Project Title

Confirming nasogastric tube placement: Is the colorimeter as sensitive and specific as X-ray? A diagnostic accuracy study

Project Lead and Members

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National University Health System, National University Hospital, Yong Loo Lin School of Medicine

Aims

To ascertain the diagnostic measure of colorimeter, with radiographic examination as the reference standard, to confirm the location of nasogastric tubes in patients.

Project Category

Clinical Improvement, Research

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Confirming nasogastric tube placement: Is the colorimeter as sensitive and specific as X-ray? A diagnostic accuracy study

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ABSTRACT

Background: The effect of delivering enteral nutrition or medications via a nasogastric tube that is inadvertently located in the tracheobronchial tract can cause respiratory complications. Although radiographic examination is accepted as the gold standard for confirming the position of patients' enteral tubes, it is costly, involves risks of radiation, and is not failsafe. Studies using carbon dioxide sensors to detect inadvertent nasogastric tube placements have been conducted in intensive care settings. However, none involved patients in general wards.

Objective: The objective of this study was to ascertain the diagnostic measure of colorimeter, with radiographic examination as the reference standard, to confirm the location of nasogastric tubes in patients.

Design: A prospective observational study of a diagnostic test.

Setting: This study was conducted in the general wards of an approximately 1100-bed acute care tertiary hospital of an Academic Medical Center in Singapore.

Participants: Adult patients with nasogastric tubes admitted to the general wards were recruited into the study.

Methods: The colorimeter was attached to the nasogastric tube to detect for the presence of carbon dioxide, suggestive of a tracheobronchial placement. The exact location of the nasogastric tube was subsequently confirmed by a radiographic examination.

Results: A total of 192 tests were undertaken. The colorimeter detected carbon dioxide in 29 tested nasogastric tubes, of which radiographic examination confirmed that four tubes were located in the tracheobronchial tract. The colorimeter failed to detect carbon dioxide in one nasogastric tube that was located in the tracheobronchial tract, thus, demonstrating a sensitivity of 0.80 [95% CI (0.376, 0.964)]. The colorimeter detected absence of carbon dioxide in 163 tested nasogastric tubes in which radiographic examination confirmed 160 gastrointestinal and one tracheobronchial placements, demonstrating a specificity of 0.865 [95% CI (0.808, 0.907)]. The colorimeter detected one tracheobronchial nasogastric tube placement that the radiographic examination was misinterpreted.

Conclusion: The study found that the use of the colorimeter in the general ward setting was not 100% sensitive or specific in ascertaining the location of a nasogastric tube as previously reported by many studies undertaken in intensive care settings. This is the first study on the use of a colorimeter to confirm the placement of a nasogastric tube in adult

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patients in the general ward setting. More research on the use of a colorimeter in the general ward setting and its potential use in certain processes for confirming the placement of a nasogastric tube is warranted.

What is already known about the topic?

- Aspirate of pH value of 5.5 or less suggests that the NGT is in the stomach. However, the gastric fluid aspirate might be affected by proton-pump inhibitors such as H2-blockers and antacids, which may increase the pH value of the aspirate to 6 or higher.
- Aspirate of pH value of 6 or more suggests tip of NGT may be in the stomach or tracheobronchial tract (incorrect location).
- Radiographic examination is the gold standard in confirming the position of the NGT in doubtful placements. However, there are still issues of incorrect interpretation of the radiographic imaging.
- In the mechanically ventilated patients that is admitted to the intensive care unit, the colorimeter is close to 100% sensitive and specific in confirming the placement of NGT when tested against the reference standard – X-ray.

What this paper adds

- Use of the colorimeter was not 100% sensitive and specific in determining the location of the nasogastric tube when tested against the X-ray in the adult general ward setting.
- Excessive respiratory secretions may cause blockage of a patient's nasogastric tube that is located in the tracheobronchial tract which may have resulted in the colorimeter test showing an absence of carbon dioxide (false negative finding).
- The colorimeter served as an additional test to ascertain placement of the nasogastric tube in the tracheobronchial tract in one instance where radiographic image was wrongly misinterpreted as being in the gastric region.

1. Introduction

Nutrition plays a crucial role in patients' health and well-being. Patients who require enteral nutrition are commonly quite ill or debilitated, may be experiencing malnutrition, or have the potential for malnutrition. The insertion of a nasogastric tube (NGT) for enteral nutrition may be ordered for patients in situations where their nutritional intake is inadequate or consuming food via the mouth is unsafe, such as in those with dysphagia (National Institute for Health and Clinical Excellence, 2006). Given that an NGT is mainly inserted as a blind procedure, it may be inadvertently inserted or dislodged into the respiratory system. Administered feeds via a misplaced NGT has a potential risk of causing serious complications (Metheny et al., 2007) such as aspiration pneumonia or death (Phillips and Nay, 2008). In the UK, the National Health Service (England) reported 21 deaths and 79 cases of harm associated with malpositioned NGT feeding between September 2005 and March 2010 (National Patient Safety Agency, 2011). A systematic review (Sparks et al., 2011) of complication arising from the blind placement of nasoenteric feeding tubes found that 1.9% ($n = 187$) of the nasoenteric tubes were malpositioned in the tracheoonchial tract of patients. Pneumothorax and death were complications cited in the review (Sparks et al., 2011).

