Guided Feeding Tube Placement - Taster

Citation	■ Taylor SJ. Guided Feeding Tube Placement. 2022. Silhouette Publications. Bristol, UK. ISBN: 978-0-9574558-6-3.
Experience & aim	■ 20 years experience and 17 peer-reviewed papers (+3 pending) in guided tube placement. I overview the advantages and limitations of equipment & training; advanced techniques in placement and interpretation of tube position are detailed.
Conflict of interest	■ Co-chair of the Critical Care Specialist Group's NJ Team, BDA-UK, member of the NG Special Interest Group, BAPEN-UK. ■ 1-day consultancy and lecture fees (paid direct to the Tear Fund charity) (Cortrak™ now Avanos Medical Inc) and studies supported through North Bristol NHS Trust from Cortrak and Cardinal Health (IRIS®). I use both tubes in clinical practice. ■ Co-developed the Fast-Lock nasal bridle.
Disclaimer	■ Professionals should only use this information if: □ Trained adequately, to a level set by local policy, including use of the systems and placement wire-guided feeding tubes. □ The healthcare institution approves off-license methods used. □ Accepting that it is entirely at their own responsibility. ■ **This eBook is independently written;** it is not an endorsement or guarantee of any particular product.
Reviews	I am grateful to members of the CCSG (Emma Gaskin, Mary Phillips, Phillip Johnston) for the chance to revise.
Royalties	All go directly to 'Tear Fund's' relief work in Ukraine. That's the **2nd** reason not to illegally copy this book !

Contents

1 How to use

Table 1.1: Overview of use.

Topic	Topics describe	Level	Link
Background	Efficacy of EN, confirming tube position, placement techniques and the rationale for NI feeding.	General	3 , 4 , 5 ,
Equipment, Training & Preparation	Guided tube placement systems, training required and preparation for tube placement.	Trainee	

Placement	Detailed description of how to place a tube at each anatomical stage, potential problems and their solution.	Operator	
Interpretation	How to differentiate respiratory from GI placement and determine the tube's point-position.	Expert	
Background, Safety, Feeding & Maintenance	Reason & need for NI feeding, risks of tube placement, feeding, tube securement and flushing.	General	

2 Glossary

Table 2.1: Glossary of terms.

CCK	Cholecystokinin	IRIS	Kangaroo™ Feeding Tube with an integrated real-time imaging system
CI	Confidence interval	LOS	Lower oesophageal sphincter
CPN	Central parenteral nutrition	NG	Nasogastric
CRRT	Continuous renal replacement therapy	NI	Nasointestinal (i.e. duodenal or jejunal)
CS	Cross-section of an EM trace	OG	Oro-gastric
DGE	Delayed gastric emptying	PEG	Percutaneous endoscopic gastrostomy
DJ	Duodeno-jejunal (flexure)	PEG/J	Percutaneous endoscopic gastrostomy/ jejunal
EER	Estimated energy requirement	PEJ	Percutaneous endoscopic jejunostomy
EGNT	Electromagnetically-guided nasointestinal tube	PN	Parenteral nutrition

EM	Electromagnet or electromagnetic	PPE	Personal protective equipment
EN	Enteral nutrition	PPN	Peripheral parenteral nutrition
GE	Gastric emptying	PYY	Peptide YY
GIFS	GI flexure system	StEIS	Strategic Executive Information System
GORD	Gastro-oesophageal reflux disease	TEE	Total energy expenditure
GRV	Gastric residual volume	tLOSR	Transient lower oesophageal sphincter reflux
ICU	Intensive care unit	UOS	Upper oesophageal sphincter
IQR	Interquartile range	VAP	Ventilator-associated pneumonia

3 Introduction: Bedside Guidance

This book provides a background to tube placement, but concentrates on 3 methods offering bedside guidance: Cortrak™ (Avanos Medical Inc), ENvue® (Envizion Medical Inc) and IRIS (Kangaroo™ Feeding Tubes with IRIS Technology, Cardinal Health). Cortrak and ENvue use electromagnet tracking, IRIS uses direct vision. All 3 methods have some technical and training advantages or disadvantages. Cortrak has been most widely published therefore its successes and problems are detailed. Validation of IRIS training resources and assessment of use are underway. To date ENvue assessment is sparse. Be aware that best use of guided methods may change as more information becomes available.

