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Evaluation of transcricothyroid membrane ultrasonography and ultrasound guided pleural sliding sign for confirmation of endotracheal intubation

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ABSTRACT

Introduction: There are many different ways of assessing the placement of endotracheal tube. However all techniques have certain limitations for some clinical situations.With the advent and easy availability of ultrasound machine in operation theatres,various ultrasound guided techniques are being evaluated for their feasibility and accuracy to confirm endotracheal tube placement.

Aims : The aim of the present study was to assess the sensitivity,specificity, positivepredictive value and negative predictive value of the pleural sliding sign on ultrasonography and transcricothyroid membrane ultrasonography for confirming endotracheal tube placement.

Materials & Methods: This was a prospective double blinded clinical trial carried out in operation theatre on patients who were to receive general anesthesia for various surgical procedures. 100 patients of American Society of Anesthesiologist (ASA) status I and II were enrolled for the study. During intubation a 6-13 MHz linear ultrasound probe was placed horizontally over the cricothyroid membrane. Endotracheal intubation was confirmed dynamically by transcricothyroid ultrasound. Then the same probe was used to assess presence of pleural sliding sign with intermittent positive pressure ventilation. This was followed by routine confirmation with waveform capnography and auscultation.

Statistical analysis: We calculatedthe sensitivity, specificity, positive predictive value and negative predictive value of both the tests.

Results: Out of 100, 8 patients had inadvertentoes ophageal intubation. Sensitivity, Specificity, positive predictive value and negative predictive values were 97.83, 100%, 100% and 80% respectively for transcricothyroid ultrasound. With ultrasound lung sliding sign each were 100%.

Conclusion: Transcricothyroid ultrasound evaluation and positive lung sliding sign are useful methods to confirm endotracheal intubation

Keywords: Cricothyroid membrane, endotracheal intubation, pleural sliding, ultrasonography.

Key message: Transcricothyroid membrane ultrasonography and pleural sliding sign are fairly accurate methods and can be used alone or as an additional method for confirmation for endotracheal intubation.

INTRODUCTION

Endotracheal intubation is an important procedure in airway management during induction of general anesthesia, in management of various emergencies and in critical care patients.Incidence of unrecognized oesophageal intubation is rare but has high morbidity and mortality. Although a number of different methods have been recommended to confirm the correct placement of endotracheal tube, they have certain limitations in different clinical conditions. Direct laryngoscopic visualization of tube in larynx, end tidal CO^2 with waveform capnography, five point auscultation,oesophageal detector devices, various ultrasound guided techniques and other imaging modalities are some such methods.

Ultrasound (US), which is nowadays readily available in operation theaters of tertiary care hospitals, can be easily used to confirm correct endotracheal tube placement.

Transcricothyroid ultrasonography gives a dynamic visualization of tube passing through vocal cords and gives instant result. Lung sliding sign is an easy and objective way to confirm tube placement particularly in paralysed patients with intermittent positive pressure ventilation. Both the techniques are easy to learn, non invasive and pose no adverse effects to the patient.

MATERIALS AND METHODS

After approval from institutional ethical committee, 100 patients aged 18- 60 years, out of which 66 patients were male and 34 female, posted for various surgical, orthopedic, ENT and gynecological procedures were enrolled for the study. A written informed consent was obtained from them. Patients of American Society of Anesthesiologist (ASA) physical status I and II were included. Patients who had any facial or upper

airway pathology, any neck pathology, any respiratory pathology like pleural effusion, pneumothorax etc, those on anticoagulants and those refusing to participate in the study were excluded from the study. After keeping all the drugs and instruments ready for emergency resuscitation and general anesthesia, the patients were induced with routine general anesthesia with muscle relaxant. They were intubated with proper sized portex cuffed endotracheal tube (ETT).

A 6-13 MHz linear ultrasound probe was used.During the intubation process the ultrasound probe was placed horizontally over the cricothyroid membrane (dynamic phase). The transcricothyroid membrane US image which was taken before endotracheal intubation showed characteristic reverberations. A 'brief flutter' or 'snow-storm' sign was seen on the screen[1] when ETT is passed through the cords during Dynamic phase. The image of the transcricothyroid membrane US gives an acoustic shadow, referred to as the 'bullet sign'. An instructed resident confirmed the correct placement of the tube as positive or negative, which was followed by an ultrasonographic lung-sliding assessment for pleural movement, using the same probe. Lung-sliding signs were evaluated by placing the probe vertically over the second intercostal space on the right side of chest. Lung-sliding sign was positive if there was visible appreciation of pleuralmovement with intermittent positive pressure ventilation (IPPV) i.e. sliding of parietal and visceral pleura. Pleural sliding was confirmed with M mode ultrasound showing classic 'sea shore' sign with IPPV.

