Neuroanesthesia and Intensive Care

Colorimetric carbon dioxide detector to determine accidental tracheal feeding tube placement

[Un détecteur colorimétrique de gaz carbonique pour déterminer la mise en place endotrachéale accidentelle d'un tube d'alimentation]

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Purpose: To determine the accuracy of colorimetric CO₂ detection compared to the reference standard two-step radiological confirmation of feeding tube position.

Methods: A prospective study was conducted with patients presenting to a 21-bed medical-surgical intensive care unit. An adapter was developed using an endotracheal tube adapter to connect a colorimetric CO₂ detector to a feeding tube in an airtight manner. In part I of the study a feeding tube connected to the colorimeter was inserted into the endotracheal tubes of ten ventilated patients to test the device's ability to detect tracheal placement. In part II patients undergoing feeding tube insertion had tube position confirmed with the colorimeter as well as the reference standard two-step x-ray.

Results: In phase I the colorimeter correctly identified tracheal placement in all ten patients. In phase II 93/100 procedures ultimately were eligible; the colorimeter had a sensitivity of 0.88 (95% confidence interval: 0.65–1.00) and specificity of 0.99 (0.97–1.00). The device missed one of the eight tracheal placements. Agreement between the colorimeter and two-step x-ray interpretations was excellent (Kappa 0.86; standard error 0.10).

Conclusion: We describe a novel, convenient method to confirm esophageal feeding tube placement. The device is easily assembled and inexpensive, but should not be reused. Colorimetric determination of tracheal feeding tube placement with this device has excellent agreement with the reference standard two-step radiological technique.

Objectif : Déterminer la précision de la détection colorimétrique du CO₂, comparée à la confirmation radiologique de référence en deux étapes, de la position du tube d'alimentation.

Méthode : L'étude prospective a été menée chez des patients admis dans une unité de soins intensifs médicaux et chirurgicaux de 21 lits. En utilisant un adaptateur de tube endotrachéal, nous avons relié de façon étanche un détecteur colorimétrique de CO₂ à un tube d'alimentation. Dans la phase I de l'étude, un tube d'alimentation relié au colorimètre a été inséré dans le tube endotrachéal de dix patients ventilés pour vérifier la capacité de l'appareil à détecter la mise en place endotrachéale. Dans la phase II, la mise en place du tube a été confirmée par le colorimètre et par la technique radiographique en deux étapes.

Résultats : En phase I, le colorimètre a correctement reconnu la position endotrachéale chez les dix patients. En phase II, 93/100 des interventions ont été finalement admissibles ; le colorimètre avait une sensibilité de 0,88 (intervalle de confiance de 95 : 0,65–1,00) et une spécificité de 0,99 (0,97–1,00). L'appareil n'a pu identifier une des huit insertions endotrachéales. La concordance entre les interprétations du colorimètre et du rayon-x en deux étapes a été excellente (Kappa 0,86 ; erreur type de 0,10).

Conclusion : Nous avons décrit une méthode nouvelle et pratique de confirmer la mise en place du tube d'alimentation dans l'œsophage. L'appareil est facile à assembler et économique, mais ne doit pas être réutilisé. La détermination colorimétrique de la position endotrachéale du tube d'alimentation avec cet appareil présente une excellente concordance avec la technique radiologique habituelle en deux étapes.

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IN a fully conscious patient with normal mentation and sensation, accidental tracheal placement of small bore feeding tubes is easily recognized. The stimulation of the tube causes a profound gag and cough, as well as difficulty in phonation. Unfortunately, many patients who are having a feeding tube placed are not fully alert or have abnormal protective reflexes.

