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The assessment of three methods to verify tracheal tube placement in the emergency setting

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Abstract

We studied prospectively the reliability of clinical methods, end-tidal carbon dioxide ($ETCO_2$) detection, and the esophageal detector device (EDD) for verifying tracheal intubation in 137 adult patients in the emergency department. Immediately after intubation, the tracheal tube position was tested by the EDD and $ETCO_2$ monitor, followed by auscultation of the chest. The views obtained at laryngoscopy were classified according to the Cormack grade. Of the 13 esophageal intubations that occurred, one false-positive result occurred in the EDD test and auscultation. In the non-cardiac arrest patients ($n = 56$), auscultation, the $ETCO_2$, and EDD test correctly identified 89.3, 98.2*, and 94.6%* of tracheal intubations, respectively (*, $P < 0.05$ vs. the cardiac arrest patients). In the cardiac arrest patients ($n = 81$), auscultation, the $ETCO_2$, and the EDD tests correctly identified 92.6**, 67.9, and 75.3% of tracheal intubations, respectively (**, $P < 0.05$ vs. EDD and $ETCO_2$). The frequencies of Cormack grade 1 or 2 were 83.9% in the non-cardiac arrest, and 95.1% in the cardiac arrest patients. In conclusion, the $ETCO_2$ monitor is the most reliable method for verifying tracheal intubation in non-cardiac arrest patients. During cardiac arrest and cardiopulmonary resuscitation, however, negative results by the $ETCO_2$ or the EDD are not uncommon, and clinical methods are superior to the use of these devices.

Keywords: Airway management; Esophageal detector device; End-tidal carbon dioxide; Tracheal intubation; Emergency treatment

Resumo

Estudamos prospectivamente a fiabibilidade de dois os métodos clínicos, detecção de dióxido de carbono no fim da expiração ($ETCO_2$) e o uso do aparelho de detecção esofágica (EDD) para verificar a entubação traqueal em 137 adultos no departamento de emergência. A posição do tubo endotraqueal foi testada imediatamente após entubação com o EDD e pelo monitor $ETCO_2$, seguida de auscultação torácica. A visualização por laringoscopia foi classificada de acordo com os graus de Cormack. Ocorreram 13 entubações esofágicas tendo-se verificado um falso positivo no teste EDD e na auscultação. Nos doentes que não fizeram paragem cardíaca ($n = 56$), a auscultação, o $ETCO_2$, e o teste EDD identificaram correctamente respectivamente 92.6**, 67.9, e 75.3% das entubações traqueais (**, $P < 0.05$ vs EDD e $ETCO_2$). A frequência dos graus 1 e 2 de Cormack foram de 83.9% no grupo sem paragem cardíaca, e 95.1% nos doentes com paragem cardíaca. Em conclusão, a monitorização do $ETCO_2$ foi o método mais fiável para confirmar a entubação traqueal nos doentes que não estavam em paragem cardíaca. Contudo durante a paragem cardíaca e a reanimação cardiopulmonar não são raros os resultados negativos pelo $ETCO_2$ ou o EDD, e os métodos clínicos são superiores ao uso destes aparelhos.

Palavras chave: Abordagem da via aérea; Aparelho de detecção esofágica; Dióxido de Carbono no fim da expiração; Entubação traqueal; Departamento de emergência

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Resumen

Estudiamos en forma prospectiva la confiabilidad de los métodos clínicos, la detección de dióxido de carbono espiratorio ($ETCO_2$), el dispositivo detector esofágico (EED) para verificar la intubación traqueal en 137 pacientes adultos en el departamento de emergencias. Se probó la posición del tubo endotraqueal, inmediatamente después de intubar, por medio de EDD, monitor de $ETCO_2$, seguido por la auscultación del tórax. Las visiones obtenidas por la laringoscopía fueron clasificadas por la escala de Cormarc. De las 13 intubaciones esofágicas ocurridas, se obtuvo un falso positivo con EDD y auscultación. En los pacientes que no se encuentran en paro cardíaco, la auscultación, la detección de $ETCO_2$, y prueba con EDD identificaron correctamente 89.3, 98.6 y 94.6% de las intubaciones traqueales, respectivamente (*, $P < 0.05$ vs. pacientes de paro cardíaco). En pacientes en paro cardíaco ($n = 81$), la auscultación, la detección de $ETCO_2$, y la prueba con EDD identificaron correctamente 92.6**, 67.9 y 75.3% de las intubaciones traqueales, respectivamente (**, $P < 0.05$ vs EDD y $ETCO_2$). La frecuencia de Cormack grado 1 o 2 fue 83.9% en el grupo sin paro cardíaco, y de 95.1% en los pacientes en paro cardíaco. En conclusión, el monitoreo de $ETCO_2$ es el método mas confiable de verificar la intubación traqueal en pacientes que no se encuentran en paro cardiorrespiratorio. Durante el paro cardiorrespiratorio y la reanimación cardiopulmonar, sin embargo, no son infrecuentes resultados negativos al usar $ETCO_2$ o EDD, y los métodos clínicos son superiores al uso de estos dispositivos.

