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Application of Manometry to Verify Nasogastric Tube Placement in Intubated, Mechanically Ventilated Patients: A Prospective Descriptive Study

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Abstract

Objective: Confirmation of nasogastric tube (NGT) placement is sometimes difficult in clinical practice. Hence, the purpose of this study is to validate the accuracy of manometry for intragastric NGT placement confirmation in intubated, mechanically ventilated patients.

Methods: A total of 100 adult patients who underwent elective open abdominal surgery and required gastric decompression were enrolled in this prospective descriptive study at a university-affiliated teaching hospital. The position of NGTs was verified by two blinded investigators, of whom the first investigator used the manometric technique and the second investigator used a fiberscope for verification. The manometric technique involved using a cuff pressure manometer to verify NGT placement. The primary measurements, sensitivity and specificity of the manometric technique in verifying NGT placement were calculated according to the standard findings of fiberoptic inspection.

Results: In 81 of 100 NGT placements, intragastric placement was interpreted by the manometric technique. All of these 81 placements were confirmed by fiberoptic inspection. The manometric technique was therefore 100% sensitive. The 19 placements interpreted as extragastric placement by the manometric technique were confirmed by fiberscopy as being in the oral cavity, trachea, or esophagus, indicating 100% specificity. These results revealed 100% accuracy of the manometric technique in verifying intragastric placement of NGTs in intubated, mechanically ventilated patients.

Conclusions: The manometric technique is a convenient, inexpensive, and highly accurate method for verifying NGT placement. This technique may be used to verify correct NGT placement for the purpose of gastric decompression and in those environments where a roentgenogram is not available.

Keywords: Nasogastric tube; Manometry; Mechanically ventilated patients; Intragastric placement

Introduction

Placement of a nasogastric tube (NGT) is a common procedure in the intensive care unit and operating room for reasons of gastric decompression, nutrition, and drug administration. Intubated patients are at especially high risk for NGT placement complications [1,2]. These complications usually result from misplacement of NGTs, which may lead to failed gastric decompression, aspiration pneumonia, pneumothorax, or intracranial penetration [3-5]. Many methods have been described to determine correct placement of NGTs, including epigastric auscultation during air inflation, aspiration of gastrointestinal contents, and use of capnography [6,7]. All these techniques have been reported unreliable, and 2-step radiography is still considered the gold standard in verifying NGT placement if any doubts exist concerning the position [8]. However, the roentgenogram is time consuming, expensive, and does not provide 100% accuracy [9,10]. Accordingly, the development of cost-effective and reliable techniques to confirm NGT placement is imperative in the present healthcare environment.

The utility of manometry to verify pulmonary misplacement of NGTs has been reported previously. In 1994, Swiech et al. described a series of 46 nonmechanically ventilated patients in whom NGT placement was checked using a pressure gauge [11]. They found that on inspiration, positive pressure readings indicated gastric NGT placement, and negative pressure readings indicated pulmonary misplacement of NGTs. The authors therefore proposed that pressure gauge reading was a safe and reliable technique to determine tracheal malpositioning of NGTs in nonmechanically ventilated patients. However, the use of manometry to verify NGT placement has not been investigated in intubated, mechanically ventilated patients, who particularly tend to suffer complications related to NGT placement.

The purpose of this study was to validate the efficacy of the manometric technique in verifying NGT placement in intubated, mechanically ventilated patients. The accuracy of the manometric technique in identifying NGT location was compared with the standard findings of fiberoptic inspection.

Materials and Methods

This study was approved by the Research Ethics Committee of E-DA Hospital (IRB number: EMPR-097-049), a 1200-bed university-affiliated teaching hospital. Written, informed consent was obtained from each patient prior to conducting all procedures. The study was conducted in the operating room of E-DA Hospital. The study participants comprised 100 consecutive adult patients (age, >18 y) who required general anesthesia and endotracheal intubation along with placement of an NGT prior to undergoing elective open abdominal surgery. Patients were excluded if they had evidence of nasal, pharyngeal, esophageal, or gastric disease, extreme hemodynamic instability, morbid obesity (body mass index>40 kg/m^2), or any contraindication for nasal placement of an NGT.