4 Enteral nutrition

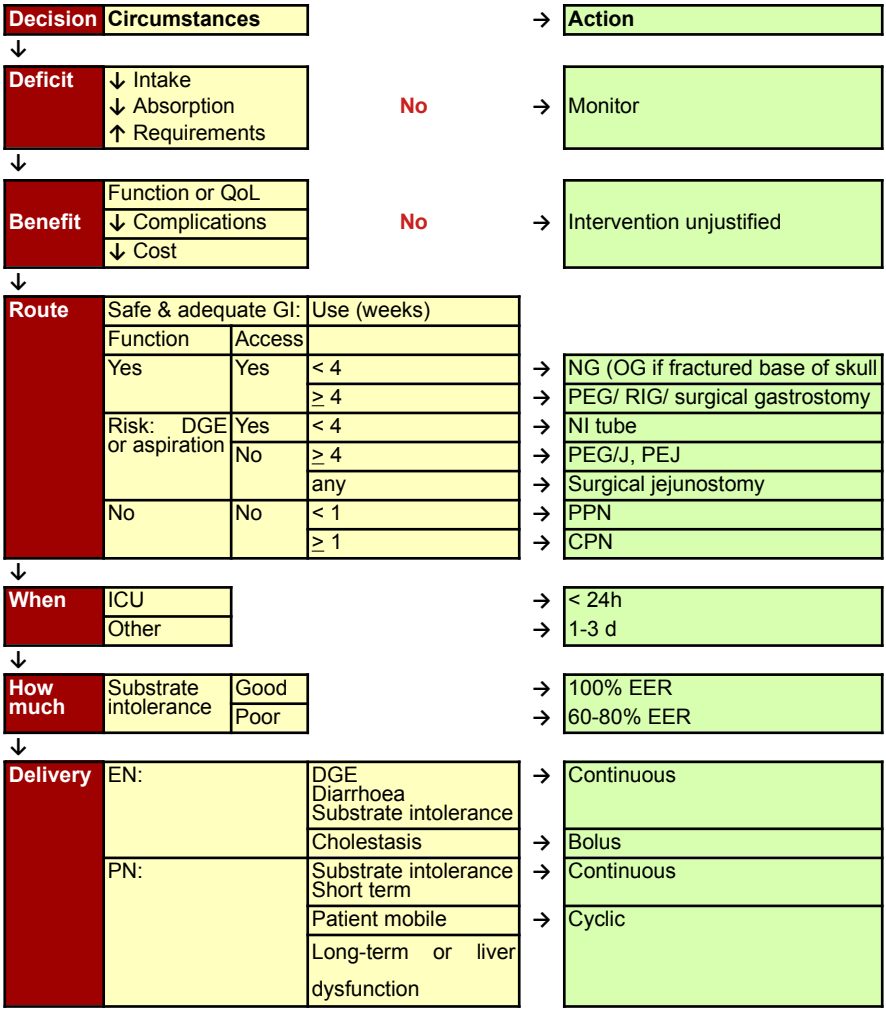
4.1 Efficacy

When oral intake fails to meet nutrition requirements, about 6% of hospital patients require invasive enteral nutrition (EN) [Elia, 2015]. EN is at least as effective as parenteral nutrition (PN) when the gut is accessible and has adequate function, but reduces infection risk and cost [CCN 1.0, 2021].

4.2 Choice of route

Route should be chosen based on accessibility, safety and the anticipated duration of nutrition support (Figure 4.1). Nasointestinal (NI) feeding is mostly required to overcome delayed gastric emptying (DGE).

Figure 4.1: Decision to delivery.



5 Confirming tube position

Weigh risk of tube misplacement versus delay to feeding as an overall risk. Guided tube placement in real time has two advantages during:

- Placement: Most common complications could be avoided and
- Confirmation: Tube position would be known immediately obviating delays to feed and drugs and reducing X-ray cost and risk.

Inadequate training would make both guided tube placement and confirmation unsafe. And, when guided tube placement is not relied upon for confirmation, the advantages of immediacy of use and cost reduction are lost. In these cases, simple but reliable methods of confirmation may be safer and cost-effective. Adequate training is the key.

