Naso-Enteral Tube Safety in Anaesthetised Patients: Examining the Potential Impact of a Novel Introducer Device on Patient Safety.

MSc Medical Device Technology and Business.

Griffith College, Dublin.

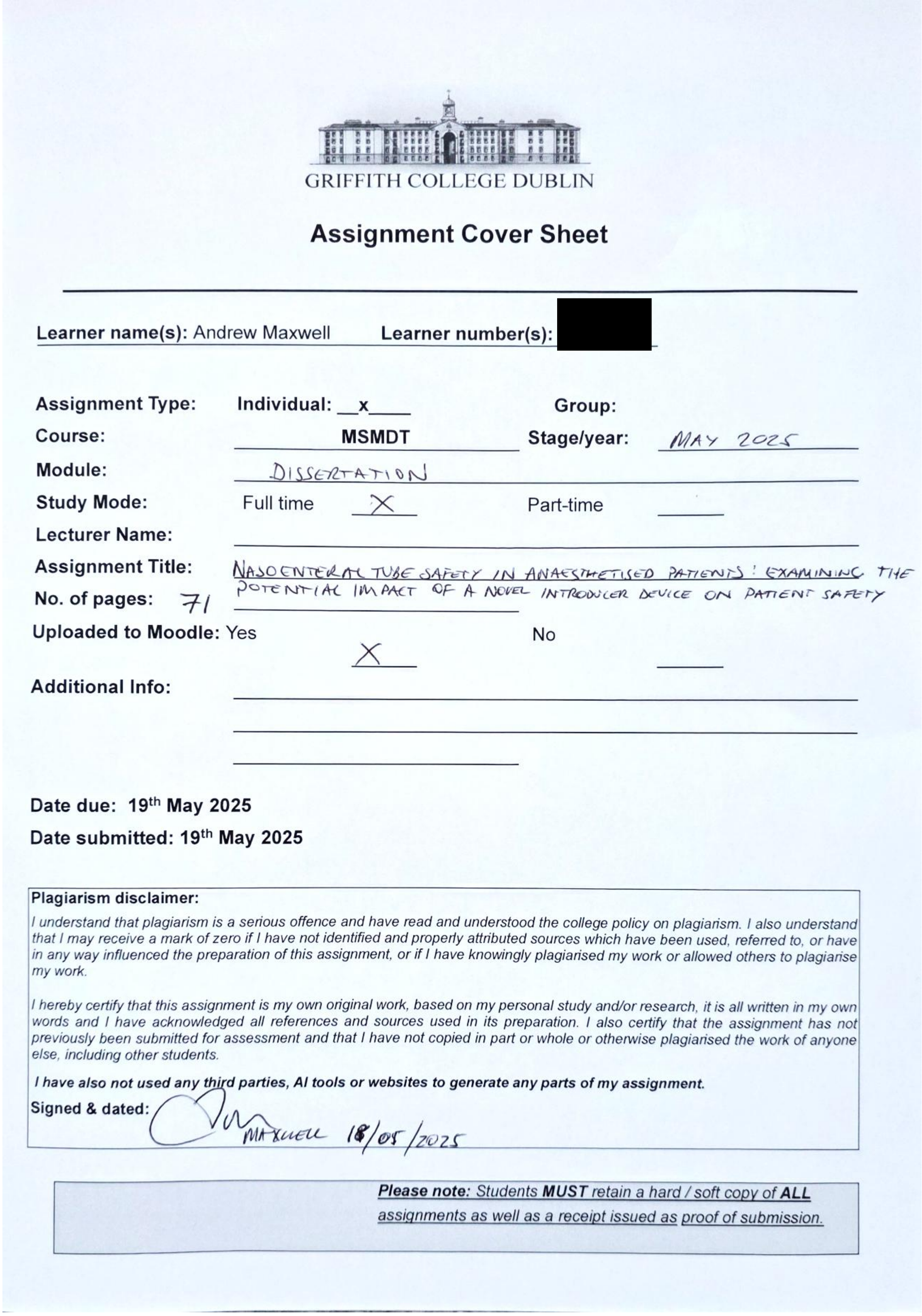
Dr Andrew Maxwell

dr med MRCEM FCAI PgDip

May 2025.

Supervisor: Mr Brian Kearney.

Declarations.



GRIFFITH COLLEGE DUBLIN

Assignment Cover Sheet

Learner name(s): Andrew Maxwell **Learner number(s):** [redacted]

Assignment Type: **Individual:** __x____ **Group:**

Course: **MSMDT** **Stage/year:** MAY 2025

Module: DISSERTATION

Study Mode: Full time X Part-time ______

Lecturer Name:

Assignment Title: NASOENTERAL TUBE SAFETY IN ANAESTHETISED PATIENTS: EXAMINING THE POTENTIAL IMPACT OF A NOVEL INTRODUCER DEVICE ON PATIENT SAFETY

No. of pages: 71

Uploaded to Moodle: Yes X No ______

Additional Info:

Date due: 19th May 2025

Date submitted: 19th May 2025

Plagiarism disclaimer:

I understand that plagiarism is a serious offence and have read and understood the college policy on plagiarism. I also understand that I may receive a mark of zero if I have not identified and properly attributed sources which have been used, referred to, or have in any way influenced the preparation of this assignment, or if I have knowingly plagiarised my work or allowed others to plagiarise my work.

I hereby certify that this assignment is my own original work, based on my personal study and/or research, it is all written in my own words and I have acknowledged all references and sources used in its preparation. I also certify that the assignment has not previously been submitted for assessment and that I have not copied in part or whole or otherwise plagiarised the work of anyone else, including other students.

I have also not used any third parties, AI tools or websites to generate any parts of my assignment.

Signed & dated: MAXWELL 18/05/2025

Please note: *Students* ***MUST*** *retain a hard / soft copy of* ***ALL*** *assignments as well as a receipt issued as proof of submission.*

Acknowledgements.

I would like to thank the following people for their support in completing this dissertation:

My wife Mairéad, my parents, sisters, and friends for their continued encouragement, support and understanding.

Drs Margaret Doherty (Consultant anaesthesiologist, Mater Misericordiae University Hospital, Dublin), JR Sheehan (Consultant Anaesthesiologist, Cork University Hospital, Cork) and Jonathan Roddy (Consultant Anaesthesiologist, University Hospital Limerick) for their encouragement and supervision.

Dr Ming Chen Chong, Anaesthetic intern, University Hospital Limerick, for helping with data collection.

The staff at the Departments of Anaesthesia in MMUH, CUH and UHL for participating in my research.

All the ICU and theatre nursing and HCA staff at MMUH, CUH and UHL, in particular Ms Maria Dowling for her valuable contributions to the study implementation.

Mr Brian Kearney for his help and encouragement throughout the dissertation process.

Mr Oengus Harding-Smith for his input with the initial prototype device.

Table of Contents:

List of Tables.

List of Figures.

List of Abbreviations.

ASPEN – American Society for Parenteral and Enteral Nutrition

BAPEN – British Association for Parenteral and Enteral Nutrition

CFR – Code of Federal Regulations

CO_2 – Carbon Dioxide

DL - Direct Laryngoscopy

ESPEN – European Society for Parenteral and Enteral Nutrition

EN – Enteral Nutrition

EU MDR – European Union Medical Device Regulation

FDR – Food and Drug Administration

FT – Feeding Tube

GI – Gastrointestinal

ICP: Intracranial Pressure

ISO – International Organisation for Standardization

KCal – Kilocalorie

Ml – Millilitre

NEX – Naris to Ear to Xiphisternum

NFLP – Neck Flexion with Lateral Pressure

NG – Nasogastric

NGT – Nasogastric Tube

NHS – National Health Service (UK)

OG – Orogastric

OGT - Orogastric Tube

PN – Parenteral Nutrition

PVC – Polyvinyl Chloride

SORT – Sniffing position, Orientation of the NGT, Rotation to opposite side, Twisting movement of the NGT

VL: Video Laryngoscopy

Abstract.

Introduction: Nasogastric tubes (NGTs) are enteral access devices used to provide nutrition to critically ill patients requiring intensive care, or to improve surgical conditions in patients undergoing certain surgeries. The insertion of NGTs is particularly challenging in patients who are anaesthetised and intubated; complication rates are higher and initial success rates are often lower in this population. Misplacement of NGTs is often associated with potentially serious complications. This dissertation assessed the common practice of NGT insertion and investigated how improving the process through the use of a dedicated introducer device may reduce patient complications.

Methods: Three research projects were performed. The first was a prospective multicentre service evaluation which assessed a sample of NGT insertion in clinical practice across three Irish hospitals for methods used, success rates, and other variables. The second was a survey of practicing anaesthesiologists which assessed their opinions on and attitudes towards NGT insertion in general. Thirdly, a mannequin-based study was performed in which a prototype nasogastric tube introducer device was compared to standard insertion methods. A literature review was performed which examined much of the available evidence on NGT insertion in anaesthetised patients, including insertion methods and complication rates.

Results: The “blind” method of inserting NGTs was the most common initial technique used, and it is a prevalent method across the world for intubated patients. Several other techniques are described in the literature, all of which have both advantages and disadvantages, but may be superior to the “blind” method which has the lowest success rate. Pulmonary NGT misplacements identified in the study had used the blind method for insertion in 83% of cases. Many anaesthesiologists agree that NGT insertion in intubated patients can be challenging, and there is a willingness to try new techniques which may be more reliable. A prototype introducer device was found to reduce insertion times in a mannequin study when compared to other methods.

Conclusions: NGT insertion in intubated patients is technically challenging and potentially dangerous. A more reliable method is needed, but it must be safe and effective and should be easy to use. A dedicated device may be useful.

Chapter 1: Introduction.

Purpose of the Research.

The purpose of this body of work is to investigate the risks and complications associated with nasogastric tube insertion in anaesthetised patients, and to examine how patient safety might be improved through the introduction of a novel introducer device designed to aid insertion and help prevent these complications. Furthermore, it will assess the attitudes of a sample of practising Anaesthesiology and Intensive Care specialists towards the adoption of a new technique designed to improve success rates.

Enteral tubes are flexible conduits which are inserted into the gastrointestinal (GI) tract via the nose or mouth, most commonly nasogastric tubes (NGTs) or orogastric (OGTs) (Halloran *et al.*, 2011). These tubes are used to access the GI tract for a variety of reasons, but can be summarised as 1) delivery of feed or medications to the stomach or small intestine; 2) drainage of stomach or bowel contents; and 3) to decompress the stomach during surgery of the abdomen to improve surgical conditions (Sigmon and An, 2022). Nasogastric tube insertion is associated with several risks, including the risk of misplacement in the airway or oesophagus. Although methods of insertion and confirmation of positioning have been refined in modern medical practice, NGT insertion remains a procedure which carries a potential risk of serios injury and death. The practice of NGT insertion has been the subject of widespread attention, education, and risk-reducing efforts across the UK and Ireland in recent years (NHS, 2016b; Medical Protection Society, 2017; HSIB, 2020).

The insertion of NGTs in patients who are under anaesthesia may be challenging, with low success rates among many of the common techniques (Ou *et al.*, 2021). Complications may include coiling or kinking of the NGT, pneumothorax, mucosal injury, bronchial perforation, and infections such as pneumonia or pulmonary abscess (Marderstein *et al.*, 2004; Prabhakaran *et al.*, 2012; Miyamoto *et al.*, 2024). Aside from the patient safety concerns, operator experience is another important component of the task, which may be cumbersome and/or prolonged if initial insertion is unsuccessful. As will be discussed below, many experienced anaesthesiologists and critical care specialists commonly find the task to be difficult, as elucidated through the primary research performed for this manuscript.

The goal of this dissertation is to investigate how a novel introducer device designed to assist nasogastric tube insertions in anaesthetised patient might positively impact patient safety, by reducing the rates of misplacement and other associated complications. This manuscript will focus mainly on the insertion of NGTs in patients under anaesthesia – either in the operating theatre or in the critical care setting.

The primary questions which I intend to answer are:

1. What types of NGTs are most commonly used in the anaesthesia and intensive care setting?
2. What techniques are commonly used for NGT insertion in current practice?
3. What are the success and misplacement rates for the most common techniques?
4. What equipment or devices are currently used for NGT insertion?
5. How long does the procedure typically take?
6. How easy do practitioners find the procedure?
7. Could a new medical device improve the task for either the patient (through reduction in complications) or the practitioner (through faster and/or more reliable insertion).
8. Would practicing anaesthesiology and intensive care clinicians adopt this new technique into their practice? What barriers would prevent them from doing so?

Context.

Among medical specialties, anaesthesia has long been regarded as a champion for patient safety. Great leaps in reducing perioperative morbidity and mortality have been made within anaesthesia over the last several decades, with anaesthesia arguably safer than ever (Gaba, 2000). Much research has been done on improving patient outcomes from invasive anaesthesia procedures such as central venous access, intubation and regional anaesthesia. However, although NGT insertion is regarded as a vital medical intervention and is routinely performed in the intensive care setting, the insertion technique has changed little over the years. Although specific methods of NGT insertion have more recently been described in an attempt to improve success rates, they have not been widely adopted. The rate of misplacement of NGTs into the respiratory tract, for example, has remained relatively consistent throughout the literature, but is often underestimated (Taylor and Manara, 2021).

For these reasons, a more reliable approach is needed in order to ensure that insertion of NGTs is performed safely and in a timely manner, with minimum delay and minimal risk to the patient. A dedicated introducer device may help achieve this goal. However, the factors influencing the uptake and use of such a device in healthcare settings is unclear. Factors such as ease of use, cost, reliability and safety may all play a role in an end user's decision to use the device in clinical practice.

Objectives of the Dissertation.

The objectives of this work are as follows:

1. To assess the current methods for NGT insertion and the associated complication rates through literature review,
2. To perform a prospective multicentre service evaluation to elucidate what techniques are commonly used and what (if any) complications or misplacements occurred during routine NGT placement scenarios in clinical settings,
3. To survey a sample of working anaesthesiologists and seek their opinions on the utility of a novel technique for NGT insertion in anaesthetised patients,
4. To perform a mannequin based randomised controlled trial comparing current methods to a novel introducer device, and to investigate any potential safety, time or convenience impact of the new device.

Structure of the Dissertation.

In this manuscript I will present the findings of the literature review and background to the problem of NGT insertion in anaesthetised patients, focusing on what complications may occur and the rates of misplacement in the airway. Current methods of NGT insertion will be presented, compared and contrasted. Current technologies and recent advancements will be discussed, such as imaging and camera-based methods of NGT insertion. Confirmatory tests and their relative strengths and limitations will also be discussed. Next, I will present the research methodology employed to collect and analyse relevant data pertaining to the insertion of NGTs in a number of Irish hospitals, as well as the methodology used to identify a potential role for a novel introducer device. Finally, I will discuss the findings of the primary research performed in the course of preparing this dissertation work, and discuss the conclusions and recommendations formed by this research.

Chapter 2: Literature Review.

History of Enteral Feeding.

Some of the earliest reports of enteral feeding via the upper gastrointestinal tract date as far back as the 12th Century, with notable further exploration of the technique being made from the 15th century onwards (Chernoff, 2006). Capivacceus, an Italian scientist and philosopher, is first credited with using a hollow tube to provide liquid to a patient via the oesophagus. A leather oesophageal feeding tube was developed by Jon Baptist von Helmont in 1646, and Herman Boerhaave hypothesized in the early 17th century that flexible catheters could be used for gastric feeding. Accomplished English anatomist John Hunter documented his use of an orogastric tube in feeding a patient who had developed a reduced ability to swallow, a technique which was further used and popularised after the treatment of an injured soldier during the Napoleonic wars in the early 19th century (Pareira, 1959).

Modern day enteral access tubes were first developed in the early 1900s, initially as a means of accessing the duodenum rather than the stomach. Polish-American physician Dr Abraham Levin is credited with developing the modern nasoenteral tube in 1921, inserted via the nose which improved patient comfort and shorted the insertion time (Tashiro *et al.*, 2010). Around the same time as advancements in enteral access tube technology were being made, there was also significant interest in the refinement of the nutritional materials being delivered to patients via these feeding devices. Although early feeding attempts used a heterogeneous mix of foodstuffs such as milk, eggs, bullion (and alcoholic beverages such as whiskey or wine), specific feeds began to be developed for use in surgical patients around the 1930s (Harkness, 2002; Chernoff, 2006). Nutritional science further progressed through the 1950s with a comprehensive understanding of human nutritional requirements, and the utilisation of automated enteral feeding of essential macro- and micronutrients in patients at risk of malnutrition remains essential today.

Current Trends in Enteral Nutrition.

In modern times, it is well recognised that the preferred method for supplementing nutrition in patients who may be unable to otherwise consume their daily nutritional requirements through oral intake alone is Enteral Nutrition (EN). Equally, EN is recommended over *parenteral* nutrition (PN), whereby nutrition is delivered to the patient intravenously, whenever possible (Singer *et al.*, 2023). Three major international authorities on enteral and parenteral nutrition (ASPEN, BAPEN and ESPEN) have published extensive guidelines and recommendations on the initiation and delivery of supplemental nutrition in the patients at risk of malnutrition, notably those admitted to intensive care units with critical illness. Current guidelines recommend that, when necessary, EN should be initiated within 24-48 hours of admission to an intensive care facility. In their 2022 consensus statement, the American Society for Parenteral and Enteral Nutrition (ASPEN) recommended that EN be commenced within 24-48 hours of admission in all patients at risk of malnutrition, including those in the critical care setting (Bechtold *et al.*, 2022). Equally, their European counterparts ESPEN have similar recommendations in their 2023 guidelines for nutrition in hospitalised patients, suggesting a maximum delay of 48 hours before supplemental nutrition is initiated (Singer *et al.*, 2023). Consequences of delayed feeding may include reduced immunity through decreasing the integrity of the GI tract as a barrier to microorganisms, increased inflammation and even increased mortality (Pillai, 2005; Bechtold *et al.*, 2022). Commencing enteral feeding early is therefore essential in managing critically ill patients who are at risk of, or experiencing, malnourishment.

Current enteral feeding regimens consist of a mix of carbohydrates, protein in the form of peptides or amino acids, lipids in the form of triglycerides, fibre, and micronutrients including essential vitamins and minerals such as phosphorous, potassium and magnesium (Doley, 2022). Carbohydrates are generally provided as maltodextrin, fats are provided as triglycerides from vegetable and fish oils, and the protein elements may be derived from soy, pea and or cow's milk sources (Doley, 2022; Nutricia, 2024). The caloric content of formulas also differ depending on the nutrition goal, but are usually between 1kcal/ml (isocaloric) and 2kcal/ml (energy dense)(Preiser *et al.*, 2021; Nutricia, 2024). The exact type of formulation used is dependent on several factors, including patient or disease specific factors, timing of initiating feeding, as well as the exact composition of the available formulas. For example, a feed supplement containing hydrolysed proteins with a lower fibre content may be better suited to critically ill patients in the intensive care setting. Other additional considerations may include the electrolyte balance of the patient receiving enteral nutrition, where a reduced sodium feed may be appropriate, for example.

What Types of Enteral Access Tubes Exist?

There is a wide range of enteral access devices in clinical use. They may be broadly divided into short term use and long term use (Doley, 2022). They may also be classified by their insertion location and/or desired final position. For example, a nasogastric tube which is advanced beyond pylorus of the stomach and the duodenum into the second part of the small intestine is thereafter termed a nasojejunal tube, which is one method of short term, post-pyloric feeding. In contrast, a gastrostomy or jejunostomy implies the creation of an artificial opening, called a stoma, through the abdominal wall and into the stomach or small intestine, and these are used for longer term feeding in patients who are unlikely to regain their ability to eat normally (Preiser *et al.*, 2021; Doley, 2022). The focus of this work is on the safety of short-term enteral access devices used mainly in anaesthetised patients in the critical care and surgical settings. Short term use is generally defined as less than 6 weeks duration (Doley, 2022). As such, gastrostomy, jejunostomy and other percutaneous enteral access methods will not be discussed further as they are beyond the scope of this dissertation.

Simple gastric tubes may be inserted via the nose (nasogastric, NG) or mouth (orogastric, OG). There are several subtypes of these devices, each with distinct advantages and disadvantages. These are summarised in *Table 1*.

Lumens	Type	Material(s)	Features	Advantages and Disadvantage(s)	Clinical Uses	References
Single	Levin	Polyurethane		Softer material compared to PVC, improves comfort at cost of more difficult insertion.	Feeding or drainage	(Cleveland Clinic, 2022)
	Dobhoff	Polyurethane	Tungsten weighted tip		Feeding or drainage	(Boyes and Kruse, 1992;

			to aid insertion			Sigmon and An, 2022)
	Fine bore	Polyurethane, silicone	Metallic stylet wire to provide rigidity during insertion	Smaller diameter and polyurethane material improve comfort. Narrow bore makes clogging more likely.	Feeding only	(Rassias *et al.*, 1998)
	Ryles	PVC	Weighted tip		Drainage or feeding. PVC: Short term use only.	(Yeung *et al.*, 2023)
	Kangaroo IRIS	Polyurethane	Integrated camera for visualising anatomy during insertion.	Significant costs: £95 per feeding tube, plus monitor (£5500 in 2010). Higher initial rate of misplacement.	Feeding only	(Hemington-Gorse *et al.*, 2011; Covidien, 2012, p.2; Taylor *et al.*, 2021)
Double	Salem Sump	PVC, silicone	Double lumen design with air vent to allow pressure equalisation between stomach and external atmosphere.	Used for drainage or irrigation.	Drainage, irrigation (e.g. in poisoning). Unsuitable for feeding. PVC: Short term use only (<7-14 days)	(Nickson, 2019; Smith *et al.*, 2021; Kusz, 2021; Cardinal Health, 2025)

Table 1: Summary of different types of enteral access tubes.

How Are Enteral Tubes Inserted Currently?

Traditionally, blind insertion has been the dominant insertion technique for NGTs (Taylor *et al.*, 2023). This method involves inserting the tip of the NGT into one of the nostrils as an initial entry point, and advancing it to the desired final length, usually estimated from the distance from the naris to the ear to the xiphisternum (NEX) or a similar formula (Sanaie *et al.*, 2017; Boeykens *et al.*, 2023). Blind NGT insertion has a low initial success rate, estimated to be between 40-58% by Sanaie and colleagues, but as low as 34% in one study by Appukutty and Shroff (Appukutty and Shroff, 2009; Sanaie *et al.*, 2017). The question of quite where these unsuccessful attempts are located during insertion is worthy of further discussion and investigation. Most end up curling in the mouth or the throat, but a significant minority of these are erroneously inserted into the respiratory tree, which predisposes to serious complications, discussed below.

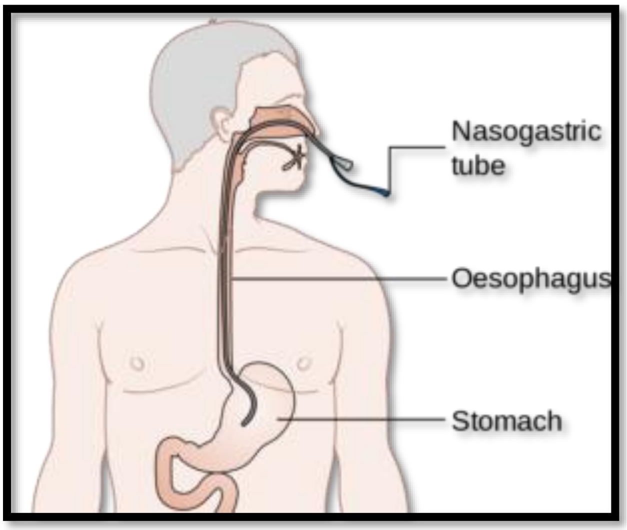


Figure 1: Nasogastric tube insertion length (Oxford Medical Education, 2015)

An obvious drawback of the blind method is that the NGT may occasionally enter the airway at the point where the oesophagus and trachea branch from the pharynx. This can easily be appreciated when the anatomy of the area is seen, as shown in *Figure 2*, below, where the close proximity of the oesophageal inlet and the trachea is visible. This "blind" method is commonly employed in awake and co-operative patients, and signs of misplacement may be more obvious in this cohort, such as coughing or respiratory distress (Halloran *et al.*, 2011; Koo, 2016). However, in patients whom are sedated and perhaps paralysed under anaesthesia, insertion may be more challenging and signs of misplacement may be less obvious or absent altogether (Halloran *et al.*, 2011). Nonetheless, blind insertion remains the most common method in this patient population also (Sanaie *et al.*, 2017). The dichotomy of using blind insertion of NGTs, with its associated risks or failure and misplacements, in vulnerable patients is an interesting observation and is discussed further in chapter 5: conclusions and recommendations.

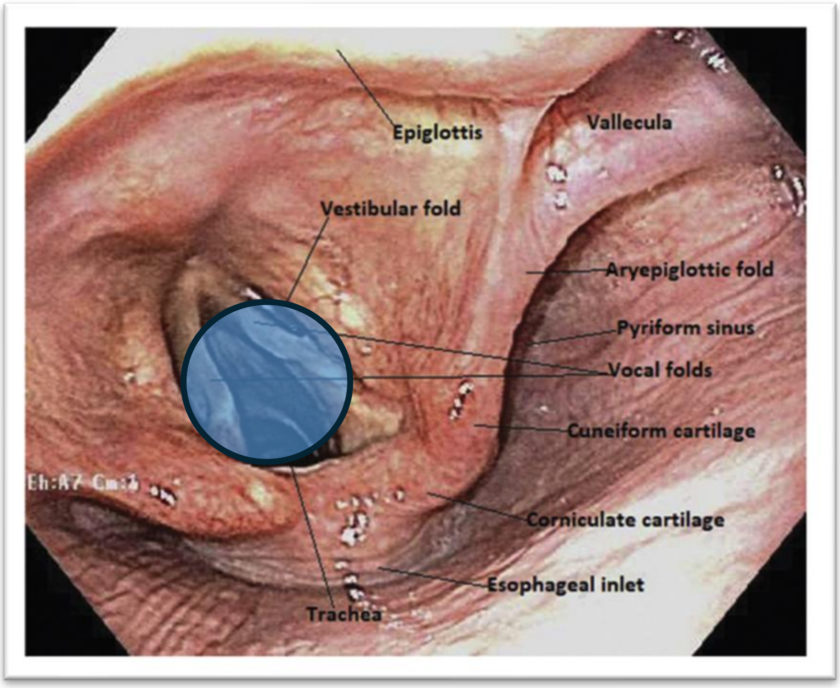


Figure 2: Anatomy of the larynx during endoscopy. The blue circle represents the location of an endotracheal tube. Note the (right) pyriform sinus and peri-laryngeal cartilage structures, the most common sites of NGT impaction (Fatima, 2019).

