A 21/22 cm (female vs. male) insertion depth of endotracheal tube is suitable for Indian ethnic groups.

Keywords: Endotracheal Intubation; Depth of ET Tube; Placement of Tube; Tracheal Tube.

Introduction

Endotracheal intubation is a routine emergency procedure in Emergency Medicine practice. The procedure is performed by many clinicians with different levels of experience in airway management. Although Emergency Endotracheal intubation may be a life saving procedure, proper positioning of endotracheal tube in the trachea is necessary for adequate airway patency. Malpositioning of endotracheal tube causes a serious life threat to the intubated patient. Deep endotracheal tube insertion can result in irritation of the carina, excess coughing, hyperventilation, mainstem bronchus intubation, atelectasis, hypoxemia, barotrauma, hemodynamic instability, and rarely, tube thoracostomy for presumed pneumothorax (Owen et al 1987). Shallow insertion depth increases the risk of extubation, aspiration, or pressure from the cuff on the cords or subglottic area, which may result in subglottic stenosis. Accidental right mainstem bronchus intubation seen in as many as 10% of patient, is associated with left sided atelectasis, right sided tension pneumothorax and decreased survival (Zwillich et al 1974).

The American Heart Association (JAMA1992) and the European Resuscitation Council (Nolan et al 2005) recommend bilateral auscultation of the chest to

diagnose and prevent endobronchial intubation. Brunel et al (1989), however, found that 60% of endobronchial intubations in patients in intensive care occurred despite equal breath sounds on examination. Even continuous auscultation could not detect endobronchial intubation in 79 cases reported in the Australian Incident Monitoring Study done by Klepper et al (1993).

Several techniques have been described to confirm the depth of endotracheal tube placement prior to radiological evaluation by post procedure chest radiograph (CXR). These include tube depth, auscultation of the lungs, and observation of symmetrical chest movements, cuff palpation in suprasternal notch, the Chula formula, fibre optic bronchoscopy, etc. However, all these methods have their own limitations and till date, there is no convincing method to determine or predict the ideal depth of placement of endotracheal tubes prior to radiological evaluation.

We compared the sensitivity and specificity of different bedside methods of verifying correct placement of endotracheal tube that are, bilateral auscultation of the chest, observation of symmetrical chest rise, use of the cm scale printed on the tube for tube depth and a combination of all three methods. We further hypothesised that sensitivity and specificity of these clinical methods would increase as with an operator of experience more than 6 years.

Methods

The study included 298 adult participants above 18 years of age who were emergently intubated by direct laryngoscopy in departments of Emergency and intensive unit at Peerless Hospital, Kolkata. The duration of the study was of 1 year and 6 months, from July 2015 to December 2016. The participants were added in our study only after they met our inclusion and exclusion criteria. The inclusion criteria were: (i) adults (age >18 years) and, (ii) no visible and / or radiographic deformity of trachea, vertebral column, mandible, sternum & clavicle. The exclusion criteria were, (i) Age < 18 years,(ii) Patients having congenital or acquired abnormality of vertebral column, mandible, sternum & clavicle, (iii) High risk for aspiration of gastric contents, (iv) Chest radiograph, in which position of the carina could not be determined, (v)Post intubation chest radiograph, in which the bottom line of mandible is not identified.

Design

For the purpose of the study patients undergoing emergency intubations during the study period was recruited for the study after taking proper consent. After intubation by using conventional direct laryngoscopy with a standard endotracheal tube the resident / registrar doctor or the consultant or PGT / PDT or MO / RMO, who were present were asked to record their findings of insertion depth of endotracheal tubes in cm, bilateral auscultation of the chest and their observation of bilateral chest movements in a sequentially numbered form. These forms were kept in the Emergency Department and ITU / ICU complex in sealed opaque numbered envelopes which were completed only after the procedure. Each envelope contained two instructions: where the endotracheal tube had to be placed in relation to the carina (that is, endobronchially or endotracheally), and which clinical test(s) had to be used by the two study doctors to verify the position of the tube. Each doctor or operator filled up the forms without consulting each other and the forms were then retained in the envelope and resealed.

