

Comparison of Upper Airway Ultrasonography with Standard Waveform Capnography and Auscultation to Verify Correct Placement of Endotracheal Tube after Intubation

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ABSTRACT

Introduction: Verification of correct endotracheal tube (ETT) placement and avoidance of esophageal, endobrocheal intubation has important implications. Ultrasonography (USG) is an indispensable method in ETT position confirmation. It is reliable and easily available. Ultrasound (US) is an accessible tool with reproducible results, inexpensive and pain free. Also there are no harmful effects on the patient and thus ethically justified.

Material and methods: The probe is placed horizontally starting from cricothyroid membrane upto suprasternal notch and then given a slight 30° tilt to left (also to right) to rule out esophageal intubation. The esophagus will be empty on USG in case of tracheal intubation.

Results: ETT placement came out to be 98.5%. Our κ value came out to be 0.92. Thus upper airway sonography is in very good correlation with waveform capnography in correct tracheal tube confirmation. **CONCLUSION-** Upper airway USG can replace endtidal carbon dioxide (ETCO₂) monitoring as the gold standard modality in verification of correct endotracheal intubation. With adequate experience and future reserch on this topic covering a larger population and varied working environment, USG can emerge as the primary modality as the 'point of care' for confirming endotracheal intubation even in emergency situations.

Keywords: Upper Airway Ultrasonography, Standard Waveform Capnography, Placement of Endotracheal Tube

INTRODUCTION

As the decades unfold, there has been a great revolution in the airway management skills. Inability to adequately confirm the placement of endotracheal tube in a pharmacologically paralysed patient (as in elective operation theatre) or patients landing in emergency department, can be a catastrophic situation.¹ According to 2015 ACLS guidelines (advanced cardiovascular life support) for CPR (cardiopulmonary resuscitation) by American Society of Anaesthesiologists, a confirmatory procedure must be carried out to rule out esophageal or endobrocheal intubation.² There are a number of methods for evaluation of tracheal placement of ETT, to begin with intubation under direct visualization, bilateral lung auscultation, radiographic confirmation, capnography which can be both qualitative (colorimetric carbondioxide detector) and quantitative (continuous waveform), misting of ETT. In more advanced centre, direct fibroptic visualization of ETT, CO₂ detection device and ultrasonography have come up with new hopes. In 2010 ACLS guidelines for CPR, quantitative

waveform capnography (ETCO₂,end tidal carbondioxide) proved to be a gold standard for adequate endotracheal tube placement confirmation. The above methods have their own supporting and opposing arguments.³ No single method is ideal in all elective and emergency situations and many factors such as patient, physician and institution related spring up. There are two studies on waveform capnography to confirm tracheal placement of ETT in the victims of cardiovascular arrest postintubation that have shown 100% sensitivity and specificity in the placement of ETT. This goes a long way for waveform capnography to attain a dominating and successful position as a gold standard for confirming correct ETT position.^{3,4} We are using this method as a final confirmatory method of tracheal placement of ETT in our day to day general anaesthesia procedures (elective, emergency aswell as critical care settings). Unfortunately ETCO₂ is not omniavailable, neither is its presence feasible everywhere as in small centres.

Therefore we hypothesize to use USG (ultrasonography) as an indispensable method in ETT (endotracheal tube) position confirmation. It is reliable, easily available especially in todays era where obstretics and gynaecology procedures aswell as USG guided regional blocks are being used quite frequently. US (ultrasound) is an accessible tool with reproducible and reliable results, inexpensive and pain free. Also there are no harmful effects on the patient and thus ethically justified. There are several supporting evidence that prove that USG prove to be a boon in ETT confirmation in elective aswell as emergency room settings.⁵

Study aimed to verify the correct placement of ETT in elective operation theatre patients and its comparison with currently used gold standard method of waveform capnography and auscultation and estimation of approximate time taken for US verification.