The incidence of inadvertent insertion of NGTs into the respiratory tract is estimated to be between 1.5 and 3.2% according to several studies (Sorokin and Gottlieb, 2006; de Aguilar-Nascimento and Kudsk, 2007; Halloran *et al.*, 2011; Taylor and Manara, 2021). When this occurs, the risk of associated major pulmonary and thoracic complications is approximately 27-28% for the general hospital population, but may be up to 57% in patients already admitted to intensive care with critical illness (Sorokin and Gottlieb, 2006). The mortality rate from NGT insertion is estimated to be approximately 0.3% as a result of these potential major complications (Rassias *et al.*, 1998).

Such complications will not only impact patient satisfaction and outcomes but will also impart a financial cost of managing the complications on the healthcare institution, as well as potential litigation and financial compensation. Examples of these increased costs are discussed in more detail in Chapter 5.

Traditionally, when blind insertion of an NGT fails in an intubated patient, insertion under direct vision using a laryngoscope would be a common rescue technique. In this method, laryngoscopy is performed and the NGT is inserted to the level of the pharynx where the tip is directly observed. The NGT can be manipulated from above to steer it towards the oesophagus while being directly visualised. If the tip of the NGT cannot be directed towards the oesophagus under direct vision, a grasper (such as the angled Magill forceps) can be used to grasp the NGT in the pharynx and move it directly into the upper oesophagus (Furutani *et al.*, 2020). This technique is depicted in *Figure 3*. Although this method may be more successful as compared to blind insertion, it is more time consuming and labour intensive, and may be stimulating for the patient, resulting in cardiovascular responses such as hypertension, tachycardia and raised intracranial pressure (Burney and Winn, 1975; Mahadevaiah *et al.*, 2022).

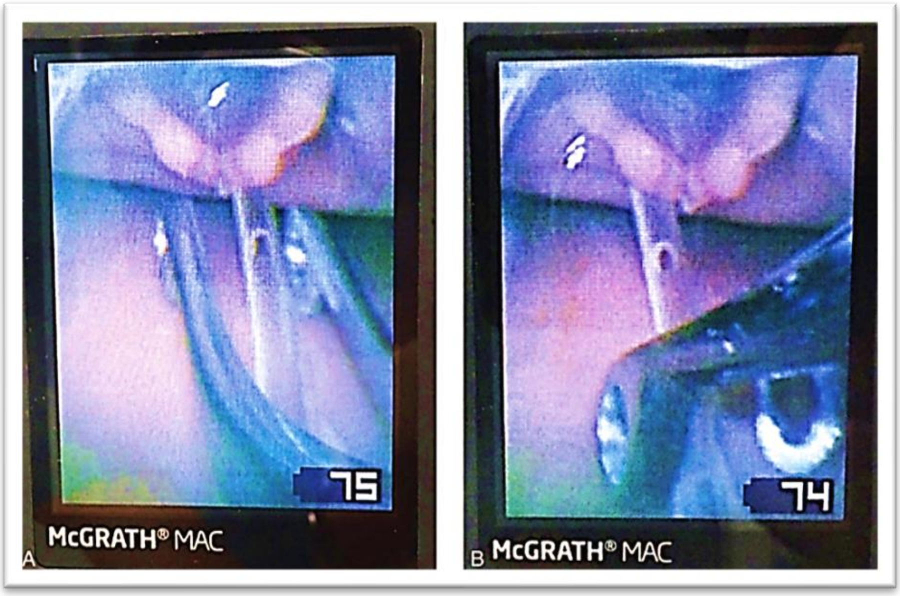
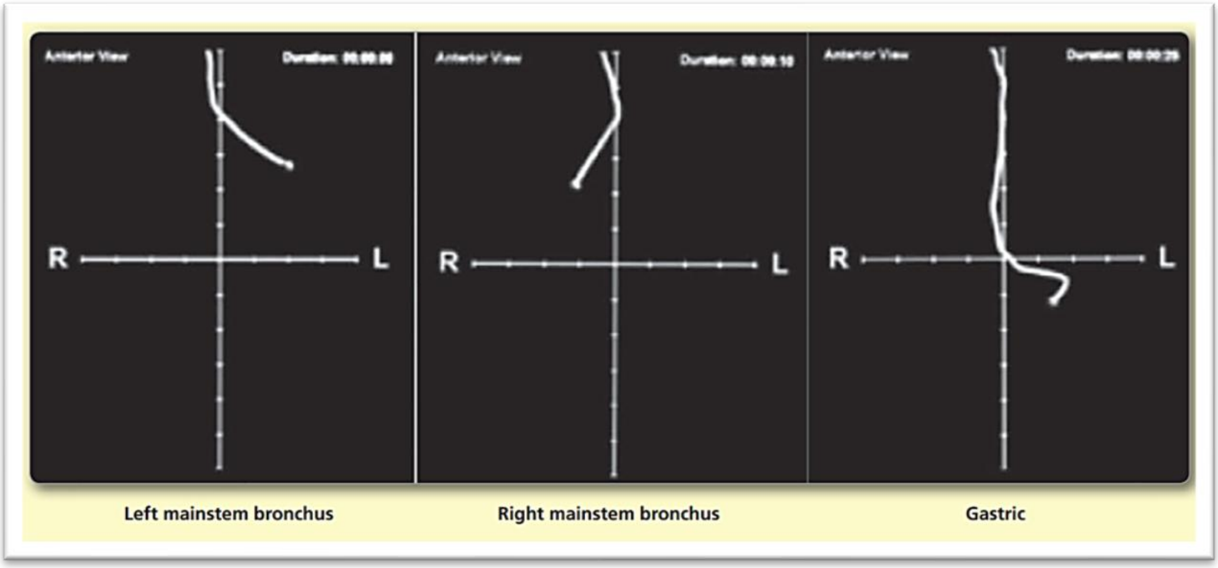


Figure 3: Insertion of NGT demonstrated using a (video) laryngoscope and modified Magill forceps (Furutani et al.*, 2020). The Fenestrated NGT is seen between the prongs of the forceps. The nearby tracheal opening is seen at the top of the image, just above the NG tube.*

To address the increased difficulty with NGT insertion in anaesthetised and intubated patients, a number of methods have been developed and described in the literature. These can be broadly classified into "specific manoeuvres" and "device-based" methods. Specific manoeuvres include neck flexion, neck flexion with lateral pressure (NFLP), the SORT manoeuvre, reverse Sellick manoeuvre (anterior displacement of the larynx) and neck rotation, for example (Appukutty and Shroff, 2009; Tashiro *et al.*, 2010; Sanaie *et al.*, 2017).

Device based insertion may make use of modified or repurposed existing medical devices as makeshift introducers, or may be purpose-build devices for NGT insertion. Examples include a split endotracheal tube which can be used to intubate the oesophagus and a conduit which can be peeled away, or a guidewire over which the NGT can be inserted (Appukutty and Shroff, 2009). Other methods include using an airway exchange catheter or intubating stylet as a rigid introducer to which the NGT is tied for insertion and subsequently liberated after insertion is confirmed (Tsai *et al.*, 2012; Kim *et al.*, 2016).

A device-based system manufactured by Avanos Medical® uses electromagnetic tracing, which is displayed on a monitor in real time, to guide insertion and help recognise misplacement during insertion. The CORTRAK EAS™ (enteral access system) displays a tracing of the NGT tip during insertion, which allows specially trained operators to recognise deviations from the expected path during NGT insertion. Where the NGT tip is seen to deviate from the midline before the expected distance to the stomach, it may represent misplacement in the airway. This early recognition allows the operator to withdraw the NGT before serious injury may be caused (Taylor *et al.*, 2023). An example tracing of NGT insertion is seen in *Figure 4*. The proprietary NG tubes are significantly more expensive than standard tubes, approximately £51 vs £7 for a standard NG tube (National Institute for Health and Care Excellence, 2016, p.1).



Left mainstem bronchus **Right mainstem bronchus** **Gastric**

Figure 4: Electromagnetic trace generated during NGT insertion using the CORTRAK Enteral Access System. With correct placement in the oesophagus, the tracing should stay in the midline (Y axis) until below the

Xiphisternum (represented by the horizontal X axis). Deviation before this point might indicate endobronchial placement, necessitating withdrawal of the tube and repeating the attempt (Bourgault et al.*, 2017).*

More recently, video laryngoscopy has been much more widely adopted as a means of performing laryngoscopy for intubation. Miyamoto and colleagues investigated its role in NGT insertion in intubated patients undergoing CPR during cardiac arrest. They concluded that, compared to blind NGT insertion, video laryngoscopy was protective in reducing the risk of laryngopharyngeal mucosal injury (Miyamoto *et al.*, 2024). Their study also confirmed that although blind NGT insertion may be perceived as uncomplicated, accidental insertion of the NGT into the airway may occur even when insertion appears to have been smooth (Maxwell, 2024; Miyamoto *et al.*, 2024). The main advantages of video laryngoscopy over blind insertion in this study was the real-time observation of the NGT movements at the laryngeal level, which allowed the operator to anticipate pulmonary misplacement or kinking of the NGT which would risk mucosal injury from the sharp points formed at the point of flexion.

What Are the Complications of NGT Insertion in Anaesthetised Patients?

Complications from NGT insertion are varied in location and severity. They can broadly be divided into complications from misplacement (pulmonary, oesophageal or intracranial), repeated attempts (mucosal trauma, bleeding) or prolonged insertion (cardiovascular responses such as high blood pressure, raised intracranial pressure) (Fassoulaki and Athanassiou, 1985; Dziewas *et al.*, 2003; Miyamoto *et al.*, 2024).

First pass success rates are generally lowest in blind insertion techniques compared to other methods (Appukutty and Shroff, 2009). Where placement into the stomach is not successful, the NGT tip may be misplaced into the respiratory tract (trachea, bronchi, parenchyma or pleural space). The NGT may also become curled up in the pharynx or oesophagus which exposes the patient to risk of aspiration into the lungs if feed or fluids are administered through the misplaced tip. Even if feed or fluid are not administered through a misplaced NGT, significant thoracic complications can occur from the traumatic insertion into the delicate airways. These may include pneumonia or pulmonary abscess by the introduction of microorganisms into the respiratory tree as the NGT passes through the upper airways and pharynx, bronchial perforation, or pneumothorax (Pillai, 2005). Such complications may be potentially disastrous in patients whose critical illness necessitates the insertion of the NGT to begin with.

Ozer and Benumof initially demonstrated, with the use of fibreoptic endoscopic examination, that the most common sites of impaction of NGTs in anaesthetised and intubated patients were the arytenoid cartilages and the piriform sinuses (Ozer and Benumof, 1999). These findings have led to the development of some of the specific techniques previously mentioned, such as neck flexion with lateral pressure to help close the piriform sinuses. These findings are reproduced in *Figures 5 and 6*, below.

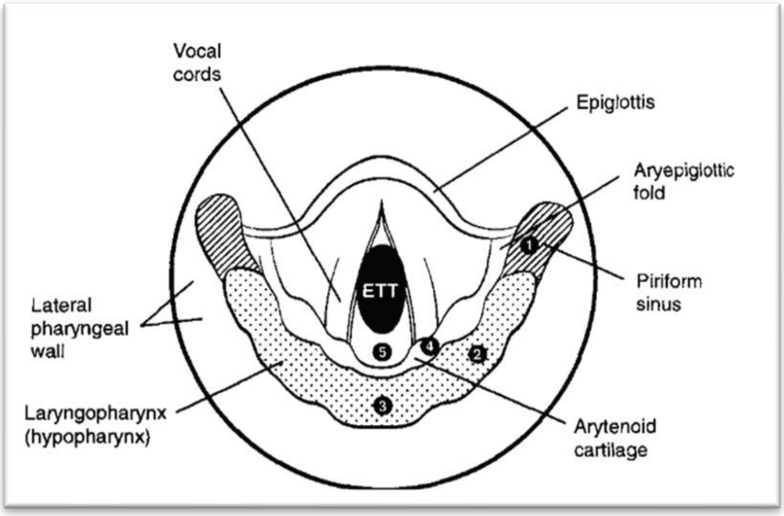


Figure 5: Schematic demonstrating the common sites of impaction of NGTs inserted in intubated patients (Ozer and Benumof, 1999)

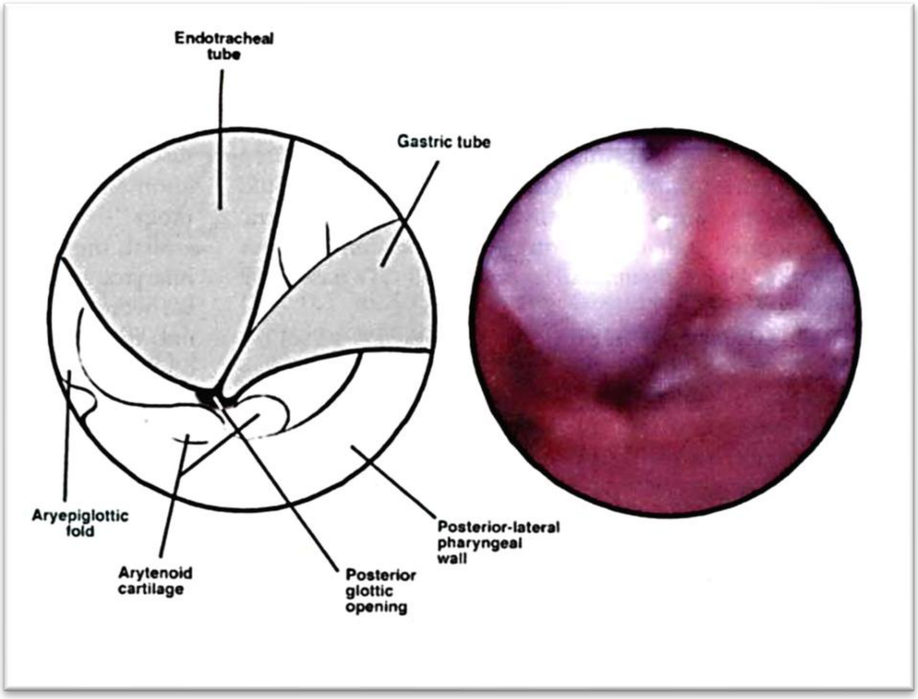


Figure 6: An example of tracheal misplacement of a nasogastric tube past a cuffed endotracheal tube (Ozer and Benumof, 1999).

How Is Successful Nasogastric Tube Positioning Confirmed?

The gold standard for confirming nasogastric tube position is a chest radiograph which demonstrates the tip of the NGT below the level of the diaphragm, along with three other important criteria. All four criteria must be met in order for the NGT to be considered "safe to use" (NHS, 2016a, p.47). However, there are time and financial costs associated with the routine use of x-rays, as well as the radiation exposure to the patient (Robles-González *et al.*, 2024). *Figures 7A-D* depict correct and incorrect placements of NG tubes on chest x-ray (Bickle *et al.*, 2014). Other methods have been employed in order to reduce the reliance on x-ray, although many of these have become outdated or proven unreliable and potentially dangerous, such as auscultation for bubbling over the stomach area or qualitative pH testing strips (NHS, 2016a, pp.13–15). An acceptable alternative to the chest x-ray is the use of quantitative pH testing strips. A result below pH 5.5 is consistent with aspiration of gastric fluid. However, this result does not determine the origin of the fluid sampled, and in patients who may have recently aspirated gastric contents into their lungs, a false positive result may occur which has the potential to confuse matters (Jones, 2020). In recent years, the use of live bedside ultrasound imaging as an alternative to x-ray has been proposed (Zatelli and Vezzali, 2017). Another method involved the use of capnography to detect Carbon Dioxide (CO2) by sampling the gas withdrawn through the NGT at an insertion distance limit of approximately 30cm. If CO2 is detected, this may represent endotracheal misplacement at an early stage, before major injury may be caused (Meyer *et al.*, 2009; Jones, 2020, p.20).

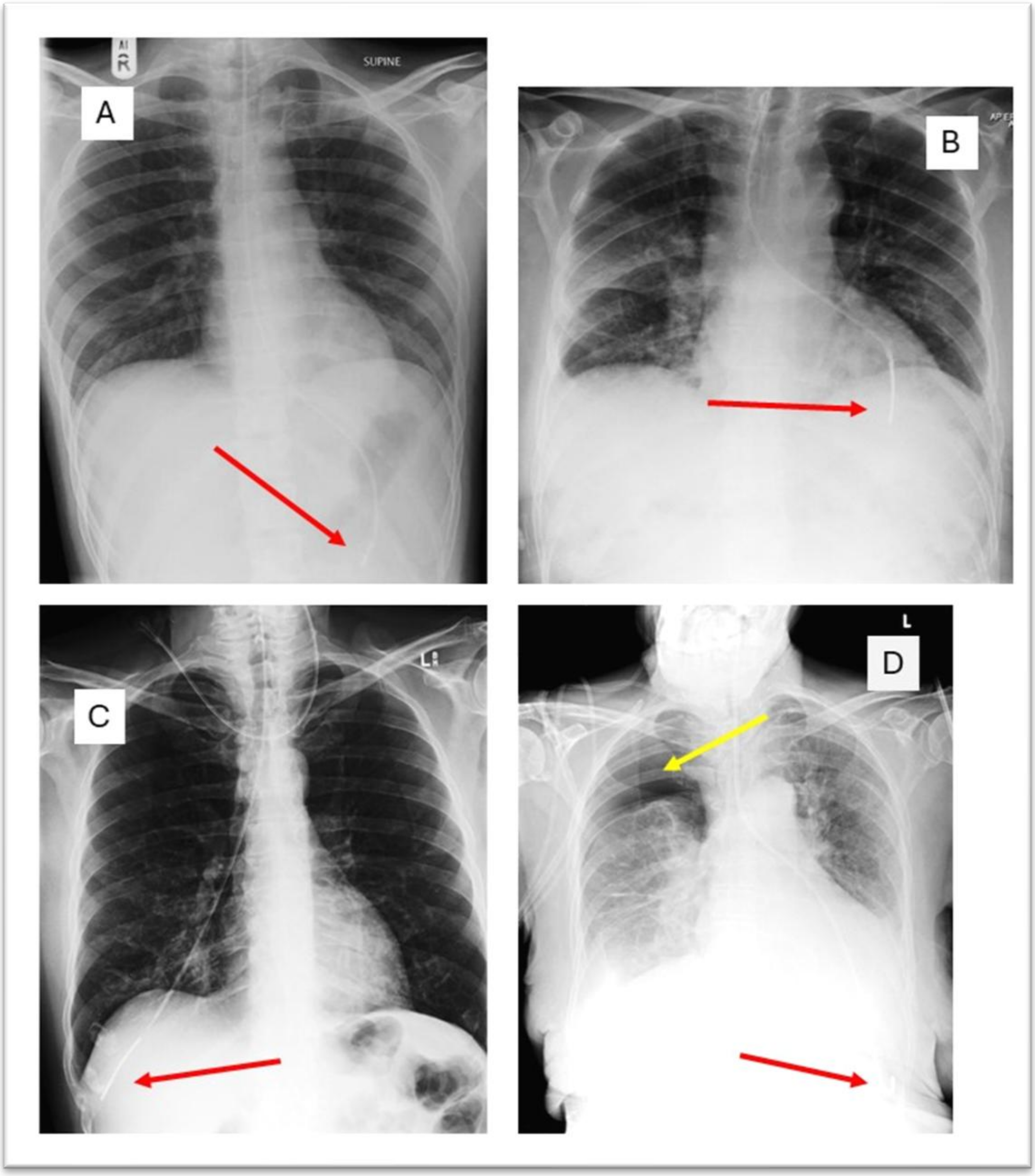


Figure 7A: Correctly sited nasogastric tube. The tip is below the diaphragm and crosses the midline below the diaphragm. B: NG tube misplaced within the left main bronchus. It crosses the midline well above the diaphragm. C: Misplaced tube with tip in lower lobe of the right lung. D: Misplaced tube in lower lobe of left lung, with large right pneumothorax (yellow arrow) likely from previous failed attempts prior to x-ray (Bickle et al.*, 2014).*

Critical Analysis of the Literature.

Much of the research which exists on NGT insertion in anesthetised patients can be classified into two main groups: retrospective studies of NGT complications in hospital patients which contain a sub-population of anaesthetised patients (such as Sorokin and Gottleib, Rassias et al and de Aguilar-Nascimento), or prospective randomised controlled studies comparing different types of NGT insertion in the anaesthetised patient population (such an Sanaie et al, Tsai et al and Kim et al). There was a lack of prospective data specific to the variation of methods used in anaesthetised patients in routine clinical practice, which is what this work intended to assess. Additionally, the available retrospective analyses focused more on fine bore feeding tubes, whereas the prospective randomised controlled trials dealt more with wide bore NG tubes. Nonetheless, the complications seemed to be consistent between the two groups of research.

Chapter 3: Research Methodology.

1. Retrospective Service Evaluation of a Series of NGT Insertions in Routine Clinical Practice.

The research methodologies employed for this dissertation were mostly qualitative in nature, with a focus on the methods currently used for NGT insertion, and the experiences of those performing the procedure. Quantitative analysis was performed with respect to certain aspects of the procedure, such as the time taken to successful insertion of NGT in both clinical practice and mannequin-based simulations. For ease of analysis and interpretation, continuous data (such as time taken to insertion, or years of operator experience) were grouped into defined time categories. This allowed for the data to be easily represented as categorical data in a bar or pie chart, as presented in the analysis section below.

The first part of the primary research performed was to evaluate how NGTs are currently inserted across several clinical sites within Ireland. The service evaluation was performed across 3 major Irish teaching hospitals: Mater Misericordiae University Hospital Dublin, Cork University Hospital, and University Hospital Limerick. The purpose of this service evaluation was to clearly assess and understand how the procedure is performed in real clinical practice, using data from three centres to reduce bias of local practices in a single centre.

The following factors were assessed for each NGT insertion preformed over the study period:

Question	Purpose	Results (n)
Level of experience	To determine any difference in practices or success rates between groups of more experienced vs less experienced practitioners.	6 years: 23 4-6 years: 13 1-3 years: 11 <1 year: 6 Not recorded: 1
How long did the procedure take?	To determine how long the procedure takes on average, or when difficulty is encountered. To identify the baseline time to which a new technique/device might be compared.	< 1 minute: 21 1-5 mins: 20 5-10 mins: 9 10-20 mins: 3 >20 mins: 0 Abandoned: 1
What equipment was used?	To identify any additional equipment which may be used in the insertion, what is the true cost and environmental impact of such equipment requirements.	Laryngoscope, disposable blades, second NG tube if first attempt failed, sachets of lubricant, Magill forceps.
What malposition occurred?	To more clearly estimate the true incidence of NGT malposition in a prospective way.	Coiled in mouth/throat: 19 Actual/suspected insertion into respiratory tract: 6 1st attempt successful: 27 Not specified: 2.
What technique was used?	To determine the level of knowledge and awareness	Blind: 35 Neck flexion: 4

	among anaesthesiologists regarding specific NGT insertion techniques.	Digital manipulation: 5 Laryngoscope (DL/VL): 9 Laryngoscope + Magill: 1
What medication was used?	To determine if any supplementary sedation or muscle paralysis was required in addition to baseline sedation specifically for the procedure, and any cost impact or potential adverse associations with these.	Sedatives: Propofol (n=5), midazolam (n=1), fentanyl (n=1). Muscle relaxants: rocuronium (n=1). Performed immediately after induction dose of anaesthesia: n=28. Already under GA (in theatre) or sedated (ICU): 6 Not Specified: 5 No additional medication: 4 Other: not required due to low level of consciousness (2) or tolerated procedure well without sedation (1).
How was the position confirmed?	Are anaesthesiologists complying with local guidelines and policies in confirming NGT placement. What is the cost of these methods (e.g. X-ray).	Aspiration of gastric contents: n=23 Auscultation: n=8
What type of airway was in place?	Do certain types of artificial airway affect the ability to insert the NGT, or influence which method is used?	Oral ETT: 50 Tracheostomy Tube: 1 Post induction/Pre-intubation: 2 Not specified: 1
Where was the procedure performed?	Were NGT more likely to be successful in theatre or ICU settings? Is there a greater need for a new technique in either setting?	Theatre: 28 ICU: 24 Resuscitation Room: 2

Table 2: Service evaluation questions, with rationale and responses received (n=54).

For data collection, a questionnaire was placed in two main clinical areas: operating theatres where NG tubes were likely to be inserted, such as emergency theatres, upper gastrointestinal (GI) surgery, or robotic surgery, and Intensive Care Units. Staff were asked to complete the data collection for any NGT insertion that they performed as part of a patient’s routine care in any location. The data collection form was completed by an assistant during the procedure, or as soon as possible after the NGT insertion had been performed successfully or unsuccessfully. *Table 3* represents the data collection form used.

Section 1: Determining current nasogastric tube insertion *practices* in anaesthetised patients. To be completed for each NG tube insertion event.		
1.	What is your level of experience in Anaesthesia/Critical Care? Please circle your answer.	• <1 year • 1-3 years • 4-6 years • >6 years
2.	How long did the overall NGT insertion take? (Starting from the time the first NG tube is inserted into the nostril, ending when the anaesthetist satisfied that the final NGT is ready for use or for radiological confirmation). **All attempts** at insertion during the **same event** by the same individual should be timed as one "event".	If possible, please record an accurate time for the overall episode (minutes and seconds): _________ If unable to provide a precise time, please indicate the approximate time (by noting start and end times): • <1minute • 1-5mins • 5-10 mins • 10-20 mins. • >20 mins.
3.	What equipment was used for during the insertion attempt(s)? Include additional medications e.g. sedation, muscle relaxant. Specify quantity of NG tubes, and any specific qualities (e.g. refrigerated, different brand or material). More than one can be selected.	• Additional NG tube(s) Specify: ________________________________ • Original NG tube was re-used on repeated attempt(s) • Laryngoscope • Magill forceps • Cut endotracheal tube • Lubricating jelly sachets: ____________ • Other (Specify): _____________________
4.	If not successful on 1st attempt, specify what malposition occurred. More than one can be selected, but please elaborate.	• Coiled in mouth/throat. • Inserted into respiratory tract (e.g. audible respiratory sounds through NG tube). • Other • Unsure (please elaborate). _____________
5.	What technique(s) were used for NGT insertion?	• Blind • Other (specify): ______________________

6.	Were any medications used to facilitate NG tube insertion (e.g. sedation bolus in ICU).	• Medications (and doses) used specifically for NGT insertion: 1. 2. 3. • Performed immediately after induction/not applicable.
7.	How was the NG tube position confirmed? Was more than one method used (e.g checked intra-op and confirmed on post op X ray)? Did the tests correlate? Please elaborate.	• Aspiration of gastric content • Litmus test • Radiographic confirmation • Direct surgical confirmation during laparotomy/laparoscopy • Other (specify): _______________
8.	What type of airway was in place prior to NGT insertion?	• Oral ETT • Tracheostomy • Other (Specify) ____________
9.	Where did the procedure take place?	• Theatre • ICU

Table 3: Data collection form following NGT insertion.