We have taken post procedure Chest radiograph (CXR) as gold standard to determine the ideal insertion depth of endotracheal tubes. Goodman et al (1976) found that the carina overlay T5, T6 or T7 on portable radiographs and recommended that ideal positioning of the endotracheal tube tip to be at the T2-T4 level with the neck in the neutral position. They also evaluated the position of mandible relative to the vertebral bodies on radiograph and found that mandible projected over C5 or C6 when neck is in neutral position and at the T1 level or below when neck is in flexion position and above C3-C4 when neck is in extension position. This criteria described by Goodman et al (1976) was followed for confirming endotracheal tube depth by measuring the distance of endotracheal tube tip from the carina with neck flexion, extension and neutral position.

The principal investigator collected these envelopes, compared the tube position with the post intubation Chest X–rays, and entered the raw data in the excel sheet which then was analyzed by a medical statistician. From the results of these analyses the lead investigator had concluded the outcome of the study.

Statistical Analysis

289 adult patient's above 18 years of age were included in our study and 59 datas from patients below 18 years age group, patients whose post intubation Chest X-rays could not be interfered were

excluded from the study.

The data were entered into XL file and were imported into Statistical Software package (SPSS ver. 19.0). Data were validated through logical checks and finally, this software was used for statistical analysis. First of all, based on detection of post intubation by CXR-PA after emergency intubation by operators (doctors), 'endotracheal position' were considered as "True Positive' and 'endobronchial position & others' were treated as "Ture Negative". We tried to evaluate the diagnostic performance of operator's 3 different clinical tests individually or in combination. The operators' performances were evaluated in 3 options for diagnostic purpose of endotracheal position:

i) Operator's opinion by combining 3 clinical tests

ii) Operator's opinion by bilateral auscultation

iii) Operator's opinion by bilateral chest movement

We calculated sensitivity, specificity, positive predicted value (PPV) and negative predicted value (NPV) were calculated for comparison of 3 different options for diagnostic purpose of endotracheal position. Average depth of intubation for men and women were compared for statistical significant difference by using Students' t-test for endotracheal, endobronchial and others position separately. We also tried to evaluate the diagnostic performance of the operators based on their designations (they were classified into 2 categories (PGT / PDT vs. Consultant / MO / RMO / Registrar / Resident) and length of year experience (6 months to 5 years Vs. >=6 years) for 3 different options.

Results

We have observed that most of the operators belong from an age group of 26-35 years (83.2%, n=248), followed by 36-50 years (14.1%, n=42), and least (2.7%, n=8) from the age group of <25 years. Among them 199 (66.8%) were male operators and 99 (33.2%) were female operators.

Table 1: Sex Distribution of Operators / Doctors

Sex	Frequency (n)	Percentage (%)
Female	99	33.2
Male	199	66.8
Total	**298**	**100**

