ORIGINAL RESEARCH

Evaluation of Manual Cuff Palpation to Confirm Proper Endotracheal Tube Depth

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Abbreviations:
CXR = chest radiograph
ED = emergency department
EM = emergency medicine
ETT = endotracheal tube
ICU = intensive care unit

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Abstract

Introduction: In the prehospital setting, optimal endotracheal tube (ETT) depth may be approximated using the patient's sex or height, and assessed by auscultation. Even when using these methods, the ETTs still may be placed at inappropriate depths.

Problem: This study assessed the inter-rater reliability and accuracy of manual cuff palpation (ballottement) at excluding an improperly placed ETT depth in adult patients.

Methods: This is a prospective, observational, pilot study in a convenience sample of adults recently intubated in the prehospital, medical floor, intensive care unit, or emergency department settings of an urban, teaching hospital. Two physician participants separately performed ballottement on each intubated subject and rated the ballottement as none, weak, or strong prior to assessment of appropriate depth using a chest radiograph (CXR). Results were compared for simple agreement and compared to the CXR to estimate accuracy.

Results: Of 163 patients, 27 (17%) had an inappropriate ETT depth. Physician assessments of ballottement agreed in 79% of patients (95% CI = 72–85%). Chest radiograph assessment found the ETT in the "strong" ballottement group properly placed in 93%, as compared to 77% in the "weak", and 42% in the "none" groups. Combining "weak" and "strong" ballottement, the sensitivity was 96% (95% CI = 93–100%), specificity was 26% (95% CI = 9–43%), and accuracy was 85% (95% CI = 79–90%).

Conclusions: Manual cuff palpation is a simple and reproducible technique that is sensitive, but nonspecific, in identifying intubations of appropriate depth.

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Introduction

Proper endotracheal tube (ETT) placement is an essential aspect of emergent airway management. The first priority is to ensure that the tube is in the trachea. A second priority is to ensure proper depth in the trachea. Deep ETT insertion depth can result in irritation of the carina, excess coughing, hyperventilation, mainstem intubation, atelectasis, hypoxemia, barotrauma, hemodyanamic instability, and rarely, tube thoracostomy for presumed pneumothorax. 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. Right mainstem intubations occur in 2% of all prehospital intubations and 25% of cardiac arrests.[1,2] Even as many as 15% of ETT placements in the intensive care setting are inadequate.[3,4]

A chest radiograph (CXR) is one of the most effective means of confirming ETT depth, and various definitions of appropriate ETT depth have been recommended (Figure 1).[5–9] However, a great number of intubations take place in the prehospital setting or in places where CXRs are not immediately available. Use of a lighted stylet may be helpful, but the stylet is not always available, whereas listening to breath sounds is unreliable.[8,10–13] Several methods to estimate appropriate ETT depth (Figure 2) have been described, although some studies have demonstrated the recommendation of 21 cm in

>2 cm above carina and > 2 cm below cords[5]
3–5 cm (optimally 4 cm) from carina[6]
5 ±2 (3–7) cm from the carina[7]
Midway between medial ends of clavicles[8]
Level of T3 or T4 vertebrae[7]
3.4–5 cm above the tangent line (from lower aspect) of aortic knob[9]

Figure 1—Radiographic criteria for optimal endotracheal tube (ETT) depth

women and 23 cm in men also may lead to inappropriate ETT depth.[3,5,6,12–13]

A quick, accurate, and reliable, bedside maneuver performed immediately after securing the ETT that does not require accessory equipment or knowledge of the patient's height would be helpful. Manual cuff palpation (also known as ballottement) is a method for determining whether the ETT is at appropriate depth. It consists of palpating the pilot balloon by applying pressure in the suprasternal notch).[3,4,16–18] If use of this technique is shown to be effective, it also could be useful in loud ambient environments, such as helicopters, in which auscultation of breath sounds may not be feasible. The goal of this study was to determine the accuracy and inter-rater reliability of manual cuff palpation (ballottement) in determining appropriate depth of the ETT in adult patients prior to obtaining a CXR.