Tracheal placement can result in significant morbidity, and is not prevented by a cuffed endotracheal tube.¹ The complication rate for feeding tube placement may be as high as 4.4%.² Complications include pneumothorax, atelectasis, pleural effusion, bronchopleural fistula, hydrothorax, empyema, mediastinitis, pneumonitis, esophageal perforation and pneumonia.³

Auscultation of air in the stomach has been classically used to confirm placement, but air infused into the pleural space can just as easily be heard over the upper abdomen.⁴ This method, as well as other tests that confirm placement after the tube is fully advanced takes place when the tube may already have perforated the bronchus. Further methods include fluoroscopy, endoscopy and direct visualization. These techniques are labour intensive, expensive, and add extra discomfort or radiation to the patient.⁵

The safest way to ensure esophageal placement of the feeding tube is the "two-step" technique, first described in 1989.² The feeding tube is inserted part way, to a distance approximating a point a few centimetres past the carina (30 cm of tube length). An *x-ray* is taken to confirm midline position past divergence of the carina, after which the feeding tube is advanced and a second *x-ray* is taken to confirm position below the diaphragm. If the tube is in the bronchus, it is removed. If the tube is above the carina, bronchial or esophageal placement cannot be determined. The tube is advanced a short distance and the first-step *x-ray* is repeated. This technique is safe and accurate and is the reference standard for confirming feeding tube placement, however the technique is also time-consuming, expensive and inconvenient.

Electronic capnographs that use infrared absorption spectrometry, generally used to measure end-tidal CO₂ and confirm endotracheal tube placement, have been used to confirm esophageal placement of feeding tubes.^{5,6} These devices are expensive and are not always available where feeding tubes are being inserted. Colorimetric end-tidal CO₂ devices use a sulfonephthalein-impregnated pH-sensitive filter paper as an indicator that changes from purple to yellow in the presence of carbon dioxide.⁷ They were developed to confirm endotracheal tube placement, so unlike the

FIGURE Assembly of study device. CO₂ = colorimetric end-tidal CO₂ detector; ET3.5 = 3.5-mm endotracheal tube adapter; ET7 = 7-mm endotracheal tube adapter; FT = feeding tube; NA = 15-mm nipple adapter; SY = body of a 3-mL syringe.

electronic capnographs they have no adapters for feeding tubes and no sampling stream to ensure a flow of gases through the feeding tube. They are single use and disposable, and can be easily stocked anywhere in the hospital.

In 1998 Thomas *et al.* described a study of ten patients for whom colorimetric end-tidal CO₂ detection was used to document proper feeding tube placement.⁸ In 2002 a larger study of 53 patients⁹ used a disposable tracheostomy tube inner cannula with a 15-mm snap-lock connector to attach the feeding tube to the colorimeter. This study also reported 100% accuracy in determining tube placement. While showing impressive results, the sample size of these two studies was modest, and neither team attempted to overcome the potential problem of gas sampling.

We have developed an alternative method for using colorimetric CO₂ detectors to confirm feeding-tube placement. Two types of adapters were developed (Figure) using materials readily available in most intensive care units (ICU). In addition, suction was added to ensure gas sampling through the feeding tube.

The purpose of our study was to assess the accuracy of this novel colorimetric CO₂ detection device in detecting appropriate feeding tube placement with that of the reference standard involving the two-step radiological confirmation.

Methods

After Queen's University and Affiliated Teaching Hospitals Health Sciences Human Research Ethics approval, this study was undertaken in the 21-bed medical-surgical ICU of the Kingston General Hospital.

The authors developed two methods for attaching the feeding tube to a colorimetric CO₂ indicator (Easy Cap II, Nellcor Puritan Bennett, Pleasanton, CA, USA) from materials readily available in the hospital (Figure). The adapter from a 3.5-French endotracheal tube (Mallinckrodt, St. Louis, MO, USA) connects to the intake of the colorimeter and forms a snug fit in to the feeding tube (Entriflex, Sherwood Davis & Geck, St. Louis, MO, USA). For institutions without pediatric endotracheal tubes, the body of a 3-mL syringe has a Luer-Lok (Becton Dickinson & Co, Franklin Lakes, NJ, USA) to connect to the feeding tube while the adapter from a 7-French endotracheal tube (Mallinckrodt, St. Louis, MO, USA) connects to the intake port of the colorimeter and fits into the body of the syringe. Low-wall suction is briefly applied to the outflow of the colorimeter by using a 15-mm nipple tip adapter.