Palabras clave: Manejo de vía aérea; Dispositivo detector de intubación esofágico; Dióxido de carbono espiratorio; Intubación traqueal; Tratamiento de emergencias

1. Introduction

Tracheal intubation is the most reliable method for securing and maintaining a patient's airway. However, unintentional esophageal intubation as a complication in emergency tracheal intubation occurs in 8% of the attempts, and the consequences are catastrophic if misplacement of the tube in the esophagus is not recognized [1]. Thus, various methods for verifying tracheal intubation and distinguishing it from esophageal intubation have been developed. Among these, end-tidal carbon dioxide ($ETCO_2$) detection and the esophageal detector device (EDD) are most commonly used along with clinical means in emergency settings.

Among clinical signs, auscultation of the chest is the most common method, and direct visualization of the tube between the cords is one of the most reliable signs of correct tracheal placement [2]. $ETCO_2$ detection is a well-established method for verifying the correct placement of the tracheal tube (ETT) used in the operating room [3,4] and in emergency situations [5,6]. The EDD has been described in the anesthesia [7–9], and more recently in the emergency medicine [10]. This method confirms tracheal intubation by the aspiration of air from a correctly placed ETT, and has been shown to be as effective as an $ETCO_2$ detector, not only in the operating room [11], but also in emergency situations [12–14].

Although many studies have been performed to demonstrate the efficacy of these methods, conflicting results were reported [12,15–18]. The different results in these reports may be attributed to the study populations and to the study designs. However, fewer data are available for evaluating these methods in two distinct emergency populations, i.e. non-cardiac arrest versus cardiac arrest patients in a comparative manner. Therefore, we developed a rigid protocol [19], and evaluated prospectively the accuracy and dependability of these methods for verifying tracheal intubation in our emergency department. The purpose of this study was thus to evaluate three different methods for immediate detection of the tube position; clinical signs, $ETCO_2$, and the EDD in the emergency department.

2. Materials and methods

With Institutional Review Board approval, the study was performed in the department of emergency and critical care medicine of an urban university hospital. We enrolled 137 consecutive adult patients prospectively who were transported by ambulance and underwent emergency tracheal intubation in the emergency department between June 1998 and September 1999. Tracheal intubation is not a method of choice for securing airways for ambulance personnel in Japan. Therefore all of the tracheal tube placements in this study were achieved in our emergency department.

Immediately after intubation and ETT cuff inflation, an aspiration test was performed by connecting an EDD (a self-inflating bulb; Tube-Check B; Ambu, Inc., Linthicum, MD; capacity 75 ml) to the ETT. The bulb was compressed before it was connected to the ETT. After the EDD test was performed and the EDD was disconnected, five manual breaths with 100% oxygen were delivered via a resuscitator bag as $ETCO_2$ was monitored with an infrared carbon dioxide analyzer (BSM-8502; Nihon Koden Kogyo K.K., Tokyo, Japan), which displayed $ETCO_2$ levels and the pattern of the waveform. The lowest $ETCO_2$ level detected by the

$ETCO_2$ monitor was 2 mmHg. During the five manual breaths, auscultation of the chest was performed by intubators. The intubators were then asked to classify the views obtainable at laryngoscopy according to the Cormack grade (grade 1, most of the glottis is visible then there is no difficulty; grade 2, if only posterior extremity of the glottis is visible then there may be slight difficulty; grade 3, if no part of the glottis can be seen, but only the epiglottis, then there may be fairly severe difficulty; grade 4, if not even the epiglottis can be exposed then intubation is impossible except by special methods) [20]. The Cormack grades greater than 3 were confirmed by staff physicians. The number of intubation attempts and any events that occurred were also recorded. All intubations were performed by second year residents or fellows under the close supervision of, or assisted by, the staff physicians in our department. We did not allow more than 30 s for an intubation attempt and the tests. Confirmation of the tube position was made by staff investigators with use of clinical methods including visualization of the tube between the cords, breath sounds, tube fogging, chest rise, and absence of sounds over the epigastric area.

To calculate and compare the sensitivity and specificity of each method, the following definitions were used: true positive—the bulb reinflates in <4 s, there are detectable $ETCO_2$ levels at the fifth breath, and the tube is in the trachea; true negative—the bulb does not reinflate or requires >4 s, there are no detectable $ETCO_2$ levels at the fifth breath, and the tube is in the esophagus; false positive—the bulb reinflates in <4 s, there are detectable $ETCO_2$ levels at the fifth breath, and the tube is in the esophagus; false negative—the bulb does not reinflate or requires >4 s, there are no detectable $ETCO_2$ levels at the fifth breath, and the tube is in the trachea.