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MATERIAL AND METHODS

After obtaining a waiver of consent from Institutional Ethics Committee, a prospective observational study was conducted on 50 adult patients (age 20-50 years) of ASA grade I-II posted for elective surgeries in operation theatre of PGIMS Rohtak.

Exclusion Criteria- ASA grade III-IV, grossly abnormal neck anatomy, neck distortion, surgery on neck (eg. thyroid, oesophagectomy). Only first intubation attempt was considered. Considering the above exclusion criteria only 28 patients adequately met the demands and 22 patients were excluded (thyroid surgeries, neck tumors, tracheostomy).

All intubations were done by the residents. The researchers performed the upper airway USG examination after placement of ETT by the residents. The resident did not confirm any thing about ETT placement (ETCO₂ reading or under vision intubation). The researcher noted his/her finding. The final decision on correct placement was made by ETCO₂ detection (exhaled CO₂ ≥4 mmhg after >or =5 breaths and detection of characteristic CO₂ waveform).

The results were compared after completion of the study. ETCO₂ waveform detection and USG images were compared, to determine the sensitivity and specificity of bedside USG examination and its possibility to determine accuracy of correct endotracheal intubation and its possible future use over and above ETCO₂ detection. Also the verification time required (total time required for USG confirmation taken as the time from endotracheal intubation to USG confirmation) was calculated. The procedure of USG confirmation did not interfere in overall patient intubation procedure or surgery. Rather the procedure was done simultaneously along with waveform capnography confirmation and subsequent auscultation as is routinely practiced in our theatre. Neither ETCO₂ nor auscultation was allowed to bias the USG results. It was ensured that only two residents one for intubation and other for ETCO₂ confirmation were involved in our case study. Results were not discussed out aloud and only by gestures. Only first intubation attempt was considered.

USG procedure

Adi et al in his research to study the feasibility of upper airway USG in confirming ETT position has described a method of USG of upper airway which it is found to be superior to other contemporary procedures. Rather than single point placement of USG probe (linear high frequency 10-15 MHZ), a complete upper airway examination from cricothyroid membrane to suprasternal notch is much more confirmatory in not only confirming tracheal placement but also to rule out esophageal intubation.⁷ The probe is placed horizontally starting from cricothyroid membrane upto suprasternal notch and then given a slight 30° tilt to left (also to right) to rule out esophageal intubation (situated on left in 90% of individuals and on right in rest 10%). The esophagus is empty on USG in case of tracheal intubation.

Confirmation of ETT placement - In case of tracheal intubation two hyperechoic parallel lines in both horizontal and vertical views (in place of characteristic reverberation

artifact as seen in empty trachea). Esophageal intubation- there is reverberation artifact in trachea and two hyperechoic lines in esophagus/distended esophagus with empty trachea.

Research tools

All intubation procedures involved only two residents having atleast two years of experience.

The researcher involved in USG confirmation of ETT had adequate training in airway USG. The capnography monitor faced away from the sonographer.

Postintubation verification of ETT was confirmed and validated by both residents by observation of clinical signs, quantitative waveform capnography, auscultation and pulse oximetry. Only then the tracheal tube was secured.

All clinical decisions were taken based on capnography results and the USG was not involved in any decision making. The results were recorded independently by the researcher. The primary outcome we studied was comparison of the results and agreement between USG result and ETCO₂ confirmation in locating the ETT after intubation. Also our aim was to study the time USG takes to confirm ETT placement in a static mode. Once the results tally USG can be considered superior or atleast equal to ETCO₂ in confirming ETT location. Data collection- all the patients were comparable with respect to age, sex, surgery and ultrasound image used. After adequate localization of ETT researcher took an image of ETT in trachea (or esophagus) (figure 1,2,3).