Phase I – ten endotracheal placements

For the first phase of the study, we wanted to ensure the device could detect tracheal placement. A convenience sample of ten intubated patients who would not suffer from a brief disconnection from positive pressure ventilation was selected. Feeding tubes were inserted into the endotracheal tube and the device was attached to the feeding tube. Low wall suction was applied to the opposite end of the detector for approximately five seconds. A change in indicator colour from purple to tan or yellow was considered a positive result.

Phase II – evaluation in 100 intubated patients

In the second stage of the study 100 consecutive intubated patients were enrolled. Any adult patient admitted to the ICU who was being ventilated and required a small-bore feeding tube was considered eligible.

Exclusion criteria were patient or decision maker's refusal of a feeding tube, contraindication to feeding tube placement, or difficult insertion requiring direct laryngoscopy. Patients who for any reason required repeated insertions (most often accidental tube removal) could be enrolled more than once. The unit of analysis was procedures performed.

For each procedure a feeding tube was inserted in the standard manner as for the two-step radiological technique, which served as the reference standard. Twenty-five centimetres approximates the distance from the lips to the carina in most patients, so the tube was inserted a distance of approximately 30 cm, adjusted to patient size. Before the first *x-ray* was taken, the device was attached to the feeding tube and a colorimetric determination of placement was made. This result was recorded on the study form. After recording the result, the first chest roentgenogram was obtained. If the feeding tube had passed distal to the carina, the position (esophageal or tracheal) was recorded on the study form. If the feeding tube was proximal to the carina and position could not be determined, it was advanced the required distance and the *x-ray* repeated without redoing the CO₂ detection. If there were difficulties in repositioning requiring withdrawal of the tube, the device was connected again and recorded before taking another chest roentgenogram.

Clinical intervention (removal of a tracheal feeding tube *vs* advancement) was based solely on roentgenogram interpretation, not on colorimetric measurement.

Statistical analysis

For the ten intubated patients in phase I, the percentage that the colorimetric detector changed colour (from purple to tan or yellow) was calculated as an indication of the frequency of correct detection of endotracheal placement.

In phase II, each eligible procedure was classified according to the results of the CO₂ based determination of feeding tube placement and the chest roentgenogram determination of tube placement. The latter was considered the reference standard in these analyses. The kappa statistic¹⁰ was used to describe agreement between the CO₂ based and chest roentgenogram determinations. Kappa coefficients were interpreted according to the following a priori criteria: $\kappa > 0.75$ indicated excellent agreement, $0.40 \leq \kappa \leq 0.75$ good agreement, and $\kappa \leq 0.40$ marginal agreement.¹⁰ Standard measures of diagnostic validity (sensitivity, specificity) with exact confidence intervals were also calculated.¹⁰

Results

Phase I

The colorimetric CO₂ detector changed colour in all ten of the procedures when the feeding tube was placed down the endotracheal tube. In most of the patients, the colour change occurred before the device was placed on suction, but there were some patients whose colorimeter did not change until suction was applied. Colour changes were obvious and there was no confusion about the result.

Phase II

One hundred procedures were involved in the study. Seven of the encounters were excluded from the analysis because of failure to complete the form indicating radiologic result (six) or breach in protocol (one; *x-ray* prior to colorimetric determination). The colorimeter agreed with the radiologic interpretation in the case of the protocol breach.

Results from the remaining 93 patient procedures are shown in the Table. Eight of the encounters (8.6%) involved tracheal placement, the remaining 85 (91.4%) were esophageal. There was one incorrect result in each category, giving a sensitivity of 0.88 (95% confidence interval 0.65–1.00) and a specificity of 0.99 (0.97–1.00). The Kappa was 0.86 (excellent agreement) with a standard error of 0.10.