Methods

Design

This study was a prospective, observational study in a convenience sample of intubated adult patients. No funding was received for this study, which was approved, with waiver of informed consent by the Institutional Review Board.

Setting and Population

The study was performed in the prehospital, emergency department (ED), general medical unit, and intensive care unit (ICU) settings of an urban, Level-I trauma center, tertiary referral, teaching hospital with a 63,000 patient/year visit ED census. Enrollment in the study began in July 2002 and ended June 2005.

Eligible subjects all were adult (age >18 years) undergoing intubation as part of their standard medical care, and for whom CXR to confirm ETT placement had not yet been obtained. Exclusion criteria were intubation with a non-cuffed ETT, recent trauma or surgery involving the neck or sternum, or patients felt to be at risk for any reason.

Participant physicians either were emergency medicine (EM) residents (36) or EM faculty (10) who attended a 15-minute training session on the manual cuff palpation (ballottement) method. The training session included a description of the technique, review using an illustrative diagram, and hands-on use of an endotracheal tube to demonstrate pressure on the ETT cuff transmitting pressure to the pilot balloon. The method was again reviewed by a faculty attending (DL, KC) with a participating resident immediately prior to subject enrollment.

21 cm (females) or 23 cm (males) at corner of mouth for orotracheal technique[12]
26 cm (females) or 28 cm (males) at nares for nasotracheal technique[13]
Distance from cricoid to xiphoid[14]
Distance from right mouth corner to the right mandibular angle + distance from the right mandibular angle to center of manubrium[6]
4 + (body height/10 cm) at right upper canine (Chula formula)[5]
[body height (cm)/5] - 13 at right mouth angle[15]

Figure 2—Methods to predict appropriate endotracheal tube (ETT) depth

Study Protocol

The medical management of patients was not altered by the process. Patients were intubated using a cuffed ETT and proper tracheal (not esophageal) placement was confirmed consistent with the current standard of care (such as visualized passage of the ETT through the cords, audible breath sounds, fogging of the tube during expiration, end-tidal carbon dioxide detection). Cuff pressure was left to the discretion of the intubating clinician and respiratory therapist. In general, this was slightly more than required to avoid air leak, and was not standardized nor recorded. After confirmation of tracheal intubation, and prior to obtaining a CXR, manual cuff palpation of the ETT was performed by each of two trained physician participants, each blinded to the intubation and to the results of the other. Convenience sampling occurred as patients were enrolled only if two physicians trained in the technique were immediately present so as to not delay obtaining the CXR.

Manual Cuff Palpation Technique

To perform the procedure, the ETT cuff is compressed through the skin at the suprasternal notch with the fingers of one hand while the pilot balloon of the ETT is held between the thumb and forefinger of the other hand (Figure 3). The physician performing the procedure recorded a subjective measurement of force as either "none", "weak", or "strong". "None" indicated that no pressure transmission was appreciated. "Weak" indicated that some pressure transmission was appreciated in the pilot balloon, and "strong" indicated an obvious, easily appreciated transmission of the pressure.

Measurements

Data were collected by six of 36 trained EM residents by and three of the 10 trained EM faculty. Two participants, each blinded to the intubation and the assessments of the other investigator and any prior CXR, recorded their manual cuff palpation findings of "none", "weak" or "strong", on separate numbered data sheets.

The depth of the ETT in centimeters, at the teeth (for orally intubated subjects), was recorded before and after CXR to ensure ETT displacement had not occurred. A CXR, obtained with the head and neck in the neutral position, then was reviewed by the clinician to confirm appropriate tube depth. The criterion standard for appropriate ETT depth was whether depth was acceptable to the clin-

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Figure 3—Illustration of manual cuff palpation (ballottement) technique