Thereafter another anesthetist confirmed endotrachealplacement of ETT by auscultation of lungs and end tidal CO^2 ($ETCO^2$) monitoring. The resident and anesthetist were blinded to each other's assessments. An independent observer noted the time required for transcricothyroid membrane US confirmation as the time after intubation till the time the observing resident gave the result based on his observation. The time required for obtaining result after pleural sliding sign was measured as time after intubation till the observer gave result after ascertaining pleural slide with IPPV on US.

Statistical analysis: Based on study by Chou HC et al[2], we considered prevalence of oesophageal intubation as 0.15% and desired precision of 0.05% with 95% confidence interval. We calculated the sample size of 100 for calculating sensitivity and specificity of the diagnostic test. Sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) were calculated with 2 x 2 tables, using Microsoft 2007 Excel software; those values are presented together with their 95% confidence interval.

RESULTS

Table 1 shows the data of patients posted for various surgical procedures. Out of the hundred patients intubated in our study, 8 patients had inadvertent oesophageal intubation. Table 2 shows the results after transcriothyroidmembrane ultrasound and table 3 shows the results after confirmation of ventilation with pleural sliding sign. Table 4 shows the time required for getting the result for each of the two ultrasound based test. Table 5 shows the sensitivity, specificity, positive and negative predictive values of the tests.

Table1: Patients posted for various surgeries

	MALE	FEMALE
SURGERY	22	15
ENT	18	10
ORTHO	8	7
GYNACOLOGY	0	20

Table 2: Results after transcricothyroid membrane US

	Transcricothyroid membrane ultrasound results		
	Bullet sign +ve (tracheal intubation)	Bullet sign –ve (oesophageal intubation)	Total
Tracheal Intubation*	90	02	92
Oesophageal Intubation*	0	08	08
TOTAL	90	10	100

*Actual results based on confirmation by waveform capnography and auscultation

Table 3: Results of pleural sliding sign on US

	Pleural sliding sign on US		
	Sliding sign + ve (tracheal intubation)	Sliding sign –ve (Oesophageal intubation)	Total
Tracheal Intubation*	92	0	92
Oesophageal Intubation*	0	08	08
TOTAL	92	08	100

*Actual results based on confirmation by waveform capnography and auscultation

Table 4: Time required for confirmation of result by two tests:

	Time required for confirmation MEAN +/- SD (seconds)
Transcricothyroid US	0
Pleural sliding sign	08
P value <0.001	

Table 5: Showing the sensitivity, specificity, positive and negative predictive values of the tests.

	Transcricothyroid Membrane US % (95 % confidence interval)	Pleural sliding sign % (95 % confidence interval)
Sensitivity	97.83 % (92.37-99.74%)	100 % (96.07- 100%)
Specificity	100% (63.06- 100 %)	100 % (63.06- 100 %)
Positive predictive value	100%	100%
Negative predictive value	80 % (50.39- 94.03%)	100%

DISCUSSION

Due to significant mortality & morbidity associated with incorrect placement of endotracheal tube in all critical patients, reliable confirmation procedures for endotracheal intubation are essential. Auscultation of chest, end tidal CO_2 levels, esophageal detector devices are currently used as methods for confirmation of endotracheal tube placement[3-7].

Although number of different methods have been recommended to confirm the correct placement of endotracheal tube, but there is currently no full proof method available. Different primary methods can be applied to confirm correct ETT placement for example direct laryngoscopic visualization of the vocal cords.Due to trauma, oral bleeding, secretions, vomitus and edema of intra-oral structures or altered anatomy and inadequate mouth opening direct laryngoscopic visualization may not always be possible.

To overcome these problems different secondary or indirect methods such as chest X-ray and/or detection of exhaled carbon dioxide are also routinely applied.$ETCO_2$ is used routinely as an indirect method of correct ETT placement confirmation due to its high specificity and sensitivity but it may yield false positive or false negative results.

A lot of studies compared $ETCO_2$ monitoring with esophageal detector devices [7] for confirmation of correct ETT placement and found that EDD was more accurate in emergency intubations. However Li et al[8] reported that the $ETCO_2$ monitoring is not always reliable for verification of correct ETT placement due to high rate of false positive and negative results.