2. Survey of Anaesthesiologists Regarding Their Experiences and Attitudes Towards NG Tube Insertion in Intubated Patients.

The second body of qualitative research performed was to investigate how anaesthesiologists approach the task of NGT insertion. A paper based or online survey (www.surveymonkey.com) was distributed to all staff in each of the three anaesthesia departments, the two media asking identical questions. The survey was designed to evaluate what techniques are widely known or used for NGT insertion, how practitioners feel about the task, how often they find it difficult to perform successfully, and how they would feel about adopting a novel technique which may aid them in this task. *Table 4* outlines the questions which comprised this survey.

Q1	Based on your experiences, what subjective difficulty rating would you assign the task of inserting an NG tube in an anaesthetised patient?	• Not difficult at all • Sometimes difficult • Often difficult (<50% of the time) • Regularly difficult (>50% of the time)
Q2	What would be your usual approach in the event of a failed first attempt at NGT insertion? More than one can be selected.	• Re-use the first NG tube with a modified technique • Use a fresh NG tube • Laryngoscope • Magill forceps • Other (specify): _______________ ____________________________
Q3	Are you aware of any specific techniques which have been described, which may increase the first pass success rates of NGT insertion in anaesthetised patients? Please describe them.	
Q4	If a simple new technique was developed for NGT insertion in anesthetised patients which hypothetically increased first pass success rates close to 100%, how likely would you be to use such a technique?	• I would not change my current practice. • I would use it as a last resort. • I would use it only if my initial attempt failed. • I would use it regularly. • I would use it every time.

Table 4: Determining current attitudes towards nasogastric tube insertion in anesthetised patients.

A total of 82 survey responses were received from actively practising anaesthesiologists of all grades. The findings of this survey are discussed in detail in Chapter 4: findings and analysis.

3. A Mannequin Based Randomised Controlled Trial Assessing the Utility and Potential Uptake of a Novel Medical Device.

The final body of primary research performed was to compare a technique using a new, purpose-built introducer device to that of current practice. A mannequin-based study was performed using a prototype introducer device to assist anaesthesiologists with NGT insertion. The performance of the device was compared to the anaesthesiologist's unrestricted choice of technique.

A size 7.0mm ID Portex® oral endotracheal tube (ICU Medical™, California, USA) was placed in an airway training mannequin (Laerdal™, Norway) and secured at a distance of 22cm with a cotton tie prior to beginning the study. A size 14French Ryles-type NG tube (Vygon™, France) was to be inserted by the candidate on instruction from the observer. Attempt 1 was performed using the operator's own preference, using available equipment such as Macintosh laryngoscope and Magill forceps, which were provided on request of the anaesthetist. Lubricating jelly (OptiLube™, Optimum Medical, UK) was used as standard in all procedures. After the insertion was completed, the NG tube was removed, and a demonstration of the trial device was performed with the opportunity for questions but without hands on practice. Attempt 2 utilised the prototype introducer device immediately following the demonstration, but without any practice attempt by the candidate. The time to insertion and rates of misplacement were recorded. For the first attempt, the stopwatch was started when the NG tube first entered the nostril and was stopped when the NGT was seen to enter the stomach by the observer. For the 2nd attempt, the stopwatch was started when the introducer device was inserted into the mouth, and stopped at the same time point.

Continuous data (insertion time) was collected along with categorical data in the form of user feedback. Users were asked to give feedback on factors such as ease of use, and likelihood of use in clinical practice, measured using a five-point Likert scale (*Table 5*). The results of this study are discussed in Chapter 4.

Attempt 1 (Anaesthetist's Choice)	
What technique was used? (circle)	• Blind • Laryngoscope • Laryngoscope + Magill forceps • Video Laryngoscope • Slit ETT Other (Specify): ______________________ ____________________________________
How long did the procedure take?	___ Min ____ Sec
Any Misplacement? (circle)	• Successful on 1st attempt • Coiled in mouth/throat • Respiratory tract • Other (specify) _________________ ______________________________
What is your level of experience in anaesthesia?	• <1 year • 1-3 years • 3-6 years • >6 years
Attempt 2 (Trial Device)	
How long did the procedure take?	___ Min ____ Sec
Any Misplacement?	• Successful on 1st attempt • Coiled in mouth/throat • Respiratory tract • Other (specify) _________________
Ease of use?	• Very Easy • Somewhat easy • Neutral • Difficult • Very difficult
How often might you use this device for NGT insertion if it were commercially available?	• Every time • Only if my initial attempt failed • Sometimes • Rarely • Never

Please explain your answer above. What factors may influence your decision?	
Do you see any advantages or disadvantages to this device over current methods?	Advantages: Disadvantages:
Please provide any feedback that you wish to on the trial device.	

Table 5: Data collection form for mannequin-based study.

Sampling Technique

Study participants were selected from anaesthesia departments where I was employed as a Specialist Registrar in Anaesthesia at various times. All departments consisted of a mix of consultant anaesthesiologists and/or intensivists, and non-consultant anaesthesiologists (including Interns, Senior House Officers, Registrars and Specialist Registrars). Some departments also had advanced nurse practitioner members. All departments had strong academic or clinical research engagement and output, and research activity was actively encouraged within each department. Once the study had been designed, and subsequently approved by a nominated consultant with any necessary ethical approval, all clinical members of the department were informed of the study activity via email to the departmental emailing list. Data collection forms were placed in all sites where NGT insertion was likely to take place.

All department members were informed of the study and how to participate using the forms following any insertion of an NGT. Nursing staff in the clinical areas were also informed of the study, so as to help recruit potential participants during any NGT insertion event in which they may have been involved. The data collection forms were placed in the relevant clinical areas, near the computers or theatre anaesthetic machine, for high visibility. Over the course of the study, it was necessary to perform regular reminders to staff to complete the forms after an NGT insertion event, as it there was an initial low uptake despite NGT insertion activity being observed clinically (for example, recent admissions of patients to intensive car, where NGT insertion would be routing standard of care in many cases). There was no selection bias towards recruiting study participants, the study was open to all members of all grades from each department. It was observed initially that more NGT events tended to be missed when performed in ICU, likely a result of the clinical workload and acuity of the delivery of care, which meant that research participation was a lower priority, especially during out of hours when staff numbers would be lower. To tackle the problems with recruitment, it was necessary to take steps to increase uptake. All NG tubes stored in the clinical areas were labelled with a sticker as a reminder to potential study participants to engage with the data collection.

Research Design.

Figure 8 demonstrates the overall research design pathway for the service evaluation and survey. *Figure 9* shows the research methodology design for the mannequin study.

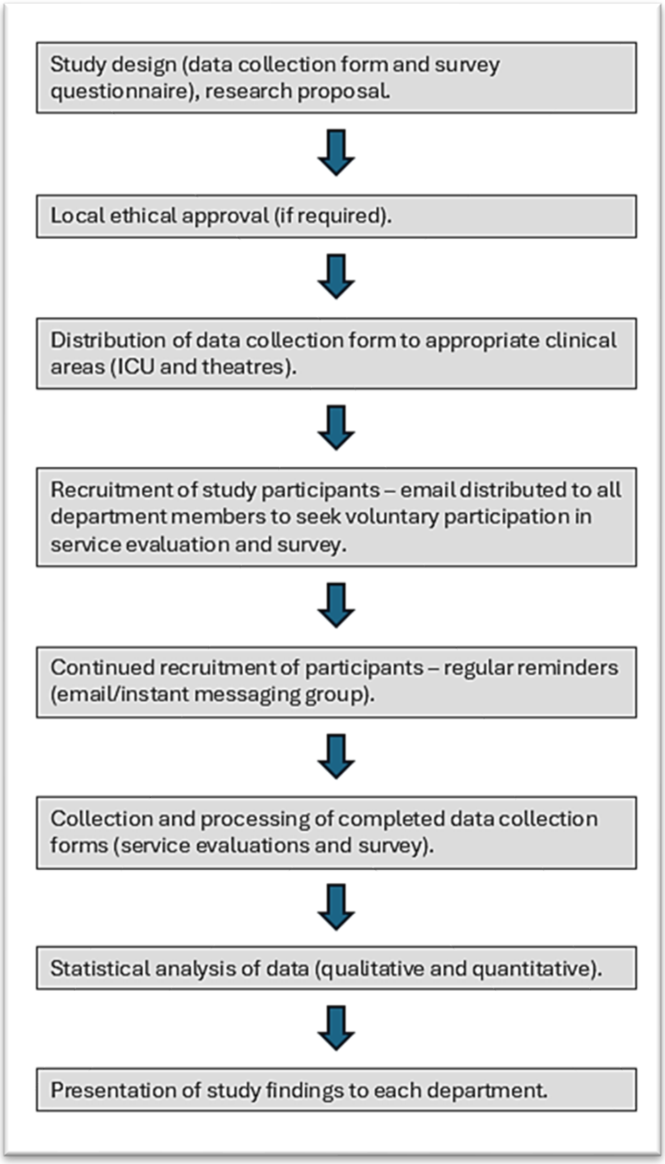


Figure 8: Study design for service evaluation of NGT insertions.

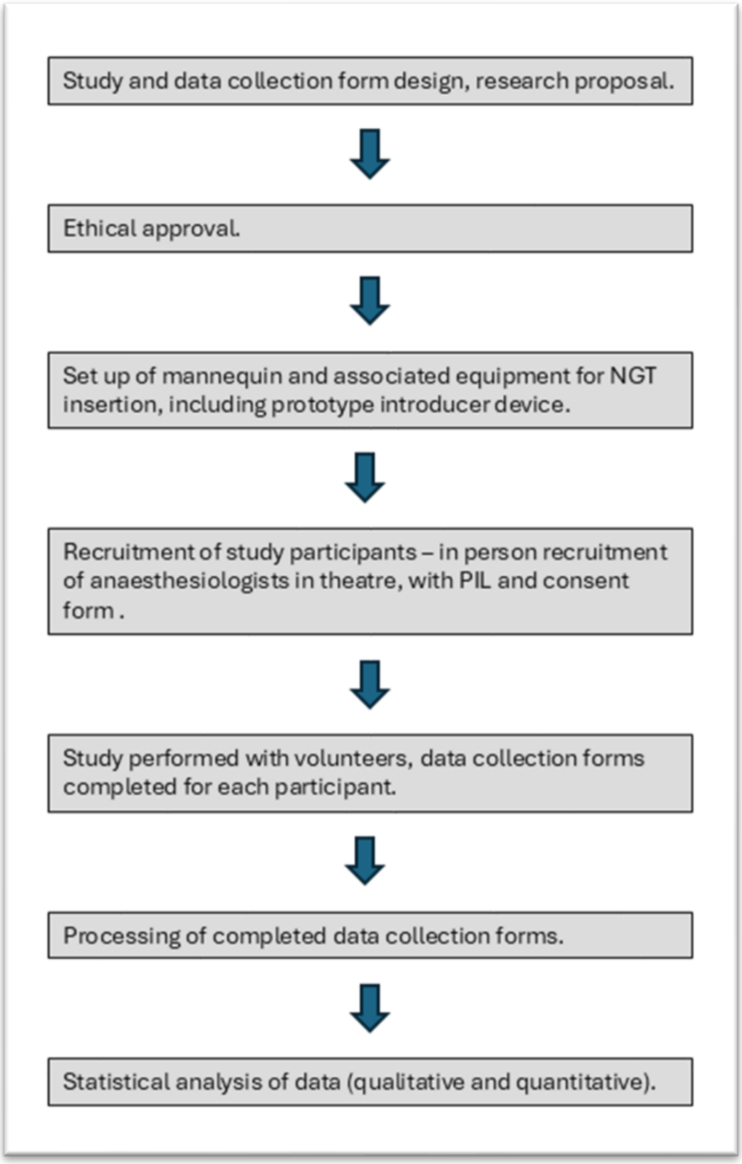


Figure 9: Study design for survey questionnaire.

Data Analysis Strategy.

For the service evaluation study, response data was manually collated into an excel spreadsheet. The responses were numbered from 1 to 64. Responses which did not meet the inclusion criteria (i.e. insertion of an NGT into an anaesthetised patient) were excluded from the data analysis. From there, the quantitative data was inputted into pie charts or bar charts, and results were expressed as a percentage of the overall number of responses. Where trends were identified, such as accidental misplacement into the respiratory tract, then sub-analysis was performed to determine which insertion technique was used in these cases, or the experience of the anaesthesiologist, for example. For qualitative data such as the specific insertion technique(s) used, or knowledge of specific insertion techniques, the responses were categorised according to similarity. For example, “finger in pharynx”, “finger used to guide NGT” and “finger in mouth” and other similar variations were all classified as “digital assistance in pharynx”. Similarly for the survey responses, knowledge of specific or names insertion techniques were coded together in groups, such as variations of “jaw thrust” and “pull trachea upward”.

For the mannequin study, the mean time taken for insertion, in seconds, was calculated for both attempts by dividing the total time by the number of attempts after exclusions (n=7).

Ethical considerations and consent to participate.

For the service evaluation study and the survey questionnaire, the study information and data collection forms were distributed to all members of the department. Initially, both forms were paper-based and distributed together in clinical areas. However, in order to reduce paper wastage, the survey was moved to electronic means, as each participant was required to complete the survey only once, but could participate in an unlimited number of NGT insertions using the paper forms. The information emails contained a summary of the study requirements and an outline of the data collection process, for both the service evaluation and the survey. Consent was implied once the participant had read the email and data collection forms or survey and agreed to participate by submitting data collection forms. Participation was voluntary, and the participant could withdraw at any time. As there was no collection of personal identifiable data of either staff or patients, the General Data Protection Regulation did not apply.

For the mannequin study, specific informed consent was obtained from each participant. This was obtained by distributing a participant information letter (PIL) and consent form in advance, and the participants were invited to participate after reading the PIL and signing the consent form.

Chapter 4: Findings and Analysis.

Results of NGT Insertion Surveillance Study.

Across the three institutions involved, a total of 64 instances of NGT insertion were received and reviewed. Ten responses were excluded from analysis due to being incomplete (n=3), insertion time recorded incorrectly (n=2), or because the patient was not under anaesthesia (n=5). This left a total of 54 responses for analysis with respect to intubated patients. The results are outlined below.

Regarding Question 1, the level of operator experience in anaesthesia (in years) is displayed in *Figure 10*. As can be seen from the chart, there was a preponderance for middle-grade and senior anaesthetists performing the procedure.

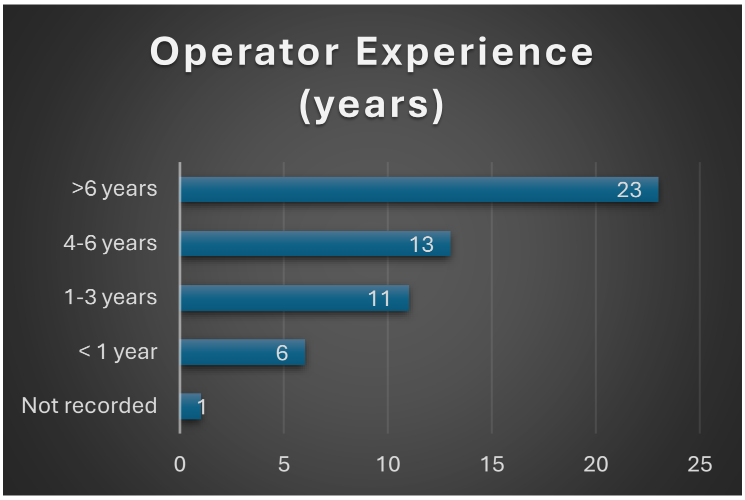


Figure 10: Operator experience in anaesthesia, in years (n=54).

The time taken to completed NG tube insertion as assessed in Question 2 is displayed in *Figure 11*. Time to insertion was divided into time categories which, although not externally validated, were defined in order to crudely correspond to any difficulty encountered during insertion. Longer insertion times have previously been correlated with more difficult insertion, potential misplacement, and risk of mucosal injury as reported by Miyamoto and colleagues (Miyamoto *et al.*, 2024). Thirty-nine percent of insertions (n=21) were deemed completed in under 60 seconds, with the remaining 61% taking a variably longer time to insert. The longest prospectively recorded insertion attempt was 9 minutes and 6 seconds; however, 3 attempts were estimated to take between 10 and 20 minutes when the data collection form was completed retrospectively. One attempt was abandoned after 2mins and 37 seconds due to futility, as the decision the decision to place the NG tube was reversed after encountering difficulty even with video laryngoscopy.

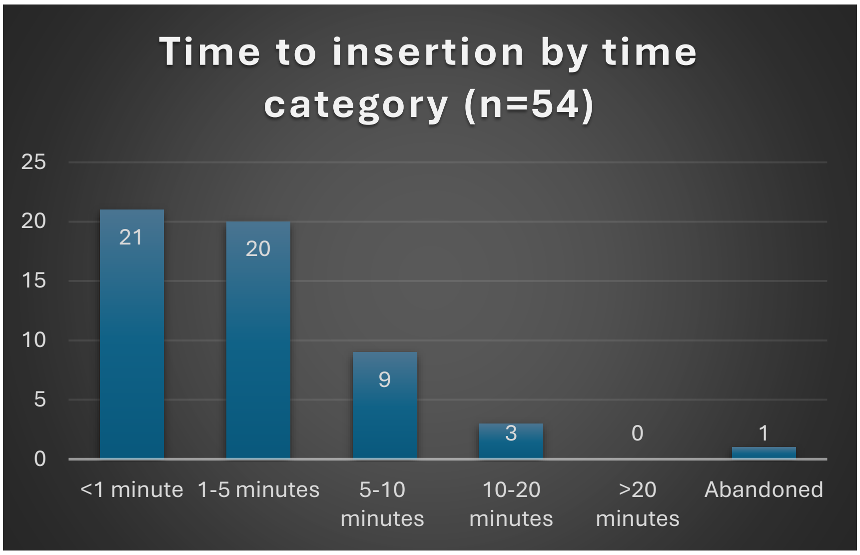


Figure 11: Time taken to NGT insertion.

The majority (61%, n=33) of insertions did not specify and additional materials or equipment above and beyond universal precautions and the NG tube itself. A laryngoscope was used in 21/54 insertions (38.8%), with a Magill forceps also used in 9 of these (16.6%). A modified, slit endotracheal tube was used in 2 attempts (3.7%). It is unclear if the time taken to prepare the ET tube for the purposes of NG insertion was included in the overall time taken for the procedure. One of these attempts utilising a slit ET tube took between 1 and 5 minutes, and the other took between 5 and 10 minutes. It is likely, however, that with the initial attempts being unsuccessful after the timer had been started, procurement and modification of the endotracheal tube used would have been included in the time recorded.

With regards to initial successful insertion and the occurrence of misplacements, only 50% of procedures were successful on the first attempt (27/54). Of the remaining 50%, the majority of NGTs were felt to be coiled in the mouth or throat (35% overall, n=19), but there was an 11% (n=6) rate of actual or suspected insertion into the respiratory tract (*Figure 12)*. This is higher than the 1.5-3.2% range found by Sorokin and Gottlieb, which may be explained by the prospective nature of this study. Taylor and Manara previously noted that airway misplacement is underreported, and therefore the prospective method used in this survey may have been more likely to capture these otherwise underreported events (Taylor and Manara, 2021). It is not beyond possibility that this rate of NGT misplacement is in fact more accurate than some previously published studies. In the six cases of actual or suspected insertions into the respiratory tract which occurred, 83% (n=5) utilised the blind insertion method on the first attempt. There was no association between operator experience and risk of respiratory tract misplacement; 2 of these misplacements occurred where the operator had more than 6 years' experience, one had 4-6 years, two had 1-3 years and one was not recorded (but had more than 1 year).

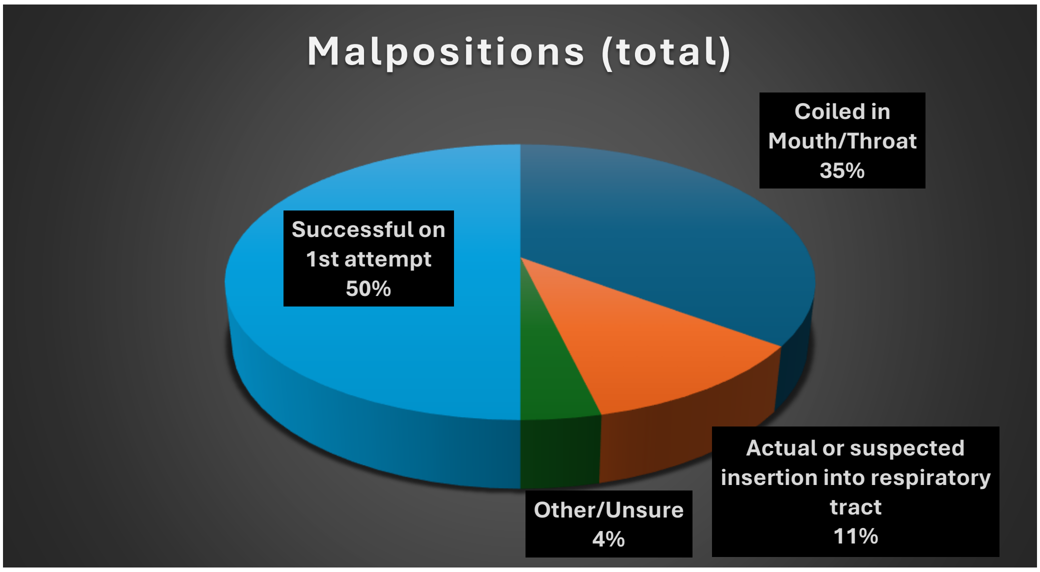


Figure 12: Total malpositions (n=54).

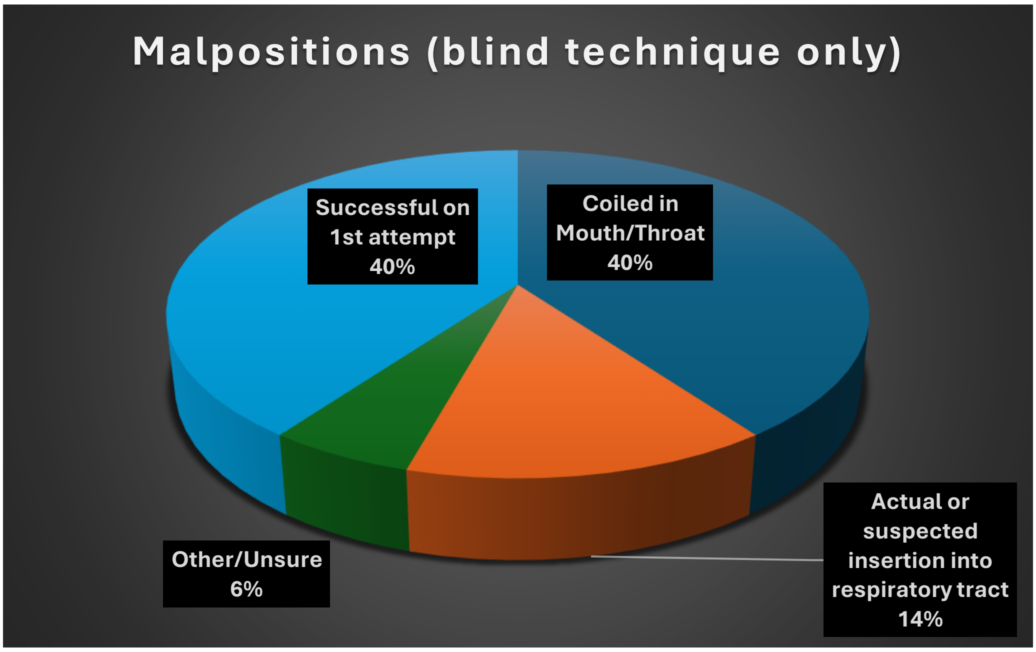


Figure 13: Malpositions by blind technique only (n=35).

The most common initial insertion technique was the blind method (n= 35, 64.8%). When the blind insertion attempts were analysed separately, the first pass success rate decreased from 50% to 40%, and the suspected or confirmed respiratory tract misplacement rate increased from 11% to 14.2% (*Figure 13*). This correlates with previous findings that blind NGT insertion is less likely to be successful, and may be more unsafe than other methods (Sanaie *et al.*, 2017; Taylor *et al.*, 2023; Miyamoto *et al.*, 2024). Other methods that were used on the first attempt included laryngoscopy, digital manipulation of the NGT in the back of the pharynx, and neck flexion. These are shown in *Figure 14*.

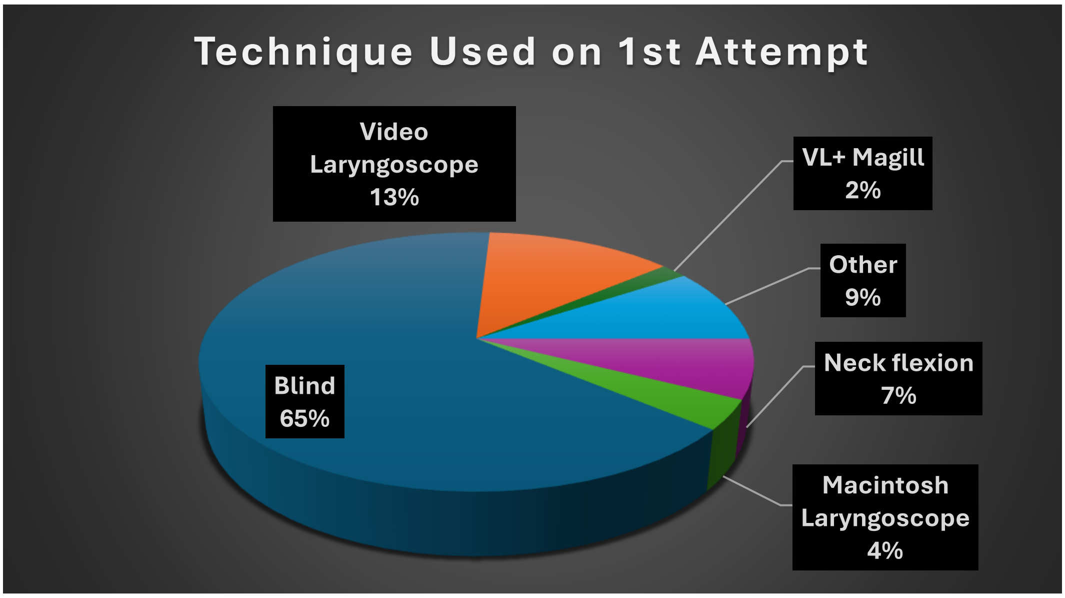


Figure 14: Technique used on 1st attempt at NGT insertion (n=54).