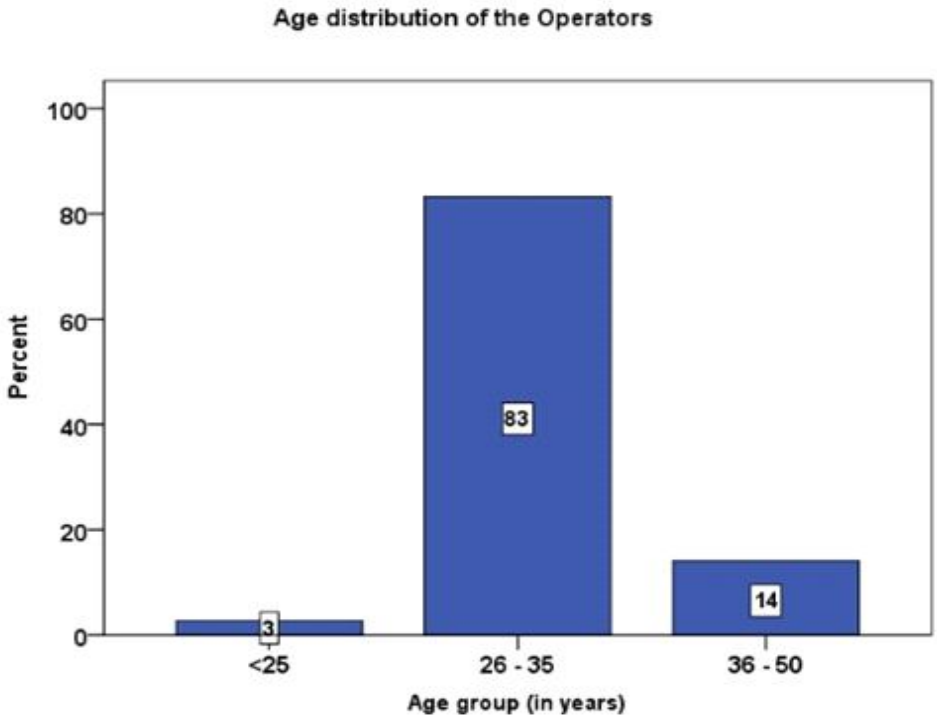

Fig. 1: Age Distribution of Operators / Doctors

Table 2: Designation of the Operator / Doctor

Group	Frequency (=n)	Percentage (%)
Consultant	22	7.4
Registrar/ Resident	74	24.8
MO/ RMO	9	3.0
PGT/ PDT	193	64.8
Total	**298**	**100**

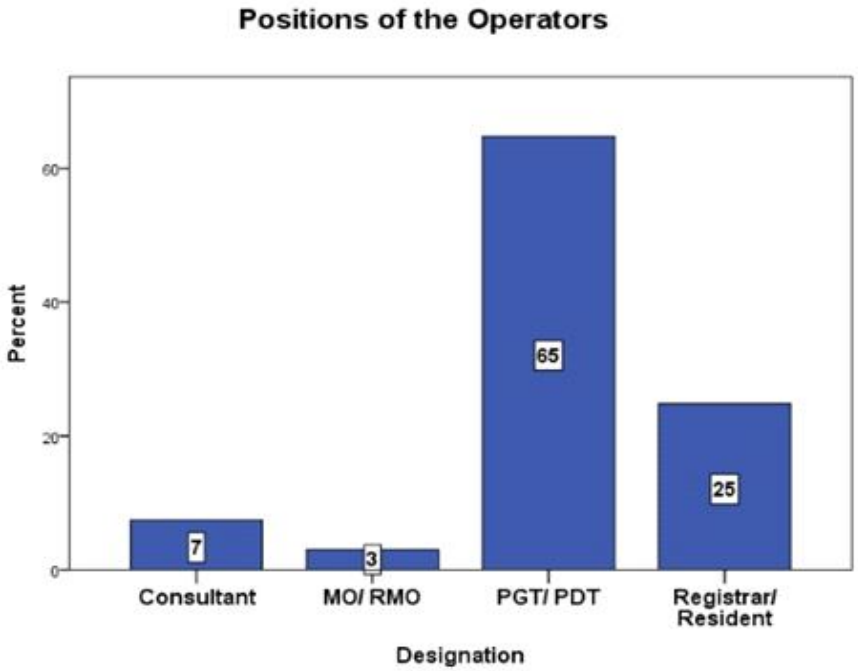

Fig. 2: Designation of the Operator / Doctor

Operators were either a post graduate trainee (PGT/ PDT) of emergency medicine or an residential medical officer (RMO/ MO) or a registrar/ resident or a consultant of the department of Emergency Medicine in Peerless Hospital & B.K. Roy Research Centre with most frequently observed designation is PGT/ PDT (n=198, 64.8%). We also calculated the experience of the operator in years and 195 (65.4%) having experience of 1-5 years, 69 (23.3%) having experience of 6-10 years 26 (8.7%) having experience of 10-20 years.