STATISTICAL ANALYSIS

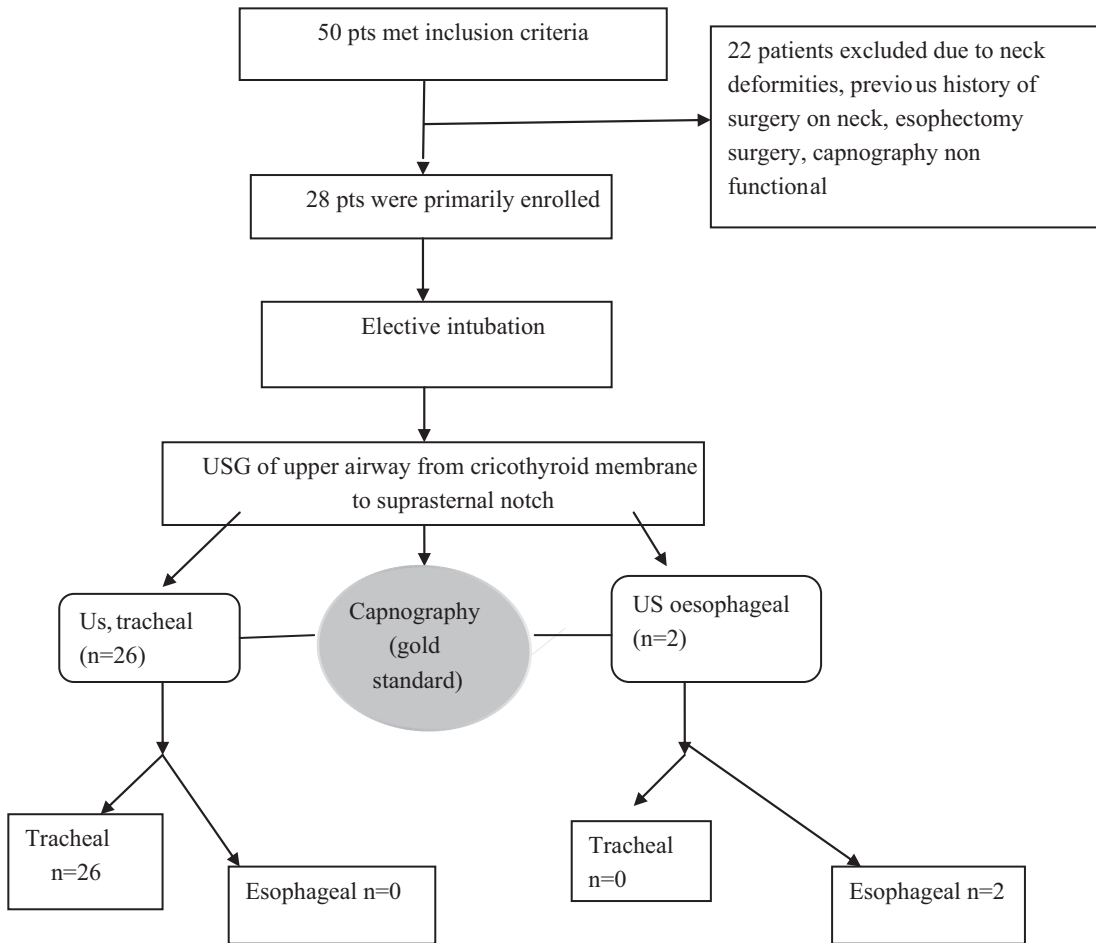
Analysis of data was done using SPSS version 17. Data is reported as mean ±SD or proportions as appropriate. Kappa values were calculated from observations of table 2. In our study we need to know the strength of agreement of a new technique (USG) with results obtained by an already well established technique (ETCO₂ confirmation) over and above which would have occurred by chance. Interpretation criteria-

k – 0.81 to 1	very good
k – 0.61 to 0.81	good
k- 0.41 to 0.61	moderate
k- 0.21 to 0.41	fair
k- <0.2	poor

Considering that an α value of atleast 0.8 is required to correctly prove the hypothesis, the number of patients to be included came out to be 20. We took 50 patients to increase the power of study (assuming a 10% drop out rate).