Complications arising from misplaced NGTs are preventable (Metheny et al., 2007). Thus, the National Health Service (2015) designated misplaced NGTs as a 'Never Event'. Thus, confirming the position of an NGT prior to commencing enteral nutrition is imperative to ascertain that an NGT is not in the respiratory system after the initial insertion, as well as prior to administering medication or feeds via the NGT (National Health Service, 2013). The National Patient Safety Agency (2011) recommends performing a pH test of the NGT aspirate as a first-line test to confirm the internal position of the NGT. A pH value of 5.5 or less suggests that the NGT is in the stomach; a pH value of 6 or more may indicate intestinal or respiratory placements of the NGT (Taylor, 2013). The use of pH indicators in some instances was limited in diagnosing the correct placement of the NGT as it relied on the operator's interpretation of color change and testing technique (Boeykens et al., 2014). Furthermore, the pH of the gastric fluid aspirate may be increased to 6 or higher by antacids and acid inhibitors (Boeykens et al., 2014; National Patient Safety Agency, 2011). In a cross-sectional study, Taylor (2013) found that 22% of the NGT positions could not be confirmed using a pH test due to the interaction of patients' aspirate with acid inhibitor medications, which altered the pH of the gastric aspirate to alkaline.

Another reason for not being able to check the location of the NGT using a pH test is when no aspirate can be obtained from the NGT. When this occurs, or when a patient is receiving medications such as H2-blockers, the National Patient Safety Agency (2011) recommends radiographic imaging (X-ray) as the second-line test for confirming the placement of the NGT. Furthermore, an X-ray is considered the gold standard (Metheny et al., 2007) and the only acceptable method besides a pH test (National Health Service, 2013) for confirming the position of an NGT.

In fact, some institutions recommend in their policy that a chest X-ray should be taken immediately after the insertion of an NGT to confirm its correct placement and prior to commencing enteral nutrition (Rauen et al., 2008). However, the use of an X-ray for confirming the location of

a nasoenteric tube is not failsafe. For example, Aguilar-Nascimento and Kudsk (2007) reported that only 71.6% out of the 2696 radiographs obtained in their study confirmed that an NGT was in the correct position. This finding could be attributed to misinterpretations of the X-ray image by inexperienced personnel (Lamont et al., 2011; Lee and Mason, 2013; National Patient Safety Agency, 2011; Taylor, 2013) where 45 out of 100 incidences of feeding into the lungs reported to the National Health Service (UK), were associated with misinterpretations of X-rays (National Patient Safety Agency, 2011). Recent sentinel events of respiratory complications were attributed to the misdiagnosis of traditional methods (litmus test, auscultation, and bubbling) in confirming the location of an NGT as not being in the respiratory tract. These sentinel events serves as an impetus for an acute care tertiary hospital to adopt the National Patient Safety Agency (UK) recommendations for using X-rays as a second-line method for confirming the placement of an NGT (Tho et al., 2011). During the implementation of using X-rays for confirming the placement of an NGT, the hospital faced many challenges that impacted both the patients and the hospital. The impact on patients included delays in nutritional intake and multiple exposures to X-rays resulting in increased costs, while from the hospital's perspective, an increased amount of processes and manpower required were observed when using X-rays to confirm the placement of an NGT was introduced (Tho et al., 2011). Although the harmful effects of an X-ray are debatable, the Environmental Health Directorate of Western Australia advocated that an unnecessary X-ray should be avoided (Environmental Health Directorate, 2006). In view of the impact of the adoption of X-rays to the patients and healthcare institutions, there is a need to identify alternative methods that are comparable to X-rays to confirm the placement of NGTs in patients in the general ward setting.

1.1. Carbon dioxide devices to confirm the location of NGTs

The capnograph and colorimeter are two devices attached to the patient's endotracheal tube to detect carbon dioxide (CO_2), which confirms that the tube has been correctly inserted into the tracheobronchial tract (Chau et al., 2011). It has been suggested that CO_2 monitoring has the potential to differentiate respiratory from non-respiratory endotracheal tube placements (Intensive Care Society, 2014) and it is a potentially viable alternative for checking the placement of NGTs (Smith et al., 2014). Thus, the applications of the capnograph and colorimeter have been extended to verifying the correct placement of NGTs (Roberts et al., 2007). The presence of CO_2 denotes the inadvertent placement of an NGT in the trachea and an absence of CO_2 signifies the correct placement of an NGT in the gastrointestinal tract (Munera-Seeley et al., 2008).

The capnograph, compared to the colorimeter, is expensive, complex, and commonly unavailable, especially in general ward settings (Milsom et al., 2015). However, the colorimeter is cheaper than radiography. The cost of an X-ray examination was US$795 and the cost for a colorimeter was US$23, which amounted to a total of US$328,335 and US$9752, respectively, for the 424 tests undertaken during the study (Munera-Seeley et al., 2008). Thus, disposable colorimetric devices seem to be a more viable alternative compared to the capnograph in confirming the placement of NGTs (Burns et al., 2006).