5.1 Risk: Misplacement & complication

Blind tube placement can result in misplacement (detected and undetected: 1.6%), major complications (0.5%, predominantly pneumothorax and/ or pneumonia) and death (0.16%). This does not include misplacement in the nasopharynx, oesophagus, hiatus hernia and GOJ (17-23%) with the attendant aspiration risk [Rayner, 2013; Rollins et al, 2012]. For example, when a tube is close to the GOJ, tilting the head 'chin down' may pull the feed port into the oesophagus.

By comparison, only ~20 undetected misplacements ('NEVER event') are

reported per year in the UK out of 790,000 tubes per year purchased [NPSA, 2008, NHSI, 2016]. These misplacements can cause complications from the procedure or subsequent fluids given. Thus complications and death associated with detected misplacement, that is the procedure alone, may be 100-200 fold the rate of NEVER events. Misplacement can occur in any patient group but are most common during mechanical ventilation (60%) [Sparks et al, 2011], critical illness (74%) and depressed consciousness (96%) [Sorokin and Gottlieb, 2006]. Risk of misplacement increases from 2.1% to 32% when there has been previous misplacement and risk of pneumothorax increases from 5% after the first misplacement to 36% after ≥3 [Marderstein et al, 2004].

Complications are common with respiratory misplacement (3.2%), pneumothorax (1.2%) and death (0.5%) despite 1.5 X-ray checks per tube and 3.7 per patient [de Aguilar-Nascimento and Kudsk, 2007]. However, in children, although infusion increases complication risk, infusion and non-infusion cases contributed equally to overall deaths (29%) and major complications (57%) [Metheny and Meert, 2013]. Misplacement occurs with large- as well as fine-bore tubes [Metheny, 2007]. Pneumothorax rates are of a similar order to that from central line placement (1.9%) [Ayas et al, 2007] and tracheostomy haemorrhage and fistulation (1.9%), respectively [Shah et al, 2012]. Feeding tube placement is therefore not a low risk procedure.

5.2 Delay to feeding

Inability to confirm tube position either occurs through failure of method,

expertise or availability. Confirmation by pH fails when an aspirate is not obtained or pH exceeds the threshold due to misplacement or idiopathic or iatrogenic achlorhydria [Gilbertson et al, 2011].

Alternatively, in addition to irradiation, X-ray confirmation delays tube use. Hospital-wide, X-ray confirmation took a median of 2.1 hours (IQR: 1.2-5.0), was significantly longer when requested on a non-ICU) ward (+2.4h) and at night (+6.8h) [Taylor and Manara, 2021]. The delay exceeded critical drug time thresholds of 2h (eg. Systemic antibiotic, anti-retroviral, chemotherapy) in 51% of cases. The above underestimates the problem of delay by not including the time from needing the tube to the request. In addition, in the 16.6% requiring a follow-up X-ray because of tube misplacement, the median delay to confirmation increased to 4.8h (IQR: 3-10.4). In 2.5% tube position was uncertain [Taylor and Manara, 2021]. Uncertainty is associated with being male, body length causing the tube to be off-screen, BMI and removal of guide-wire reducing visibility [Torsy et al, 2020].

Further delays are incurred because of the need to re-position tubes found in the oesophagus (21.5%) and hiatus hernias (1%) [Rollins et al, 2012] or pharynx (0.8%) and oesophagus and GOJ (16.8%) [Rayner, 2013]. In addition, successful placement only occurred in 93% of gastric and 60% of intestinal placements, 19% (97% intestinal) requiring subsequent fluoroscopic placement [de Aguilar-Nascimento and Kudsk, 2007].

The delay to X-ray confirmation contributes to cumulative nutritional deficit

and poses a significant risk when patients repeatedly remove their NG tube or are critically ill. In stroke patients, the delays to tube placement, X-ray confirmation and feeding were 2.6, 8 and 9 hours, respectively [Brazier et al, 2017].

Early versus late EN is associated with reduced mortality (30%) and infection (17%) [CCN 2.0, 2021], so, delayed or inaccurate confirmation may increase overall complications and treatment cost. Conversely, guided tube placement can confirm tube position immediately after placement [Taylor et al, 2020b; 2021].