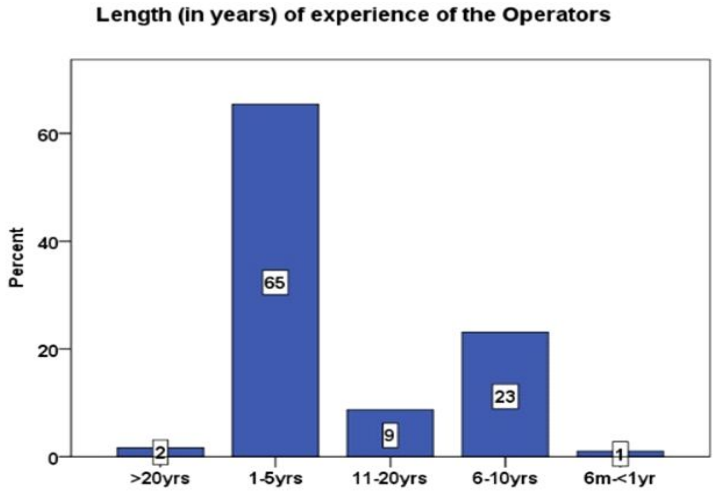

Fig. 3: Length of Experience (in years) of Operator / Doctor

Table 3: Length of Experience (in years) of Operator / Doctor

Length	Frequency	Percent
6m-<1yr	3	1.0
1-5 yrs	195	65.4
6-10 yrs	69	23.2
11-20 yrs	26	8.7
>20 yrs	5	1.7
Total	**298**	**100**

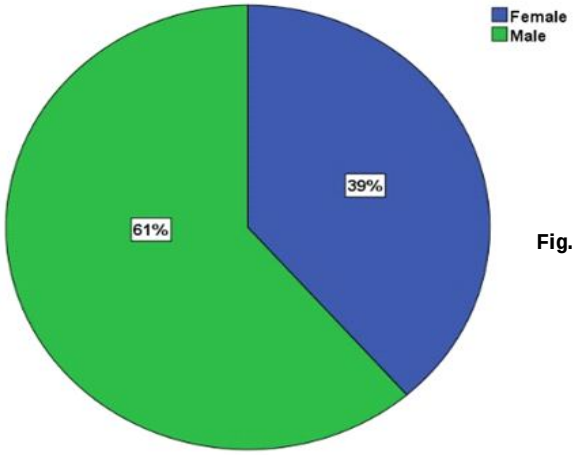

Fig. 4: Sex Distribution of Patients

About patient's included in the study it was observed that 100 (33.6%) of them were of >67 years, 72 (24.2%) were between 48-57 years, 51 (17.1%) were between 58-67 years. Male patients were 183 (61.4%) and female patients were 115 (38.6%).

Table 5 describes that post intubation Chest X-ray confirmed that among 298 (100%) cases, in 261 (87.5%) cases E.T. tube was in proper position, i.e. inside the trachea and above the carina, in 20 (5.9%) cases E.T. tube was inside the right bronchus and in 17 (5.7%) cases in other positions (either at the carina or endoesophageal etc).

Table 4: Age distribution of Patients

Age Group	Frequency (=n)	Percentage (%)
18-27 yrs	23	7.7
28-37 yrs	21	7.0
38-47 yrs	31	10.4
48-57 yrs	72	24.2
58-67yrs	51	17.1
>67yrs	100	33.6
Total	**298**	**100**

Table 5: Detection of post-intubation E.T. tube position confirmed by CXR-PA after emergency intubation by operators

E.T tube Position	Number (%)
Endotracheal position	261 (87.5)
Endobronchial position	20 (5.9)
Others	17 (5.7)
Total	**298 (100)**

Table 6: Comparison of operator's opinion by combing 3 clinical tests about E.T. tube position with E.T. tube Position as per CXR-PA, post-intubation (Gold standard)

Operator's opinion by combined 3 clinical test	Detection by CXR-PA (Gold standard)		Total
	Endotracheal	Non-Endotracheal	
Endotracheal	261	17	278
Non-endotracheal	0	20	20
Total	**261**	**37**	**298**

Sensitivity = 100%; Specificity = 51%; PPV = 93%; NPV = 100%

Table 7: Comparison of operator's opinion by bilateral chest auscultation about E.T. tube position with E.T. tube Position as per CXR-PA, post-intubation (Gold standard)

Operator's opinion by bilateral auscultation	Detection by CXR-PA (Gold standard) Endotracheal	Non-endotracheal	Total
Equal	258	19	277
Unequal / absent	3	18	21
Total	**261**	**37**	**298**