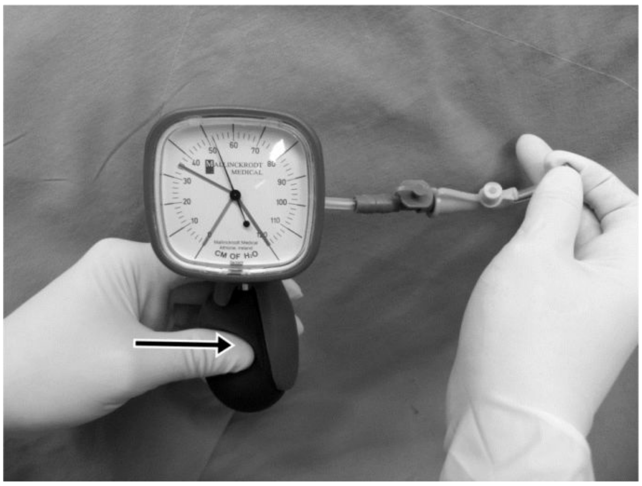

Figure 1: Set up of the manometric technique with a handheld manometer and nasogastric tube. The manometer is connected to the nasogastric tube *via* the proximal end of a suction tube. Because this setting is not a specialized device, the nasogastric tube must be occluded by inflating the air pump of the manometer (arrow) to ensure no air leaks from the manometric assembly prior to each measurement.

A prospective descriptive trial was performed. Following application of standard monitoring, patients were anesthetized and intubated with standard procedures. After tracheal intubation, mechanical ventilation was delivered with a tidal volume of 8 ml/kg-12 ml/kg and a respiratory rate of 8-12/min. Nurse anesthetists of E-DA Hospital performed NGT insertions. Before NGT placement, the ideal depth of NGT insertion for each patient was determined by measuring the length from the nose, to the earlobe, to the midline between the xiphoid process and the umbilicus [12]. With the head in the neutral position, a fully lubricated 16 Fr. NGT (Pacific Hospital Supply Co., Ltd, Miaoli, Taiwan) was then inserted through the nose to the premeasured length. Two blinded investigators, who were absent during the NGT insertions, then verified the NGT locations by the manometric technique and fiberoptic inspection, respectively.

The manometric technique involved using a cuff pressure manometer (Mallinckrodt Medical GmbH, Hennef, Germany) attached to the proximal end of an NGT. The proximal end of a disposable suction catheter (Sigma Medical Supplies Co, Taipei, Taiwan) was used as an adaptor to connect the manometer to the NGT (Figure 1). After ensuring no air leaks from the manometric setting, the first observer applied the manometric technique to verify NGT locations according to the following protocol (Figure 2).

1. The air pump was first inflated to clear secretion and rule out any obstruction of the tube that could interfere with pressure transmission. Upward pressure while inflating the air pump would indicate cases of tube obstruction or intraesophageal placement. When an NGT was placed in the stomach, the changes in pressure upon air inflation were insignificant due to high compliance of the abdominal compartment (Figure 2-A).

2. The baseline pressure readings on the manometer were obtained. If the pressure reading was zero (equal to the atmospheric pressure), the location of the tube was thought to be intraoral. If the pressure reading was above zero, either an intragastric, intraesophageal, or intratracheal placement was presumed. If the pressure readings showed synchronous changes with the pressure of mechanical ventilation, this finding was additionally recorded.

3. Pressure changes were observed under gentle epigastric palpation. If pressure swings were noted with epigastric palpations, an intragastric placement was considered (Figure 2B); otherwise, an extragastric placement was considered.

4. Finally, an intragastric placement was interpreted only in the event of trivial changes in pressure while inflating the air pump, positive baseline pressure readings, and presence of pressure swings during epigastric palpations; if not, an extragastric placement was interpreted.

After the first observer had finished the verification of NGT placement using the manometric technique, the second observer entered the operating room and used a fiberscope (Olympus LF-TP tracheal intubation fiberscope; Olympus Optical Co, Ltd, Japan) to confirm NGT placement. The fiberscope was inserted via mouth to check NGT location, which was recorded as intragastric, intraoral, intratracheal, or intraesophageal. The findings of the manometric technique and fiberoptic inspection were noted in every trial. Based on the fiberscopy findings, the NGT was further advanced to reach the stomach if the tube was located in the esophagus or was reinserted if the tube was in the mouth or the tracheobronchial tree. The following procedures after the fiberoptic inspection were not enrolled for data analysis. Finally, the stomach placement of each subject was confirmed by direct palpation of NGTs during open abdominal surgery. The primary outcome measurements in this study were the sensitivity and specificity of the manometric technique for verifying NGT placement. Additionally, adequacy of NGT drainage and occurrences of nasal, oropharyngeal, or esophageal trauma were recorded in the post-anesthesia care unit.