5.3 Confirmation method: Risk-based

5.3.1 Summary

- **Expert only placement:** Regardless of technique expertise reduces failure to detect misplacement and complications arising from that failure. It does not reduce complications during a purely blind placement [Marderstein et al, 2004] but almost zero's undetected misplacement using guided techniques.
- **Combined techniques**:
  - **2-stage:** i) CO2 detection can detect tracheal misplacement prior to ii) end-of-procedure confirmation. This could pre-empt complications where blind placement + X-ray at 40cm or EM-guided (Cortrak or ENvue) placement can only detect post-carina respiratory misplacement.
  - **Future:** Combining a tracking system with direct vision (IRIS) would permit an operator to know the tube position within an organ and anatomy

immediately ahead of the tube tip.

- **Safety of confirming tube position:** Expert, guided tube placement is safer during and at end-of-procedure confirmation of position than blind placement and pH and/ or X-ray. Regulatory authorities (eg. FDA, NHSI) don't currently support this because inexpert use led to adverse events. Instead, authorities should regulate expert-level training for guided placement and standalone confirmation in order to realise its higher safety and lower cost.
- **Nasal bridles:** Universal bridle placement can reduce tube use and thereby subsequent placement and complications by ~40%.

5.3.2 CO_2, pH and X-ray

No confirmation technique is risk-free from inaccuracy or misinterpretation. Assumption that traditional methods (eg. pH) are accurate, lacks evidence [Milsom et al, 2015]. However, real-time tube guidance may improve patient outcome by pre-empting lung trauma and, through immediate confirmation, facilitating timely feeding and medication. Depending on authority, gastric pH thresholds of 4.0-5.5 are the 1st-line confirmation method. However, using pH indicator sticks and a gastric threshold of ≤5.5 only gives an overall accuracy of 76-77%; 66% of oesophageal samples were ≤5.5 [Rowat et al, 2018]. Conversely, while a pH threshold of ≤4.0 theoretically excludes lung and 95% of oesophageal placements [Ni et al, 2014] and usually indicates gastric position, it leads to a modest increase in X-ray use. This will delay feed and medicine and increase irradiation and cost. However, gastric pH confirmation is only valid when there has

been no regurgitation [Jones, 2020]. Furthermore, pH thresholds between 5.0-6.0 can fail to differentiate tube position because this pH is present in samples from the stomach (18.3%), small intestine (5.1%) and lung or pleural fluid (0.7%) [Metheny et al, 1998]. Unfortunately even with a pH threshold of 5.0, confirmation was impossible in 44% (17% no aspirate, 27% pH>5.0) [Taylor et al, 2014a] and necessitated X-ray. Failure to obtain a pH $\leq$5.0 was associated with use of proton-pump inhibitors (PPIs) but not enteral feed or H2-blockers.

To accurately measure pH, sticks must be buffered against the acidity of sterile water or 0.9% NaCl to avoid false positive results. Alternatively, to allow re-checking of tube position once in use, flush with water tested to have a pH$\geq$6.0.

Because of misinterpretation, X-ray, theoretically the 'gold standard', is associated with more undetected misplacements (45%) than other techniques (eg. pH 9%), 57% of the deaths [NPSA, 2011] and the greatest delays to feeding [Taylor et al, 2014a] (5.2). Factors that predispose X-ray checks to undetected misplacement include:

- **Difficult interpretation**: pH is simple. X-ray requires 4 'gastric criteria' checks: a. Tube descends centrally, b. bisects the carina, c. crosses the diaphragm in the midline and d. deviates to the left [Lee and Mason, 2013]. It may not always be possible to move leads or drains that may interfere with interpretation.
- **Context**: The interpreter may not witness physical signs of misplacement that would otherwise prompt further investigation or may match the wrong X-ray to a tube placement.

Like pH, X-ray confirmation will not prevent traumatic lung injury during blind placement unless preceded by use of tracheal CO_2 detection (capnography/ capnometry) at 30cm or X-ray at a 40cm tube depth (-5cm if oral instead of nasal) [Taylor, 2013a]. The 2-stage X-ray technique reduced but did not eliminate bronchopulmonary placement because of some instances of protocol non-compliance [Marderstein et al, 2004]. In addition, carina depth varies by 8.5cm [Rice et al, 2003] so tube length required to show deviation into a bronchi on X-ray is uncertain. Compliance might improve by combining CO_2 detection at 30cm with sonography at final position, correctly locating 97% of weighted tube tips (vs X-ray) [Vigneau et al, 2005].