Continuous variables are presented as mean $\pm$ S.D., and normal variables are presented as percentages. The data were analyzed for sensitivity (true positives/true positives + false negatives $\times$ 100), specificity (true negatives/true negatives + false positives $\times$ 100), positive predictive value (true positives/true positives + false positives $\times$ 100), and negative predictive value (true negatives/true negatives + false negatives $\times$ 100). Mc Nemar's test for paired samples was used to calculate χ^2-statistics.

Statistical significance was accepted when $P < 0.05$.

3. Results

One hundred thirty-seven patients underwent 150 attempts at emergency tracheal intubation in our emergency department. All of the attempts were performed by the oral route. No neuromuscular agents were used for intubation attempt in the non-cardiac arrest patients. The indications for intubation included acute respiratory failure, airway protection and cardiac arrest (Table 1). In 16 cardiac arrest patients, respiratory problems (bacterial pneumonia; $n = 3$, aspiration pneumonia; $n = 5$, pulmonary edema; $n = 4$, bronchial asthma; $n = 1$, pulmonary contusion; $n = 2$, and tension pneumothorax; $n = 1$) were noted.

In a total of 150 attempts at tracheal intubation, 13 esophageal intubations occurred. The $ETCO_2$ test indicated all of the esophageal intubations (Table 2).

Table 1
Patient characteristics

Variable	Values
Age (year)	66 ± 15
Sex (male/female)	87/50
Height (cm)	159 ± 9
Weight (kg)	57 ± 13
Indications for intubations	
Non-cardiac arrest	56
Acute respiratory failure	27
Pneumonia	10
Acute pulmonary edema	9
Other	8
Airway protection	29
Cardiac arrest	81

Table 2
Results in patients with or without cardiac arrest in association with the use of auscultation, the $ETCO_2$ monitor, and EDD

Variable	Non-cardiac arrest	Cardiac arrest	Total
Esophageal intubations	$n = 4$	$n = 9$	$n = 13$
Auscultation			
Specificity (%)	100	88.9	92.3
PPV (%)	100	98.7	99.2
$ETCO_2$			
Specificity (%)	100	100	100
PPV (%)	100	100	100
EDD			
Specificity (%)	100	88.9	92.3
PPV (%)	100	98.4	99.1
Tracheal intubations	$n = 56$	$n = 81$	$n = 137$
Auscultation			
Sensitivity (%)	89.3	92.6*†	91.2
NPV (%)	40	60.0	52.0
$ETCO_2$			
Sensitivity (%)	98.2‡	67.9	80.3
NPV (%)	80	25.7	32.5
EDD			
Sensitivity (%)	94.6§	75.3	83.2
NPV (%)	51.7	28.6	36.1

PPV, positive predictive value; NPV, negative predictive value. *, $P < 0.0001$ vs. $ETCO_2$; †, $P = 0.0054$ vs. EDD; ‡, $P < 0.0001$; §, $P = 0.006$ vs. the cardiac arrest group.

Table 3
Cormack grades

	Non-cardiac arrest	Cardiac arrest	Total
Cormack grade	56 (100%)	81 (100%)	137 (100%)
1	27 (48.2%)	49 (60.5%)	76 (55.5%)
2	20 (35.7%)	28 (34.6%)	48 (35%)
3	7 (12.5%)	4 (4.9%)	11 (8.0%)
4	2 (3.6%)	0 (0%)	2 (1.5%)

However, one false-positive result in the EDD test and by auscultation occurred.

In 137 tracheal intubations, auscultation indicated most accurately the tube position among the tests. When the results were divided into two groups, i.e. the non-cardiac arrest and cardiac arrest groups, more remarkable differences were found. In the non-cardiac arrest group, the $ETCO_2$ method had the highest sensitivity compared with that of auscultation and the EDD test, although no statistical significant was observed. The $ETCO_2$ test gave only one false-negative result in a patient with pulmonary embolism in this group. In the cardiac arrest group, on the other hand, the sensitivity of auscultation was the highest among the tests with statistical significances. The $ETCO_2$ and the EDD tests failed to indicate 26 and 20 correctly positioned ETTs, respectively. One false-positive result in the EDD test occurred in a cardiac arrest patient with marked gastric distension caused by bag-mask-valve ventilation. There were significant differences in sensitivity in the EDD and the $ETCO_2$ tests between the non-cardiac arrest and the cardiac arrest groups.