Characteristics of patients and specific events were expressed as mean ± SD (range) unless otherwise noted. The sensitivity and specificity of the manometric technique for verifying NGT placement were calculated according to the standard findings of fiberoptic inspection. SPSS 10.0 (SPSS Inc., Chicago, IL) was used for data analysis.

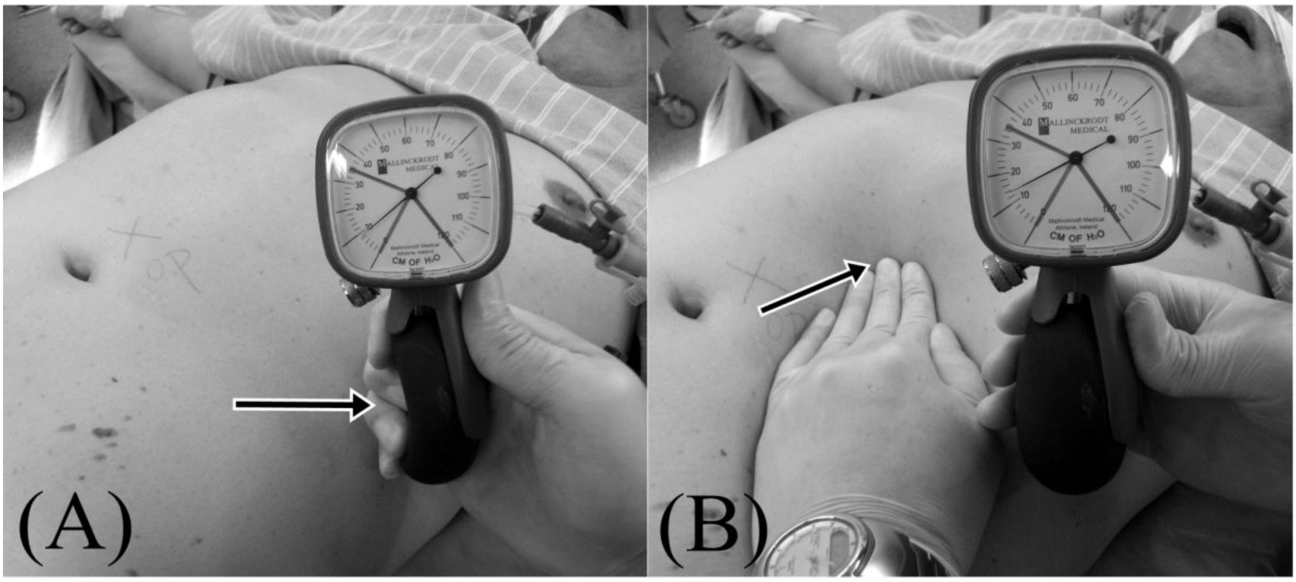

Figure 2: The manometric technique for verification of nasogastric tube placement (baseline pressure reading: 8 cmH_2O). (A) Air inflation test: the intragastric placement of a nasogastric tube shows only minimal changes in pressure upon air inflation (arrow). (B) Epigastric palpation test: pressure swings associated with manual compressions of upper abdomen (arrow) are observed when a nasogastric tube is placed in the stomach.

Results

One hundred patients met the eligibility criteria and were enrolled in this study. The trial protocol was completed in all patients. Thus, a total of 100 NGT placements were analyzed. Characteristics of patients and specific events are summarized in Table 1. Intragastric placement of NGTs was successful at the first attempt in 81 of the 100 patients. The results of the manometric technique and the fiberoptic inspection for interpreting NGT placement are shown in Table 2. The 81 intragastric placements interpreted by the manometric technique were all confirmed by fiberoptic inspection, indicating 100% sensitivity and no false negatives. The remaining 19 of 100 placements, which did not fulfill the criteria of intragastric placement, were determined by fiberscopy as being in the oral cavity, trachea, or esophagus. Therefore, the manometric technique demonstrated no false positives and was 100% specific. These results indicated a 100% accuracy of the manometric technique for verifying intragastric NGT placement in intubated, mechanically ventilated patients.

Sex (male/female)	71/29
Age (year)	59 ± 14 (28–84)
Weight (kg)	64 ± 10 (38–95)
Height (cm)	162 ± 9 (134–179)
Body mass index (kg/m^2)	24 ± 3 (17–36)
Success rate at first attempt (%)	81 (81%)

Table 1: Characteristics of patients and specific events (n=100). Values are expressed as means ± SD (range) or number (percent).