In instances where the first attempt at NGT insertion was not successful, the most common technique employed as a rescue method by the anaesthesiologists surveyed was to perform laryngoscopy with a Magill forceps (65%). Other techniques included manipulating the NGT in the throat with the operator's fingers (digital assistance), lateral neck pressure, and using a split endotracheal tube inserted into the oesophagus as a conduit (*Figure 15*).

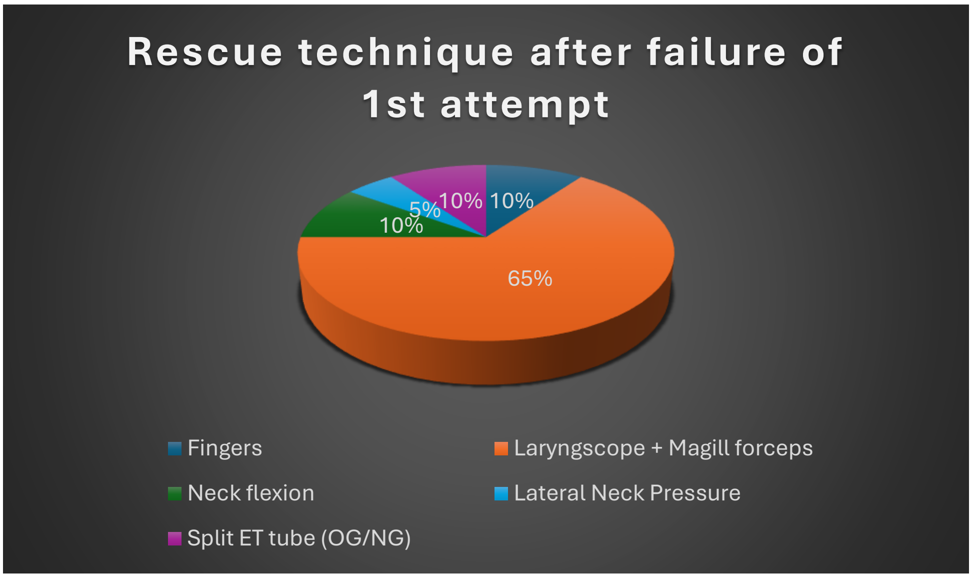


Figure 15: Techniques used on subsequent attempts after a failed NGT insertion.

When analysing the drugs used specifically to facilitate insertion of the NG tube, the majority of insertions were found to have been performed immediately following the induction of anaesthesia for surgery or invasive ventilation (51.9%, n=28). Six insertions (11.1%) were performed in patients who were already adequately sedated or under full general anaesthesia such that further medication was not required. In four cases, it was stated that no medications were used specifically for the NGT insertion. These may represent cases where ongoing sedation was sufficient for the NGT insertion, as in the other 6 cases, but they may also represent cases where no medications were ongoing but yet no specific sedation was required. This scenario was also reported, in three cases; two patients had a reduced level of consciousness while not receiving sedation or anaesthesia, and one patient was awake but yet tolerated the procedure well without the need for sedation. Where medications were administered specifically for the purposes of NGT placement, the most common drug used was propofol, an intravenous sedative drug commonly used for continuous sedation in the intensive care setting. Propofol was specifically administered in five cases, with the mean dose being 47 milligrams in the four cases where the precise dose was specified (range 20 – 100mg per patient). Other sedative agents used included the opioid fentanyl (1 case, 50micrograms) and the benzodiazepine sedative midazolam (1 case, 2 milligrams). The final specified medication was rocuronium, a paralysing agent used to produce muscle relaxation to facilitate tracheal intubation or to provide optimum surgical conditions. Rocuronium was specifically given for NGT insertion in 1 case, at a dose of 50 milligrams. It is worth noting that the 28 cases where NGTs were inserted immediately after the induction of anaesthesia, the patient is likely to have received any combination of sedatives including midazolam and propofol, and opioid such as fentanyl, and a muscle relaxant such as rocuronium to facilitate the tracheal intubation. *Figure 16* summarises these findings.

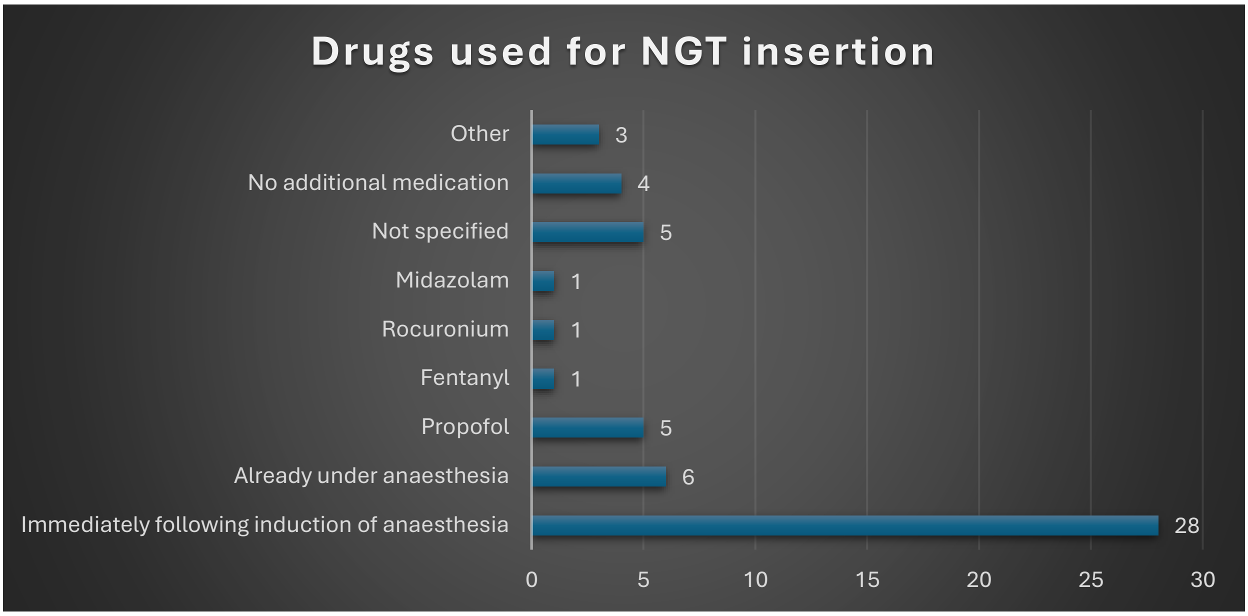


Figure 16: Drugs used for NGT insertion.

Oral endotracheal tubes were the predominant airway in place during the NGT insertions observed in this study (92.5%, n=50), an expected finding. Two patients had the NGT inserted after the induction of anaesthesia but before the tracheal intubation. This is an interesting approach which avoids the discomfort of inserting the NGT before anaesthesia and avoids some (but not all) of the difficulty associated with inserting an NGT when an endotracheal tube is present. One patient had a tracheostomy tube in situ prior to the NGT insertion (*Figure 17*).

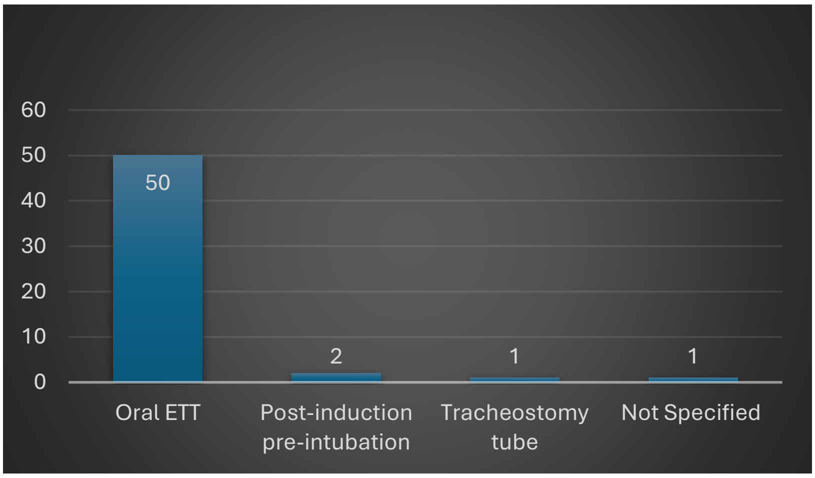


Figure 17: Type of airway in place during NGT insertion.

The intention of Question 7 was to elucidate the confirmatory tests which are used in clinical practice at the bedside or in the operating theatre to at least temporarily satisfy the operator that the NGT insertion has been successful enough to proceed to the formal confirmatory tests, such as chest x-ray or quantitative litmus paper testing. The responses contained a range of methods used, some of which are likely to have been initial bedside tests (such as aspiration of gastric contents and auscultation of air bubbles over the upper abdomen on injection of air through the NGT) as well as some methods which were likely secondary formal tests (such as CXR) which were not clearly delineated as such. Nonetheless, useful information was garnered from the responses received. Aspiration of gastric contents from the NGT was the initial confirmation of correct placement in 42.6% of cases (n=23). Auscultation of air bubbles over the stomach area upon injection of air through the NGT was used in 14.8% (n=8) of insertions. This method of confirmation has repeatedly been proven as unreliable, and it is interesting to see the reliance on this method in these particular clinical settings. Three cases were directly confirmed in the stomach by the operating surgeons at laparotomy.

The number of NGT insertions by location were broadly similar, with 52% taking place in the operating theatres and 48% in the critical care setting (ICU and ED Resuscitation Room) (*Figure 18*).

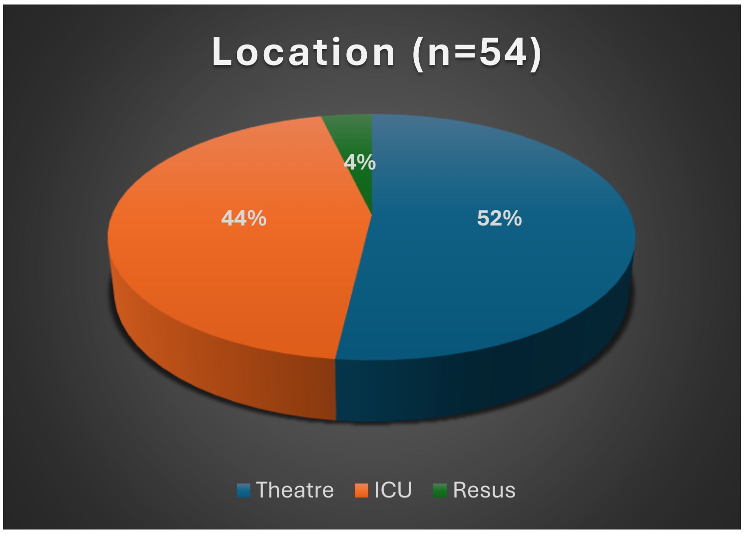


Figure 18: Location of NGT insertion procedure.

Results of survey of practicing anaesthesiologists regarding their approach to NGT insertion.

Eighty-two responses were received to this survey. The majority of respondents (65.9%) had more than 6 years of experience in anaesthesia and/or critical care (*Figure 19*). However, there was a relative lack of familiarity with many of the techniques described in the literature for aiding NGT insertion, with 32% of respondents unable to name a specific method. Nonetheless, many established techniques were represented in the survey responses including the use of laryngoscopy, a slit endotracheal tube, or a frozen NGT (*Figure 20*).

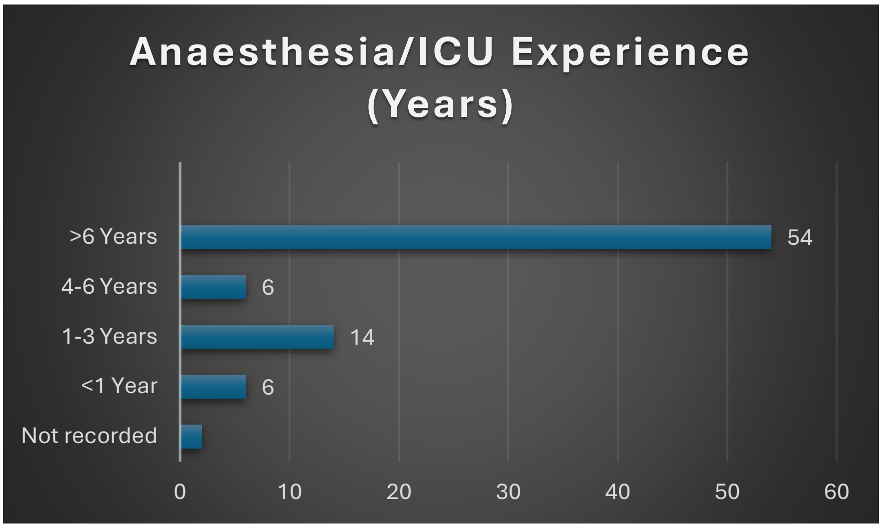


Figure 19: Anaesthesia experience among survey respondents.

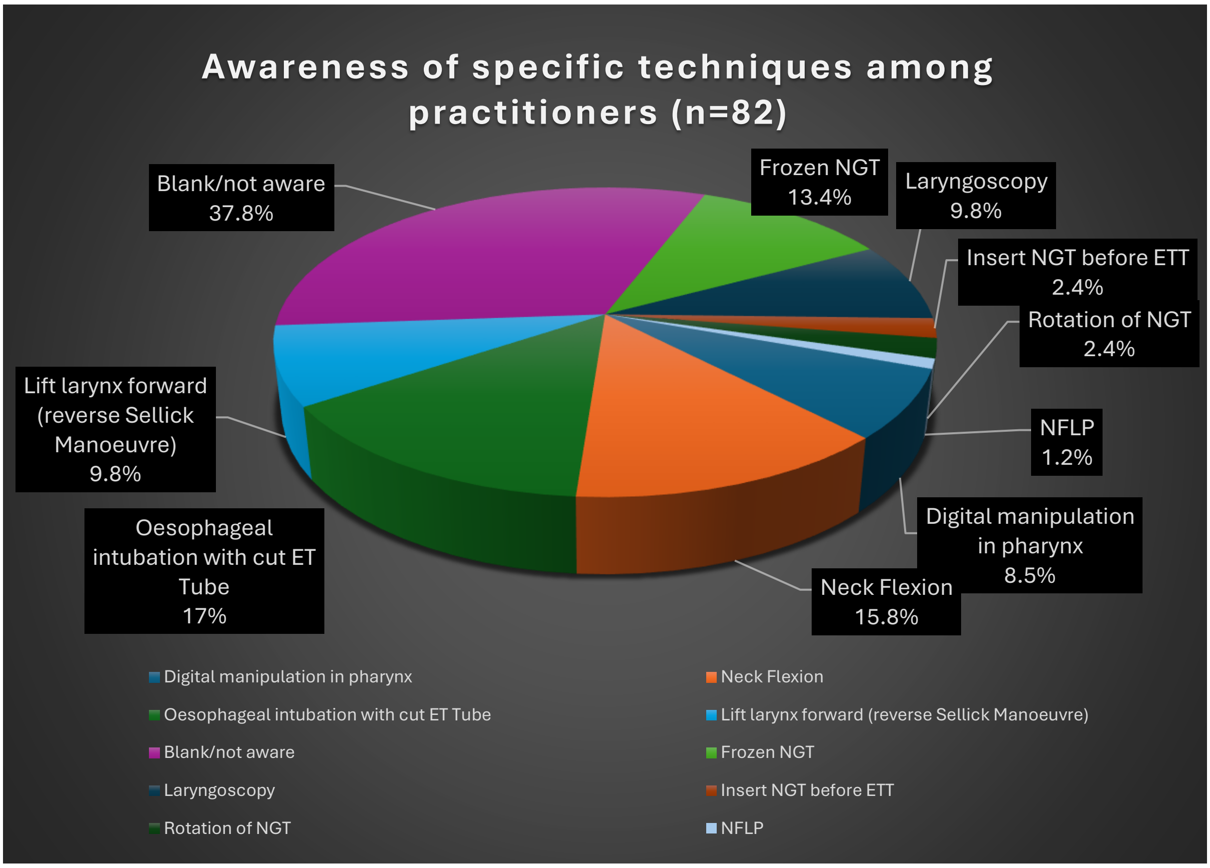


Figure 20: awareness of specific techniques for NGT insertion among anaesthesiologsts.

With respect to rescuing a failed attempt at NGT insertion, there was a preference for reusing the first NGT in 51% of responses (*Figure 21*). Sixty percent would use a laryngoscope to aid them, while 40% would use a Magill forceps. Four respondents stated that they would routinely use a cut endotracheal tube inserted into the oesophagus if their first attempt failed. Digital manipulation of the NGT in the pharynx, neck flexion, jaw thrust, and the use of a frozen NG tube were all mentioned once. These techniques were represented in the data seen in the prospective service evaluation performed, and seem to accurately reflect the current clinical practice observed. The re-use of a nasogastric tube which has been previously misplaced or otherwise unsuccessful, even immediately preceding any subsequent attempt, could be considered noteworthy. The NGTs are sterile, single use devices which may become contaminated with micro-organisms from the nose, mouth, pharynx or oesophagus during an initial insertion attempt. Any subsequent attempts at insertion which enter the airway will result in the introduction of these micro-organisms into the respiratory tract, which may predispose to a respiratory tract infection.

It can be appreciated that such an event in a patient who is already critically ill may be potentially devastating.

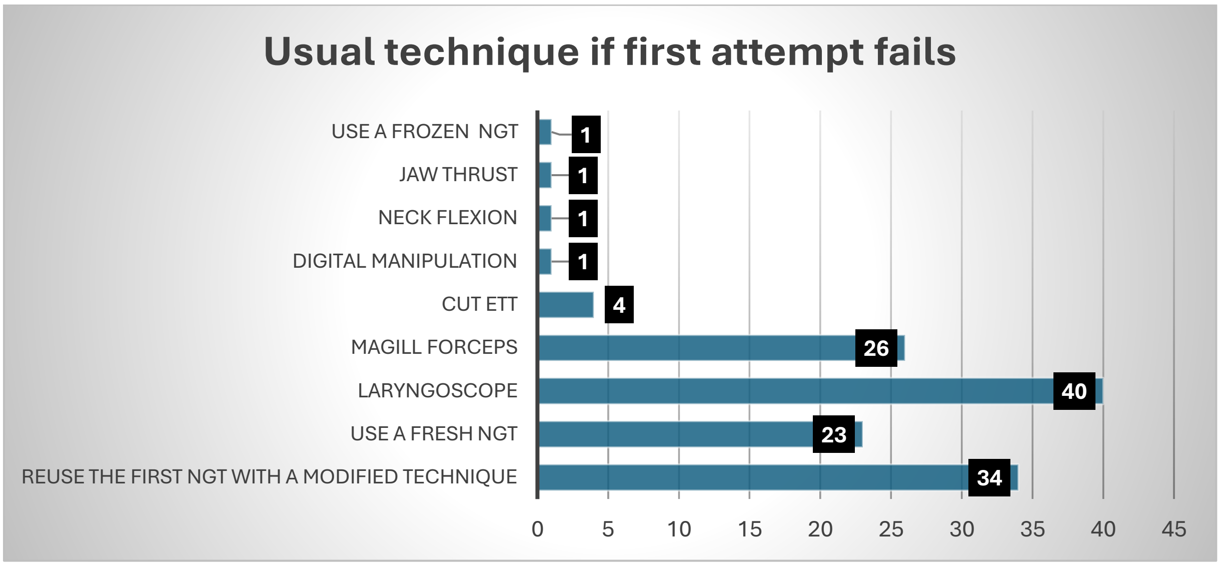


Figure 21: What would be your usual approach in the event of a failed first attempt at NGT insertion? More than one can be selected.

There was a mixed response to the willingness of practitioners to adopt a hypothetical new, more reliable NGT insertion technique (*Figure 22*). A total of 78% of respondents stated that they would adopt a novel technique either every time they site an NGT (40%), or regularly (38%). Eighteen percent said they would only use it if their initial attempt failed, and just 3.7% would only use it as a last resort. Those respondents who would not use, or only use a new technique as a last resort, were notable for the use of laryngoscopy, a cut endotracheal tube, or the reverse Sellick manoeuvre as their preferred methods of NGT insertion. Overall, there appears to be an appetite among practicing anaesthesia and intensive care specialists for a more reliable technique for NGT insertion, based on these findings. This again appears to support the hypothesis that NGT insertion methods are currently suboptimal in one way or another, and that there is a desire from many anaesthesiologists for better methods.

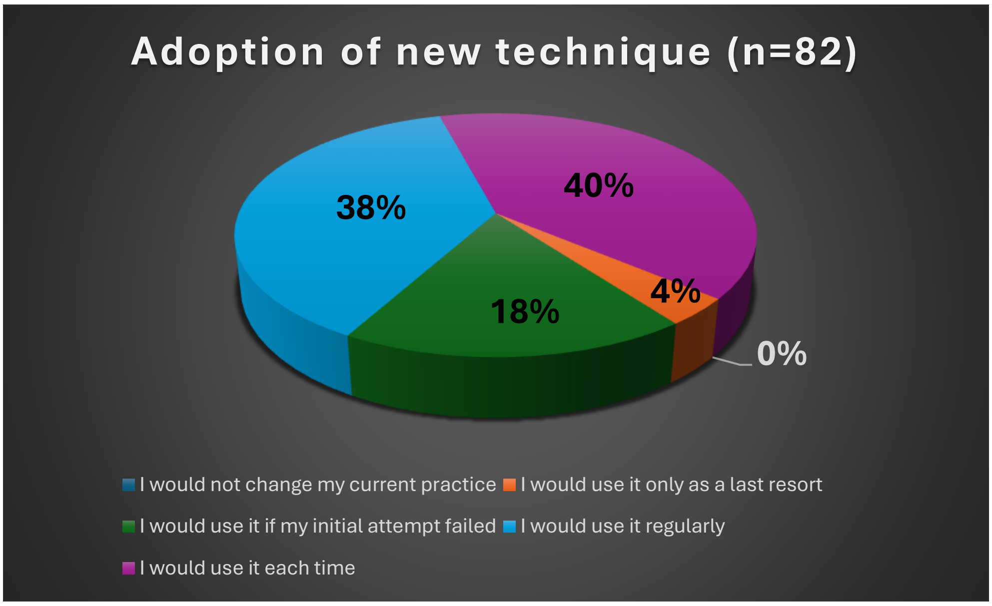


Figure 22: Willingness among anaesthesiologists to adopt a new NGT insertion technique.

Results of mannequin-based study.

A total of 9 attempts were recorded in the mannequin study. There were 2 outliers which resulted from a technical issue with the mannequin, which was not anatomically accurate for the purposes of NGT insertion at the level of the nose. This meant that the NGT coiled in the nasal cavity of the mannequin without ever reaching the introducer device, an event which would be exceptionally rare in human subjects. To combat this in future attempts, a nasopharyngeal airway (NPA) was partially inserted into the nostril to prevent impaction of the NGT in the nose. Care was taken to avoid the NPA inadvertently interfering or assisting with the insertion by being inserted too deeply. The results are summarised in *Table 6*.

Operator	Attempt 1 Technique	Attempt 1 Time (sec)	Attempt 2 Time (sec)
1	Laryngoscope	38	83
2	Blind	128	24
3	Blind, Laryngoscope	79	165
4	Laryngoscope + Magill	40	60
5	Laryngoscope	99	42
6	Laryngoscope	28	466
7	Blind	153	29
8	Laryngoscope	50	25
9	Laryngoscope	26	29

Table 6: NGT insertion attempts using operator's choice of technique vs dedicated introducer device.

When the 2 outlier insertion attempts (3 and 6) were excluded, the mean time to insertion using the anaesthetist's choice of technique was 79 seconds. The mean time using the introducer device was 39 seconds (rounded to the nearest whole second) – a reduction of 51% between the mean of both groups. Of particular note is that the majority of candidates in this study used a laryngoscope for their first attempt (which is in contrast to the 65% blind insertion rate seen in the real clinical setting of the prospective service evaluation) and that the two longest first attempts both utilised the blind technique, where the time saving was maximal with the trial device, where both 2nd attempt times reduced by 81% compared to the first attempt. This again demonstrates that even in the simulated mannequin setting, laryngoscopy appears superior to blind NGT insertion, at least in terms of time to successful insertion.

Feedback on the introducer device was collected from study participants. The main perceived advantages and disadvantages of the device from the study participants are summarised in *Table 7*.

Advantages	Disadvantages
• Can be useful to improve time to insertion • High success rates • Time saving/faster insertion/shorter time to insertion • Lower risk of oral/dental trauma compared to laryngoscopy • Lower risk of operator injury compared to digital assisted technique • Higher chance of success • Viable adjunct to difficult NGT insertions • Less stress • Less sedation required	• Learning curve, new skill acquisition • Risk of dental trauma • Risk of extubation • Cost • Operator dependent • Environmental impact (single use) • De-skilling with laryngoscope + Magill forceps technique

Table 7: Perceived advantages and disadvantages of the prototype introducer device when used for NGT insertion in a mannequin.

The study participants felt that the device would be potentially beneficial in reducing time to insertion through having a higher success rate, as well as other benefits including reducing operator stress or a lower requirement for procedural sedation. Participants also expressed concerns regarding the potential disadvantages of such a device, including the learning curve and training associated with its use, the environmental impact of a single use disposable device, and the reduction in skills required to successfully place an NGT using the traditional laryngoscopy and Magill forceps method.