5.3.3 Direct vision

This involves identification, by camera, of the:

- Nasal or oral cavity.
- Pharynx: Pale mucosa with visible blood vessels.
- Airway: Epiglottis/ glottis/ vocal cords or endotracheal tube (ETT).
- Respiratory tract: Trachea, a non-collapsible tube with cartilaginous rings, carina, bronchi, ETT or tracheostomy cuff.
- Oesophagus: Collapsed, fluid-filled, fluted, pulsing tube with blood vessels ending in a z-line.
- Stomach: Cavernous space, folds or rugae, mucosal 'speckles' (superficial blood vessels), gastric pits and a lighter mucosa towards the antrum.

■ Intestine: Villi in duodenum part-1.

The above anatomical markers enabled recognition of the nasal or oral cavity (97.8%), respiratory tract (100%), oesophagus (97.6%), stomach (100%) and intestine (100%) and differentiated the trachea-oesophagus, oesophagus-stomach and stomach-intestine in 100% of tube placements [Taylor et al, 2021]. However, there can be more difficulty differentiating the gastric antrum from duodenum part-1 [Wischmeyer et al, 2018].

5.3.4 Electromagnet (EM) tracing

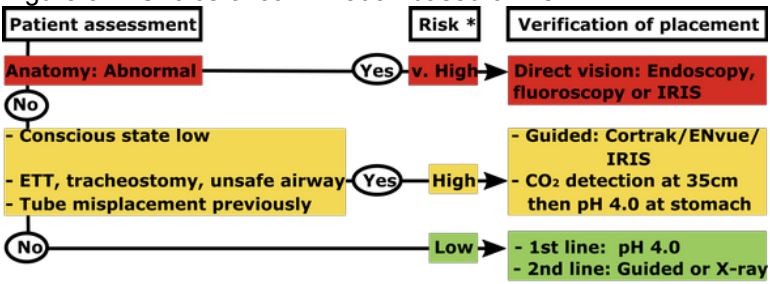
This involves interpreting tube position from an EM trace. EM-guided placement warned of initial lung misplacement in ~5% and pre-empted trauma in most. In addition, confirming tube position by EM trace instead of X-ray would reduce the delay feeding and medicines by 185±264 minutes [Bear et al, 2016]. In terms of accuracy, EM traces agree with X-ray with contrast in 100% [Powers et al, 2011; 2013] and without contrast in 85-89% [Carter et al, 2018; McCutcheon et al, 2018]. It was thought that the EM trace may be more accurate than X-ray alone because of its depth trace [Powers et al, 2013]. NG data is sparse, but 100% of EM interpretations as gastric (n=105) or hiatus hernia (n=1) were confirmed by X-ray or CT [Taylor et al, 2014a]. More data is required.

5.3.5 Choice of 1st and 2nd-line methods of gastric confirmation

A clinician should base the choice of confirmation on perceived risk (Figure 5.1). Compared to most individual confirmation methods, expert-led, guided placement