The colorimeter device changes color when it is exposed to CO_2 (Munera-Seeley et al., 2008). As the colorimeter is disposable and designed for single use, it offers advantages in cost and mobility over capnographs (Munera-Seeley et al., 2008). It is also convenient and affordable for patients (Roberts et al., 2007).

A systematic review on the use of CO_2 devices to confirm NGT placement found that all studies included in the review had been conducted in intensive care units (Chau et al., 2011). The sensitivity of the devices ranged from 0.88 to 1.00 and the specificity ranged from 0.95 to 1.00 with an area under the receiver operating characteristic (ROC) curve of 0.9959 (Chau et al., 2011). The few studies (Fuchs et al., 2007; Howes et al., 2005; Munera-Seeley et al., 2008) that did not find the CO_2 sensor 100% reliable in the review were attributed to technical issues (such as the clogging of NGTs) blocking the flow of air through the tube and re-use of the colorimeter. Controlling these study errors may produce more accurate results.

The use of an X-ray to confirm the NGT location negatively impacts the patient in terms of increasing cost, multiple exposures to X-rays, and an increased burden on the hospital's processes and manpower (Tho et al., 2011). Furthermore, the use of an X-ray does not completely eradicate the problem of the misplacement of an NGT (National Health Service, 2013; National Patient Safety Agency, 2011). Colorimetric capnography was identified as a feasible, less time-consuming, less cumbersome, and cheaper alternative to X-ray for confirming the location of an NGT prior to feeding. To our knowledge, there has been no study comparing the use of a colorimeter to confirm the correct placement of NGTs in patients in the general ward setting. For the moment, X-ray remains the gold standard for confirming the location of an NGT (Metheny et al., 2007). Thus, the aim of this study was to fill the gap in knowledge about the sensitivity and specificity of using a colorimeter to confirm the placement of an NGT in the general ward setting with the use of X-ray findings as the reference standard.

2. Method

The aim of this study was to ascertain the sensitivity and specificity of the Easycap II colorimeter in ascertaining the position of NGTs using X-ray as the reference standard. The prospective study was conducted in the general wards of an approximately 1100-bed acute care tertiary hospital of an Academic Medical Center in Singapore. All patients in the general wards with an NGT requiring feeding during the study period were eligible to be recruited into the study. The waiver of written consent was requested from and approved by the Domain Specific Review Board of the study hospital. Verbal consent for performing the colorimeter test was obtained from the participants or their next-of-kin and documented in the investigator's file as required by the Domain Specific Review Board. The

Domain Specific Review Board has an ethics oversight for studies conducted on human subjects at the study site.

2.1. Instrument

The index test used is the Nellcor™ Easycap II adult colorimetric CO_2 detector (Covidien, 2010) which is a device that detects the presence of CO_2. A change in color from purple to yellow on the colorimeter indicates the presence of an end-tidal CO_2 of more than 15 mmHg and no change in color indicates the presence of an end-tidal CO_2 of less than 4 mmHg. The color brown indicates CO_2 levels between 4 mmHg and <15 mmHg. The reference standard used to confirm the location of the NGT is an X-ray examination. The location of the NGT is based on the ward's doctor interpretation of the X-ray image. An X-ray report can also be accessed by the doctor to assist in the interpretation of the image.

2.2. Recruitment

The nurses in the study ward informed the research investigator of potential participants. Patients who were having an NGT inserted for the purpose of enteral feeding during the study period were recruited and enrolled into the study.

2.3. Procedure

The nurses from the study wards were asked to contact the research nurse or investigator during office hours when there is a doubtful placement of an NGT that requires X-ray confirmation. Instances of a doubtful placement of an NGT would be when no aspirate was obtained, or when the pH of the aspirate drawn from the NGT was ≥6 and the color of the aspirate was tan to off-white.

Episodes of NGT feeding were excluded when:

- the gastric aspirate was pH 5 or less;
- the feeding occurred outside office hours;
- a patient was on continuous enteral nutrition;
- an NGT had been inserted for the purpose of stomach washout, intermittent suction, gastric intestinal bleeding (monitoring of bleeding), etc.;
- an NGT was blocked, as confirmed by the presence of resistance when flushing 10 ml of air into the NGT;
- patients with acute medical conditions required and were receiving intensive medical intervention, e.g. desaturation, medical escalation, resuscitation, etc.

The research nurses were trained by the investigator on the procedure of carrying out the CO_2 test using the colorimeter, the protocol, and how to complete the study documentation. The research nurses or investigator of the study performed the colorimeter test at patients' bedside in the following manner: (1) the research nurse or investigator would connect a syringe and flush in 10 ml of air through the NGT to clear any blockage, (2) the syringe would then be removed, (3) the colorimeter would be connected to the proximal end of the NGT, (4) the color on the colorimeter would be read after a minimum of six breaths (FDA, 2011), and (5) after the reading, the colorimeter would be removed.