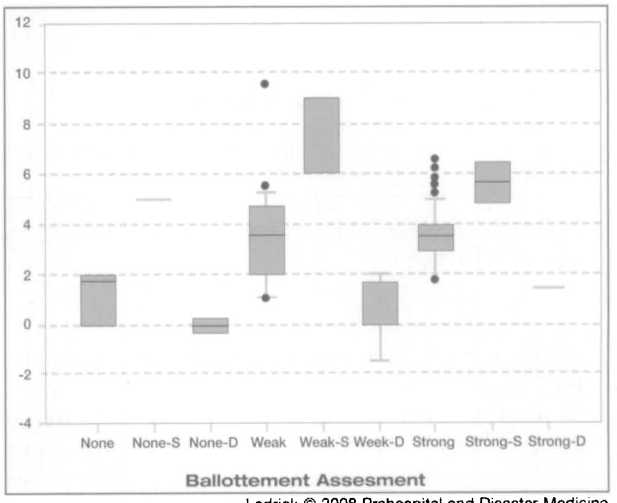

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Figure 4—Carina to ETT Tip Distance (cm) versus Ballottement Assessment.
This box-whisker plot illustrates median values (line within bars), 25th and 75th percentile values (box edges), 10th and 90th percentile values (error bars of whiskers) and outliers (dots). The ballottement assessments were 'none', 'weak' or 'strong', from left to right, at appropriate depth, shallow (S) or deep (D).

ician and did not require repositioning. The distance from the carina to the tip of the ETT also was measured with a digital picture archiving and communications system (Kodak Directview Web Software v 5.2 and 5.2.1, Eastman Kodak Co, Rochester, NY) prior to any ETT repositioning (Figure 4).

Additional data recorded on each of the subjects included age, gender, study number, type of intubation (oral versus nasal), and location (prehospital, ICU, medical unit, or ED) where the subject was intubated.

Data Processing

Data were processed using SAS version 8.0 (SAS Institute, Cary, NC). Subjects were categorized into three groups based on the first physician's ballottement assessment—none, weak, or strong. The independent physician's assessment was used only for the inter-rater reliability study. Because inter-rater reliability was good, using the first physician's assessment for grouping was justified. For inter-rater reliability, "weak" and "strong" assessments were combined into one category and compared to the "none". McNemar's matched-pairs test was used to determine the level of agreement between the two physicians. The Kappa statistic also was calculated.

Finally, assuming the CXR assessment of proper placement was the criterion standard, the sensitivity, specificity, and positive and negative predicted values of ballottement as a diagnostic test were calculated, along with 95% confidence intervals.

Results

A total of 163 patients were enrolled, with the majority, 86 (53%), intubated while in the emergency department, 45 (28%) ICU patients were enrolled, 22 (13%) were intubated in the prehospital setting, and four (2%) were intubated on a medical ward. Nine patients were intubated nasally and 154 were intubated orally. No subjects were excluded based on neck trauma or surgery, non-cuffed tube, or medical risk. None of the patients had either esophageal intubation or hypopharyngeal (above cord) ETT placement. The average age of the patients was 63 ±16 years (±SD), and 58% were male. Twenty-seven (17%) tubes were repositioned by clinicians, 17 (10%) were too deep, and 10 (6%) were shallow. Of the deep intubations, 10 (6%) were at or below the carina.

Inter-Rater Reliability

The differences in ballottement assessments between the two participant physicians are in Table 1. Raw agreement between raters was 79% (95% CI = 72–85%). For simplicity, the "weak" and "strong" categories were combined (collapsing to a 2 x 2 table). The ETT depth did not vary much between the groups with a "weak" or "strong" assessment, but did vary between these groups and the group of those who had an assessment of "none". "None" was the assessment for 7% of patients by the first physician and 6% by the independent second physician. The two physician's ballottement assessments agreed for 93% (95% CI: 88–97%) of the patients. McNemar's matched-pairs test showed no significant difference between physicians (test value = 0.33, df 1, p-value = 0.6). The Kappa statistic was 0.41 (95% CI: 0.14–0.69), which is considered as moderate agreement.

Accuracy

The three ballottement groups were similar with respect to the traditional measurement of centimeter markings at the teeth. However the "none" group had a shorter distance from the tip of the ETT to the carina than the "weak" and "strong" groups. More of the "strong" ballottement group had a properly placed ETT depth on CXR than did the "weak" or "none" groups (Table 2).