The ultrasound as a 3rd generation EDD[9] may act as a good alternative to confirm correct placement of ETT .US can be used in different ways to assess tube position. Chou et al assessed the tube position with horizontally placed convex probe in suprasternal window[2]. Other studies have scanned complete upper airway anatomy to confirm tube position.[10] Transcricothyroid membrane scanning involves visualization of change in reverberation artifacts due to endotracheal tube. Presence of tube in trachea shows bullet like artifact in trachea and no shadow in oesophagus. Presence of oesophageal intubation will give a classic double tract sign i.e presence of reverberations due to air mucosal artifacts in trachea and reverberations due to presence of tube in oesophgus[10]. Indirect methods of assessment include visualization of diaphragmatic movements and pleural sliding by US.

We have studied transcricothyroid membrane US as it gives immediate dynamic assessment while passing tube and confirmation by presence of bullet sign. Pleural sliding sign is also easy and objective method to ascertain the tube position by detecting pleural sliding with IPPV.

Transcricothyroid membrane US gave two false negative results in our study possibly reflecting that the dynamic movement was missed by the observer. This may indicate the need for a greater practice for this US assessment.

In patients who have not sustained cardiac arrest $ETCO_2$ monitoring has shown high sensitivity in verifying tracheal ETT placement. Gramc et al [4] reported that auscultation of breath sounds and capnography in cardiac arrest patients, and capnometry and $ETCO_2$ monitoring in non cardiac arrest patients are reliable methods to confirm tracheal ETT placement due to their 100% sensitivity.

Capnography is also a reliable method in out of hospital and out of Operation Theater scenarios to verify tracheal ETT placement. However, $ETCO_2$ detection depends on the patient's mechanism for CO_2 excretion and therefore can fail in circulatory, ventilatory and metabolic dysfunctions e.g. cardiac arrest, pulmonary embolism.[4,5,11] As ultrasound is easily available now days in casualty and intensive care units of all tertiary care hospitals, it can function as a potential tool in confirming correct endotracheal tube placement. Back and forth movement of parietal and visceral pleura over each other which is commonly referred as Sliding sign[11] is a feature representing a normal ventilating lung. Sliding sign can be noted in both positive and negative pressure ventilation.

Chest auscultation was found to be unreliable in inexperienced hands[3,5]. Transtracheal illumination have high failure rate 13-16%[5]. Esophageal detector device have overall sensitivity of 61 to 87%. It has poor sensitivity in pulmonary edema and transbronchealobstruction.[6,7] Fogging of endotracheal tube with ventilation also has proven to be unreliable.[12] Lung sliding sign which gives anatomic evidence

of ventilating lung can be shown by ultrasound. In functional ventilation parietal and visceral pleurae can be visualized as distinct bright interface or echogenic lines. With ventilation these surfaces slide upon each other. This should indicate tracheal intubation[7].

Weaver[13] et al showed that evaluating this sliding sign is highly sensitive and specific for differentiating tracheal versus esophageal intubations. As sliding sign is dependent on anatomic landmarks, patient does not need intact metabolic function and normal blood flow. Ultrasound is already in use in Operation Theater for nerve blocks and central line placements. Potential pitfall of sliding sign detection can occur in pneumothorax case. In pneumothorax and lung blebs lung sliding sign may give false negative results. To overcome this problem bilateral lung scan is recommended. Similarly ARDS which take some time to develop and lung contusion unless they are very severe will not obliterate the lung sliding sign bilaterally. Lung sliding can be seen in both hemithorices within 30 seconds.Sliding sign can be seen with transcutaneous probe in both B mode & M mode of ultrasound even more clearly in color and power Doppler technology.

Ma[14] et al found that US was 100% sensitive and 97% specific in confirming tracheal position of the tube by studying real time tracheal and oesophageal intubations in cadavers.Sim[15] et al showed that the evaluation of lung sliding sign can help to identify proper tracheal tube placement, positive predictive value is almost 100% in cardiac arrest patients and very high in non-cardiac arrest patients.Transtracheal ultrasound is a useful tool to confirm endotracheal intubation with an acceptable degree of sensitivity and specificity. It can be used in emergency situation as a preliminary test before final confirmation by capnography.[16]

However lung sliding sign is useful only in paralysed patients who are not spontaneously breathing. If a spontaneously breathing patient is intubated, pleural sliding will not reflect successful endotracheal intubation as spontaneous breathing efforts by patients will givefalse positive results. This is one of the limitations of our study that our finding regarding pleural sliding cannot be extrapolated to spontaneously breathing patients.

This also underlines the importance of a clinician to have a battery of tests in his armamentarium to be used as per clinical condition of patient.

CONCLUSION

Despite the limitations we can make simple conclusion on the basis of this study that withUS based lung sliding andtranscricothyroid ultrasonography, we can confirm the correct placement of endotracheal tube with high sensitivity.

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