This procedure is non-invasive and takes about 10–15 mins to perform. The patient would then be sent for an X-ray, which is the usual practice and not part of the research study. Subsequently, the research nurses or investigator followed up on the X-ray findings by extracting the information from the clinical system and recorded the findings on the data collection form. The study was conducted over a period of approximately three years from August 2009 to June 2012.

2.4. Sample size and data analysis plan

Postulating that the negative predictive value is 100% with an aim to obtain a lower 95% CI of 90%, 180 negative cases would be required for this study (Kadam and Bhalerao, 2010; Machin et al., 2011). Factoring a 5% positive rate, a total sample size of 190 subjects was to be recruited. Data was analyzed using a univariate analysis and diagnostic analyses, such as sensitivity, specificity, and ROC curve. Sensitivity is the ability of a test, which in this case was the Easycap II colorimeter, to correctly classify the presence of a disease (Lalkhen and McCluskey, 2008; Parikh et al., 2008) whereas specificity is the ability of a test to correctly classify the disease-free condition (Lalkhen and McCluskey, 2008; Parikh et al., 2008). A positive predictive value is the proportion of subjects with a positive test of the disease or condition whereas a negative predictive value is the proportion of subjects with a negative test who do not have the disease (Lalkhen and McCluskey, 2008; Parikh et al., 2008). The ROC curve plots both the sensitivity and specificity of a test and is a measure of the accuracy of the test (Lalkhen and McCluskey, 2008).

3. Results

The study was conducted from August 2009 to June 2012. A total of 157 patients were included in the study, of which 83 (52.9%) were male (see Table 1). The mean age of the patients was 74 years (SD = 14.3). The majority of the patients were Chinese (74.5%) and admitted to the general medicine unit (49.0%). The majority of the patients had only one episode of CO_2-X-ray test performed (83.4%) and the maximum amount of times the tests were performed on a patient was four times ($n = 3$).

Of the 157 patients included in the study, 192 episodes of a doubtful placement that required an X-ray to ascertain the location of the NGT were included in the study. Rigid polyvinyl chloride tubes made up 75.5% of the NGTs, whereas flexible tubes made up the remaining 24.5%. No aspirate was found in 153 (79.7%) of the episodes of a doubtful placement of the NGT (Table 2). The remaining 39 (20.3%) episodes drew aspirates of a pH value of 6 or more.

X-rays confirmed that 185 (96.4%) of the NGTs were located in the gastrointestinal tract; 153 (79.7%) of them were in the stomach and 32 (16.7%) were in the esophagus. Five (2.6%) NGTs were confirmed by X-rays to be located in the tracheobronchial tract. The location of two NGTs were not confirmed by X-rays.

Table 1
Patient characteristics ($n = 157$).

Characteristics	
Age	
Mean(SD)	74 (14.3)
Median (range)	77 (27 to 98)
Gender	
Male	83 (52.9%)
Female	74 (47.1%)
Race	
Chinese	117 (74.5%)
Malay	28 (17.8%)
Indian	8 (5.1%)
Others	4 (2.5%)
Disciplines	
General Medicine	77 (49.0%)
Neurology	31 (19.7%)
Neurosurgery	16 (10.2%)
Oncology/Hematology	12 (7.6%)
Hepato/Gastroenterology	7 (4.5%)
Respiratory	5 (3.2%)
General Surgery	3 (1.9%)
Geriatric	2 (1.3%)
Endocrine	2 (1.3%)
Cardiology	2 (1.3%)
No. of tests performed per patient*	
1	131 (83.4%)
2	20 (12.7%)
3	3 (1.9%)
4	3 (1.9%)

* Test refers to Easycap II and X-ray.

The Easycap II colorimeter device were applied to the NGT to test for a presence or absence of CO_2 prior to the X-ray examination. The absence of CO_2, whereby there is no change of color on the Easycap II colorimeter device when attached to the NGT was observed, signify a negative test and is suggestive that the NGT is not located in the tracheobronchial tract and is supposedly in the gastrointestinal tract (GIT). Of the 192 colorimeter tests performed, the device showed an absence of CO_2, in 163 (84.9%) of the NGTs tested. The corresponding X-ray examinations confirmed that 160 NGTs were located in the GIT (Fig. 1). Thus, the proportion of correctly identified placements of the NGT in the GIT (true negative finding on the index test) by the Easycap II colorimeter device is 98.16%. One NGT was confirmed by X-ray to be located in the tracheobronchial tract. However, the corresponding index test using the colorimeter showed an absence of CO_2 (false negative finding on the index test). This patient was observed to have excessive respiratory secretions during the colorimeter test procedure.

Table 2
Characteristics by episode ($n = 192$).