Of the 136 appropriate depth intubations, 84 were rated as strong, 47 as weak and five had absent ballottement. Of

	None	Weak	Strong
None	5	2	2
Weak	6	49	13
Strong	1	11	74

Table 1—Ballottement assessments by participating physicians (3 x 3)

	Chest Radiograph Placement Assessment	
Ballottement Assessment as a Diagnostic Test	*ETT Appropriate Depth*	*Inappropriate ETT Depth*
Present	131	11 deep 9 shallow
None	5	6 deep 9 shallow

Table 3—Ballottement result versus appropriate endotracheal tube (ETT) depth by chest radiograph
*5 in each of these groups were "very deep"

	Teeth (cm)	Carina to ETT tip (cm)	Adequate EET Depth
Ballottement Assessment	*Mean ±SD*	*Mean ±SD*	*Mean (95% CI)*
None	23.6 ±2.1	1.37 ±1.57	42 (14–70%)
Weak	23.4 ±1.5	3.37 ±2.21	77 (67–88%)
Strong	23.1 ±2.9	3.56 ±1.28	84 (88–98%)

Table 2—Ballottement assessments by participating physicians (3 x 3) (ETT = endotracheal tube)

the 10 shallow intubations, ballottement was strong in four, weak in five, and absent in one. Of the 17 deep intubations, ballottement was strong in two, weak in nine, and absent in six cases.

This study also examined the accuracy from a diagnostic testing perspective by comparing ballottement assessment ("weak/strong" as "present" vs. "none") to CXR placement assessment (appropriate depth, not appropriate depth) (Table 3). The sensitivity of ballottement to predict appropriate ETT depth was 96% (95% CI = 93–100%), specificity 26% (95% CI = 9–43%), positive predictive value 87% (95% CI = 81–92%), negative predictive value 58% (95% CI = 30–86%) and accuracy 85% (95% CI = 79–90%). If very deep ETT placement (at or below carina) was the primary concern, the specificity was 50% (95% CI = 19–80.9%) and the negative predictive value 42% (95% CI = 14–70%)

Discussion

Suprasternal palpation of the ETT tip (not cuff) has been used to assess correct ETT placement in neonates and infants, and originally was described in 1834 by Blundell.[8,19] In 1993, Pollard and Lobato presented a modification of this method in which gentle, repetitive pressure in the suprasternal notch, indirectly over the ETT cuff, is sensed in the pilot balloon as the ETT is advanced (or withdrawn) into an appropriate position.[4] Since the suprasternal notch normally is above the carina by 5 ±2 cm in adult cadavers, ballottement of the ETT cuff in this location predicts optimal ETT depth.[20] This manual cuff palpation (ballottement) method accurately guided appropriate ETT depth in all of the 82 anesthesia subjects. In 1994, Schwartz *et al* reported the use of cuff palpation to confirm adequate ETT position, instead of guiding ETT placement, and found that even when used in combination with clinical assessment (auscultation, chest rise), that as many as 15% of 271 intensive care endotracheal tubes were malpositioned <2 cm from the carina on CXR.[3] In 1995, Goldman *et al* and Okuyama *et al* described the use of manual cuff palpation to guide appropriate ETT placement in all 75 adult and 59 pediatric anesthesia patients, respectively.[16,17] More recently, in 2000, Pattnaik and Bodra modified this ballottement technique by alternately pressing in the suprasternal notch over the ETT cuff while feeling distention in the pilot balloon, as well as by squeezing the pilot balloon while sensing distention of the ETT cuff in the suprasternal notch.[18] This ballottement method was used to guide adequate position in all of the 120 patients in the ICU.

The present study is unique as it is the first to assess the inter-rater reliability of ballottement in predicting ETT depth, including endotracheal tubes placed in the prehospital or emergency department settings, with raters blinded to intubation technique, each other's results, and radiographic findings. With minimal training, the test has reasonable reliability in assessing tube placement. Accuracy, however, was much lower than anticipated, and certainly lower than many prior studies, with the exception of Schwartz *et al*.[3,4,16–18] The majority (90%) of shallow intubations had false positive ballottement. It is a greater concern that many deep (65%) and very deep (50%) intubations (at or below the carina) had false positive ballottement.