Of the 19 extragastric placements, 12 were located in the oral cavity, 3 in the trachea, and 4 in the esophagus. In 9 of the 12 intraoral placements, increasing pressure was observed while inflating the air pump; the remaining 3 demonstrated absence of upward pressure. In all patients with intraoral placements, the baseline pressures were zero, and pressure changes associated with mechanical ventilation or epigastric palpations were absent. In the 3 intratracheal placements, pressure changes during air inflation and epigastric palpations were absent, but the baseline pressures showed positive readings and synchronous changes with the pressure of mechanical ventilation. In the 4 intraesophageal placements, the baseline pressures all showed positive readings. Pressure changes associated with mechanical ventilation were absent, but increasing pressure during air inflation was noted. Three patients with intraesophageal placements also demonstrated absence of pressure swings during epigastric palpations; the other presented pressure swings during palpation of the upper abdomen.

In all 19 patients in whom NGT placement failed at the first attempt, intragastric placement was successful within 3 subsequent attempts. Two placements required the assistance of Magill forceps under direct laryngoscopy. Correct placement of NGTs was confirmed by direct palpation of the NGTs during surgery in all 100 patients. Drainage was adequate in all patients, and none demonstrated significant nasal, oropharyngeal, or esophageal complications in the post-anesthesia care unit.

Findings of manometry technique	Interpretation of manometry (n=100)		Interpretation of fiberscopy (n=100)			
	Intragastric	Extragastric	Intragastric	Intraoral	Intratracheal	Intraesophageal
	(n=81)	(n=19)	(n=81)	(n=12)	(n=3)	(n=4)
Upward pressure while inflating air pump						
Presence	0	13	0	9	0	4
Absence	81	6	81	3	3	0
Baseline pressure						
Zero	0	12	0	12	0	0
Above zero	81	7	81	0	3	4
Synchronous change of pressure with mechanical ventilation						
Presence	0	3	0	0	3	0
Absence	81	16	81	12	0	4
Pressure swings with epigastric palpation						
Presence	81	1	81	0	0	1
Absence	0	18	0	12	3	3

Table 2: The results of manometry and fiberscopy to interpret nasogastric tube placement.

Discussion

In this prospective descriptive study, we found that the manometric technique is highly accurate for verifying intragastric placement of NGTs in intubated, mechanically ventilated patients. The manometric technique criteria used to interpret intragastric placement of NGTs in this study were unequivocal and based on physical characteristics of the upper gastrointestinal tract. The positive pressure readings associated with intragastric NGT placement mainly derive from intra-abdominal pressure and positive pressure ventilation [13,14]. Although positive pressure readings were observed with both intragastric and intraesophageal placements, the opposite changes in pressure observed during air pump inflation clearly differentiated intragastric from intraesophageal placement.

The high compliance of the abdominal compartment contributes to insignificant changes in pressure observed upon air inflation when NGTs are correctly placed in the stomach. In contrast, the small diameter and lower compliance of the esophageal lumen results in the build-up of upward pressure upon air inflation when NGTs are placed in the esophagus. Furthermore, manual compression of the upper abdomen can increase intragastric pressure, and pressure swings can therefore be observed in cases of intragastric NGT placement. When all the criteria listed above are fulfilled, intragastric placement of NGT can be accurately verified.

Upward pressure while inflating the air pump was noted in all intraesophageal placements as well as 9 of 12 intraoral placements. When an NGT is curled in the mouth, it may be easily distorted and partially obstructed, causing air inflation to increase the pressure of the tube. Any obstruction of the tube may also result in false-negative interpretation even if the tube is correctly placed in the stomach. However, the protocol used in this study, in which the ideal depth of NGT insertion was previously determined, avoided further obstruction of the tube once it reached the stomach. In this study, no intragastric NGT placements were misinterpreted as extragastric using the manometric technique. Furthermore, the occurrence of a false-negative interpretation would require time for reinsertion but maintain the safety of patients.

Three of the 100 baseline pressure readings displayed synchronous changes with mechanical ventilation pressure. All these NGTs were found in the trachea by fiberscopic inspection. The cuff of an endotracheal tube forms a closed compartment in the pulmonary system. When an NGT enters the trachea, pressure in the tube lumen equals the pressure of mechanical ventilation. Thus, pressure readings on the manometer show synchronous changes with mechanical ventilation. This finding indicated that the manometric technique may be useful to verify tracheal misplacement of NGTs not only in nonmechanically ventilated patients [11] but also in intubated, mechanically ventilated patients. Nevertheless, this inference must be further validated due to our limited sample size, with only 3 tracheal placements.