Characteristics	Frequency (%)
Types of NGT	
Polyvinyl Chloride (rigid tube)	145 (75.5%)
Flexiflo (flexible tube)	47 (24.5%)
Nature of aspirate	
No aspirate	153 (79.7%)
Off-white to tan, pH $\geq$ 6 (In gastric or respiratory placement)	39 (20.3%)
Location of NGT as determined by Radiographic test	
Stomach	153 (79.7%)
Esophagus	32 (16.7%)
Tracheobronchial tract	5 (2.6%)
Unsure	2 (1.0%)
Colorimeter findings	
CO_2 present (suggestive of tracheobronchial placement)	29 (15.1%)
CO_2 absent (suggestive of GIT placement)	163 (84.9%)

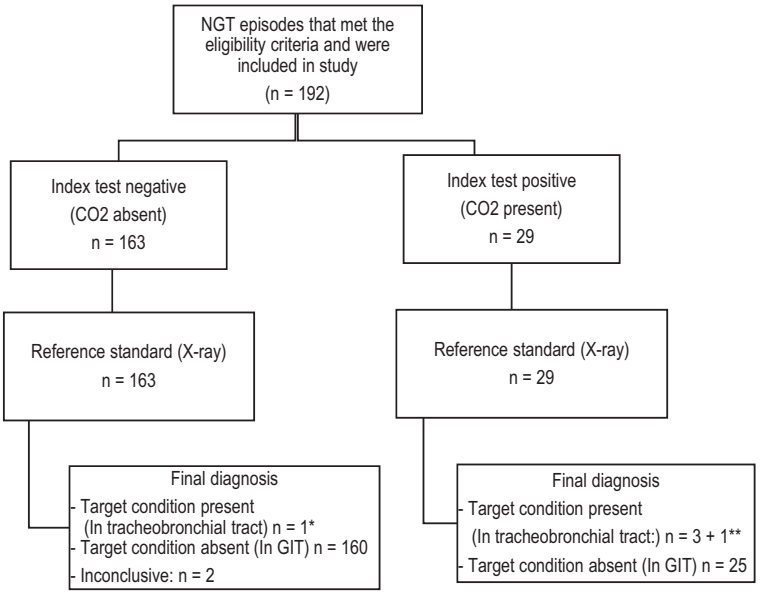
Note: GIT – gastrointestinal; CO_2 – carbon dioxide.

In the other two X-ray examination, the physician was not able to locate the outline of the NGT on the X-ray image. The respiratory physician, who is also the co-investigator in this study, reviewed the X-rays. In one of them, the physician found that the NGT was not visible on the X-ray while in the other, there was a very faint outline of the NGT in the upper one-third of the thorax but it was unclear whether the tube was in the upper esophagus or the upper trachea.

The presence of CO_2, whereby there is a change of color on the Easycap II colorimeter device when attached to the NGT was observed, signifying a positive test and is suggestive that the NGT is located in the tracheobronchial tract. Of the 192 colorimeter tests performed, the colorimeter device showed a presence of CO_2, in 29 (15.1%) of the NGTs tested (Fig. 1). The corresponding X-ray examination confirmed that only four NGTs were located in the tracheobronchial tract. Thus, the proportion of correctly identified placements of the NGT in the tracheobronchial tract (true positive finding on the index test) by the Easycap II colorimeter device is only 13.8%. Of the four NGTs confirmed by X-ray to be in the tracheobronchial tract, one of it had an X-ray being performed twice. In the first X-ray examination, the resident doctor interpreted the image as the NGT as being in the gastric region. In view that the colorimeter tested positive when applied earlier, a repeated X-ray was undertaken and the resident doctor confirmed that the NGT was in the tracheobronchial tract. The X-ray images were viewed by the respiratory physician and he confirmed that both X-ray images showed that the NGT was in the tracheobronchial tract. Nevertheless, only the result of the second X-ray image is reported in this study i.e. that the NGT is in the tracheobronchial tract.

Table 3 describes the nature of the aspirates that were drawn from the NGTs during the test, the results of the index test and the exact location of the NGT as confirmed by the X-ray examination. In both negative and positive index test results, a majority of the episodes drew no aspirates (77.30% and 93.01%, respectively) from the NGTs. Regardless of the index test result or the nature of the aspirate, the greatest proportion of the NGTs were located in the stomach. In those episodes that drew aspirate from the NGT, none of them were located in the tracheobronchial tract.

A diagnostic test analysis was undertaken for 190 episodes. Two episodes were excluded from this analysis as X-rays were unable to confirm the placement of the NGTs. From the analysis, the sensitivity of the colorimeter, when measured against the X-ray, was 0.8 [95% CI (0.376, 0.964)], the specificity was 0.865 [95% CI (0.808, 0.907)],



CO_2 – Carbon Dioxide; X-ray – radiographic imaging; GIT – Gastrointestinal tract
* Patient observed to have excessive lung secretions when the index test was performed.
** An X-ray examination of the NGT was interpreted by the resident doctor as being in the stomach whereas the corresponding colorimeter test was positive for presence of CO_2 suggestive of tracheobronchial placement of the NGT. A repeated X-ray was undertaken and it confirmed that the NGT was in the tracheobronchial tract.

Fig. 1. Summary of study test findings.

Table 3
Nature of aspirate and diagnostic test results ($n = 192$).

