PREHOSPITAL CARE

Prehospital determination of tracheal tube placement in severe head injury

Š Grmec, Š Mally

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See end of article for authors' affiliations

Correspondence to: Dr Š Mally, Zdravstveni Dom, dr Adolfa Droica, Ulica talcev 9, Maribor, Slovenia; stefan.mally@guest.arnes.si

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Objectives: The aim of this prospective study in the prehospital setting was to compare three different methods for immediate confirmation of tube placement into the trachea in patients with severe head injury: auscultation, capnometry, and capnography.
Methods: All adult patients (>18 years) with severe head injury, maxillofacial injury with need of protection of airway, or polytrauma were intubated by an emergency physician in the field. Tube position was initially evaluated by auscultation. Then, capnometry and capnography was performed (infrared method). Emergency physicians evaluated capnogram and partial pressure of end tidal carbon dioxide ($EtCO_2$) in millimetres of mercury. Determination of final tube placement was performed by a second direct visualisation with laryngoscope. Data are mean (SD) and percentages.
Results: There were 81 patients enrolled in this study (58 with severe head injury, 6 with maxillofacial trauma, and 17 politraumatised patients). At the first attempt eight patients were intubated into the oesophagus. Afterwards endotracheal intubation was undertaken in all without complications. The initial capnometry (sensitivity 100%, specificity 100%), capnometry after sixth breath (sensitivity 100%, specificity 100%), and capnography after sixth breath (sensitivity 100%, specificity 100%) were significantly better indicators for tracheal tube placement than auscultation (sensitivity 94%, specificity 66%, $p<0.01$).
Conclusion: Auscultation alone is not a reliable method to confirm endotracheal tube placement in severely traumatised patients in the prehospital setting. It is necessary to combine auscultation with other methods like capnometry or capnography.

Severe head injury is major cause of death and disability in young adults.[1 2] The main aim of patient care in the early stages of management should be to prevent or minimise the risk of secondary brain injury (hypotension, hypoxia, oedema).[3] The optimal prehospital interventions are still debated, but evidence suggests that patients with severe head injury in particular benefit significantly from prehospital rapid sequence intubation and field stabilisation.[4] Endotracheal intubation with planned neuromuscular block and in-line cervical alignment remains the gold standard in airway management for trauma patients.[5 6] In this process verification of endotracheal tube placement is of vital importance because unrecognised oesophageal intubation can prove rapidly fatal (death, brain damage).[7] Oesophageal intubation as a complication of emergency airway management in non-arrest patients occurs in 17%–25% of all attempts.[8 9] In many published studies the incidence of missed and unrecognised oesophageal intubation in the prehospital setting was various and contradictory in severely injured patients.[10–16] The aim of our study was to evaluate three different methods (auscultation, capnometry, capnography) for immediate confirmation of tube placement in severe head injury in the prehospital setting.

METHODS

This prospective study was performed at the Emergency Medical Service—Prehospital Unit of Maribor with the approval of the ethical review board of The Ministry of Health and accordant to Slovenian law. Adult patients over 18 years who were intubated by emergency physicians, with severe head injury (Glasgow coma scale (GCS) <9) or maxillofacial injury with need of airway protection or polytrauma were included in the study. All of them were intubated considering current recommendations by method of rapid sequence intubation in trauma[17–19]; patients were preoxygenated by a bag-mask-valve device with 100% oxygen, manual in-line axial stabilisation of head and neck was performed, and the anterior portion of rigid cervical collar removed. Intravenous drugs were given.

(A) sedative-hypnotic: etomidate 0.1–0.2 mg/kg or thiopental 0.5–2.0 mg/kg or ketamine 0,5–1,0 mg/kg and midazolam 0.04–0.07 mg/kg;

(B) neuromuscular relaxants: succinylcholine 1.0–1.5 mg/kg or vecuronium 0.3–0.4 mg/kg

(C) adjunct medication such as opioids (fentanyl 1–3 μg/kg) or lydocain 1.0–1.5 mg/kg.