Chapter 5: Conclusions and Recommendations

Enteral tubes have played an important role in patient care for over 100 years. As the practice of anaesthesia and intensive care has evolved over the same period, the insertion of nasoenteral tubes in anaesthetised and intubated patients has become an integral part of the management of patients requiring nutrition or gastrointestinal drainage in critical care and surgical settings. Potential complications arising from the insertion and use of enteral tubes are extensive and varied, although the actual incidence of serious complications is relatively low, with a fatality rate of approximately 0.3% in certain vulnerable patients (Rassias *et al.*, 1998). Studies from Rassias, Sorokin and Gottleib, and De Aguilar-Nascimento and Kudsk have found high mortality rates associated with pulmonary misplacements of nasogastric tubes, of 4%, 14.3% and 17% respectively (Rassias *et al.*, 1998; Sorokin and Gottlieb, 2006; de Aguilar-Nascimento and Kudsk, 2007). Although pneumothorax was the most common cause of death from pulmonary misplacements, deaths from NGT insertion may result from other causes such as major haemorrhage from repeated attempts (Smith *et al.*, 2018). These studies highlight the potentially serious risk of the seemingly straightforward procedure, as well as the need to improve how the procedure is performed compared to existing practice. Although anaesthesiologists are generally aware of the potential for pulmonary misplacement of nasogastric tubes around the time of insertion, full appreciation for the severity of any adverse outcomes associated with these misplacements seems to be lacking. This may explain to some degree why, despite the obviously poor initial success rates reported across the literature, anaesthesiologists continue to employ this as a primary technique in the majority of cases, presumably in an effort to complete the task quickly and at the least inconvenience, rather than perhaps the in the safest way.

Blind insertion generally has a low initial success rate, approximately 34-58% according to some studies, yet it remains the most common technique used both in the literature and as confirmed by the primary research conducted for this dissertation at 50% (Appukutty and Shroff, 2009; Sanaie *et al.*, 2017). Numerous techniques have been developed and described in an effort to increase the chances of successful insertion, or to help reduce complications, when compared to blind insertion. A 2021 meta-analysis by Ou et al compared several reported techniques for NGT insertion, including using the right lateral decubitus position, reverse Sellick manoeuvre, frozen NGT, Neck Flexion with Lateral Neck Pressure (NFLP) technique, slit endotracheal tube and video laryngoscopy, among others (Ou *et al.*, 2021). Although many of the described techniques resulted in a higher first pass success rate as compared to their control groups, the authors found that only two methods resulted in any time saving for the operator: techniques using video assistance, and the reverse Sellick manoeuvre. Not all techniques are possible in all patients, and practitioners may need to familiarise themselves with many techniques to be prepared for a variety of clinical scenarios. For example, video laryngoscopy may not be advisable or possible in certain patient cohorts, such as raised intracranial pressure (Burney and Winn, 1975; Maxwell, 2024). Many of these techniques were seen in use in the prospective service evaluation performed.

Other methods which utilise purpose-made devices have been commercially available or recently developed, including the CORTRAK™ Enteral access system (Avanos Medical) or the Kangaroo™ IRIS camera-based system. These methods have the advantage of allowing real-time monitoring of the NGT tip during insertion using electromagnetic tracking (CORTRAK™) or video images (Kangaroo™ IRIS) (National Institute for Health and Care Excellence, 2016; Taylor *et al.*, 2021). Their main disadvantages are their costly proprietary monitoring systems and modified NG tubes, as well as the need for training and maintenance of competence (Taylor *et al.*, 2023). Additionally, CORTRAK™ does not prevent misplacement entirely and has been implicated in deaths reported to the NHS, despite no additional time saving over cheaper conventional methods (Lim *et al.*, 2017; Taylor *et al.*, 2019). Therefore, it can be concluded that the ideal method remains to be elucidated.

Although the ideal method may be hypothetical, it seems logical that video laryngoscopy in combination with radiological evidence of correct final positioning represents the best current method. All anaesthesiologists and critical care specialists should be familiar with laryngoscopy, by definition, as part of regular airway management. As such, there is an inherent familiarity with video laryngoscope technology and the anatomy of the upper airways. As demonstrated by Miyamoto and colleagues, video laryngoscopy was protective against laryngopharyngeal mucosal injury and pulmonary misplacement as compared to blind insertion in intubated during cardiac arrest, without any significant prolongation of insertion time (Maxwell, 2024; Miyamoto *et al.*, 2024). However, one limitation of this method is that although oesophageal entry can be visualised and confirmed in real time, the NGT may become impacted or coiled in the lower oesophagus, which may not be fully appreciated with laryngoscopy alone. Therefore, it remains essential to confirm the tip position in the stomach using radiographic confirmation or pH testing where appropriate. Drawbacks of video laryngoscopy include the possibility of hypertension, tachycardia, raised intracranial pressure, and it's limitation to patients with good mouth opening (Maxwell, 2024). Nonetheless, the use of video laryngoscopy appears to be safer, less traumatic, more reliable and roughly equivalent in insertion time when compared to the blind insertion method.

There is currently no consensus on the best method for NGT insertion, perhaps reflective of the fact that all current methods have some disadvantages. Instead, recommendations from international expert groups and authorities such as ASPEN, BAPEN and the UK NHS seem to focus on early recognition of misplacement rather than preventing it from happening altogether. In the absence of robust evidence for supporting one method over another, it remains at the discretion of the operator to select the best method for a given clinical situation, with a focus on recognition of misplacement through appropriate confirmatory testing, such as chest x-ray and pH testing, with knowledge of the limitations of such tests.

Through the primary research conducted in the preparation of this dissertation, there appears to be a reasonable level of awareness of many techniques for NGT insertion among anaesthesia and ICU specialist doctors, yet there is also an appetite for a more reliable method of insertion. The blind insertion method was the dominant technique used across the theatres and intensive care units in three Irish model 4 university hospitals, comprising 65% of all primary insertion attempts. The overall first pass success rate was 50%, and the rate of suspected respiratory tract misplacement was 14%, which is higher than that reported in many studies. This may because of the prospective nature of this data collection, as opposed to the retrospective analysis used in other studies, where under-reported incidents of misplacement have been identified in retrospect which may otherwise have gone unrecorded (Taylor and Manara, 2021). It may also be possible that a proportion of the suspected insertions into the respiratory tract were not actually in the respiratory tract, as the data collection relied on the anaesthetist's observations, as opposed to formal confirmatory testing or imaging of a misplaced NG tube. Nonetheless, any suspected misplacements were rectified at the bedside due to some indication to the operator which raised the suspicion of a misplacement. This is likely to be representative of the clinical situations where undocumented pulmonary misplacements were discovered in retrospect in other studies, for example new pneumothorax and a correctly sited NG tube on an x-ray. One of the six respiratory tract misplacements identified in this project was in fact initially identified on the confirmatory chest x-ray.

This research work added several key findings to the existing literature on NGT insertion in intubated patients. With respect to insertion times, although 39% of insertions could be considered very straightforward (inserted in under 1 minute), 50% of all insertions were unsuccessful on the first attempt and required a subsequent rescue manoeuvre. Almost 22% of insertions took between 5 and 20 minutes, which undoubtedly resulted in adverse events such as laryngopharyngeal mucosal injury, tachycardia, hypertension, raised intracranial pressure, a requirement for sedation or muscle relaxant and potential pulmonary misplacement, although only potential pulmonary misplacement was specifically recorded. It also confirmed that the blind technique was the one most likely to be associated with actual or suspected respiratory tract misplacing, with 83% of those misplacement associated with the blind technique as the first method if insertion. An additional finding of interest was that in 8 of the 54 NGT insertions (14.8%), auscultation was the primary method used for initial confirmation. This method has repeatedly been shown to be unreliable, and it is interesting to see that it remains in use as commonly as was seen in the study.

The requirements for sedation and muscle relaxation of patients undergoing NGT insertion was also analysed for this work. The specific use of sedation, mainly propofol but also midazolam and fentanyl, was reported in 7 instances overall (13%). However, a significant proportion of all insertion were performed immediately following induction of anaesthesia in preparation for intubation. Although the precise drugs and doses were not initially thought to be within the scope of this work, it is likely, but not certain, that all of these cases involved at least an IV anaesthetic induction agent, an opioid, and a muscle relaxant in order to provide optimum conditions for tracheal intubation. Although these conditions are not ideal for NGT placement as previously discussed, they are potentially more optimal than a patient who is tracheally intubated but not deeply anaesthetised and fully muscle relaxed, such as a patient under moderate sedation in the intensive care unit. This may mean that any potential NGT insertion assisting devices need to be suitable for use in both situations. When analysing the use of medications for NGT insertions which were *not* performed immediately after induction of anaesthesia, sedation was used in 27% of cases. This too may add to the financial and environmental costs of NGT insertion, in addition to disposable materials such as gloves and NGT packaging and laryngoscopy equipment, including disposable blades and batteries for video laryngoscopes.

Muscle relaxation in the intensive care unit has previously been associated with an increased risk of critical care myopathy, or muscle weakness, and such drugs should be used cautiously and at the lowest dose required (Renew *et al.*, 2020; Welhengama *et al.*, 2021). The use of neuromuscular blocking drugs used for the specific purpose of NGT insertion must be taken into consideration in the overall context of the patient's clinical picture and expected outcome. Techniques or devices used for NGT insertion which can help avoid or reduce the use of neuromuscular blocking drugs may be useful in this context, as they may have another indirect effect on patient morbidity.

A mannequin-based study was performed which compared current methods to a prototype novel introducer device. Anaesthesiologists performed NGT insertion using their own method of preference, followed by the prototype device. After a brief demonstration of the device in the mannequin (circa 30 seconds), and without hands-on practice with the device, mean insertion times for each group was reduced by 51% compared to the first attempt. Feedback was generally positive regarding the device's ease of use and utility for NGT insertion, including higher chance of success, faster insertion, and ease of insertion compared to laryngoscopy, for example. However, although some operators felt that there was a lower risk of dental or soft tissue injury from the prototype device, others felt that the risk might be theoretically higher and should be given consideration. Other notable points included the need or training and further practice. Nonetheless, the 51% reduction in insertion time without ever having seen or used the device previously implies that there is potential for such a solution to be useful. The time saving was greatest when the blind technique was used initially. It can be surmised that with further practice, and validated clinical trial data, that users may be less apprehensive regarding future use, and insertion times may be reduced further.

The interest of anaesthesiologists in a new, more reliable technique was expressed in responses to both the electronic survey and in feedback from the mannequin study performed. Such a solution would need to be inexpensive, readily available at the bedside, and easy to use, according to the feedback. The ideal solution would not require extensive specialist training or the deployment of specialist teams and would yield a high success rate with repeatable and predictable results. Such an ideal method would also be suitable for use in all patient groups (for example, raised intracranial pressure or restricted neck movement) by competent operators. It should yield a cost benefit as compared to other methods, whether this is through cheaper consumables or reducing the need for integrated proprietary technology such as monitor displays, or by a reduction in confirmatory testing or complications and their associated healthcare costs, for example prolonged ICU admission due to pneumothorax or pneumonia. Based on the feedback from the anaesthesiologists in the mannequin study, the device would also need to have a minimal environmental impact, and a low risk of accidental extubation, dental injury, or soft tissue injury.

Implications of this Research.

From the research performed for this dissertation, it can be concluded that blind insertion remains a common technique for NGT insertion in anaesthetised and intubated patients. Additionally, although other techniques are known by many anaesthesiologists, they are not necessarily used on every occasion, despite the potential drawbacks of the blind technique. The reason for this disparity seems to be the relative ease and speed of the blind technique, in the approximately 50% of occasions attempts where it is successful, which appears to be the most convenient compared to most other methods. This is coupled with the fact that misplacements are erroneously perceived to be less common or less serious than they are reported in the literature. The results of this research may go on to inform policymakers and producers of local, national, or international guidelines on the use of NGTs and their role in enteral feeding of critical care patients, of the need to address the specific insertion techniques used in placing NGTs in anaesthetised patients who require the insertion of a nasogastric tube. Future guidelines may discourage the use of the blind technique altogether in an effort to reduce patient harm from misplaced NGTs. Such guidelines may take into account the opinions and existing knowledge of those performing the task of NGT insertion, such as those expressed in the questionnaire survey performed for this dissertation.

Strengths and Weaknesses of Primary Research Methods.

The main strengths of the research performed for this dissertation were the prospective and multicentre nature of the service evaluation, which eliminated some of the bias associated with a study performed in a single centre, or a retrospective analysis where the data quality may have been uncertain or incomplete. Most of the responses to both the service evaluation and the survey questionnaire were from senior practicing anaesthesiologists with more than 6 years of experience. This reduces the possibility that the results were due to insufficient skill or proficiency in the technique. The research was able to highlight several interesting points surrounding the practice of NGT insertion across three major Irish teaching hospitals with high standards of practice. The first key point is the proportion of blind insertions as 65% of overall attempts. The second interesting finding was the higher than previously reported actual or suspected insertion of the NGT into the respiratory tree.

Next, 51% of responses to the survey regarding attitudes towards the procedure stated that they would reuse the original NGT for subsequent attempts at insertion if the first attempt failed. This is notable because it risks contamination of the respiratory tree if subsequent attempts also result in misplacement after passing through the pharynx or upper oesophagus on earlier attempts. Repeat misplacement rates after failed first attempts may be as high as 32%, and therefore reusing an NGT which has previously been unsuccessful, and potentially contaminated, may increase the risk of serious pulmonary complications when used in this way (Sparks *et al.*, 2011).

Finally, the research highlighted the use of modified split endotracheal tubes as a conduit for NGT insertion. Such off label use and modification of commercially available medical devices may risk causing harm to patients, and professional risk to the user, as it may violate the regulatory approval certification for the device. Controversies surrounding off label use of medical devices have recently gained widespread media attention across Ireland (O'Sullivan, 2025). It is possible that local, regional or national policies may be implemented which address this issue in the future, meaning that other methods will need to supersede these.

The main limitations of the research include the relatively low number of samples for analysis. There is a risk that some of the conclusions may be open to inaccuracies due to the low number of samples, for example the higher rate or actual or suspected insertions into the respiratory tree during the service evaluation. Another limitation would be the use of composite end points in some areas of the research, again using the actual or suspected insertion of the NGTs into the airways as an example. It is possible that there may be on overestimation if *suspected* pulmonary misplacements were in fact *not* in the airways. However, it is also possible that the underappreciation of pulmonary misplacements seen in previous research may also have occurred in this study, where such misplacements were erroneously attributed to being coiled in the mouth or throat during data collection. This may balance out any inaccuracies overall. Most of the prior studies of NGT insertions took place in North America where NGTs are often placed by doctors, ICU nurses, Physician Assistants and other health professionals where there may be a mix of skills and competencies. Conversely, all of the operators in this research were anaesthesia and intensive care specialty doctors who may be more likely to correctly identify pulmonary misplacement during insertion versus successful GI placement.

Next, although there was an intention to record the drugs used specifically for NGT insertion which provided valuable insight into the medications used, many of the insertions took place immediately following induction of anaesthesia. It may have been useful to record these specific drugs and doses also, however this would have added more complexity to the data and may not have revealed any significant trends. It is reasonable to conclude that regardless of the exact drugs and doses used, the patient was deemed to be at a depth of anaesthesia which was compatible with laryngoscopy and intubation in all cases.

The insertion times were precisely recorded using a stopwatch and a separate observer where possible, however some data forms were completed retrospectively by the practitioner, for example in the morning after a night shift, and they were asked to estimate the time. This may have introduced error where the true time was over- or underestimated. Nonetheless, the perception of time taken may be as important as the actual time taken, similar to the rate of perceived exertion used in exercise testing. Finally, the adverse events associated with NGT insertion were limited to either coiling of the NGT or misplacement. Other adverse events such as dental injury, bleeding, hypertension, tachycardia, were not recorded. Again, this was to avoid excessive complexity in the data collection process in order maximise the number of complete responses received and to keep the additional workload on the study participants during their normal work to a minimum. It was felt that seeking too much data would have made compliance with the project more difficult, particularly as it took place in a relatively high acuity clinical setting and relied on the goodwill and cooperation of the doctors.

Regarding the mannequin-based study on the prototype NGT introducer device, there are inherent disadvantages associated with the use of a mannequin in place of human subjects. These limitations include the simulated anatomy which may not be truly representative of NGT insertion, as seen by the technical artefact experienced in 2 of the 9 insertions. The difference in resistance and compliance of the material relative to human mucosa and muscular structures of the pharynx, larynx and oesophagus may have influenced the NGT and device insertion and performance as compared to human tissues. There was also no possibility of assessing the risk of potential adverse effects such as bleeding, sore throat and dental injury between the techniques. Again, numbers included in this study were low, which was due to time constraints between the final study design and implementation, and the dissertation submission. However, the overall study appeared to be of a satisfactory fidelity for its intended purpose, and the same study repeated with a higher number of participants would be worthwhile in assessing any reduction in misplacement of NGTs, for which this study was unfortunately not powered.

The potential financial burden of misplaced NG tubes.

If current techniques result in a pulmonary misplacement of approximately 2% (range 1.5-3.2%), then the healthcare costs directly relating to any subsequent adverse events can be estimated from this number (Rassias *et al.*, 1998; Sorokin and Gottlieb, 2006; de Aguilar-Nascimento and Kudsk, 2007; Halloran *et al.*, 2011; Taylor and Manara, 2021). The daily cost of ICU admission varies widely between countries, but in 2012 was estimated to between €1168 to €2025 (€1551-€2689 in 2025) in general intensive care units in four European countries; Germany, Italy, the Netherlands and the United Kingdom (Tan *et al.*, 2012). As an example, Iatrogenic pneumothorax has previously been associated with both prolonged ICU and hospital stays in patients who developed pneumothorax after ICU admission; 17.5 days in ICU versus 7 days for those who did not develop pneumothorax (De Lassence *et al.*, 2006). The financial cost of a single case of ventilator associated pneumonia (VAP), as another example, was £8829 in a 2017 study (£11,869 in 2025) in a UK cardiac surgical intensive care unit and $40,000 in a 2013 study ($54,911 in 2025) in a general intensive care unit in the USA (Zimlichman *et al.*, 2013; Luckraz *et al.*, 2018).

Thus, at a daily cost of €2000, an intensive care department with 1500 NGT insertions over a 3-year period (500 per year) may conservatively see an additional cost of €50,000 if five patients (0.3%) develop a pneumothorax which prolongs their stay by just five days, at a 2% misplacement rate. Higher numbers of ICU admissions, NGT insertions, misplacements, or ICU stays prolonged by greater than 5 days may result in yet higher figures. When all major adverse events are considered (pneumothorax, pneumonia, abscess, empyema, death), the associated financial costs may be significant, and a strategy aimed at reducing pulmonary misplacement of NGTs may save money in addition to reducing patient harm. A cost-benefit analysis of any device-based solution would need to consider all factors, including clinician preference and any adverse events associated with any proposed solution.

Any adverse events relating to the use of a dedicated NGT introducer system would form part of the cost-benefit analysis of any such system, as mentioned above. Sufficient clinical trial data may provide useful evidence for or against any proposed devices for NGT insertion, based on the relative occurrence of adverse events in a control group (standard practice) versus an intervention group (device or system). Adverse events may be common between both arms of the study, such as bleeding, mucosal injury or dental injury. However, other unanticipated events may be associated with the use of a dedicated device and not standard practice. One example of this might be a higher risk of accidental extubation of the patient, where the tracheal breathing tube is inadvertently removed at some point during the procedure, a concern which was raised in the mannequin study.

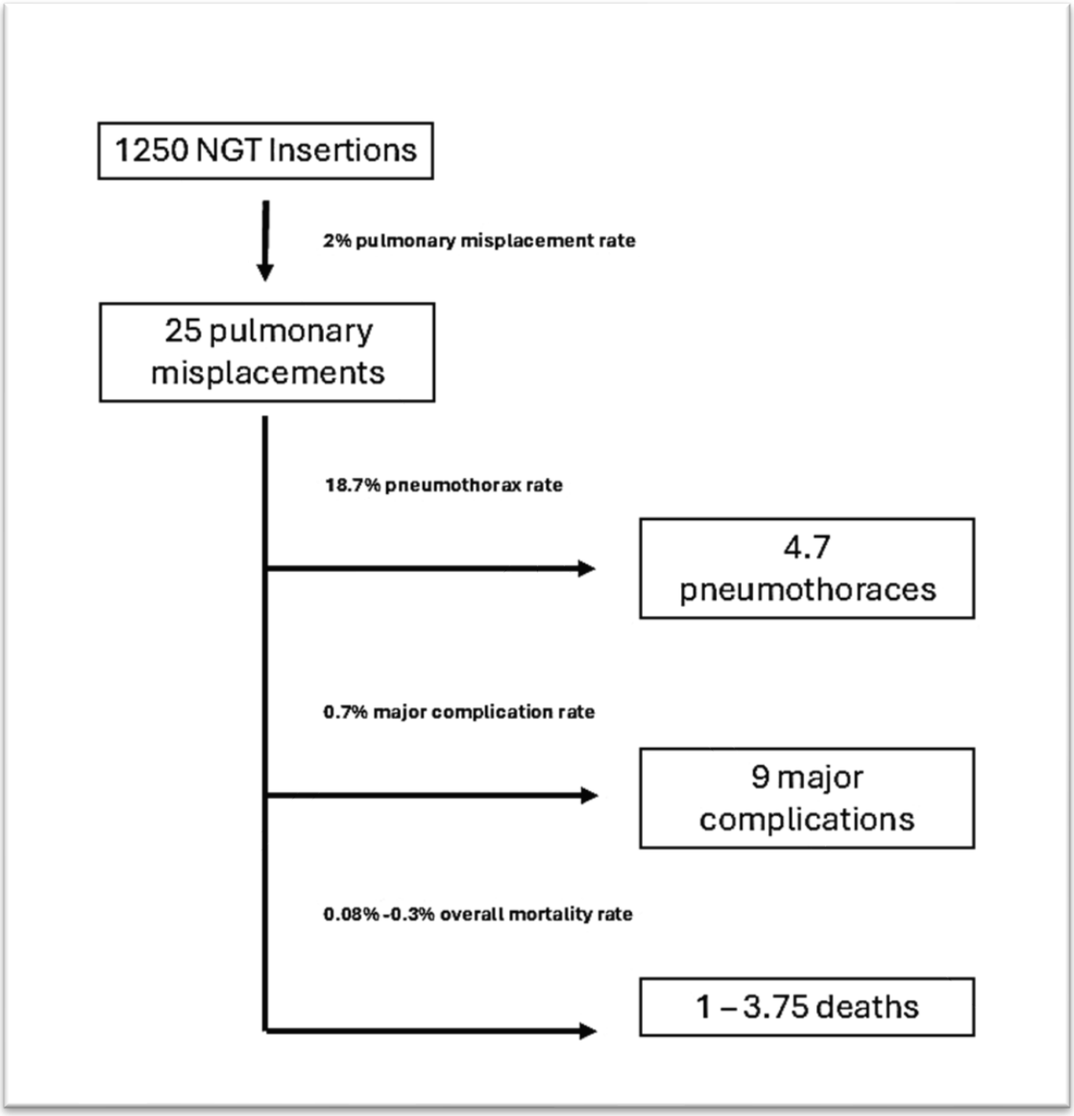


Figure 23: Estimated complication rates for 1250 NGT insertions. A figure of 2% was used as an approximation, generally 1.5-3.2% is quoted in various studies. Sparks et al (2011) found a pneumothorax rate of 18.7% across 9931 fine bore feeding tube insertions. Rassias et al (1998) found a major complication rate of 0.7%, and an overall mortality rate of 0.3%, whereas the overall mortality rate found by Sparks et al was 0.08% (8/9931) (Rassias et al.*, 1998; Sparks* et al.*, 2011).*

According to a 2024 report from the National Office of Clinical Audi (NOCA), there were 11,008 admissions to intensive care units in Ireland in the year 2022 (National Office of Clinical Audit, 2024, p.15). Of these 11,008 admissions, 51% (5,614) were invasively ventilated though either tracheal intubation or tracheostomy, and 46% received enteral or parenteral nutrition support (National Office of Clinical Audit, 2024, pp.66, 75). Patients receiving enteral nutritional support were more likely to be sicker than those who could eat and drink, and thus it is more likely that those receiving enteral nutritional support were in the cohort of patients also requiring invasive ventilation support. Assuming that all of the 5,614 invasively ventilated patients underwent NGT insertion once, then potentially up to112 misplacements may have occurred nationally, resulting in 78 major complications. Three additional ICU days per complication would be in excess of €300,000 in additional costs using a rate of €2000 per day.

Regulatory requirements for a novel introducer device.

Any prospective medical device must satisfy the regulatory requirements for market approval in the intended markets. In Europe, any such device must be CE marked and must be manufactured by a company whose quality management system (QMS) is ISO 13485 compliant, and also comply with the EU MDR2017:745 which governs the design, manufacturing, distribution, sale and surveillance of medical devices marketed in the EU (European Parliament, 2017; National Standards Authority of Ireland, 2025). Clinical trials pertaining to the use of any such device should be of sufficient international standard, such as ISO 14155:2011 (European Parliament, 2017, p.9). In the USA, FDA approval must be obtained before a medical device may be sold in the USA. Such approval is governed by the Code of Federal Regulations CFR 21, Subchapter H (Medical Devices).

Future Research.

Future research should focus on high quality, prospective randomised controlled trials which would test the hypothesis that blind NGT insertion is inferior to other methods at preventing unintentional misplacement of NGTs into the respiratory tract of anaesthetised patients. The primary outcome should be the occurrence of NGT misplacement into the respiratory tract. Such studies would need to be adequately powered to demonstrate a statistically significant difference between the two study arms. They should assess secondary outcomes such as any difference in medications used, variations in blood pressure and heart rate during the insertion, and the presence of any bleeding or trauma from the techniques used. They should follow patients to a defined time period, such as 30 days, to monitor for the occurrence of pulmonary complications such as pneumothorax, pneumonia and pulmonary abscess. They should monitor study patients for length of hospital stay and intensive care stay to identify any trends which may be associated with an increase in patient morbidity and associated increase in healthcare costs.

Any new technological developments, such as the prototype trial device used in this research work, should undergo clinical testing which assesses its clinical effectiveness and usability such that robust clinical validation can be provided to regulatory authorities and potential customers.

Summary.

In summary, NGT insertion is commonly performed in intubated and ventilated patients in critical care and theatre settings. A wide variety of insertion methods exist, and there is no universally agreed standard method. Different clinical situations may require different methods. What is clear, however, is that misplacement of NGTs is common, potentially catastrophic, underappreciated and underreported. Care must always be taken when inserting NGTs in intubated patients due to the risk of inadvertent pulmonary misplacement in this vulnerable cohort, and operators must take all available steps to reduce these risks. Healthcare costs associated with NGT misplacement are potentially significant and may be reduced through improved awareness of the actual risks and complications, and specific training in formal NGT insertion techniques. There may be a role for dedicated introducer devices which account for the difficulties encountered in intubated patients with respect to NGT insertion. Any such devices would need to meet the necessary regulatory requirements applicable to design controls, biocompatibility, functionality, usability, and clinical efficacy.