Colorimeter test	Nature of aspirate	Location of NGT			
		Tracheobronchial tract $n = 5$ (2.6%)	Stomach $n = 153$ (79.7%)	Esophagus $n = 32$ (16.7%)	Unsure $n = 2$ (1.0%)
CO_2 absent (index test negative) ($n = 163$, 84.89%)	No aspirate $n = 126$ (77.30%)	1** (0.79%)	100 (79.36%)	24 (19.04%)	1 (0.79%)
	Aspirate* $n = 37$ (22.70%)	–	32 (86.49%)	4 (10.81%)	1 (2.70%)
CO_2 present (index test positive) ($n = 29$, 15.1%)	No aspirate $n = 27$ (93.10%)	3 + 1*** (3.70%)	19 (70.37%)	4 (14.81%)	0
	Aspirate* $n = 2$ (6.90%)	–	2 (100.00%)	0	0

NGT – nasogastric tube; CO_2 – carbon dioxide.
The location of the NGT is based on the doctor's interpretation of the X-ray image.
A negative index test suggests that the NGT is not located in the tracheobronchial tract i.e. it is in the gastrointestinal tract.
A positive index test suggests that the NGT is located in the tracheobronchial tract.
* Aspirate off-white to tan, pH 6 (the color or pH of this aspirate suggests that the NGT is either in the stomach or the tracheobronchial tract).
** Patient has excessive respiratory secretions.
*** One X-ray was interpreted as the NGT being in the gastric region whereas the corresponding colorimeter tested presence of CO_2. A repeated X-ray was undertaken which confirmed that the NGT was in the respiratory system.

the positive predictive value was 0.138 [95% CI (0.055, 0.306)], and the negative predictive value was 0.994 [95% CI (0.966, 0.999)] (Table 4). The area under the ROC curve was 0.835 [95% CI (0.630, 1.0), $p = 0.011$] (Fig. 2).

4. Discussion

The impetus for using a colorimeter is that it is a less invasive, cheaper, and more time-saving alternative to using an X-ray which is considered the gold standard for confirming the location of an NGT. Although the CO_2 colorimeter has been investigated in a few studies, these have largely been conducted in intensive care settings and mainly in patients who are mechanically ventilated (Bennetzen et al., 2014; Chau et al., 2011; Munera-Seeley et al., 2008). This current study is the first of such studies to be undertaken in adult patients in the general ward setting of a hospital.

Table 4
Diagnostic test ($n = 190^{*}$).

Colorimeter test	Radiographic test: location of NGT	
	Respiratory system	Gastrointestinal tract
CO_2 present (test +ve)	4	25
CO_2 absent (test −ve)	1	160

CO_2: carbon dioxide; CI: confidence interval; NGT: nasogastric tube.
* The data of two tests were excluded from this analysis as the doctor was unsure of the location of the NGTs from viewing the X-ray image.
Diagnostic test: sensitivity = 0.8 [95% CI (0.376, 0.964)]; specificity = 0.865 [95% CI (0.808, 0.907)]; positive predictive value = 0.138 [95% CI (0.055, 0.306)]; negative predictive value = 0.994 [95% CI (0.966, 0.999)].

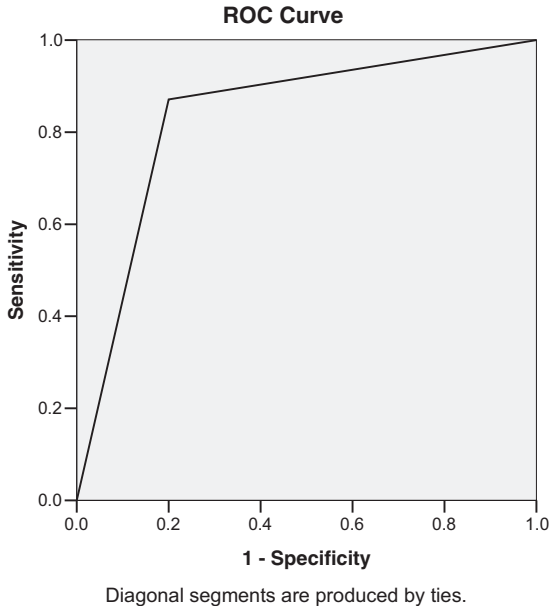


Fig. 2. Receiver operating characteristics (ROC) for the diagnostic accuracy of the colorimeter findings against the X-ray examination findings.