Cricoid pressure was applied and released after intratracheal intubation. Intubating stylet was used in all patients. Tube position was initially evaluated by auscultation (patient in supine position; auscultation of both infraclavicular fossa, fifth intercostal space in mid-axillary line on both sides and epigastrium). Initial capnometry was performed with BCI Capnocheck Model 20600A1 (BCI International, Waukesha, Wiscosin, USA). Capnography and further capnometry was performed with Propaq Encore, Model 200EL (Protocol Systems, Beaverton, Oregon, USA). There were no important differences in $EtCO_2$ values between these two devices measured in healthy subjects (Pearson's correlation was 0.99 with mean (SD) ΔX 0.5 (0.2) mg Hg). Seven physicians took part in this study, each of them with more than two years of experience in emergency medicine and all with continuing education in ATLS. They determined CO_2 waveform, value of $EtCO_2$ (mm Hg), and clinical signs (auscultation). Intial value of capnometry and value of capnometry and capnogram at the seventh breath was recorded. Final determination of tube placement was performed by direct visualisation with laryngoscope. The protocol used to read values was: initial capnometry value (BCI Capnocheck connector is placed on the endotracheal tube immediate after intubation) is read by first medical technician who helps intubating and ventilating the patient. At the same time the physician auscultates the lung to determine tube position. After initial reading of $EtCO_2$ the second medical technician exchanges BCI Capnocheck connector with Propaq Encore connector and both capnometry and capnography are monitored and values read at the seventh breath and continuously in short intervals until arrival in hospital. Sensitivity, specificity, positive and negative predictive values were calculated using standard formulas. Statistical methods used were Student's *t* test, χ^2 test, and McNemar's test. The Bonferoni correction was applied for multiple comparisons between specificity, sensitivity, and predictive values (table 1). Analysis of variance was used to determine significant differences in confirmation times between three methods. All p values were two tailed and a p value of less than 0.05 was considered significant.

RESULTS

Data were collected prospectively from March 1998 until March 2002. Eighty one patients with head injury were included. There were 58 patients with severe head injury, six patients with maxillofacial trauma requiring intubation for airway protection, and 17 polytraumatised patients, some of them in haemorrhagic shock. Fifty two (64.2%) were men and 29 (35.8%) women with mean (SD) age 42.6 (18.6) years. Mean (SD) GCS value was 6.1 (2.6). Mean (SD) MEES (the Mainz emergency evaluation scoring) value was 18.9 (4.5). Table 1 shows the results.

At the first attempt 73 patients (90.1%) were intubated endotracheally and eight into the oesophagus. Afterwards endotracheal intubation was made in all without complications. The determination of tube placement made by emergency physicians was incorrect in eight cases using auscultation (9.8%); four results (4.9%) were false negative (tracheal position was misdiagnosed as oesophageal) and four false positive (oesophageal position was recognised as endotracheal). Using initial and additional (after sixth breath) values of capnometry and capnography determination of tube placement was correct in all cases. Capnometric initial $EtCO_2$ value varied from 18–78 mm Hg with the mean (SD) 38.4 (18.4) mm Hg; after the sixth breath $EtCO_2$ varied from 25–65 mm Hg with the mean (SD) 41.4 (21.3). There was no significant difference between initial and following $EtCO_2$ values ($p = 0.78$). The fastest determination of tube placement was performed by initial capnometry, read at the time of tube fixation. Determination by auscultation followed in 5–10 seconds after (mean (SD) 7.1 (2.8) s), the time difference was significant ($p<0.05$). Repeated capnometric (capnographic) values at seventh breath were read after 21.4 (5.7) seconds after initial $EtCO_2$.