A positive ballottement test following intubation in the prehospital setting may give a false sense of security, and always should be accompanied by other methods of assessing ETT depth, such as auscultation for breath sounds, watching for bilateral chest rise, and sensing lung compliance with the bag.

In contrast to several of the initial studies where ballottement was a dynamic part of the intubation process, the present study used the ballottement method to assess appropriate ETT depth after the endotracheal tube already had been secured, similar to the study of Schwartz *et al*.[3,4,16–18] It is possible that "dynamic" ballottement, during the intubation process, has greater accuracy for appropriate tube placement, since in each of these studies there were no malpositioned ETT depths, whereas "static" ballottement, performed after the ETT is secured, was less accurate in the present study and that by Schwartz *et al*.[3] It also is possible that the ballottement method is more accurate when performed by experienced anesthesiologists than by emergency physicians with minimal training in the technique.

There are several limitations to this study, the greatest of which might be the definition of appropriate ETT depth determined by clinicians repositioning the tube. Although there is inconsistency among experts regarding appropriate ETT depth, most would agree that ETT depth <2 cm from the carina is too deep, since neck flexion could result in mainstem intubation, and that ETT depth from the carina greater than 7 cm is too shallow, and could increase the risk for extubation or glottic injury, especially with neck extension.[21,22] If the definition of appropriate ETT depth was from 2 to 7 cm from the carina, the specificity and accuracy would diminish (21% and 81%, respectively) without changes in the sensitivity, negative predictive value, or the conclusions

The rate of ETT placement with the tip being too deep (at least 17% in general and 6% very deep) was similar to that observed in previous studies.[3,4] However, the small numbers of patients with a ballottement assessment of "none", as well as for patients with sufficient ETT depth, lead to great uncertainty (wide confidence intervals) in the validity of point estimates for negative predictive value and specificity, respectively. Although ballottement is not meant to detect esophageal intubation, the predictive ability of ballottement for esophageal intubation remains unknown, since none occurred in this study. Non-palpable ballottement more commonly implied deep rather than shallow ETT placement, but also could theoretically indicate esophageal intubation.

Additionally, the number of subjects intubated during the study period, and why many of these were excluded is unknown. It is likely that the demands of a busy emergency department hampered study enrollment, since participating physicians were primarily responsible for patient care and research assistants were not available. It also is possible that patients were excluded because of characteristics that could have made cuff palpation less accurate. It also is unknown how many subjects were enrolled by each of the participants. Two of the participants (DL, KC) were more interested in the study outcome than others, and enrolled the majority of the subjects, whereas inexperienced participants may have been reluctant to enroll subjects. Although the technique is easy to learn and has good inter-rater reliability, it may be that inexperienced participants have lower accuracy.

Future research could focus on the effects of body habitus, neck size, anatomic abnormalities, forces applied in the sternal notch, and cuff inflation pressures (or volumes) on accuracy. Also, a repeat of this study using providers more experienced in the technique could yield different results. Since improper ETT depth may be more of a danger in small or pediatric patients, further study could address the utility of ballottement in comparison to auscultation, chest rise, or other methods of predicting proper ETT depth in these patients.

Although this technique may have greatest utility in the prehospital setting, its use by physicians in the hospital was studied because of the immediate availability of chest radiography, and to minimize ETT movement prior to verification of ETT depth. Further research should address the ability of prehospital personnel to accurately assess ETT depth using the ballottement method in the prehospital environment.

Conclusions

Manual cuff palpation (ballottement) is a simple technique that is reasonably reproducible after minimal training, and has high sensitivity in identifying intubations of appropriate depth. The technique is limited in identifying intubations of inappropriate depth.