4.1. Sensitivity of the colorimeter in differentiating tracheobronchial placement

Sensitivity is a measure of the ability of the index test i.e. the colorimeter, to correctly classify that the NGT is in the tracheobronchial tract as confirmed by the X-ray reference standard. Our study found that the sensitivity of the colorimeter in confirming the location of the NGT in the tracheobronchial tract was 80%. This means that 20% of the NGT that was located in the tracheobronchial tract was not detected by the colorimeter due to an absence of CO_2. This false negative result was probably attributed by a blocked NGT associated with the patient's excessive respiratory secretions stopping the flow of air through the NGT and colorimeter. The sensitivity of the colorimeter in this current study was lower than in a systematic review that reported that the sensitivity of blindly inserted nasoenteric tubes in mechanically ventilated patients was 100% in one study, 88% in another study, and in one other study, there were no misplaced tube (Bennetzen et al., 2014). The sensitivity (86.76%) in the study by Munera-Seeley et al. (2008) is quite close to the findings of this current study. The tracheobronchial placement of the nasoenteric tube, which was incorrectly classified as being in the GIT, was attributed to the blockage of the colorimeter (Bennetzen et al., 2014; Munera-Seeley et al., 2008). Similar to this current study, Munera-Seeley et al. (2008) observed that the patients had abundant secretions that may have caused a blockage of the tube, resulting in the false negative findings (Bennetzen et al., 2014).

4.2. Specificity of colorimeter in differentiating GIT placement

Specificity is a measure of the ability of the colorimeter to correctly classify that the NGT was not in the tracheobronchial tract but in the GIT. The specificity of the colorimeter in this current study was 86.5%. In the previous studies reported in a systematic review of blindly inserted nasoenteric tubes, the specificity of the colorimetric capnography ranged from 99% to 100% in all three studies, an almost perfect specificity (Bennetzen et al., 2014). In the study with 99% specificity, there was only one episode in which the colorimeter detected a presence of CO_2 of an NGT that was located in the GIT. The author attributed the false positive reading to contamination of the colorimeter as a result of multiple use. Another study done by Munera-Seeley et al. (2008) attributed the false positive reading of the colorimeter to the presence of swallowed air. In this current study, the colorimeter detected 13.5% of the CO_2 of the NGTs that was located in the GIT. This finding is much higher than in previous studies of blindly inserted nasoenteric tubes which had minimal or no incorrectly classified NGT in the GIT by the colorimeter test (Bennetzen et al., 2014; Elpern et al., 2007; Munera-Seeley et al., 2008). This current study differed from all previous studies in that the previous studies had been conducted in intensive care settings with patients who were intubated and were not taking food orally (Chau et al., 2011). This current study was conducted in the general ward setting where patients might already have been consuming food. It has been suggested that medications such as Antacids and other similar class of drugs administered via the NGT may produce CO_2 (Thomson, 2009; Moffat, 2014). However, upon reviewing the medication records, it was found that the patients were not prescribed Antacids. Consultation with a gastroenterologist at this current study's hospital revealed that the presence of CO_2 is expected due to the breakdown of food by microorganisms in the gastrointestinal tract, thereby producing CO_2.

4.3. Predictive measures of colorimeter

In this study, the positive predictive value is a measure of the ability of the colorimeter to predict the likelihood of the NGT being in the tracheobronchial tract given a positive test. The positive predictive value is highly correlated to the prevalence of the disease or condition (Parikh et al., 2008). The positive predictive value of the colorimeter in this study is poor (PPV = 13.8%). This result

is expected as the prevalence of the NGT being malpositioned in the tracheobronchial tract is small; – there were only five incidences in 190 episodes of doubtful placements.

The negative predictive value is a measure of the ability of the colorimeter to predict the likelihood of the NGT not being in the tracheobronchial tract given a negative test. The negative predictive value in this study is 99.4%. A predictive measure close to 100% would make the test as good as the gold standard (Parikh et al., 2008). This makes the colorimeter a good predictor of the NGT not being in the tracheobronchial tract given a negative test. The findings from this current study demonstrated higher negative predictive value than a study reported in a systematic review which ranged from 88% to 100% (Bennetzen et al., 2014).

4.4. X-ray interpretation

Although X-rays can provide the exact location of the NGT, literature has reported incorrect diagnoses of NGT placements of as much as more than a quarter of the X-rays interpreted (Aguilar-Nascimento and Kudsk, 2007). The National Patient Safety Agency (2011) attributed this to the misinterpretations of X-ray by inexperienced personnel. The likelihood of the misinterpretation of an X-ray was observed in this current study where an X-ray of an NGT was read as being in the gastric fundus when it was actually in the tracheobronchial tract. Fortunately, the colorimeter detected the presence of CO_2 and correctly diagnosed the placement of the NGT in the tracheobronchial tract. The positive colorimetric test result was highlighted to the ward nurse, and a repeated X-ray examination was performed and the tracheobronchial placement was confirmed by the doctor. In this situation, the use of a colorimeter to diagnose the placement of the NGT was able to prevent an incident that could have arisen from a misinterpretation of the initial X-ray image.

4.5. Summary

Findings from previous studies conducted in intensive care settings had found close to perfect sensitivity and specificity in CO_2 detection devices (Bennetzen et al., 2014; Chau et al., 2011). This current study was conducted in the general ward setting. This current study found a slightly lower sensitivity (80%) and specificity (86.5%) of the colorimeter when used at the bedside. This study suggest that the colorimeter cannot replace X-rays as the gold standard for confirming the location of the NGT. Nevertheless, it may still serve as an additional screening tool in institutions that uses a two-stage process for inserting an NGT into patients (Intensive Care Society, 2014). This current study addresses the gap in the evidence on the use of a CO_2 colorimeter to check the placement of NGTs of adult patients in the general ward setting. This current study which was undertaken in the general ward found unexpected results of the significant numbers of presence of CO_2 detected by the colorimeter of NGTs located in the GIT which was not seen in previous studies that were conducted in the intensive care unit. This current study also provides insights of the presence of aspirate of NGTs located in the esophagus which was not reported in previous studies to the best of the author's knowledge.