In a sample of anaesthesiologists surveyed across three large anaesthesia departments in Ireland, there appears to be a consensus that NGT insertion may occasionally be difficult, and there is appetite for more reliable methods of insertion. A prototype introducer device performed well in a small mannequin-based comparison against standard methods. Any medical device marketed in the EU or USA must comply with the relevant regulatory requirements for that market.

References

de Aguilar-Nascimento, J.E. and Kudsk, K.A. (2007) ‘Clinical Costs of Feeding Tube Placement’. *JPEN. Journal of Parenteral and Enteral Nutrition*, 31(4), pp. 269–273. DOI: 10.1177/0148607107031004269.

Appukutty, J. and Shroff, P.P. (2009) ‘Nasogastric Tube Insertion Using Different Techniques in Anesthetized Patients: A Prospective, Randomized Study’. *Anesthesia & Analgesia*, 109(3). Available at: https://journals.lww.com/anesthesia-analgesia/Fulltext/2009/09000/Nasogastric_Tube_Insertion_Using_Different.23.aspx.

Bechtold, M.L. *et al.* (2022) ‘When Is Enteral Nutrition Indicated?’ *Journal of Parenteral and Enteral Nutrition*, 46(7), pp. 1470–1496. DOI: 10.1002/jpen.2364.

Bickle, I., Campos, A. and Johari, A. (2014) ‘Nasogastric Tube Positioning’. In *Radiopaedia.Org*. Radiopaedia.Org. DOI: 10.53347/rID-30966.

Boeykens, K., Holvoet, T. and Duysburgh, I. (2023) ‘Nasogastric Tube Insertion Length Measurement and Tip Verification in Adults: A Narrative Review’. *Critical Care (London, England)*, 27(1), p. 317. DOI: 10.1186/s13054-023-04611-6.

Bourgault, A.M., Aguirre, L. and Ibrahim, J. (2017) ‘Cortrak-Assisted Feeding Tube Insertion: A Comprehensive Review of Adverse Events in the MAUDE Database’. *American Journal of Critical Care*, 26(2), pp. 149–156. DOI: 10.4037/ajcc2017369.

Boyes, R.J. and Kruse, J.A. (1992) ‘Nasogastric and Nasoenteric Intubation’. *Critical Care Clinics*, 8(4), pp. 865–878. DOI: 10.1016/S0749-0704(18)30229-X.

Burney, R.G. and Winn, R. (1975) ‘Increased Cerebrospinal Fluid Pressure During Laryngoscopy and Intubation for Induction of Anesthesia’: *Anesthesia & Analgesia*, 54(5), p. 687???690. DOI: 10.1213/00000539-197509000-00028.

Cardinal Health. (2025) *Kangaroo^{TM} Nasogastric & Salem Sump^{TM} Tubes | Cardinal Health*. Available at: https://www.cardinalhealth.com/en/product-solutions/medical/enteral-feeding/gastrointestinal-products/nasogastric-tubes.html (Accessed: 9 March 2025).

Chernoff, R. (2006) ‘An Overview of Tube Feeding: From Ancient Times to the Future’. *Nutrition in Clinical Practice*, 21(4), pp. 408–410. DOI: 10.1177/0115426506021004408.

Cleveland Clinic. (2022) *Nasogastric Tube: What It Is, Uses, Types*. *Cleveland Clinic*. Available at: https://my.clevelandclinic.org/health/treatments/24313-nasogastric-tube (Accessed: 9 March 2025).

Covidien. (2012) ‘User Manual, Kangaroo Feeding Tube with IRIS Technology, Console and Accessories’. Available at: https://www.cardinalhealth.com/content/dam/corp/web/documents/Manual/cardinal-health-kangaroo-feeding-tube-with-iris-technology-user-manual.pdf (Accessed: 11 April 2025).

De Lassence, A. *et al.* (2006) 'Pneumothorax in the Intensive Care Unit: Incidence, Risk Factors, and Outcome'. *Anesthesiology*, 104(1), pp. 5–13. DOI: 10.1097/00000542-200601000-00003.

Doley, J. (2022) 'Enteral Nutrition Overview'. *Nutrients*, 14(11), p. 2180. DOI: 10.3390/nu14112180.

Dziewas, R. *et al.* (2003) 'Placing Nasogastric Tubes and Intracranial Pressure'. *Journal of Neurosurgical Anesthesiology*, 15(1), pp. 55–56. DOI: 10.1097/00008506-200301000-00010.

European Parliament. (2017) 'REGULATION (EU) 2017/745 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 5 April 2017 on Medical Devices, Amending Directive 2001/83/EC, Regulation (EC) No 178/2002 and Regulation (EC) No 1223/2009 and Repealing Council Directives 90/385/EEC and 93/42/EEC'. Available at: https://www.medical-device-regulation.eu/wp-content/uploads/2019/05/CELEX_32017R0745_EN_TXT.pdf (Accessed: 6 May 2025).

Fassoulaki, A. and Athanassiou, E. (1985) 'Cardiovascular Responses to the Insertion of Nasogastric Tubes during General Anaesthesia'. *Canadian Anaesthetists' Society Journal*, 32(6), pp. 651–653. DOI: 10.1007/BF03011414.

Fatima, H. (2019) 'Oropharyngeal Findings at Upper Endoscopy'. *Clinical Gastroenterology and Hepatology*, 17(12), pp. 2423–2428. DOI: 10.1016/j.cgh.2019.05.038.

Furutani, K. *et al.* (2020) 'SUZYTM Forceps Facilitate Nasogastric Tube Insertion under McGRATHTM MAC Videolaryngoscopic Guidance'. *Medicine*, 99(41), p. e22545. DOI: 10.1097/MD.0000000000022545.

Gaba, D.M. (2000) 'Anaesthesiology as a Model for Patient Safety in Health Care'. *BMJ : British Medical Journal*, 320(7237), pp. 785–788.

Halloran, O., Grecu, B. and Sinha, A. (2011) 'Methods and Complications of Nasoenteral Intubation'. *Journal of Parenteral and Enteral Nutrition*, 35(1), pp. 61–66. DOI: 10.1177/0148607110370976.

Harkness, L. (2002) 'The History of Enteral Nutrition Therapy'. *Journal of the American Dietetic Association*, 102(3), pp. 399–404. DOI: 10.1016/S0002-8223(02)90092-1.

Hemington-Gorse, S.J. *et al.* (2011) 'The Use of the Cortrak Enteral Access System™ for Post-Pyloric (PP) Feeding Tube Placement in a Burns Intensive Care Unit'. *Burns*, 37(2), pp. 277–280. DOI: 10.1016/j.burns.2010.07.011.

HSIB. (2020) 'Placement of Nasogastric Tubes Independent Report by the Healthcare Safety Investigation Branch 2019/006'. Available at: https://hsib-kqcco125-media.s3.amazonaws.com/assets/documents/HSIB_Placement_of_nasogastric_tubes_Report_V07.pdf (Accessed: 13 June 2023).

Jones, B.J. (2020) 'A Position Paper on Nasogastric Tube Safety'. Available at: https://www.bapen.org.uk/pdfs/ngsig/a-position-paper-on-nasogastric-tube-safety-v2.pdf (Accessed: 13 June 2023).

Kim, H.-J. *et al*. (2016) ‘Nasogastric Tube Insertion Using Airway Tube Exchanger in Anesthetized and Intubated Patients’. *Korean Journal of Anesthesiology*, 69(6), pp. 568–572. DOI: 10.4097/kjae.2016.69.6.568.

Koo, S. (2016) ‘Nasogastric Tube Check, Easy or Not?’ *BMJ Case Reports*, p. bcr2015214075. DOI: 10.1136/bcr-2015-214075.

Kusz, Z. (2021) ‘Nasogastric Feeding Tube in Adults and Ongoing Care Clinical Guideline V8.1’. *Royal Cornwall Hospitals NHS Trust*. Available at: https://doclibrary-rcht.cornwall.nhs.uk/DocumentsLibrary/RoyalCornwallHospitalsTrust/Clinical/Dietetics/NasogastricFeedingTubeInAdultsAndOngoingCareClinicalGuideline.pdf (Accessed: 9 March 2025).

Lim, W.F. *et al*. (2017) ‘9CLINICAL EFFECTIVENESS OF CORTRAK (ENTERAL ACCESS SYSTEM) AT ROYAL DEVON AND EXETER’. *Age and Ageing*, 46(suppl_2), pp. ii1–ii6. DOI: 10.1093/ageing/afx115.9.

Luckraz, H. *et al*. (2018) ‘Cost of Treating Ventilator-Associated Pneumonia Post Cardiac Surgery in the National Health Service: Results from a Propensity-Matched Cohort Study’. *Journal of the Intensive Care Society*, 19(2), pp. 94–100. DOI: 10.1177/1751143717740804.

Mahadevaiah, T. *et al*. (2022) ‘Comparison of Hemodynamic Response to Laryngoscopy Using Miller and McCoy Blade’. *Cureus*, 14(5), p. e24914. DOI: 10.7759/cureus.24914.

Marderstein, E.L., Simmons, R.L. and Ochoa, J.B. (2004) ‘Patient Safety: Effect of Institutional Protocols on Adverse Events Related to Feeding Tube Placement in the Critically Ill’. *Journal of the American College of Surgeons*, 199(1), pp. 39–47; discussion 47-50. DOI: 10.1016/j.jamcollsurg.2004.03.011.

Maxwell, A. (2024) ‘Comment on Miyamoto et al. Laryngopharyngeal Mucosal Injury Due to Nasogastric Tube Insertion during Cardiopulmonary Resuscitation: A Retrospective Cohort Study. J. Clin. Med. 2024, 13, 261’. *Journal of Clinical Medicine*, 13(12). DOI: 10.3390/jcm13123447.

Medical Protection Society (2017) *Nasogastric Tube Errors*. Available at: https://www.medicalprotection.org/uk/articles/nasogastric-tube-errors (Accessed: 23 April 2022).

Meyer, P. *et al*. (2009) ‘Colorimetric Capnography to Ensure Correct Nasogastric Tube Position’. *Journal of Critical Care*, 24(2), pp. 231–235. DOI: 10.1016/j.jcrc.2008.06.003.

Miyamoto, K. *et al*. (2024) ‘Laryngopharyngeal Mucosal Injury Due to Nasogastric Tube Insertion during Cardiopulmonary Resuscitation: A Retrospective Cohort Study’. *Journal of Clinical Medicine*, 13(1), p. 261. DOI: 10.3390/jcm13010261.

National Institute for Health and Care Excellence. (2016) ‘CORTRAK 2 Enteral Access System for Placing Nasoenteral Feeding Tubes (MIB48) Medtech Innovation Briefing’. Available at: https://www.nice.org.uk/advice/mib48/resources/cortrak-2-enteral-access-system-for-placing-nasoenteral-feeding-tubes-pdf-63499172779717 (Accessed: 10 April 2025).

National Office of Clinical Audit. (2024) 'Irish National ICU Audit Annual Report 2022.' Available at: https://d7g406zpx7bgk.cloudfront.net/x/ecb6eeefe8/irish-national-icu-audit-annual-report-2022-final.pdf (Accessed: 16 April 2025).

National Standards Authority of Ireland. (2025) *ISO 13485 Management System for Medical Devices | NSAI*. Available at: https://www.nsai.ie/certification/medical-devices/iso-13485-management-system-for-medical-devices/ (Accessed: 6 May 2025).

NHS. (2016a) 'Initial Placement Checks for Nasogastric and Orogastric Tubes'. Available at: https://www.england.nhs.uk/wp-content/uploads/2016/07/Resource_set_-_Initial_placement_checks_for_NG_tubes_1.pdf (Accessed: 11 April 2025).

NHS. (2016b) 'Patient Safety Alert. Nasogastric Tube Misplacement: Continuing Risk of Death and Severe Harm.' Available at: https://www.england.nhs.uk/wp-content/uploads/2019/12/Patient_Safety_Alert_Stage_2_-_NG_tube_resource_set.pdf (Accessed: 20 March 2024).

Nickson, C. (2019) *Nasogastric and Orogastric Tubes*. *Life in the Fast Lane • LITFL*. Available at: https://litfl.com/nasogastric-and-orogastric-tubes/ (Accessed: 9 March 2025).

Nutricia. (2024) *Nutrison*. *Nutricia IE*. Available at: https://www.nutricia.ie/hcp/pim-products/nutrison.html (Accessed: 8 March 2025).

O'Sullivan, C. (2025) 'CHI Accused of Using Off-Label Treatment without Consent'. 11 May. Available at: https://www.rte.ie/news/health/2025/0511/1512267-bladder/ (Accessed: 12 May 2025).

Ou, G.-W. *et al.* (2021) 'Comparison of Different Methods of Nasogastric Tube Insertion in Anesthetized and Intubated Patients: A Meta-Analysis'. *World Journal of Clinical Cases*, 9(26), pp. 7772–7785. DOI: 10.12998/wjcc.v9.i26.7772.

Oxford Medical Education. (2015) *Nasogastric (NG) Tube Placement*. *Oxford Medical Education*. Available at: https://oxfordmedicaleducation.com/clinical-skills/procedures/nasogastric-ng-tube/ (Accessed: 4 April 2025).

Ozer, S. and Benumof, J.L. (1999) 'Oro- and Nasogastric Tube Passage in Intubated Patients: Fiberoptic Description of Where They Go at the Laryngeal Level and How to Make Them Enter the Esophagus'. *Anesthesiology*, 91(1), pp. 137–143. DOI: 10.1097/00000542-199907000-00022.

Pareira, M.D. (1959) *Therapeutic Nutrition with Tube Feeding*. [Language Material, Electronic Resource]. [object Object]. Springfield, Illinois: Charles C Thomas Available at: http://catalog.hathitrust.org/Record/001579273 (Accessed: 2 March 2025).

Pillai, J.B. (2005) 'Thoracic Complications of Nasogastric Tube: Review of Safe Practice'. *Interactive CardioVascular and Thoracic Surgery*, 4(5), pp. 429–433. DOI: 10.1510/icvts.2005.109488.

Prabhakaran, S. *et al.* (2012) 'Nasoenteric Tube Complications'. *Scandinavian Journal of Surgery*, 101(3), pp. 147–155. DOI: 10.1177/145749691210100302.

Preiser, J.-C. *et al.* (2021) 'A Guide to Enteral Nutrition in Intensive Care Units: 10 Expert Tips for the Daily Practice'. *Critical Care*, 25(1), p. 424. DOI: 10.1186/s13054-021-03847-4.

Rassias, A.J., Ball, P.A. and Corwin, H.L. (1998) 'A Prospective Study of Tracheopulmonary Complications Associated with the Placement of Narrow-Bore Enteral Feeding Tubes'. *Critical Care*, 2(1), pp. 25–28.

Renew, J.R. *et al.* (2020) 'Neuromuscular Blockade Management in the Critically Ill Patient'. *Journal of Intensive Care*, 8(1), p. 37. DOI: 10.1186/s40560-020-00455-2.

Robles-González, M. *et al.* (2024) (16) 'Verification of Nasogastric Tube Positioning Using Ultrasound by an Intensive Care Nurse: A Pilot Study'. *Healthcare*, 12(16), p. 1618. DOI: 10.3390/healthcare12161618.

Sanaie, S., Mahmoodpoor, A. and Najafi, M. (2017) 'Nasogastric Tube Insertion in Anaesthetized Patients: A Comprehensive Review'. *Anestezjologia Intensywna Terapia*, 49(1), pp. 57–65. DOI: 10.5603/AIT.a2017.0001.

Sigmon, D.F. and An, J. (2022) 'Nasogastric Tube'. In *StatPearls*. Treasure Island (FL): StatPearls Publishing. Available at: http://www.ncbi.nlm.nih.gov/books/NBK556063/ (Accessed: 8 March 2025).

Singer, P. *et al.* (2023) 'ESPEN Practical and Partially Revised Guideline: Clinical Nutrition in the Intensive Care Unit'. *Clinical Nutrition (Edinburgh, Scotland)*, 42(9), pp. 1671–1689. DOI: 10.1016/j.clnu.2023.07.011.

Smith, A.L. *et al.* (2018) 'Deaths Associated with Insertion of Nasogastric Tubes for Enteral Nutrition in the Medical Intensive Care Unit: Clinical and Autopsy Findings'. *Proceedings (Baylor University. Medical Center)*, 31(3), pp. 310–316. DOI: 10.1080/08998280.2018.1459400.

Smith, A.L. *et al.* (2021) 'Unsuitability of Sump Tubes for Delivery of Enteral Nutrition and Medications to Intensive Care Unit Patients'. *Baylor University Medical Center Proceedings*, 34(5), pp. 560–565. DOI: 10.1080/08998280.2021.1930487.

Sorokin, R. and Gottlieb, J.E. (2006) 'Enhancing Patient Safety During Feeding-Tube Insertion: A Review of More Than 2000 Insertions'. *Journal of Parenteral and Enteral Nutrition*, 30(5), pp. 440–445. DOI: 10.1177/0148607106030005440.

Sparks, D.A. *et al.* (2011) 'Pulmonary Complications of 9931 Narrow-Bore Nasoenteric Tubes During Blind Placement'. *Journal of Parenteral and Enteral Nutrition*, 35(5), pp. 625–629. DOI: 10.1177/0148607111413898.

Tan, S.S. *et al.* (2012) 'Direct Cost Analysis of Intensive Care Unit Stay in Four European Countries: Applying a Standardized Costing Methodology'. *Value in Health: The Journal of the International Society for Pharmacoeconomics and Outcomes Research*, 15(1), pp. 81–86. DOI: 10.1016/j.jval.2011.09.007.

Tashiro, J., Vietrogoski, R.A. and Swan, K.G. (2010) 'Abraham Louis Levin: Demystifying the Duodenum'. *Journal of Trauma: Injury, Infection & Critical Care*, 69(6), pp. 1583–1587. DOI: 10.1097/TA.0b013e3181e74589.

Taylor, S. *et al.* (2021) 'Integrated Real-Time Imaging System, "IRIS", Kangaroo Feeding Tube: A Guide to Placement and Image Interpretation'. *BMJ Open Gastroenterology*, 8(1), p. e000768. DOI: 10.1136/bmjgast-2021-000768.

Taylor, S. and Manara, A.R. (2021) 'X-Ray Checks of NG Tube Position: A Case for Guided Tube Placement'. *The British Journal of Radiology*, 94(1124), p. 20210432. DOI: 10.1259/bjr.20210432.

Taylor, S.J., Allan, K. and Clemente, R. (2019) 'Undetected Cortrak Tube Misplacements in the United Kingdom 2010-17: An Audit of Trace Interpretation'. *Intensive & Critical Care Nursing*, 55, p. 102766. DOI: 10.1016/j.iccn.2019.102766.

Taylor, S.J., Karpasiti, T. and Milne, D. (2023) 'Safety of Blind versus Guided Feeding Tube Placement: Misplacement and Pneumothorax Risk'. *Intensive and Critical Care Nursing*, 76, p. 103387. DOI: 10.1016/j.iccn.2023.103387.

Tsai, Y.-F. *et al.* (2012) 'Nasogastric Tube Insertion in Anesthetized and Intubated Patients: A New and Reliable Method'. *BMC Gastroenterology*, 12(1), p. 99. DOI: 10.1186/1471-230X-12-99.

Welhengama, C., Hall, A. and Hunter, J.M. (2021) 'Neuromuscular Blocking Drugs in the Critically Ill'. *BJA Education*, 21(7), pp. 258–263. DOI: 10.1016/j.bjae.2021.02.002.

Yeung, H.Y., Lam, R.P.K. and Tsui, M.S.H. (2023) 'Comparing the Utility of the Weighted Corflo® and the Comforsoft® Nasogastric Feeding Tubes in Administering Activated Charcoal: A Randomised, Cross-over, Non-Inferiority Manikin Study'. *Hong Kong Journal of Emergency Medicine*, 30(6), pp. 394–401. DOI: 10.1177/10249079231177853.

Zatelli, M. and Vezzali, N. (2017) '4-Point Ultrasonography to Confirm the Correct Position of the Nasogastric Tube in 114 Critically Ill Patients'. *Journal of Ultrasound*, 20(1), pp. 53–58. DOI: 10.1007/s40477-016-0219-0.

Zimlichman, E. *et al.* (2013) 'Health Care-Associated Infections: A Meta-Analysis of Costs and Financial Impact on the US Health Care System'. *JAMA Internal Medicine*, 173(22), pp. 2039–2046. DOI: 10.1001/jamainternmed.2013.9763.

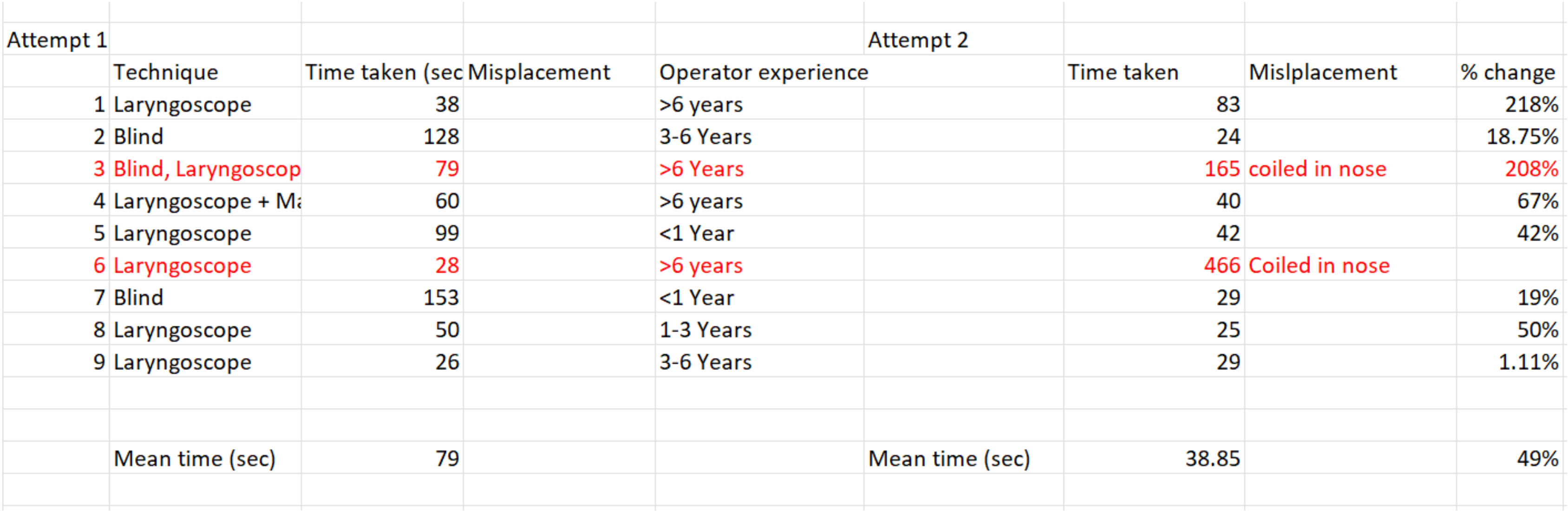
Appendix A: NGT Insertion Responses.