RESULTS

A sample of 28 patients were analysed and the accuracy of bedside upper airway USG for confirming ETT placement came out to be 98.5%. Our κ value came out to be 0.92. Thus upper airway sonography is in very good correlation with waveform capnography in correct tracheal tube position confirmation. The sensitivity and specificity have been mentioned. Table 1 shows the demographic and medical characteristics of all the patients that were comparable with respect to age, gender, ASA grade and physical status. Majority of intubations were tracheal with only two esophageal intubations. Table 2 shows the types of surgeries



Flowchart of study

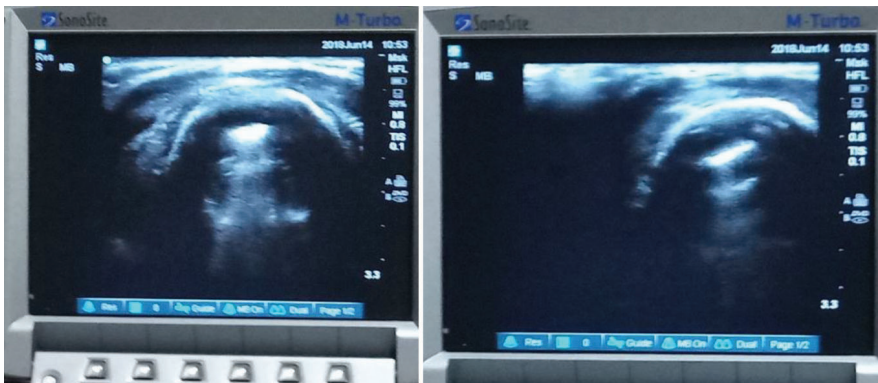


Figure-1: Image of trachea showing reverberation artifacts (non intubated)



Figure-2: Tracheal intubation showing two hyperechoic parallel lines in horizontal plane

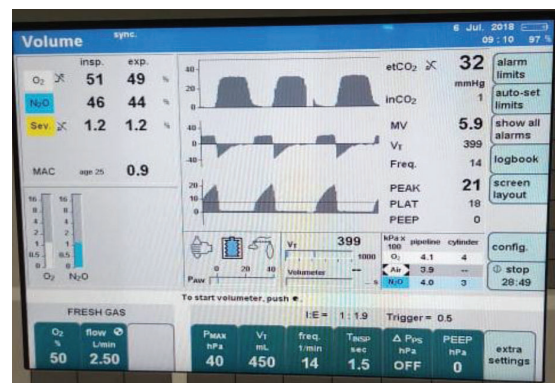


Figure-3: ETCO₂ GRAPH (considered as the gold standard for tracheal intubation confirmation)

Intubation	Tracheal (26)	Oesophageal(2)
Age in years	35.2 ±6.8	38.1±5.4
Gender		
Male	14	1
female	12	1
BMI	22.5 ±3.6	23.4 ±2.2
ASA grade I/II	20/6	1/1

Table-1: Demographic and medical characteristics of study patients

	Intubation	Tracheal	Oesophageal
1	Laposcopic cholecystectomy	5	none
2	Open cholecystectomy	3	1
3	Ileal resection	2	none
4	Appendicectomy	4	1
5	MRM	5	none
6	Fibroadenoma breast	4	none
7	Epigastric hernia	3	none

Table-2: Types of surgery

Sensitivity	97%
Specificity	100%
Positive predictive value	100%
Negative predictive value	70%

Table-3: Bedside upper airway usg characteristics for confirmation of correct ett placement

that were comparable. The head and neck, onco surgeries, burn contractures involving head and neck were excluded because of gross anatomical distortions and suspicion of difficult intubation. Table 3 shows the sensitivity and the positive predictive value of ultrasonography for detection of esophageal intubation was 100%.