4.6. Implications for practice

The nasogastric tube continues to be a common treatment modality in providing nutrition support to patients who have medical conditions such as suppressed cough, impaired gag reflex, or unconsciousness in the general wards, intensive care units or in the community (Curtis, 2013; Lortie and Charbonney, 2015). Nurses must ensure correct placement of NGTs to ensure patient safety to prevent complications. Ensuring the correct placement of a nasogastric tube is the patient safety goal of all healthcare providers. This study aimed to ascertain the use of a colorimeter as an alternative to confirm placement of the NGT, with the intent of replacing the gold standard of using X-rays. The process of having a patient undergo an X-ray procedure is fraught with many issues such as risk of dehydration due to delayed feeding, cost effectiveness, manpower involvement, and the accuracy of the interpretation of a chest X-ray report of the NGT placement. However, the study revealed that the colorimeter was not a reliable screening tool for confirming the placement of an NGT. Thus, confirming of the feeding tube placement continues to be challenging.

Special attention must be taken during drug administration through an NGT. There are problems such as drug instability, drug interaction with enteral feeds, and impaired adsorption occurring when the physiochemical, biopharmaceutical, and pharmacological properties of drugs are compromised (Zhu and Zhou, 2013). Therefore, nurses must be mindful to the possibility of false reading of the gastric aspirates which may have been altered.

Hospital administrators and nursing leaders must ensure that the policy for care of patients on feeding tubes are developed and updated constantly. The information must be disseminated and communicated to the nursing workforce if needed to ensure safe administration of fluid feeds to patients.

4.7. Limitations

One of the limitations of this study is that it was conducted at a single site, and therefore its findings cannot be generalized to other settings. Another limitation of this study is that there were only five episodes where the NGTs were inadvertently misplaced in the tracheobronchial tract. This was observed in the wide 95% CI (0.376, 0.964) in the sensitivity result and poor positive predictive value of the test (Table 3). Thus, the sample was too small to have any significant effect; further studies with larger samples are required.

Episodes of an inadvertent placement of the NGT are dependent on the expertise of the person performing the insertion of the NGT and its placement cannot be controlled. It would be unethical to assign patients to have their NGTs inserted into the tracheobronchial tract for the purpose of a study, which resulted in this study having a very small number of NGTs being inserted into the

tracheobronchial tract. Nevertheless, the limited number of inadvertent placements of the NGT in the tracheobronchial tract is testament to the expertise of the nurses at the study hospital in performing a blind insertion of an NGT.

Another limitation is the variation in duration in which the colorimeter color was read. The colorimeter is intended for the purpose of detecting CO_2 to signify the correct placement of the endotracheal tube; it should to be read after 6 breath cycles according to the manufacturer's recommendation. However, one of the research nurse read the colorimeter after five minutes. Given that the NGT tube has a smaller orifice, it might take longer for the CO_2 to be detected. The lack of clarity in the duration of the application of the colorimeter was also alluded in a systematic review (Bennetzen et al., 2014). Future research should ascertain the optimal duration of the application of the colorimeter.

5. Conclusion

Confirming the placement of an NGT prior to feeding is crucial in avoiding fluids being administered into the respiratory system due to a misplaced NGT. An X-ray examination is the current gold standard for ascertaining the location of the NGT. However, it is cumbersome, and comparatively more expensive than a CO_2 colorimeter. The portable colorimeter is also convenient to use and can potentially reduce delays in feeding. This current study found that the sensitivity and specificity values of the colorimeter is slightly less than 100%. With only five episodes of inadvertent placements of the NGT in the tracheobronchial tract, the results of this study are inconclusive in recommending the use of a colorimeter in the general ward settings. It may be useful to explore the use of the colorimeter as a first-line diagnostic test to rule out NGTs being inadvertently placed in the tracheobronchial tract.

Future studies to address the issue of blocked NGTs located in the tracheobronchial tract which is associated with excessive respiratory secretions are warranted. An exclusion of patients with excessive respiratory secretions from colorimetric testing should be considered in clinical use or future research.

Contributions

Ms Helen Chen, MN(NeuroSc), RN, contributed to the conceptualization and initial design of the study. Ms Janet Lam, MHlthSc(Edun), RN, contributed to the pilot test of the colorimeter device in the Medical Intensive Care Unit. Both Ms Helen Chen and Ms Janet Lam are from the Nursing Department of the National University Hospital.

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Conflict of interest

We declared there are no conflicts of interest.

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Ethical approval

Domain Specific Review Board, National Healthcare Group, Singapore DSRB 2009/00250.

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