References

1. Jemmett ME, Kendal KM, Fourre MW, Burton JH: Unrecognized misplacement of endotracheal tubes in a mixed urban to rural emergency medical services setting. *Acad Emerg Med* 2003;10:961–965.
2. Dronen S, Chadwick O, Nowak R: Endotracheal tip position in the arrested patient. *Ann Emerg Med* 1982;11:116–117.
3. Schwartz DE, Lieberman JA, Cohen NH: Women are at greater risk than men for malpositioning of the endotracheal tube after emergent intubation. *Crit Care Med* 1994;22:1127–1131.
4. Pollard RJ, Lobato EB: Endotracheal tube location verified reliably by cuff palpation. *Anesth Analg* 1995;81;135–138.
5. Techanivate A, Kumwilaisak K, Samranrean S. Estimation of the proper length of orotracheal intubation by Chula formula. *J Med Assoc Thai* 2005;88:1838–1846.
6. Evron S, Weisenberg M, Harow E, Khazin V, Szmuk P, Gavish D, Ezri T: Proper insertion depth of endotracheal tubes in adults by topographic landmarks measurements. *J Clin Anesth* 2007;19:15–19.
7. Goodman LR, Conrardy PA, Laing F, Singer MM: Radiographic evaluation of endotracheal tube position. *Am J Roentgenol* 1976;127:433–434.
8. Bednarek FJ, Kuhns LR: Endotracheal tube placement in infants determined by suprasternal palpation: a new technique. *Pediatrics* 1975;56:224–229.
9. Pappas JN, Goodman PC: Predicting proper endotracheal tube placement in underexposed radiographs: Tangent line of the aortic knob. *AJR* 1999;173: 1357–1359.
10. Locker GJ, Staudinger T, Knapp S, Burgmann H, Laczika KF, Zimmerl M, HŒrmann M, Frass MR: Assessment of the proper depth of endotracheal tube placement with the Trachlight. *J Clin Anesth* 1998;10:389–393
11. Sugiyama K, Yokoyama K: Reliability of auscultation of bilateral breath sounds in confirming endobronchial tube position. *Anesthesiology* 1995;83:1373.
12. Roberts JR, Spadafora M, Cone DC: Proper depth placement of oral endotracheal in adults prior to radiographic confirmation. *Acad Emerg Med* 1995;2:20–24.
13. Reed DB, Clinton JE: Proper depth of placement of oral endotracheal tubes in adults prior to radiographic confirmation. *Acad Emerg Med* 1997;4:1111–1114.
14. Shellinger RR: The length of the airway to the bifurcation of the trachea. *Anesthesiology* 1964;25:169–172.
15. Cherng CH, Wong CS, Hsu CH, Ho ST: Airway length in adults: estimation of the optimal endotracheal tube length for orotracheal intubation. *J Clin Anesth* 2002;14:271–274.
16. Okuyama M, Imai M, Sugawara K, Okuyama A, Kemmotsu O: [Finding appropriate tube position by the cuff palpation method in children] *Masui* 1995;44:845–848.
17. Goldman JM, Armstrong JP, Vaught LE, Daniel LC: A new method for identifying the depth of insertion of tracheal tubes. *Biomed Sci Instrum* 1995;31:225–228.
18. Pattnaik SK, Bodra R: Ballotability of cuff to confirm the correct intratracheal position of the endotracheal tube in the intensive care unit. *Eur J Anaesthesiol* 2000;17:587–590.
19. Jain A, Finer NN, Hilton S, Rich W: A randomized trial of suprasternal palpation to determine endotracheal tube position in neonates. *Resuscitation* 2004;60:297–302.
20. Stewart RD, LaRosee A, Kaplan RM, Ilkhanipour K: Correct positioning of an endotracheal tube using a flexible lighted stylet. *Crit Care Med* 1990;18:97–99.
21. Sugiyama K, Mietani W, Hirota Y, Matsuura H: Displacement of the endotracheal tube caused by postural change: Evaluation by fibreoptic observation. *Anaesth Pain Control Dent* 1992;1:29–33.
22. Yap SJ, Morris RW, Pybus DA: Alteration in endotracheal tube position during general anaesthesia. *Anaesth Intens Care* 1994;22:586–588.

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