Response number	Experience	Time	First Technique	Misplacement	Rescue Technique	Confirmed with:	Location	Airway in situ	Drugs Used	Equipment Used	
1	>6 years	1-5 mins	Blind	Nil	N/A	CXR	ICU	Oral ETT	Not specified		
2	>6 Years	1-5 mins	Blind	Coiled in mouth/Throat	Neck Flexion	CXR	ICU	Oral ETT	None (cardiac arrest with brain injury)		
3	< 1 Year	2mins 30 sec	McGrath VL	Coiled in mouth/Throat	N/A	Aspiration	Theatre	Post induction Pre	Post induction	VL+Magill	
4	<1 Year	2 mins	Blind	N/A	N/A	Auscultation	Theatre	Oral ETT	Post induction		
5	1-3 years	4min 42 sec	Blind	Coiled in mouth/Throat	VL	Aspiration	Resus	Oral ETT	Rocuronium 50mg	McGrath VL	
6	4-6 years	1-5 minutes	incomplete	incomplete	incomplete	incomplete	incomplete	incomplete	incomplete		
7	4-6 years	2 mins 8 sec	Blind	n/a	N/A	cxr	icu	Oral ETT	Not specified		
8	4-6 years	1-5 mins	Blind	Coiled in mouth/Throat	McGrath VL + Magill	CXR	Resus	Oral ETT	Not specified	McGrath VL + Magill	
9	1-3 years	32sec	McGrath VL	N/A	N/A	Auscultation	Theatre	Post induction Pre	Post induction	McGrath	
10	1-3 years	<1 minute	Blind	N/A	n/a	Aspiration + Surgical confirm	Theatre	Oral ETT	Post induction	McGrath	
11	4-6 years	<1 minute	Blind	N/A	N/A	Aspiration	Theatre	Oral ETT	Not specified		
12	4-6 years	<30 sec	Blind	N/A	N/A	Aspiration	Theatre	Oral ETT	Post induction		
13	4-6 years	30 sec	McGrath VL	N/A	N/A	Aspiration	Theatre	Oral ETT	Post induction	McGrath	
14	>6 years	50 sec	Blind	N/A	N/A	CXR	ICU	Oral ETT	Sedated in ICU		
15	>6 years	<1 minute	Blind	N/A	N/A	Aspiration + litmus + CXR	ICU	Oral ETT	Propofol 20mg		
16	>6 years	<1 minute	Digital assistance in pharynx	N/A	N/A	Aspiration	Theatre	Oral ETT	Post induction		
17	>6 years	15 sec	Digital assistance in pharynx	N/A	N/a	Auscultation	Theatre	Oral ETT	Post induction		
18	>6 years	40 sec	Digital assistance in pharynx	N/A	N/A	Aspiration	Theatre	Oral ETT	Post induction		

19	>6 years	<1 minute	Neck Flexion	N/A	N/A	Direct surgical (intra-op)	Theatre	Oral ETT	Under full GA		
20	>6 years	60 sec	Blind	N/A	N/A	Aspiration	Theatre	Oral ETT	Post induction		
21	>6 years	21sec	Neck Flexion	n/a	n/a	Not specified	Theatre	Oral ETT	Post induction		
22	>6 years	25sec	Neck Flexion	n/a	N/A	Auscultation	Theatre	Oral ETT	Post induction		
23	>6 years	<1 minute	Blind	N/A	N/A	Auscultation	Theatre	Oral ETT	Post induction		
24	>6 years	15 sec	McGrath VL	N/A	N/A	Aspiration	Theatre	Oral ETT	Post induction	McGrath	
25	Not intubated										
26	Not intubated										
27	Not intubated										
28	Not intubated										
29	1-3 years	4min 16 sec	Blind	Coiled in mouth/Throat	N/A	cxR	ICU	Oral ETT	Propofol 30mg		
30	4-6 years	10-20mins	McGrath + Magill	Actual or suspected insertion i Actual or suspected insertion i	N/A	CXR	ICU	Tracheostomy	Post induction	McGrath + Magill	
31	>6 years	5-10mins	Blind		VL, then cut ETT	Aspiration	Theatre	Oral ETT	Post induction	McGrath, Cut ETT	
32	>6 years	8.5 minutes total	Blind	Actual or suspected insertion i	VL, Lateral neck pressure	Aspiration	ICU	Oral ETT	Post induction	McGrath, Alternate size NGT(n=2)	
33	>6 years	5-10 mins	Blind	Coiled in mouth/Throat	McGrath VL + Magill	Auscultation	Theatre	Oral ETT	Post induction	McGrath + Magill	
34	4-6 years	1-5 mins	McGrath VL	Coiled in mouth/Throat	Cut ETT	Aspiration	Theatre	Oral ETT	Post induction	McGrath + Cut ETT	
35	1-3 years	10-20mins	Blind	Coiled in mouth/Throat	N/A	CXR	ICU	Oral ETT	Weaning phase - not sedated, tolerated procedure		
36	4-6 years	5min 39 sec	Blind	Unsure	McGrath VL	Aspiration	ICU	Oral ETT	Post induction	Magill, McGrath blade specific for NGT insertion	
37	>6 years	5-10 mins	Blind	Coiled in mouth/Throat	N/A	Aspiration + cxr	ICU	Oral ETT	Sedated in ICU		
38	4-6 years	5-10 mins	Blind	Coiled in mouth/Throat	N/A	CXR	ICU	Oral ETT	Sedated in ICU		
39	Not recorded	9 min 06 sec	Blind	Actual or suspected insertion i	N/A	Aspiration	ICU	Oral ETT	Propofol 38mg		
40	>6 years	2min 37 sec	McGrath VL	Coiled in mouth/Throat	N/a	Abandoned	Theatre	Oral ETT	Patient under GA	McGrath VL	
41	>6 years	5-10mins	Blind	Coiled in mouth/Throat	McGrath VL + Magill	Aspiration	Theatre	Oral ETT	Post induction	McGrath + Magill	
42	1-3 years	4 min	McGrath vl	Coiled in mouth/Throat	Magill	aspiration	Theatre	Oral ETT	Post induction	mcgrath, magill	
43	>6 years	3mins 50	Macintosh DL	Unsure: ETT obstructing view o	Magill	Aspiration	Theatre	Oral ETT	Under full GA	Macintosh, Magill forceps	

44	<1 Year	41 sec	Blind	n/a	N/A	CXR	icu	Oral ETT	Fentanyl 50mcg	jelly	
45	1-3 years	10-20 mins	Blind	n/a	n/a	CXR	icu	Oral ETT	midaz, fentanyl		Time does
46	>6 years	3mins	Blind	unsure	n/a	CXR	icu	Oral ETT	Not specified		
47	> 6 years	10-20 mins	Blind	Coiled in mouth/Throat	laryngoscopy	CXR	icu	not specified	none (low gcs)		
48	1-3 years	30 sec	Blind	n/a	N/A	cxr	ICU	Oral ETT	midaz 2mg		
49	1-3 years	1-5 mins	Blind	Actual or suspected insertion i	n/a - removed aftre cxr	cxr	icu	Oral ETT	propofol bolus	Jelly	Confirmed
50	<1 Year	3min 26 sec	Blind	Coiled in mouth/Throat	Magill forceps	Direct surgical (intra-op)	theatre	Oral ETT	Post induction		
51	1-3 years	5 min 19 sec	Blind	Coiled in mouth/Throat	McGrath + Magill	VL	Theatre	Oral ETT	Post induction		
52	<1 Year	3 min 54 sec	Blind	Coiled in mouth/Throat	McGrath	Aspiration	Theatre	Oral ETT	Post induction		
53	4-6 years	1-5 mins	Direct Laryngoscopy	Coiled in mouth/Throat	Direct Laryngoscopy + Magill	Aspiration	ICU	Oral ETT	nil		
54	4-6 years	5-10 mins	Blind	N/A	n/a	CXR	ICU	Oral ETT	nil		Time does
55	1-3 years	1-5 mins (2mins approx)	Digital assistance in pharyn	n/a	n/a	Auscultation	Theatre	Oral ETT	Post induction		
56	4-6 years	<1 minute	Blind	n/a	n/a	cxr	ICU	Oral ETT	nil		
57	4-6 years	<1 minute	Blind	n/a	n/a	cxr	icu	Oral ETT	nil		
58	>6 years	<1 minute	Blind + Neck flexion	n/a	N/a	Aspiration	Theatre	Oral ETT	Post induction		
59	4-6 years	1-5 minutes	Digital assistance in pharyn	n/a	n/a	not recorded	icu	Oral ETT	Post induction		
60	Not Intubated										
61	Missing insertion time										
62	Incomplete										
63	<1 Year	10-20 mins	Blind	Coiled in mouth/throat	McGrath	CXR (aspiration negative)	ICU	Oral ETT	Propofol 20+50+30mg		
64	1-3 years	1-5 mins	Blind	Actual or suspected insertion i	Blind	Auscultation + CXR	ICU	Oral ETT	Nil		

Appendix B: Mannequin study responses.



Attempt 1					Attempt 2			
	Technique	Time taken (sec	Misplacement	Operator experience		Time taken	Mislplacement	% change
1	Laryngoscope	38		>6 years		83		218%
2	Blind	128		3-6 Years		24		18.75%
3	Blind, Laryngoscop	79		>6 Years		165	coiled in nose	208%
4	Laryngoscope + Ma	60		>6 years		40		67%
5	Laryngoscope	99		<1 Year		42		42%
6	Laryngoscope	28		>6 years		466	Coiled in nose	
7	Blind	153		<1 Year		29		19%
8	Laryngoscope	50		1-3 Years		25		50%
9	Laryngoscope	26		3-6 Years		29		1.11%
	Mean time (sec)	79			Mean time (sec)	38.85		49%

9

Mannequin Study of Nasogastric Tube Insertion Techniques.

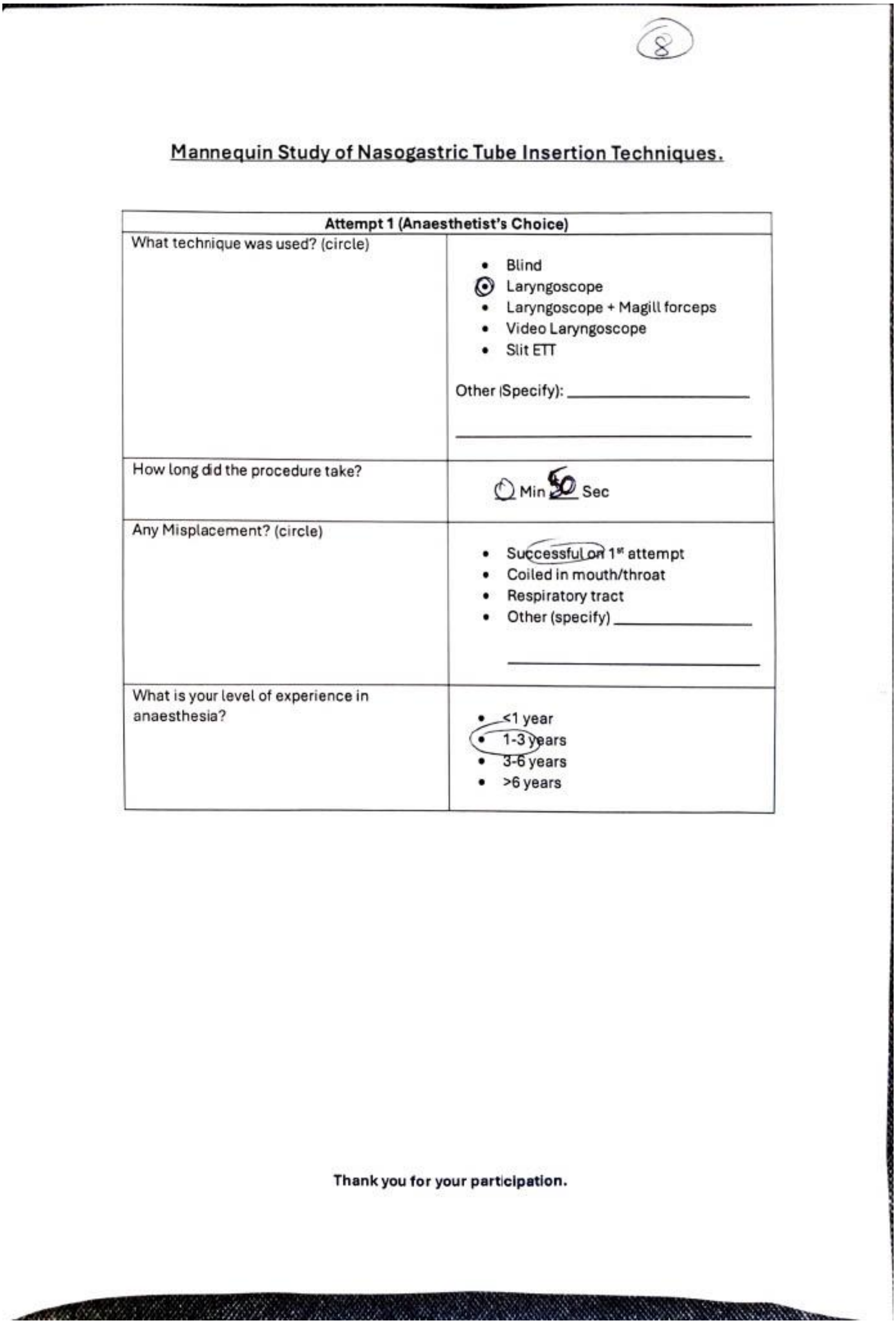
Attempt 1 (Anaesthetist's Choice)	
What technique was used? (circle)	Blind [✓ Laryngoscope] Laryngoscope + Magill forceps Video Laryngoscope Slit ETT Other (Specify): ______
How long did the procedure take?	0 Min 26 Sec
Any Misplacement? (circle)	Successful on 1st attempt [✓ Coiled in mouth/throat] × 1 Respiratory tract Other (specify) ______
What is your level of experience in anaesthesia?	<1 year 1-3 years [✓ 3-6 years] >6 years

Thank you for your participation.

⑧

Attempt 2 (Trial Device)	
How long did the procedure take?	0 Min 25 Sec
Any Misplacement?	[✓ Successful on 1st attempt] - Coiled in mouth/throat - Respiratory tract - Other (specify) ____________
Ease of use?	[✓ Very Easy] - Somewhat easy - Neutral - Difficult - Very difficult
How often might you use this device for NGT insertion if it were commercially available?	[✓ Every time] - Only if my initial attempt failed - Sometimes - Rarely - Never
Please explain your answer above. What factors may influence your decision?	I FIND USUALLY NGT PLACEMENT IN ICU PATIENTS VERY TRICKY
Do you see any advantages or disadvantages to this device over current methods?	Advantages: TIME SAVING LESS STRESS LESS CONCERN RE TEETH DAMAGE/ TRAUMA. Disadvantages: MAY LOSE SKILL OF PLACING NGT W/ MAGILL FORCEPS IN CASE DEVICE NOT AVAILABLE
Please provide any feedback that you wish to on the trial device.	THIS IS A GREAT IDEA. ESP WHEN USED IN OT MID CASE WHEN ACCESS TO PATIENT IS LIMITED

Thank you for your participation.



8

Mannequin Study of Nasogastric Tube Insertion Techniques.

Attempt 1 (Anaesthetist's Choice)	
What technique was used? (circle)	Blind [✓ Laryngoscope] Laryngoscope + Magill forceps Video Laryngoscope Slit ETT Other (Specify): ____
How long did the procedure take?	0 Min 50 Sec
Any Misplacement? (circle)	[✓ Successful on 1st attempt] Coiled in mouth/throat Respiratory tract Other (specify) ____
What is your level of experience in anaesthesia?	<1 year [✓ 1-3 years] 3-6 years >6 years

Thank you for your participation.

⑦

Attempt 2 (Trial Device)	
How long did the procedure take?	0 Min 29 Sec
Any Misplacement?	[✓ Successful on 1st attempt] • Coiled in mouth/throat • Respiratory tract • Other (specify) ______
Ease of use?	[✓ Very Easy] • Somewhat easy • Neutral • Difficult • Very difficult
How often might you use this device for NGT insertion if it were commercially available?	[✓ Every time] • Only if my initial attempt failed • Sometimes • Rarely • Never
Please explain your answer above. What factors may influence your decision?	- easy to use - swift insertion
Do you see any advantages or disadvantages to this device over current methods?	Advantages: ease of use easy insertion (less attempts) Disadvantages: - Risk of dental trauma c̄ use of extra device - Risk of inadvertent extubation.
Please provide any feedback that you wish to on the trial device.	- Very hard and rigid

Thank you for your participation.

⑦

Mannequin Study of Nasogastric Tube Insertion Techniques.

Attempt 1 (Anaesthetist's Choice)	
What technique was used? (circle)	[✓ Blind] • Laryngoscope • Laryngoscope + Magill forceps • Video Laryngoscope • Slit ETT Other (Specify): ____________________ ____________________
How long did the procedure take?	2 Min 23 Sec
Any Misplacement? (circle)	• Successful on 1st attempt [✓ Coiled in mouth/throat] • Respiratory tract • Other (specify) ____________ ____________________
What is your level of experience in anaesthesia?	[✓ <1 year] • 1-3 years • 3-6 years • >6 years

Thank you for your participation.

⑥

Attempt 2 (Trial Device)	
How long did the procedure take?	7 Min 46 Sec
Any Misplacement?	- Successful on 1st attempt - [✓ Coiled in mouth/throat] - Respiratory tract - Other (specify) ________
Ease of use?	- Very Easy - [✓ Somewhat easy] - Neutral - Difficult - Very difficult
How often might you use this device for NGT insertion if it were commercially available?	- Every time - [✓ Only if my initial attempt failed] - Sometimes - Rarely - Never
Please explain your answer above. What factors may influence your decision?	Seems very useful, if I can get NGT in place without instrumenting mouth + risking displacing ETT that would be preferable
Do you see any advantages or disadvantages to this device over current methods?	Advantages: Could be viable adjunct to technically v. difficult procedure. Disadvantages: Ø.
Please provide any feedback that you wish to on the trial device.	Potentially widening lateral dimensions to block lateral pharyngeal space - may not be an issue if bigger size used.

Thank you for your participation.

③ ⑥

Mannequin Study of Nasogastric Tube Insertion Techniques.

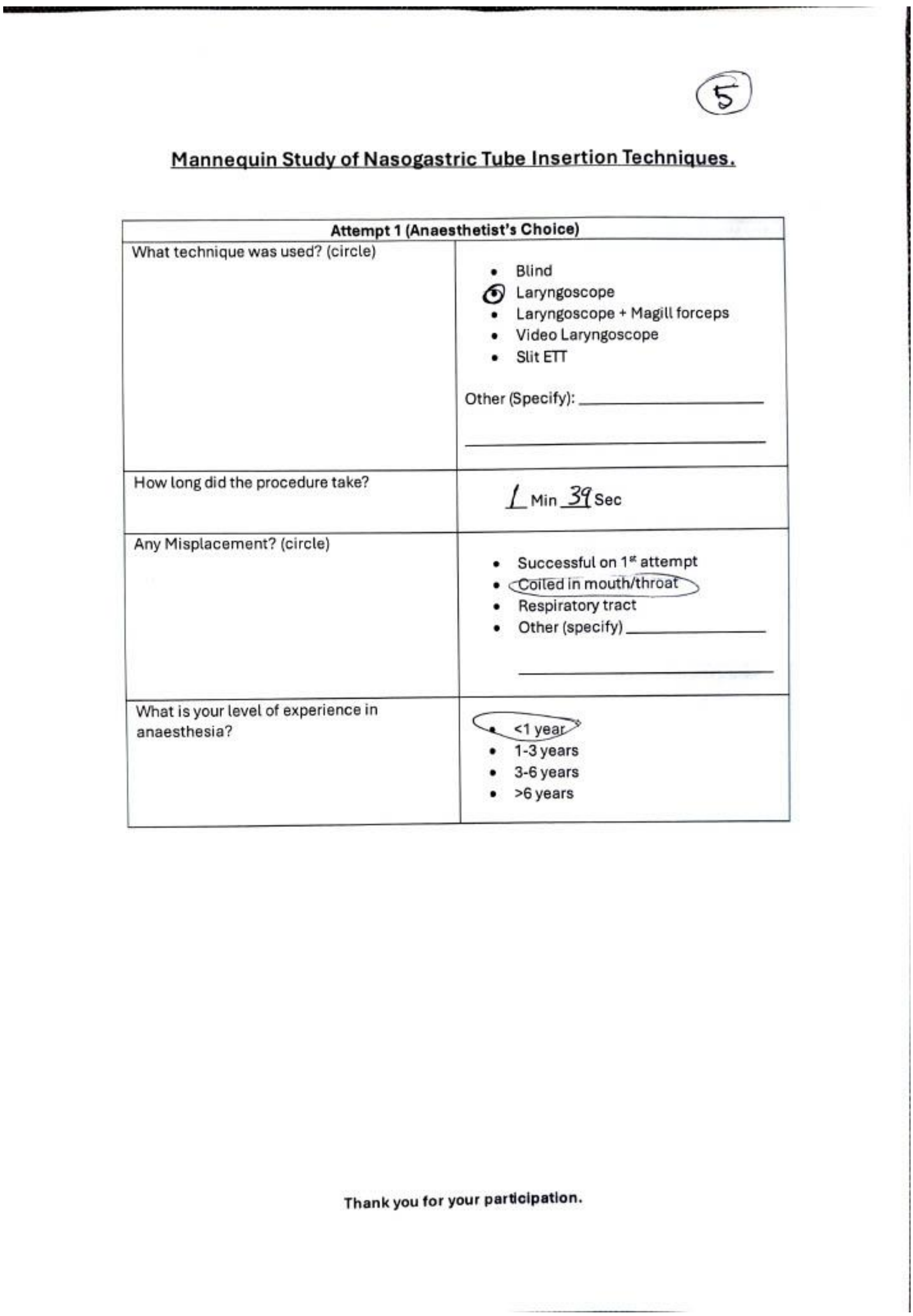
Attempt 1 (Anaesthetist's Choice)	
What technique was used? (circle)	- Blind [✓ Laryngoscope] - Laryngoscope + Magill forceps - Video Laryngoscope - Slit ETT Other (Specify): ____________
How long dic the procedure take?	0 Min 28 Sec
Any Misplacement? (circle)	[✓ Successful on 1st attempt] - Coiled in mouth/throat - Respiratory tract - Other (specify) ____________
What is your level of experience in anaesthesia?	- <1 year - 1-3 years - 3-6 years [✓ >6 years]

Thank you for your participation.

③.

Attempt 2 (Trial Device)	
How long did the procedure take?	0 Min 42 Sec
Any Misplacement?	[✓ Successful on 1st attempt] • Coiled in mouth/throat • Respiratory tract • Other (specify) ________
Ease of use?	• [✓ Very Easy] • Somewhat easy • Neutral • Difficult • Very difficult
How often might you use this device for NGT insertion if it were commercially available?	• Every time • [✓ Only if my initial attempt failed] • Sometimes • Rarely • Never
Please explain your answer above. What factors may influence your decision?	Cost of additional device
Do you see any advantages or disadvantages to this device over current methods?	Advantages: Potential rapid insertion Disadvantages: Operator dependent Potential to accidentally extubate if used incorrectly: soft tissue damage / tooth damage
Please provide any feedback that you wish to on the trial device.	Consider cost and environmental impact. Potential for use if a reusable tool developed.

Thank you for your participation.

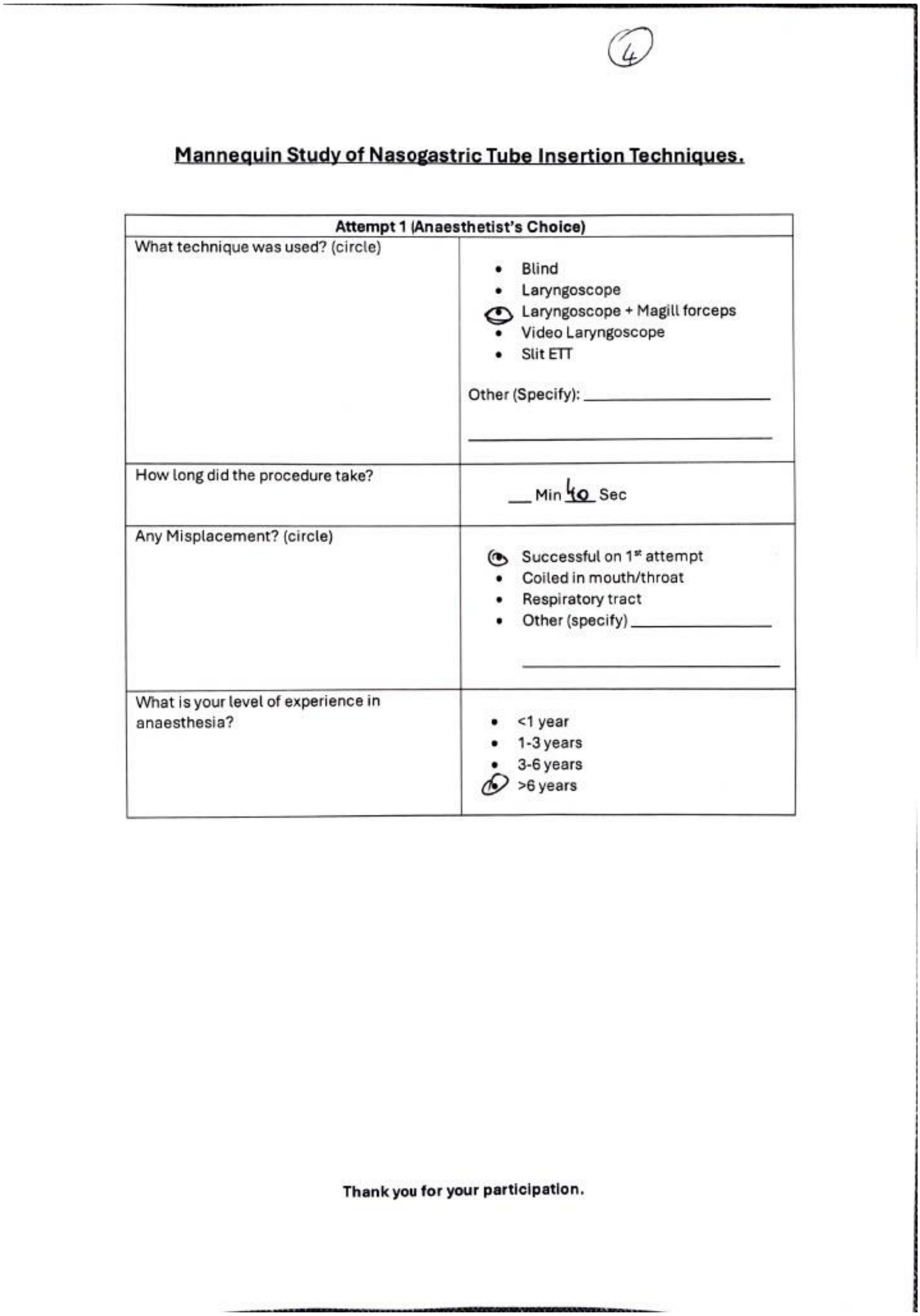


⑤

Mannequin Study of Nasogastric Tube Insertion Techniques.

Attempt 1 (Anaesthetist's Choice)	
What technique was used? (circle)	- Blind [✓ Laryngoscope] - Laryngoscope + Magill forceps - Video Laryngoscope - Slit ETT Other (Specify): ____
How long did the procedure take?	1 Min 39 Sec
Any Misplacement? (circle)	- Successful on 1st attempt [✓ Coiled in mouth/throat] - Respiratory tract - Other (specify) ____
What is your level of experience in anaesthesia?	[✓ <1 year] - 1-3 years - 3-6 years - >6 years

Thank you for your participation.



④

Mannequin Study of Nasogastric Tube Insertion Techniques.

Attempt 1 (Anaesthetist's Choice)	
What technique was used? (circle)	- Blind - Laryngoscope [✓ Laryngoscope + Magill forceps] - Video Laryngoscope - Slit ETT Other (Specify): ____________
How long did the procedure take?	__ Min 40 Sec
Any Misplacement? (circle)	[✓ Successful on 1st attempt] - Coiled in mouth/throat - Respiratory tract - Other (specify) ____________
What is your level of experience in anaesthesia?	- <1 year - 1-3 years - 3-6 years [✓ >6 years]

Thank you for your participation.

④

Attempt 2 (Trial Device)	
How long did the procedure take?	1 Min 0 Sec
Any Misplacement?	[✓ • Successful on 1st attempt] • Coiled in mouth/throat • Respiratory tract • Other (specify) ______
Ease of use?	[✓ • Very Easy] • Somewhat easy • Neutral • Difficult • Very difficult
How often might you use this device for NGT insertion if it were commercially available?	• Every time [✓ • Only if my initial attempt failed] • Sometimes • Rarely • Never
Please explain your answer above. What factors may influence your decision?	– Habit – potential need for quick decompression of stomach if surgeons ask.
Do you see any advantages or disadvantages to this device over current methods?	Advantages: – Likely to improve NG insertion time, more likely first time. Disadvantages: possibility of dislodging ETT, although this is always a possibility with Macintosh/magills
Please provide any feedback that you wish to on the trial device.	innovative device.

Thank you for your participation.