While 18 of 19 extragastric placements in this study demonstrated the absence of pressure swings with epigastric palpations, one of 4 esophageal placements demonstrated abrupt pressure swings even with gentle palpations of the abdomen. In this case, fiberoptic inspection revealed that the NGT distal tip was contacting the lower esophageal sphincter, resulting in the appearance of pressure swings during epigastric palpations. Thus, interpretation of intragastric placement should not only depend on the positive finding of epigastric palpations. The observation of pressure changes while inflating the air pump is also critical to differentiating intragastric from intraesophageal placement. Although most intraesophageal placements can reach the stomach by simply advancing the tube, in some rare cases, the tube may not have passed the distal esophagus. Whereas clinicians presently worry about pulmonary misplacement of NGTs, assuring the intragastric placement of NGTs should also be emphasized. Esophageal misplacement of NGTs may lead to massive aspiration and severe complications following the infusion of solutions [15]. Therefore, it is important to guarantee the safety of patients by confirming correct intragastric placement rather than simply detecting pulmonary misplacement.

Auscultation of an audible gurgle during air inflation and visual inspection of tube aspirates are common methods for evaluating NGT placement in many institutions. While these methods are convenient and less costly, they have been reported unreliable for NGT placement confirmation [6]. Auscultation over the stomach can detect sounds transmitted through a tube that is inadvertently present in the bronchial tree, esophagus, or pharynx [16]. Aspiration of gastric content is not always possible even when the tube is correctly positioned and may be misleading unless pH testing is performed [17]. Capnometry is another bedside method that can quickly and accurately verify intratracheal feeding tube placement [9]. However, the method does not distinguish tube placement between the mouth, esophagus, or stomach and may be incorrect if the tube lumen is not fully patent [7].

The cuff pressure manometer used in this study was originally designed to check the cuff pressure of endotracheal tubes and is widely available in intensive care units and operating rooms. By connecting it to a disposable suction catheter, it can be used to verify the correct placement of NGTs with very high accuracy. The only cost of this technique is an existing manometer and a disposable suction tube. Use of the manometric technique to verify NGT placement could be considered for the purpose of gastric decompression and in cases where a roentgenogram is not available or deemed necessary. However, if an NGT is placed for administration of medications or feedings, we still recommend a radiographic approach to confirm correct positioning of a blindly inserted tube prior to its use, since the money and time is well spent to protect patient safety [2-5].

A potential advantage of the manometric technique is that the method can not only verify the intragastric placement of NGTs but may also identify the exact location of extragastric placements. When an NGT stays in the oral cavity, the pressure reading is zero (equal to the atmospheric pressure). Once the NGT enters the esophagus, positive pressure readings along with increased pressure during air pump inflation are noted. If the tube is misplaced in the trachea, this placement can be easily recognized by synchronous changes of pressure with mechanical ventilation. Therefore, if operators continually observe pressure readings during NGT insertion, they may simultaneously identify the NGT position and adjust its movement until achieving correct placement. Use of manometry guidance may transform a blind NGT insertion into a perceivable procedure and improve the quality of NGT placement. Further study is required to validate these clinical findings.

This study has several limitations. First, the manometric technique cannot determine whether an NGT is located in the stomach or more distal gastrointestinal tract, a critical consideration for enteral nutrition. The desired depth of NGT insertion was determined to just reach the stomach in this study. Therefore, when a nasointestinal tube is indicated for administering jejunal feedings, the manometric technique may not be useful to verify correct placement. Second, this study did not validate the influence of negative pressure on pressure readings in spontaneously breathing patients. The negative pulmonary pressure elicited by inspiration may affect the pressure readings obtained from a cuff pressure manometer. Third, small-bore nasoenteral tubes, verifying placement of which was considered more difficult due to their small lumen and flexibility [18], were not evaluated in this study. Accordingly, the results of this study may not be extrapolated to these types of feeding tube until further studies have been conducted.

Conclusions

We have demonstrated that the manometric technique using a cuff pressure manometer can accurately verify NGT placement in intubated, mechanically ventilated patients. In the aim of gastric decompression or in settings where roentgenograms are not available, the manometric technique is a convenient, inexpensive, and highly accurate method to verify NGT placement. This technique may have the potential to reduce the complications of NGT placement and improve patient safety.

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Conflicts of Interest and Source of Funding

The authors have no financial conflicts of interest. No funding was provided for this work.

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