Sensitivity = 99%; Specificity = 49%; PPV = 93%; NPV = 86%

Table 8: Comparison of operator's opinion by bilateral chest movement about E.T. tube position with E.T. tube Position as per CXR-PA, post-intubation (Gold standard)

Operator's opinion by bilateral chest movement	Detection by CXR-PA (Gold standard) Endotracheal	Non-endotracheal	Total
Symmetrical	261	22	283
Asymmetrical	0	15	15
Total	**261**	**37**	**298**

Sensitivity = 100%; Specificity = 40%; PPV = 92%; NPV = 100%

Table 9: Depth of intubation (in cm) by operator as per CXR-PA, post-intubation

Position	Meansd	Median (min, Max)	t-value; with degree of freedom	p-value
Endotracheal				
Men(n=165)	22.11.1	22 (19,26)		
Women(n=96)	21.4	21 (18,25)	4.38;259 df	0.001
Total (n=261)	21.8	22 (18,26)		(Significant)
Endobronchoeal				
Men(n=11)	23.4	23 (23,24)		
Women (n=9)	23.0	23 (21,24)	1.31; 18df	0.20
Total (n=20)	23.2	23 (21,24)		(Nonsignificant)
Others				
Men (n=7)	23.1	23 (21,24)		
Women (n=10)	21.9	21.5 (20,24)	1.68; 15df	0.11
Total (n=17)	22.4	23 (20,24)		(Nonsignificant)

Table 10: Frequency distribution of operators as per their length of experience

Length	Frequency	Percentage
6 month - 5 years	198	66.4
>= 6 years	100	33.6
Total	**298**	**100.0**

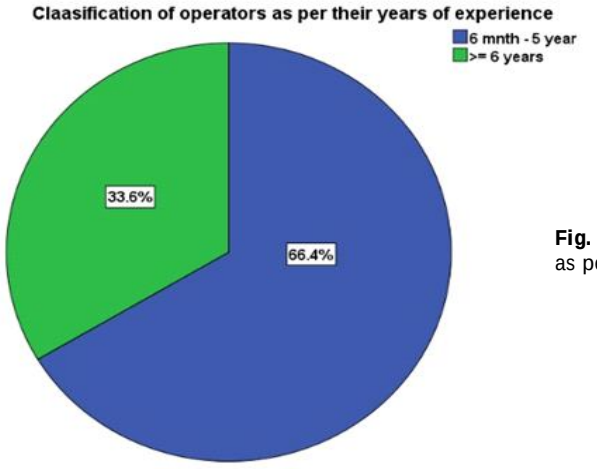

Fig. 5: Frequency distribution of operators as per their length of experience

When we analyzed whether the sensitivity and specificity of these clinical methods vary according to operator's experience (in years and as per designation), we found that sensitivity for detection of endotracheal intubation remains high irrespective of the designation or the years of experience. But specificity of combination of all three clinical methods increases to 75% with more than 6 years' experienced operator (doctor).

Table 11: Comparison of operator's opinion by combining 3 clinical tests about E.T. tube position with E.T. tube Position as per CXR-PA, post-intubation (Gold standard) by operator's length of experience and designation

Operator's experience between 6 month and 5 years

Operator's opinion by combined 3 clinical test	Detection by CXR-PA (Gold standard) Endotracheal	Non-endotracheal	Total
Endotracheal	169	15	184
Non-endotracheal	0	14	14
Total	**169**	**29**	**198**

Sensitivity = 100%; Specificity = 48%; PPV = 92%; NPV = 100%

Operator's experience >= 6 years:

Operator's opinion by combined 3 clinical test	Detection by CXR-PA (Gold standard) Endotracheal	Non-endotracheal	Total
Endotracheal	92	2	94
Non-endotracheal	0	6	6
Total	**92**	**8**	**100**

Sensitivity = 100%; Specificity = 75%; PPV = 98%; NPV = 100%

For PGT/PDT Operators :