③

Attempt 2 (Trial Device)	
How long did the procedure take?	2 Min 45 Sec
Any Misplacement?	- Successful on 1st attempt - [✓ Coiled in mouth/throat] - Respiratory tract - Other (specify) ___ Coiled in nose ✓.
Ease of use?	- [✓ Very Easy] - Somewhat easy - Neutral - Difficult - Very difficult
How often might you use this device for NGT insertion if it were commercially available?	- Every time - [✓ Only if my initial attempt failed] - Sometimes - Rarely - Never
Please explain your answer above. What factors may influence your decision?	
Do you see any advantages or disadvantages to this device over current methods?	Advantages: - less risk of bitten fingers. Disadvantages: - if limited mouth opening - - if dodgy teeth - trauma.
Please provide any feedback that you wish to on the trial device.	

Thank you for your participation.

3)

Mannequin Study of Nasogastric Tube Insertion Techniques.

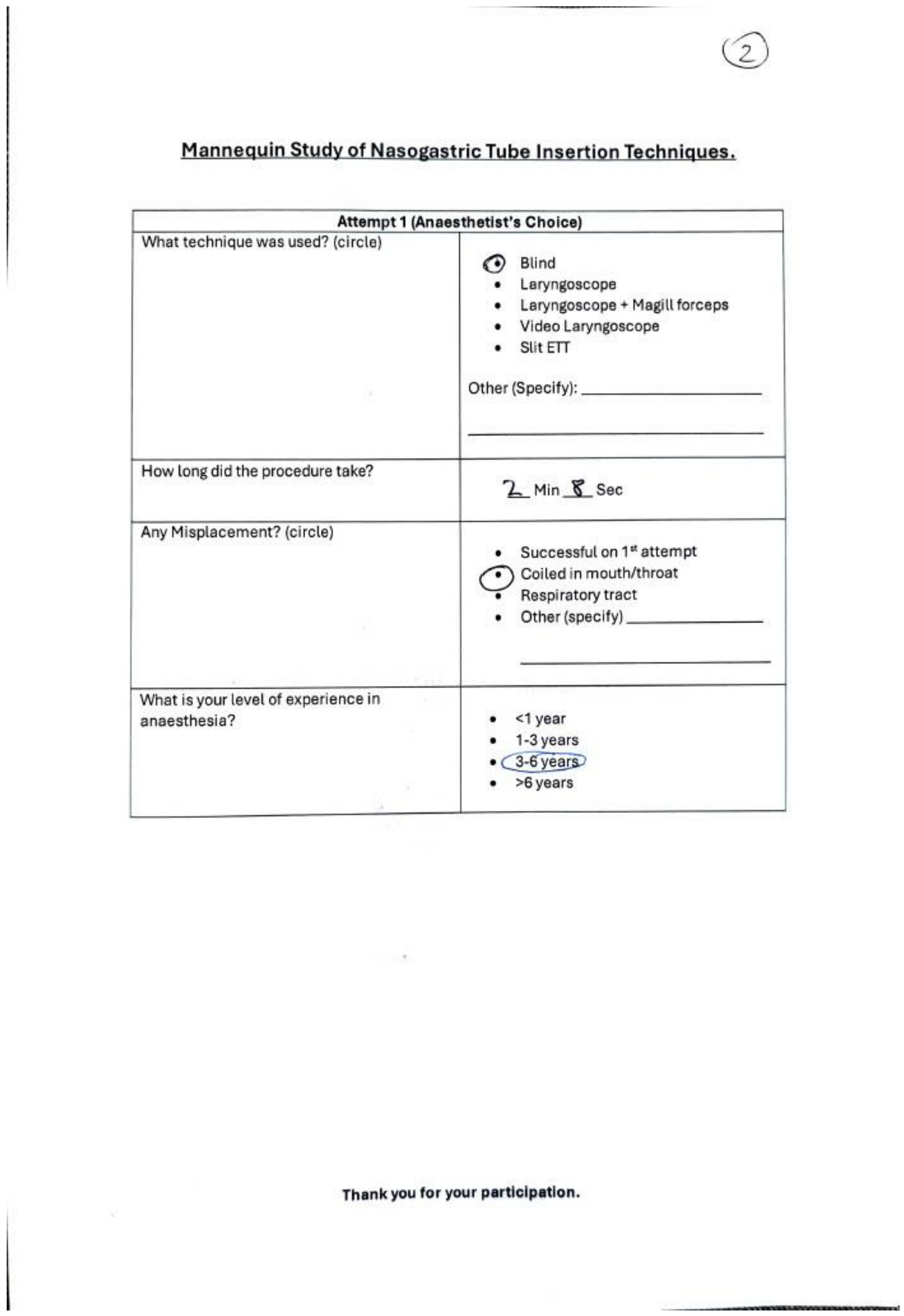
Attempt 1 (Anaesthetist's Choice)	
What technique was used? (circle)	[✓ Blind]^{1} [✓ Laryngoscope]^{2} • Laryngoscope + Magill forceps • Video Laryngoscope • Slit ETT Other (Specify): ______
How long did the procedure take?	1 Min 19 Sec
Any Misplacement? (circle)	• Successful on 1st attempt [✓ Coiled in mouth/throat] • Respiratory tract • Other (specify) ______
What is your level of experience in anaesthesia?	• <1 year • 1-3 years • 3-6 years [✓ >6 years]

Thank you for your participation.

②

Attempt 2 (Trial Device)	
How long did the procedure take?	__ Min 24 Sec
Any Misplacement?	[✓ Successful on 1st attempt] • Coiled in mouth/throat • Respiratory tract • Other (specify) ____________
Ease of use?	[✓ Very Easy] • Somewhat easy • Neutral • Difficult • Very difficult
How often might you use this device for NGT insertion if it were commercially available?	[✓ Every time] • Only if my initial attempt failed • Sometimes • Rarely • Never
Please explain your answer above. What factors may influence your decision?	Most of the time we need Laryngoscope to confirm that N/G is in stomach.
Do you see any advantages or disadvantages to this device over current methods?	Advantages: → high success rate → saves time → no risk of damage to oral cavity by putting laryngoscope Disadvantages: → Availability
Please provide any feedback that you wish to on the trial device.	

Thank you for your participation.



②

Mannequin Study of Nasogastric Tube Insertion Techniques.

Attempt 1 (Anaesthetist's Choice)	
What technique was used? (circle)	[✓ Blind] • Laryngoscope • Laryngoscope + Magill forceps • Video Laryngoscope • Slit ETT Other (Specify): ____________
How long did the procedure take?	2 Min 8 Sec
Any Misplacement? (circle)	• Successful on 1st attempt [✓ Coiled in mouth/throat] • Respiratory tract • Other (specify) ____________
What is your level of experience in anaesthesia?	• <1 year • 1-3 years [✓ 3-6 years] • >6 years

Thank you for your participation.

①

Attempt 2 (Trial Device)	
How long did the procedure take?	1 Min 23 Sec
Any Misplacement?	Successful on 1st attempt [✓ Coiled in mouth/throat] Respiratory tract Other (specify) ____________
Ease of use?	Very Easy Somewhat easy [✓ Neutral] Difficult Very difficult
How often might you use this device for NGT insertion if it were commercially available?	Every time [✓ Only if my initial attempt failed] Sometimes Rarely Never
Please explain your answer above. What factors may influence your decision?	If it is widley available and staff are well trained in it; it can be a good device to keep in case first NGT placement fails especially if time or patient condition ~~are not~~ do not permit ~~to~~ multiple trials.
Do you see any advantages or disadvantages to this device over current methods?	Advantages: - Once training is available it can be useful in critical situations or if time is of the essence. Disadvantages: - there is a learning curve to it. - Centralization of ETT underneath is a bit tricky for the untrained.
Please provide any feedback that you wish to on the trial device. Design can be slightly improved to improve seating of the ETT underneath.	Its useful once training is done especially if the practitioner - inserter - is not experienced enough in challenging situations.

Thank you for your participation.

①

Mannequin Study of Nasogastric Tube Insertion Techniques.

Attempt 1 (Anaesthetist's Choice)	
What technique was used? (circle)	• Blind [✓ Laryngoscope] • Laryngoscope + Magill forceps • Video Laryngoscope • Slit ETT Other (Specify): ______
How long did the procedure take?	__ Min 38 Sec
Any Misplacement? (circle)	[✓ Successful on 1st attempt] • Coiled in mouth/throat • Respiratory tract • Other (specify) ______
What is your level of experience in anaesthesia?	• <1 year • 1-3 years • 3-6 years [✓ >6 years]

Thank you for your participation.

Attempt 2 (Trial Device)	
How long did the procedure take?	0 Min 29 Sec
Any Misplacement?	[✓ Successful on 1st attempt] • Coiled in mouth/throat • Respiratory tract • Other (specify) ______________
Ease of use?	[✓ Very Easy] • Somewhat easy • Neutral • Difficult • Very difficult
How often might you use this device for NGT insertion if it were commercially available?	• Every time [✓ Only if my initial attempt failed] • Sometimes • Rarely • Never
Please explain your answer above. What factors may influence your decision?	potential for airway trauma c̄ device. Would use if only alternative option was laryngoscope +/- Magills.
Do you see any advantages or disadvantages to this device over current methods?	Advantages: · Less airway trauma than Laryngoscope + Magills. · Saves times. · Less sedation likely needed than for laryngoscope. Disadvantages: · Still potential for airway trauma. - ?cost.
Please provide any feedback that you wish to on the trial device.	Seems to be easy to use + ~~speech~~ reduces time taken to place NG in mannequin.

Thank you for your participation.

Appendix C: Survey Responses.

	Response	Re-use th	Use a fres	Laryngos	Laryngos	Other (please specify)	Open-Ended Response	Response	Response
									Column1
1	Sometimes difficult			Laryngosco	Magill forceps		In an intubated patient flexing of neck could facilitate	I would use it only if my initial att	>6 years.
2	Often difficult (less than 50% of the ti		Use a resh	Laryngosco	Magill forceps		Jaw thrust	I would use it every time.	>6 years.
3	Sometimes difficult	Re-use the	Use a fresh	Laryngoscope (includi		Jaw thrust by one operator whil	Yes locally but not published.	I would use it regularly.	>6 years.
4	Regularly difficult (more than 50% of t		Use a fresh NG tube			cut ett lenthways, use laryngosc	cold ngt, flex pt neck,	I would use it regularly.	>6 years.
5	Sometimes difficult	Re-use the first NG tub		Laryngosco	Magill forceps		Nope	I would use it regularly.	1-3 years
6	Often difficult (less than 50% of the time).			Laryngoscope (including video laryngoscopy)			Using a laryngoscope	I would use it regularly.	>6 years.
7	Often difficult (less than 50% of the ti		Use a resh	Laryngosco	Magill forceps		With video laryngoscope	I would use it every time.	1-3 years
8	Often difficult (less than 50	Re-use the first NG tube with a modified technique					1-Neck flexion, if possible. 2-Insert 2 fingers inside the	I would use it regularly.	>6 years.
9	Sometimes difficult	Re-use the first NG tube with a modified technique					Intubating the oesophagus with a cut ETT and passing	I would use it regularly.	>6 years.
10	Sometimes difficult			Laryngosco	Magill forc	It would depend how contamina	Refrigerated tubes have more rigidity, I often pre bend	I would use it regularly.	4-6 years
11	Sometimes difficult	Re-use the first NG tub		Laryngosco	Magill forceps		Laryngoscopy	I would use it every time.	>6 years.
12	Often difficult (less than 50	Re-use the first NG tube with a modified technique					Sit up, flex neck, use of frozen NG	I would use it only if my initial att	1-3 years
13	Often difficult (less than 50	Re-use the first NG tub		Laryngosco	Magill forceps		neck flexion with lateral pressure, reverse Sellick's ma	I would use it regularly.	>6 years.
14	Regularly difficult (more than 50% of the time).				Magill forceps		No	I would use it every time.	Less than 1 year
15	Often difficult (less than 50	Re-use the	Use a fresh	Laryngosco	Magill forc	Occasionally OG tube if only req	No	I would use it every time.	>6 years.
16	Sometimes difficult		Use a fresh NG tube		Magill forceps		Cold tube, rotate to invert curve in nasopharynx	I would use it regularly.	>6 years.

17	Sometimes difficult	Re-use the first NG tube with a modified technique					Described by who?	I would use it only if my initial att	>6 years.
18	Sometimes difficult	Re-use the first NG tu		Laryngosco	Magill forceps		.	I would use it every time.	1-3 years
19	Often difficult (less than 50	Re-use the	Use a fresh	Laryngosco	Magill forceps		Jaw thrust	I would use it every time.	1-3 years
20	Often difficult (less than 50	Re-use the	Use a fresh NG tube				No	I would use it only if my initial att	Less than 1 year
21	Sometimes difficult	Re-use the first NG tu		Laryngoscope (including video laryngoscopy)			Neck flexion	I would use it every time.	>6 years.
22	Regularly difficult (more than 50% of the time).			Laryngoscope (including video laryngoscopy)			ett tube used to pass tube into oesophagus	I would use it every time.	>6 years.
23	Sometimes difficult		Use a fresh	Laryngosco	Magill forceps		.	I would use it every time.	>6 years.
24	Sometimes difficult			Laryngosco	Magill forceps		Jaw thrust and guide the NG tube at the base of tongu	I would use it only if my initial att	>6 years.
25	Sometimes difficult	Re-use the first NG tube with a modified technique					Following the distal end of the NG with the tip of my fi	I would use it regularly.	>6 years.
26	Often difficult (less than 50% of the ti		Use a resh	Laryngosco	Magill forc	Thread through an ETT and intu	Neck flexion	I would use it regularly.	>6 years.
27	Regularly difficult (more than 50% of t		Use a fresh NG tube				Using a NG tube that has been stored in the fridge or f	I would use it regularly.	>6 years.
28	Sometimes difficult	Re-use the first NG tube with a modified technique					Intubate oesophagus with split ETT	I would use it every time.	>6 years.
29	Often difficult (less than 50	Re-use the first NG tube with a modified technique					cold tube, flex neck, pass direct under laryngoscopy.	I would use it every time.	>6 years.
30	Often difficult (less than 50% of the ti		Use a resh	Laryngosco	Magill forc	Neck flexation	Magil forceps	I would use it regularly.	1-3 years
31	Sometimes difficult	Re-use the first NG tube with a modified technique					Inserted two fingers orally into the oropharynx and gu	I would use it every time.	>6 years.
32	Regularly difficult (more than 50% of the time).			Laryngoscope (including video laryngoscopy)			No	I would use it only if my initial att	>6 years.
33	Often difficult (less than 50	Re-use the first NG tube with a modified technique					Flexing the neck	I would use it every time.	4-6 years
34	Sometimes difficult		Use a fresh	Laryngoscope (includi		Cut endo tracheal tube into oeso	Cut endo tracheal tube into oesophagus	I would use it regularly.	>6 years.
35	Sometimes difficult	Re-use the first NG tube with a modified technique					Pass NG to ETT on esophagus	I would use it as a last resort.	>6 years.
36	Regularly difficult (more th	Re-use the first NG tu		Laryngoscope (including video laryngoscopy)			Head flexion, use an ETT to go through.	I would use it every time.	>6 years.
37	Often difficult (less than 50% of the time).			Laryngoscope (including video laryngoscopy)			ETT insertion in esophagus under DL and subsequent	I would use it regularly.	1-3 years
38	Regularly difficult (more th	Re-use the first NG tu		Laryngosco	Magill forceps		Performing a jaw thrust and guiding tube in midline	I would use it every time.	1-3 years

39	Sometimes difficult			Laryngoscope (including video laryngoscopy)			NG tube with Endotracheal tube rail road	I would use it only if my initial att	>6 years.
40	Sometimes difficult			Laryngosco	Magill forceps		Stand at the patient's shoulder level, facing the patien	I would use it regularly.	>6 years.
41	Often difficult (less than 50% of the ti		Use a resh	Laryngosco	Magill forc	Split an ETT longtudinally and us	using a larmgpscope and magill's forcepts as 1st line	I would use it regularly.	>6 years.
42	Often difficult (less than 50% of the time).			Laryngoscope (including video laryngoscopy)			N/A	I would use it regularly.	1-3 years
43	Sometimes difficult			Laryngoscope (including video laryngoscopy)			Not aware of any formally described techniques, only a	I would use it every time.	>6 years.
44	Regularly difficult (more th	Re-use the first NG tube with a modified tec				Manual optimisation of ng tube	Neck flexion with jaw thrust	I would use it every time.	>6 years.
45	Sometimes difficult		Use a fresh NG tube				N	I would use it every time.	>6 years.
46	Often difficult (less than 50	Re-use the	Use a fresh NG tube				Laryngoscope with McGill. ET tube in oesophagus.	I would use it every time.	>6 years.
47	Often difficult (less than 50	Re-use the first NG tube with a modified technique					No	I would use it every time.	Less than 1 year
48	Regularly difficult (more than 50% of t		Use a fresh	Laryngoscope (including video laryngoscopy)			Tying and the ETT in the middle/ Inserting the nasogas	I would use it every time.	>6 years.
49	Often difficult (less than 50	Re-use the first NG tu		Laryngosco	Magill forceps		No	I would use it every time.	Less than 1 year
50	Sometimes difficult		Use a fresh NG tube				finger in the mouth to help direct ng	I would use it every time.	>6 years.
51	Regularly difficult (more than 50% of the time).			Laryngoscope (including video laryngoscopy)			Oesophageal intubation with split ETT, Use of Video la	I would use it regularly.	>6 years.
52	Not difficult at all		Use a fresl	Laryngosco	Magill forceps		No	I would use it regularly.	>6 years.
53	Often difficult (less than 50% of the time).			Laryngosco	Magill forceps		Use of a cooled/frozen NGT	I would use it only if my initial att	1-3 years
54	Regularly difficult (more than 50% of the time).			Laryngosco	Magill forceps		No	I would use it regularly.	1-3 years
55	Sometimes difficult	Re-use the first NG tube with a modified technique					Use of fingers to back of orophynx to guide tube	I would use it regularly.	>6 years.
56	Sometimes difficult	Re-use the first NG tu		Laryngosco	Magill forceps		No	I would use it regularly.	>6 years.
57	Sometimes difficult	Re-use the first NG tube with a modified technique					Lift the jaw anteriorly with a gloved hand inside the m	I would use it every time.	>6 years.
58	Sometimes difficult	Re-use the	Use a fresl	Laryngosco	Magill forceps		No	I would use it every time.	>6 years.
59	Sometimes difficult		Use a fresh NG tube				Cut an ETT along its full length, intubate oesphagus wi	I would use it every time.	>6 years.
60	Often difficult (less than 50% of the ti		Use a resh	Laryngoscope (including video laryngoscopy)			No	I would use it regularly.	>6 years.
61	Sometimes difficult	Re-use the first NG tube with a modified technique					No not aware	I would use it regularly.	>6 years.

62	Sometimes difficult	Re-use the first NG tube with a modified technique	Using a less flexible ng - like the ones we keep in the fr	I would use it regularly.	4-6 years
63	Regularly difficult (more than 50% of t	Use a fresh Laryngosco Magill forc Frozen NG tube	Using rigid (frozen) NGs	I would use it every time.	>6 years.
64	Often difficult (less than 50	Re-use the first NG tube with a modified technique	No	I would use it regularly.	>6 years.
65	Sometimes difficult	Re-use the first NG tu Laryngoscope (including video laryngoscopy)	Flex the patients neck forward. Try the other nostril.	I would use it every time.	1-3 years
66	Sometimes difficult	Re-use the first NG tu Laryngoscope (including video laryngoscopy)	Use cold NG from fridge	I would use it regularly.	Less than 1 year
67	Sometime difficult	Reuse the first NG tube with a modified technique	(Blank)	I would use it regularly	>6 years
68	Sometime difficult	Reuse the first NG tube with a modified technique, laryngoscope, magill force	Head to chin flexion	I would use it every time	>6 years
69	Sometime difficult	Laryngoscope, Magill forceps	Pull trachea upward	I would use it as a last resort	<1 year
70	Regularly difficult (>50% of	Reuse the first NG tube with a modified technique, laryngoscope.	No	I would use it regularly	1-3 years
71	Sometime difficult	Reuse the first NG tube with a modified technique	No	I would use it only if my initial att	4-6 years
72	Sometime difficult	Reuse the first NG tube with a modified technique, laryngoscope, magill force	Cut ETT	I would use it only if my initial att	4-6 years
73	Sometime difficult	Reuse the first NG tube with modified technique, magill forceps	(blank)	I would use it only if my initial att	1-3 years
74	Sometime difficult	Reuse the first NG tube with a modified technique, laryngoscope, magill force	(Blank)	I would use it every time	4-6 years
75	Sometime difficult	Reuse the first NG tube with a modified technique	(Blank)	I would use it only if my initial att	>6 years
76	Regularly difficult (>50% of	Reuse the first NG tube with a modified technique	Neck Flexion, neck rotation, digital assistance.	I would use it only if my initial att	>6 years
77	Sometime difficult	Reuse the first NG tube with a modified technique, laryngoscope.	No	I would use it only if my initial att	>6 years
78	Sometime difficult	Reuse the first NG tube with modified technique, magill forceps	Digital assistance	I would use it only if my initial att	>6 years
79	Sometime difficult	Reuse the first NG tube with a modified technique, laryngoscope, magill force	Cut ETT	I would use it regularly	>6 years
80	Sometime difficult	Reuse the first NG tube with a modified technique	Head tilt (flexion)	I would use it every time	>6 years
81	Sometime difficult	Reuse the first NG tube wth a modified technique, Use a fresh NG tube	No (not specifically)		
82	Sometime difficult	Reuse the first NG tube with modified technique, magill forceps	(blank)		

Appendix D: Consent to Participate Form Template.

GRIFFITH COLLEGE

Consent to take part in research

"Naso-enteral tube safety in anaesthetised patients: examining the potential impact of a novel introducer device on patient safety."

The researcher retains one copy signed by both themselves and the participant. The participant should also receive a copy of consent form as a record of what they have signed up to.

- I [ ] voluntarily agree to participate in this research study
- I understand that even if I agree to participate now, I can withdraw at any time or refuse to answer any question without any consequences of any kind
- I understand that I can withdraw permission to use data from my interview within two weeks after the interview, in which case the material will be deleted.
- I have had the purpose and nature of the study explained to me in writing and I have had the opportunity to ask questions about the study
- I understand that participation involves performing nasogastric tube insertion in an intubated mannequin.
- I understand that I will not benefit directly from participating in this research
- I understand that all information I provide for this study will be treated confidentially
- I understand that in any report on the results of this research my identity will remain anonymous. No personal data will be collected.
- I understand that extracts from my interview may be quoted in the author's dissertation or related scientific media (conferences, academic presentations, scientific publications).

- I understand that if I inform the researcher that myself or someone else is at risk of harm, they may have to report this to the relevant authorities - they will discuss this with me first but may be required to report with or without my permission
- I understand that signed consent will be stored for up to 5 years.
- I understand that under freedom of information legislation I am entitled to access the information I have provided at any time while it is in storage as specified above.
- I understand that I am free to contact any of the people involved in the research to seek further clarification and information.

Researcher Details

Name: Andrew Maxwell

Degree Programme: MSc Medical Device Technology and Business

College Details: Griffith College, Dublin.

Contact number: 0866003084

Contact mail: andrewmaxwell01@gmail.com

Name of participant:

-- --------------------

Date

Signature of research participant

Signature of researcher:

I believe the participant is giving informed consent to participate in this study

--- ---------------------

Date

Signature of researcher

Appendix E: Participant Information Letter.

GRIFFITH COLLEGE

Participant Information Letter

"Naso-enteral tube safety in anaesthetised patients: examining the potential impact of a novel introducer device on patient safety."

I would like to invite you to take part in a research study. Before you decide you need to understand why the research is being done and what it would involve for you. Please take time to read the following information carefully. Ask questions if anything you read is not clear or if you would like more information. Take time to decide whether or not to take part.

WHO I AM AND WHAT THIS STUDY IS ABOUT

My name is Andrew Maxwell, and I am a final year Anaesthesiology trainee undertaking a Masters degree in medical device technology. The purpose of this study is to assess how a novel introducer device might reduce the rates of misplacement of naso-enteral tubes inserted in anaesthetised and intubated patients, and thus improve patient safety.

WHAT WOULD TAKING PART INVOLVE?

You will be asked to place a nasogastric tube (NGT) in an intubated mannequin using your method of choice. You will then be shown how to use the dedicated introducer device, and you will then perform a second NGT insertion using the introducer device. The time to insertion will be recorded, as will any misplacement. You will also be asked for your feedback on the device itself. The data collected will involve, for example: time taken to insertion, equipment used, any misplacement that occurred, any adverse event (e.g. accidental extubation).

WHY HAVE YOU BEEN INVITED TO TAKE PART?

You have been invited to take part as a medical professional who may be required to insert NGTs or other enteral access devices in anaesthetised and intubated patients as part of their normal work. The study aims to compare standard NGT insertion methods with a new method (using the introducer device), and participants who perform this task regularly are best placed for this comparison.

DO YOU HAVE TO TAKE PART?

Participation is entirely voluntary. You retain the right to refuse participation, refuse any question and withdraw at any time without any consequence whatsoever.

Please note

- that participation is **voluntary**;
- that a decision not to consent will have **no adverse consequences**;
- that consent can be withdrawn **at any time**
- If you need to withdraw, please contact, andrewmaxwell01@gmail.com.
-

WHAT ARE THE POSSIBLE RISKS AND BENEFITS OF TAKING PART?

There are no risks to taking part. You will be tasked with placing an NGT in a high fidelity simulation, and there is no standard to which you will be compared. Misplacement or failure of NGT insertion is a well recognised complication of the procedure, and is expected to occur with some participants regardless of experience level. By participating, you will assist me in gathering knowledge on the techniques used by anaesthesiologists for NGT insertion, and you will provide me with data for investigating any potential patient safety benefits of a new NGT insertion method.

WILL TAKING PART BE CONFIDENTIAL?

Yes, taking part will be confidential. Participant data collection forms will be assigned a number in sequence on a first come basis. No personal data will be collected. Level of experience in anaesthesia will be recorded.

HOW WILL INFORMATION YOU PROVIDE BE STORED AND PROTECTED?

Signed consent forms will be retained in a folder at my personal address for up to 5 years in compliance with GDPR requirements. Under freedom of information legislation, you are entitled to access the information you have provided at any time.

WHAT WILL HAPPEN TO THE RESULTS OF THE STUDY?

The study will be used as part of my MSc dissertation work. It may also be used as a standalone scientific work which may be submitted to scientific meetings or academic journals for publication. All dissertation research projects and their content will be made accessible in the Griffith College library and could potentially be made available in online e-journals or repository.

WHO SHOULD YOU CONTACT FOR FURTHER INFORMATION?

Dr Andrew Maxwell. Email: andrewmaxwell01@gmail.com.

THANK YOU