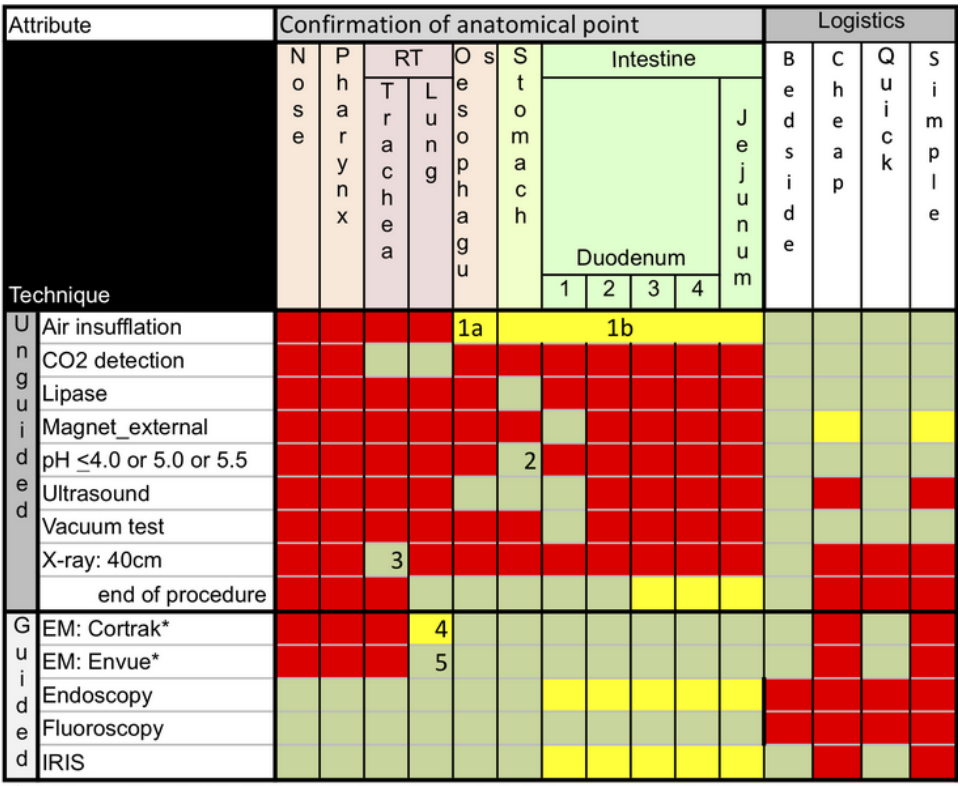
should reduce risk of trauma and give immediate confirmation of gastric or intestinal position in most conditions (Figure 5.2). Where tube position is in doubt by one method, it must be combined with another confirmatory method.

Figure 5.1: Choice of confirmation based on risk.



*Individual factors determine risk, but most patients exceed low risk.

Figure 5.2: Assessment of confirmation methods: Yes, partial, no.



1 a) Immediate belch; b) Auscultation of sound pitch: Low = stomach, high = intestine.

2 Lower threshold increases certainty of gastric position.

3 Respiratory misplacement only detectable when the a reaches a bronchus.

4 Trace artefacts can mimic or disguise lung traces.

5 Auto-warning & less risk of trace artefact (no receiver) may give higher certainty.

* Significantly abnormal anatomy can make it impossible to interpret position at that point.

Significant GI abnormality (disease, malformation, surgery or trauma) may contraindicate blind placement and necessitate real-time guidance (endoscopy, Kangaroo™ Feeding Tube with an integrated real-time imaging system [IRIS],

fluoroscopy, laryngoscopy) [Taylor, 2013a]. In addition, rarely, mucosal weakness can permit a feeding tube to exit the GI tract undetected by EM trace or X-ray [Taylor et al, 2014c]. If in such a case placement by EM trace is still thought to be appropriate, use extra caution. When there has been a previous NI placement, compare EM traces to confirm safe positioning, otherwise inject radio-contrast down the feeding tube and X-ray to check that it is within the GI trace.

EM-guidance, when compared to endoscopy, was less successful at post-pyloric placement (58% vs 86%) in the presence of GI abnormalities (eg: oesophageal/gastric surgery, fundoplication, and pancreatoduodenectomy) but with a trend to lower dislodgement (21% vs 32%) [Gerritsen et al, 2014]. However, in normal GI anatomy EM-guidance vs endoscopy had comparable success (82% vs 79%), minor adverse events and patient tolerance but required less sedation (ICU: 35% vs 64%; Ward: 0% vs 56%), had fewer false positive post-pyloric placements (3% vs 16%) and a lower cost [Kappelle et al, 2018]. In a systematic review of EM-guided, endoscopic (E), and fluoroscopic (F) placement there was similar success (EM: 85% E: 89%; F: 93%) and reinsertion rates in patients (EM:21%; E: 16%; F: 26%) but procedure time was shorter for EM-guidance (13.4±12.9 vs E: 14.9±8.7 vs F: 16.2±23.6 minutes) [Gerritsen et al, 2015b]. Procedure-related adverse events were infrequent (0.4%, 4%, and 3%, respectively) and included mainly epistaxis, but tube-related adverse event rate was lowest in EM-guidance (15% vs F: 21% vs E: 30%) and included mainly dislodgment and blockage.

A more recent meta-analysis of 4 trials involving 536 patients found no difference

between the two groups in nasointestinal placement success rate (EM: 82.6%, endoscopy: 83.1%), reinsertion rate (27.7% vs 33.1%), tube-related complications (6.3% vs 7.8%, mostly epistaxis) [Wei et al, 2020]. Overall there was no significant difference between EM and endoscopic placement in efficacy, safety and cost.