DISCUSSION

The aim of our study was to find out whether USG can replace ETCO_2 as the primary modality to confirm endotracheal intubation in elective cases. Our results show sensitivity and specificity of USG in confirming endotracheal intubation, is quite in agreement with ETCO_2 with upper hand in some cases and thus USG raises new hopes to unfold new horizons in airway management not only in elective cases but also emergency situations. Although ACLS guidelines 2010 and 2015 clearly state capnography to be gold standard and further confirmation by auscultation but both these methods have their own assets and liability.² Though ETCO_2 can detect >98% of intubation successfully but ruling out esophageal intubation is a must as inadvertent esophageal ventilation has the risk of aspiration and gastric insufflation which is specially undesirable in laparoscopic procedures. Auscultation has its limitations in obese patients and emergency settings where there is a huge level of noise to interfere in correct interpretation.^{3,4}

USG is a reliable, real time, non invasive, harmless modality with reproducible and fast results. The dynamic assessment done with USG is unparalleled by any other modality currently in use. The use of USG in central line placements, assessment

of cardiac function and obstretic and gynaecology diagnosis is already well established.^{1,4,5}

Adi et al in their study to compare the feasibility of bedside upper airway USG to verify ETT location after intubation in comparison to capnography, showed a great strength of agreement between both modalities in patients of varied age, ethnic group and indication of intubation. They also stressed the importance of USG in ruling out esophageal intubation. They proved that upper airway USG observes the upper airway in real time and correctly identifies whether the tube is in trachea or esophagus. The study enlightens the importance of adequate airway US training among the emergency physicians to use it as a point of care method in patients landing in emergency.⁷ Chun et al evaluated the portable hand held US machine in confirming the correct ETT placement. They recorded the chest wall visceral parietal pleural interface (VPPI), bilaterally in patients during all phases of airway management. They concluded that thoracic sonography may prove to be an important tool in confirming ETT placement especially in extreme conditions such as aerospace medical transport where other modalities such as capnography may not be available and auscultation might not be feasible.¹ TRUE (tracheal rapid ultrasound scan) as a modality was used by Masoumi et al. They placed a convex transducer above the suprasternal notch, but due to lower frequency of convex transducer, superficial structures of airway -trachea, air mucosa interface (lung sliding sign) are difficult to interpret. Another study used transcricothyroid membrane USG with cricothyroid membrane as a window but it has limitations that scanning depends on change in appearance of vocal cords which may not be obvious in all patient groups.^{6,8,11,12}

Adi et al used linear probe with coverage of entire airway area from cricithyroid membrane to suprasternal notch. This study formed the basis of our study as coverage of large area easily rules out esophageal intubation.⁷ Gottlieb et al used a 4S technique for endotracheal confirmation by expert and novice physicians. This technique is effective for US experts and thin patients but in novices it has its frailty for obese cadavers. Also there is quite a difference in control settings of cadavers and actual anaesthetized patients.⁹

Finally our own study has its incapacities and limitations. First our patient group consisted entirely of elective ASA grade I and II patients. Thus the results inferred cannot be applied to all patients landing in emergency who may have chest deformities, pneumothorax etc. Also patients with anatomical distortion of the neck (thyroid, tracheostomy) use of indirect methods of confirmation (lung sliding etc) may have to be used as upper airway USG relies on identification of normal airway anatomical structures along with their relationships, which may be disrupted in these patients. Lastly operation theatre environment has a controlled ideal working condition. These donot reflect the actual noisy and stressful condition of emergency department. Neither can the availability of US machine out of hospital (periphery, roadside) be assured where other methods (auscultation, misting of ETT, chest rise) may have to be relied on. The

researcher sincerely hopes that future studies will overcome all these limitations and use of upper airway USG as gold standard modality in ETT verification will see the light of the day.

CONCLUSION

Upper airway USG can replace ETCO₂ monitoring as the gold standard modality in verification of correct endotracheal intubation. With adequate experience and future research on this topic covering a larger population and varied working environment, USG will emerge as the primary modality as the 'point of care' for confirming endotracheal intubation even in emergency situations.

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