DISCUSSION

In their research Doran *et al*[20] consider endotracheal intubation in prehospital settings as a great challenge. There is a trauma patient, often with full stomach accompanied by pulmonary secretion, vomiting, bleeding, or a foreign body in the mouth, and a difficult approach to the patient prevents optimal medical care. Because of all these difficulties oesophageal intubation has a high incidence of up to 25%.[7] Knapp *et al*[21] established that auscultation is a method for tube position determination in correlation with the experience of the clinicians. In their in-hospital study more experienced physicians correctly determined tube position in all patients, whereas less experienced only in 68% of cases. In our study physicians were successful using the auscultation method in 90.2%. In four cases of false negative results the breath sounds were not clearly heard by auscultation, the chest did not rise because of obesity, or breath sounds were swamped with stomach gargling. In asthenic patients breath sounds were transmitted to epigastrium and not recognised as pulmonary sounds, so physicians because of doubtful finding and poor visualisation of vocal chords proclaimed intubation as oesophageal. False positive cases are probably attributable to oesophageal turbulent air movement imitating pulmonary sounds. An additional problem is mechanical ventilation—air is moving faster, tidal volume is greater, and gas distribution is different than in spontaneous breathing. In some cases there were some difficulties to differentiate diaphragmatic breathing from epigastric distension. Katz *et al*[22] met a wide response with studying prehospital intubations establishing 25% of them were oesophageal; when considering only trauma patients the percentage increased to 37%. Andersen and Hald[23] reported 15% unrecognised oesophageal intubations using the auscultatory method only. O'Connor and Swor[24] because of similar results claimed clinical methods alone are insufficient for determination of tube placement. In three cases where oesophageal intubation was estimated as endotracheal there was normal oxygen saturation measured by pulse oxymetry throughout the entire observation (in one case the oxymeter did not show a result probably because of peripheral hypothermia and hypotension). This phenomenon is attributed to passive pulmonary ventilation because of oesophageal and stomach distension, with the use of myorelaxanting drugs contributing to indirect ventilation causing relaxation of vocal chords. Normal values in oxymetry can also be prolonged because of hyperventilation before intubation. Oxygen saturation measurments should therefore be valued with regard to clinical signs and $EtCO_2$ values.[25–27]

Our results confirm findings that auscultation alone is insufficient to reliably determine tube position in trauma patients.

Initial capnometric value at seventh breath did prove to be efficient to confirm endotracheal position of tube in trauma patients (100% sensitivity and specificity). We confirmed what was already indicated in previous studies[8 21 24 28 29]—capnometry is a reliable method for determination of tube placement in trauma patients.

Capnography is likewise shown to be a reliable method (100% sensitivity and specificity), without regard to size or

Table 1 Predictive values for three different methods determining tube position in head trauma patients (n = 81)

	False (−)	False (+)	True (−)	True (+)	Sensitivity	Specificity	PPV*	NPV†
Auscultation	4	4	8	65	94 (88–98)	66 (58–70)	94 (88–98)	66 (56–70)
Capnometry 1 (initial)	0	0	8	73	100 (95–100)	100 (97–100)	100 (92–100)	100 (90–100)
Capnometry 2 (at 7th breath)	0	0	8	73	100 (96–100)	100 (94–100)	100 (94–100)	100 (92–100)
Capnography	0	0	8	73	100 (98–100)	100 (97–100)	100 (95–100)	100 (93–100)
					A	B	C	D

A, McNemar's test for sensitivity showed: capnometry 1, capnometry 2, capnography > auscultation ($p<0.01$). B, McNemar's test for specificity showed: capnometry 1, capnometry 2, capnography > auscultation ($p<0.01$). C McNemar's test for positive predictive value showed: capnometry 1, capnometry 2, capnography > auscultation ($p<0.01$). D, McNemar's test for negative predictive value showed: capnometry 1, capnometry 2, capnography > auscultation ($p<0.01$). *Positive predictive value; †negative predictive value.

form of capnogram. Our results are identical to those in literature.[21 24 30 31]

Capnometry and capnography enable us to continuously monitor respiratory status of the patient and to detect system disconnection, tube obstruction or dislocation, tube extraction (reports of tube migration up to 5 cm during transportation), respiratory spasm, etc.[32]

There are many studies that have confirmed and warned about consequences of inappropriate prehospital intubation.[2 10 14 15] In our opinion the importance of our study is in actualisation of a well equipped prehospital EMS unit, where members of the team are skilled to interpret and use measured values correctly.

We believe that in severe head trauma it is obligatory combining different methods to confirm endotracheal position of tube, especially in the prehospital setting. Although some authors disagree,[33 34] we strongly suggest capnometry or better, capnography should become a gold standard for a prehospital trauma team in determining tube position and continuously monitor respiratory status of patient.[16] Because of promptness, especially if the connector is set on the tube immediately after intubation,[35] initial capnometry is the best method to determine tube position and can be definitively confirmed by capnometric values or with capnographic record after sixth breath.

In conclusion, auscultation alone as a method to confirm endotracheal tube placement in trauma patients is not reliable enough. Therefore it is essential to combine it with capnometry or capnography, which represents a gold standard of prehospital trauma team equipment.

Authors' affiliations

Š Grmec, Š Mally, Emergency Medical Service, Prehospital Unit, Maribor, Slovenia

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