Depressed conscious state, the presence of artificial airways (endotracheal tube, tracheostomy) or a history of previous tube misplacement carries a high risk of misplacement. This may be mitigated by either guided placement or 2-stage confirmation at 35cm (eg. CO_2 detection) [Chau et al, 2011] then gastric (pH or X-ray) confirmation. In low risk patients confirmation by pH or X-ray may be considered (see below).

While limiting tube placement to experienced and specifically trained operators can reduce complications, they will remain common if placement is blind [Marderstein et al, 2004]. By detecting bronchial placement, using a 2-stage X-ray check, pneumothorax rates reduced significantly from 0.38% to 0.09% despite more bronchial placements (1.41% vs 2.6%) [Marderstein et al, 2004]. Substitution of CO_2 monitoring in the first stage carries a small risk. Colorimetric capnometry misclassified 2 lung placements (0.5%) as oesophageal and 1 oesophageal placement (7.5%) as a lung placement [Munera-Seeley et al, 2008]; detection may fail because of tube clogging. In a systematic review of four colorimetric capnography ICU studies the 95% confidence interval (CI) for sensitivity was 88-100% and specificity was 99-100% [Chau et al, 2011]. However, in ward patients, accuracy was lower (sensitivity: 0.80, specificity:

0.865) due to blocked intra-bronchial tubes giving a false negative and CO_2 from GI bacterial fermentation giving false positive readings, respectively [Mordiffi et al, 2016]. Until larger studies become available CO_2 detection can be considered to reduce but not eliminate pneumothorax risk, but it is cheaper as a screening technique than a 2-stage X-ray. Also CO_2 can be detected in the trachea so the tube would not need to reach the bronchi, as with X-ray, to disclose misplacement; earlier detection reduces trauma risk.

Overall cost-effectiveness must be considered in terms of **overall** clinical outcome and treatment cost. This includes complications, that may be affected by delays to feeding and medication, lung trauma or undetected misplacement together with any 2nd line confirmation following 1st line failure, in addition to tube cost. For example, it is not clinically safe or cheaper to use a tube with insufficient radio-opacity, placed blind, where pH confirmation often fails, necessitates repeated X-ray and misplacement occasionally results in major complications [Taylor et al, 2014a]. Tubes with the best radio-opacity often contain 40% barium sulphate throughout the tube wall length.

Optimal cost-effectiveness of guided placement vs pH ± CO_2 detection ± X-ray remains to be determined. Further research is needed into new or combined methods of confirming position in terms of accuracy and when these methods are most cost-effectively applied, for example, guided placement versus CO_2 detection plus pH. Lastly, practitioners should systematically record the confirmation process to prove safety before feeding and enable audit-driven improvement in practice.

5.4 Duodenal confirmation

Visualisation of villi by direct vision confirms duodenal placement. However, an EM trace is sometimes difficult to differentiate between entry into the duodenum or coiling in or back towards the posterior stomach. A positive 'duodenal screen' is indicated by a pH of ≥6.0 or insufflation of 10mL air and immediate aspiration yielding minimal return (vacuum test). The ‘vacuum effect’ screens for duodenal placement. In the original study, if insufflation of 60mL air followed by suction returned ≥40mL at <65cm tube depth in an adult, the tube port was probably gastric, but if it was followed by a return of ≤10mL at >75cm tube depth it was probably duodenal [Welch et al, 1994]. Positive predictive value was 86% However, large air insufflations may be unsafe in the intestine and insufflation of 10mL of air with <2mL air returned is useful in indicating when the tube has just passed the pylorus in adults (anecdotal findings) and children (1m to 19y, 2.2-60kg) [Harrison et al, 1997]. A second method found positive prediction of duodenal placement using clear yellow aspirate colour (93%), pepsin concentration <20 mg/mL (94%) and trypsin concentration >50 mg/mL (94%) [Gharpure et al, 2000]. However, inability to aspirate fluid frequently precludes this test, the colour determination may be subject to experience and the pepsin and trypsin tests may not be available. Screening for intestinal placement may also be done using a pH of 6.5 (sensitivity: 66%, specificity: 90%) or pH increase of 1.0 during advancement (58%, 100%, respectively) [Phang et al, 2004].

For the main Chapters and

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