Operator's opinion by combined 3 clinical test	Detection by CXR-PA (Gold standard) Endotracheal	Non-endotracheal	Total
Endotracheal	169	11	180
Non-endotracheal	0	13	13
Total	**169**	**24**	**193**

Sensitivity = 100%; Specificity = 54%; PPV = 94%; NPV = 100%

For other (MO/RMO/Registrar/Resident/Consultant) operators :

Operator's opinion by combined 3 clinical test	Detection by CXR-PA (Gold standard) Endotracheal	Non-endotracheal	Total
Endotracheal	92	6	98
Non-endotracheal	0	7	7
Total	**92**	**13**	**105**

Sensitivity = 100%; Specificity = 54%; PPV = 94%; NPV = 100%

Discussion

Intubation done in emergency either, crash intubation, rapid sequence or intubation with medication but without paralysis is an important aspect, but a successful intubation is not achieved until it is confirmed in its right position. In a study in 1995 and 2000 they did confirmation by doing ballotability test of ET tube cuff but this was done in a quiet operation room which has little to no significance in busy emergency. So we tried to find out the ET tube position confirmation by 3 techniques [3] in Indian emergency setting. In the mentioned techniques we found that for detection of endotracheal intubation the sensitivity of bilateral chest auscultation method is 99%, 100% in observation of bilateral symmetrical chest movement method and also 100% in combination of all three methods (bilateral chest auscultation, observation of bilateral symmetrical chest movement and depth of the E.T. tube from right incisor). But the specificity is very poor, 49% in bilateral chest ausculation, 40% in bilateral chest movement observation and maximum 51%, in combination of all three methods (bilateral chest auscultation, observation of bilateral

symmetrical chest movement and depth of the E.T. tube from right incisor) which all are not significant. So the clinical methods either individually or in combination to detect proper endotracheal intubation can be used as only screening method in emergency if Chest X-ray is not available, but post intubation Chest X-ray becomes mandatory due to poor specificity of the clinical methods or their combination on own.

The majority of operators doing the procedure were PGT/PDT around 64.8% and also many had work experience, 66.4%, of 6 months to 5 years. We found that sensitivity for detection of endotracheal intubation remains high irrespective of the designation or the years of experience. But specificity of combination of all three clinical methods increases to 75% with more than 6 years' experienced operator among doctors. Operators opinion after combination of all 3 tests for doctors who are PGT/PDT and consultants had specificity of 54% which was surprisingly same and had no effect irrespective of the posts held by the doctors. We had only 20 endobronchial intubation which was around 5.9% of total intubations which may show that intubation skill may be better among physicians working in ED.

We found that when single tests were taken like bilateral auscultation of chest and bilateral chest movement to know the confirmation of ET tube, PGT/PDT fared better with specificity of 50% for both the tests and consultants, registrars had only 45% and 23% specificity for the two tests separately. This was an interesting finding for which we could not find any specific explanation.

We calculated the approximate safe depth of E.T. tube from right incisor, to reduce chances of endobronchial intubation, in Indian ethnicity and we found that in Indian male it is 22cm and Indian female 21cm (significant, $p<0.001$), which differs from most of the anaesthesia textbooks and studies[3] recommending that depth of placement of ET of 21 cm and 23 cm in adult females and males, is appropriate respectively, from right incisors.

Our study has its limitations, we found a huge difference among study population of men vs women (61% vs 39%). This did not include the characteristics of difficult intubation like short neck, obesity, beard, poor mallampati score, trauma to face, etc. We may have observational bias during single tests of bilateral auscultation and chest movement. Operator experience was based on years of work experience in the field of medicine and it did not show true experience in intubation procedures.

Conclusion

We conclude that a single test on its own is not confirmatory for tube position as compared to all the 3 tests combined with Chest X-ray. In an emergency setting where there is always chaos it is better to combine all findings together to give a better sensitivity and specificity. Experienced physicians working in India will benefit from using a 21/22 cm depth for Indian ethnic groups, and this would be especially helpful for physicians in situations where auscultation is difficult or impossible and with less experience individuals in airway management. Clinicians should accept tube insertion depths that differ much from 21 cm in women and 22 cm in men with extreme caution.

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