Discussion

Previous studies have used different methods for connecting the colorimeter to the feeding tube. Araujo-Preza *et al.* used the inner cannula from a tracheostomy tube.³ The advantage of using the adapter from a pediatric endotracheal tube is that the colorimeter is designed to fit the proximal end, while the distal end comes in a range of sizes that permits selection for any feeding tube. The availability of a wide range of endotracheal tube adapters makes this device useful for any brand of feeding tube.

For this study, the guide wire (stylet) of the feeding tube was removed during CO₂ determination. Although the risk is extremely low when reinsertion of the wire is undertaken properly, perforation of the wall of the feeding tube with the wire has been described.¹¹ The adapter described allows connection of the device with or without the wire in place.

Unlike the two previous trials on colorimetric CO₂ detectors used for this purpose,^{3,8} our study addressed the issue of gas sampling. Leaving the device attached to the feeding tube and relying on patient ventilation to move CO₂ through the tube to the detector will work in most patients, but not all. During the initial development and in the first phase of this trial we

TABLE Results of 93 procedures (study Part II)

Experimental procedure determination	<i>x-ray</i> determination		
	Tracheal	Esophageal	
Colour change	7	1	8
No colour change	1	84	85
	8	85	93

Agreement between experimental (colorimetric carbon dioxide detector) and reference standard (*x-ray*) Determinations of feeding tube placement in 93 procedures.

found that some patients had to have the device connected to suction to detect tracheal placement. The use of suction gives an immediate result, removes the need for waiting and the uncertainty of whether a negative result is due to correct placement or insufficient waiting time.

The colorimetric CO₂ detector was incorrect on two occasions. Incorrect results are of the greatest concern when tracheal placement has occurred (false negative result), and complications can ensue. In retrospect, it was found that the particular colorimeter that was used for that patient had been reused for a number of patients, and it was unclear if it was still functioning. For that reason and for proper infection control the authors recommend using a new colorimeter for each test of tube placement.

The results of this study are encouraging. The Kappa values of 0.883 and 0.933 show excellent agreement with the reference standard.¹⁰ The sensitivity of 94.4 and specificity of 98.8 are high. Previous studies have both reported 100% sensitivity and specificity, but with more modest sample sizes.

The cost of using the CO₂ detector technique is significantly less than the cost of the two-step *x-ray* technique. A true cost analysis is beyond the scope of this article, but at our centre the cost of the CO₂ detector (\$11.93 Can) and the connector (\$1.21 Can) are less than the cost of a single chest roentgenogram, estimated to cost anywhere from \$25 to \$75 Canadian. Capnometry is much faster and less labour intensive than radiological interpretation, and it occurs at the bedside with the results available as the procedure is being performed. Fewer delays and ease of use should lead to greater compliance with a safe technique. Sampling tubing for electronic capnographs costs \$19.02 to our institution and are recommended for single use only, making them more expensive than colorimetric capnometers.

The practical disadvantage of performing the two-step radiologic confirmation is that it is time consuming, taking a median of 159 min.⁵ While the complications from feeding tube insertion can be severe, the majority of them are minor (when detected before feeding) and easily corrected, so clinicians often choose not to bother. Capnographic tube confirmation could save up to one hour and 45 min over the radiologic method.⁵ For critical care units without electronic capnography, the colorimetric device offers a simple and relatively inexpensive alternative.

This study has some limitations. We used a convenience sample of patients receiving a feeding tube, and although there were incentives for physicians enrolling patients and minimal inconvenience in performing the study, it is quite possible that some patients receiving feeding tubes in the ICU were not enrolled. Because both the colorimetric CO₂ detector technique and *x-ray* confirmation were performed on all patients, the results should be generalizable. To our best knowledge, the technique is applicable to any patient producing CO₂.

In summary, we describe a novel, convenient method to confirm esophageal feeding tube placement. The device is easily assembled and inexpensive, but should not be reused. Colorimetric determination of tracheal feeding tube placement with this device has excellent agreement with the reference standard two-step radiologic technique.

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