Regarding the views at laryngoscopy, more patients were classified into the Cormack grade 1 or 2 in the cardiac arrest group than in the non-cardiac arrest group (the cardiac arrest group vs. the non-cardiac arrest group, 95.1 vs. 83.9%, respectively; Table 3). However it failed to achieve a statistical significance ($P = 0.0585$).

Regarding the number of intubation attempts, 116 patients (84.7%) were successfully intubated on the first attempt, 17 patients (12.4%) were intubated on the second attempt, three patients (2.2%) were intubated on the third attempt, and one patient was successfully intubated on the fourth attempt.

4. Discussion

Unintentional esophageal intubation may occur more frequently in comatose patients and in patients outside the operating room [1]. In this study, esophageal intubations occurred in 8.7% of the intubation attempts. Contributing factors to a higher incidence of esophageal intubation include intubation under less than optimal conditions, violation of the standard technique of auscultation, and non-expert personnel attempting intubation [2]. Thus, many methods have been used to distinguish tracheal from esophageal tube placement.

Our study demonstrated that patients' status affected the performance of the $ETCO_2$ and EDD test. In the non-cardiac arrest patients, the $ETCO_2$ method gave the highest sensitivity among the tests, and appeared to be most reliable for verifying tube position in this population. In the cardiac arrest patients, on the other hand, the sensitivity of the $ETCO_2$ method significantly decreased. Similar results were obtained with the use of the EDD. However, the reasons for false-negative results differ. A high error rate in determining tracheal intubation with the use of the $ETCO_2$ method has been reported in cardiac arrest patients [6,12,13]. During cardiac arrest and cardiopulmonary resuscitation, insufficient $ETCO_2$ may be exhaled due to reduced cardiac output. In this study, the lowest $ETCO_2$ concentration measured by the monitor was 2 mmHg, and any values less than this limit were regarded as negative results. Thus, lack of $ETCO_2$ in capnometry and/or capnography in the arrested patient may not only indicate improper tube placement but also negligible cardiac output [5]. On the other hand, the EDD relies on the anatomic differences between the trachea (three dimensional structure with rigid cartilaginous rings) and the esophagus [7,8]. Thus, its performance should not be affected by the physiologic status, i.e. cardiac arrest or non-cardiac arrest. However, most of the false-negative results in the EDD test were observed in the cardiac arrest group in this study. The EDD gives false-negative results in the presence of secretion, vomitus, blood, or other fluids in the airway; endobronchial intubation; the ETT having its bevel against the tracheal wall; and a decreased functional residual capacity [2]. These mechanisms may occur more frequently during cardiac arrest and cardiopulmonary resuscitation.

Auscultation of the chest is the most common method used to ensure proper tube placement. In this study, auscultation of the chest achieved the best sensitivity among the tests in detecting tracheal intubations in the cardiac arrest patients. However, a concern regarding false-positive results does exist. The reliability of auscultation is related to a tidal volume during the test, sites of auscultation, presence of gastric distension, and experience of the examiners. A bigger tidal volume, auscultation of midaxillary lines of the chest, and absence of gastric distension may improve sensitivity, whereas auscultation of the epigastrium may improve specificity [15]. In the operating room, auscultation of the bilateral axillae gave a 100% of sensitivity to detect proper tube placement in the trachea, and an 85% of specificity to detect esophageal intubation [21]. In the same study, auscultation of the axillae and the epigastrium gave a 100% sensitivity and specificity to verify

tracheal tube placement. Another report demonstrated a 100% of sensitivity and specificity in ICU patients when auscultation was performed by experienced examiners [18].

Direct visualization of the tube between the cords is one of the most reliable signs of correct ETT placement, and recommended as a failsafe method when other methods fail to verify tube position [2]. However, sighting the tube between the cords cannot be performed in all cases of direct laryngoscopy particularly if intubation is difficult, and few studies have been done to evaluate its feasibility in the emergency setting. Cormack and Lehane classified difficult intubation into four grades according to the best view obtainable at laryngoscopy in obstetric patients. They reported that more than 99% of the patients were classified into the Cormack grade 1 or 2, i.e. the glottis is visible [20]. In our study, 95.1% of the cardiac arrest group and 83.9% of the non-cardiac arrest group were classified into the Cormack grade 1 or 2. Probably the lower frequencies of grade 1 or 2 are because intubation attempts were made by residents or fellows under unfavorable conditions, and without use of neuromuscular agents. Nevertheless, our data suggest that direct visualization of the tube between the cords is a feasible and valuable method to confirm tube placement in emergency situations particularly in cardiac arrest.

In conclusion, the $ETCO_2$ monitor is the most reliable method for verifying tracheal intubation in non-cardiac arrest patients. During cardiac arrest and cardiopulmonary resuscitation, however, negative results by the $ETCO_2$ or the EDD are not uncommon, and clinical methods are superior over the use of these devices.

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