Guided Feeding Tube Placement - Taster

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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. 						
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Royalties	All go directly to 'Tear Fund's' relief work in Ukraine. That's the 2 nd reason not to illegally copy this book !						

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Contents

1 How to use	5
2 Glossary	6
3 Introduction: Bedside Guidance.	
4 Enteral nutrition	
4.1 Efficacy	
4.2 <u>Choice of route</u>	
5 <u>Confirming tube position</u>	
5.1 <u>Risk: Misplacement & complication</u>	
1.1 <u>Kisk. misplacement & complication</u>	
5.2 <u>Delay to feeding</u> 1	
5.3 <u>Confirmation method: Risk-based</u> . 1	1 2
5.3.1 Summary	
5.3.2 <u>CO2, pH and X-ray</u>	
5.3.3 Direct vision1	
5.3.4 <u>Electromagnet (EM) tracing</u> 1	
5.3.5 <u>Choice of 1st and 2nd-line method</u>	, c
of gastric confirmation1	7
5.4 Duodenal confirmation	3
6 Efficacy of placement method2	
6.1 <u>Gastric</u>	т Л
6.2 Intestinal	4
6.2.1 <u>Blind placement: & air insufflation</u>	
manoeuvres, peristaltic tubes, pH-probe	<u>L</u>
prokinetics	5
6.2.2 Endoscopy, fluoroscopy, magnet	
assistance, ultra-sound2	6
6.3 Direct vision and EM tracing2	
7 <u>Setting up a service</u> 2 7.1 <u>General</u> 2	0
7.1 <u>General</u>	
8 Equipment	υ

8.1 <u>Cortrak</u>
8.1.1 <u>Overview</u>
8.1.2 Receiver
8.1.2.1 Alignment and levelling
8.1.2.2 <u>Relationship of receiver to body</u>
and screen 33
and screen
(LVAD)
8.2 ENvue
8.2.1 Overview
8.2.2 <u>Comparison vs Cortrak</u>
8.3 IRIS
9 <u>Training</u>
9.1 Expertise required40
9.2 Cortrak EM guidance40
9.2.1 Placement success
9.2.2 Manufacturer guidance41
9.2.2.1 Guidance to Aug 202241
9.2.2.2 Guidance from Sept 202242
9.2.3 <u>Problems with 'manufacturer</u>
interpretation'
9.2.3.1 Manufacturer guidance
9.2.3.2 Differentiating lung from GI45
9.2.3.3 Receiver mis-alignment
9.2.3.4 Overall assessment
9.2.4 <u>Misplacements</u>
9.2.5 Training and supervision
9.3 ENvue EM guidance51
9.4 IRIS: Direct vision
9.4.1 Guidance: Manufacturer & Published
51
9.4.2 <u>Accuracy</u>
9. 1 .2 <u>Accuracy</u>

9.4.3 Placement	
9.5 <u>Ultra sound</u>	
10 Preparation	55
10.1 Equipment required	55
10.2 Patient	
10.3 Tube and guide wire	
10.4 Tube length to stomach	
11 <u>Tube placement</u>	
11.1 <u>Summary</u>	61
11.1.1 <u>Caution</u>	61
11.1.2 Standard techniques	.61
11.1.3 Advanced techniques	
11.2 Equipment failure	
11.3 <u>Anatomy</u>	65
11.4 Nose or mouth	6/
11.5 <u>Pharynx</u> 11.6 <u>Lung</u>	
11.7 Oesophagus	
11.8 <u>Stomach: Upper</u>	
11.8.1 <u>General techniques</u>	71
11.8.2 <u>Specific problems</u>	73
11.8.2.1 <u>Hiatus hernia</u>	
11.8.2.2 <u>Stomach collapsed</u>	74
11.8.2.3 Distended fundus & anti-clockw	ise
circling.	75
11.8.2.4 <u>30cm flexible tip ± reve</u>	rse
Seldinger manoeuvre: Prospective	75
11.8.2.5 30cm flexible tip ± revel	rse
Seldinger manoeuvre: Retrospective	76
11.9 Stomach: Lower	76
11.9.1 Gastric fold	
11.9.2 Pylorus: High	
11.9.3 <u>NG tube</u>	
11.10 Duodenum: part-1 & super	
<u>flexure</u>	
11.11 Techniques for the intestine	
11.11.1.1 Flexible tip	81
11.11.1.2 <u>Micro-advance ± flexible tip</u>	.81
11.11.1.3 <u>Prokinetics</u>	
11.11.1.4 <u>Slack removal</u>	
11.11.1.5 <u>Wire stiffener</u>	
11.11.2 Superior flexure: Acute angle	83

53	11.11.2.1 Delays & moving anatomy	84
54	11.11.2.2 Abdominal massage	84
55	11.11.3 Advance stalls: Flaccid stomach.	84
55	11.11.3.1 Loop	85
56	11.11.3.2 <u>Coil</u>	
57	11.11.3.3 Retrograde movement	
59	11.11.4 <u>Tube kinked</u>	
61	11.11.4.1 Cause	87
61	11.11.4.2 Detection	88
61	11.11.4.3 Removal	
61	11.11.4.4 Prevention	
62	11.12 Duodenum part-2 to jejunum	
65	12 Interpretation: Direct vision	90
65	12.1 <u>Tube position</u>	
67	12.2 Anatomy	91
68	12.2.1 Mouth and nose	
70	12.2.2 Pharynx, epiglottis and airway	
70	12.2.3 Respiratory tract	96
71	12.2.4 Oesophagus1	02
71	12.2.5 <u>Stomach</u> 1	
73	12.2.6 Intestine1	
		40
73	13 Interpretation: EM guidance1	10
74	13.1 Tube position1	18
74 <u>lockwise</u>	13.1 <u>Tube position</u> 1 13.1.1 <u>Summary of EM interpretation:</u> 1	18 18
74 <u>lockwise</u> 75	13.1 Tube position1 13.1.1 Summary of EM interpretation:1 13.1.2 Anatomy versus tra	18 18 <u>ce</u>
74 lockwise 75 <u>reverse</u>	13.1 Tube position1 13.1.1 Summary of EM interpretation:1 13.1.2 Anatomy versus tra characteristics1	18 18 <u>ce</u> 19
74 lockwise 75 <u>reverse</u> 75	13.1 Tube position	18 18 <u>ce</u> 19 20
74 lockwise 75 <u>reverse</u> 75 <u>reverse</u>	13.1 Tube position	18 18 <u>ce</u> 19 20 22
74 lockwise 75 reverse reverse 75	13.1 Tube position 1 13.1.1 Summary of EM interpretation: 1 13.1.2 Anatomy versus tra characteristics 1 13.1.3 Midline deviation 13.1.4 Differentiate lung from GI traces 13.1.5 GI flexures	18 18 <u>ce</u> 19 20 22 23
74 lockwise 75 reverse 75 reverse 76 76	13.1 Tube position	18 <u>ce</u> 19 20 22 23 26
74 lockwise 75 reverse 75 reverse 76 76 76	13.1 Tube position 1 13.1.1 Summary of EM interpretation: 1 13.1.2 Anatomy versus tra characteristics 1 13.1.3 Midline deviation 13.1.4 Differentiate lung from GI traces 13.1.5 GI flexures 13.1.6 EM artefacts: Confused traces 13.2 Anatomy in detail	18 18 19 20 22 23 26 27
74 lockwise 75 reverse 75 reverse 76 76 77 77	13.1 Tube position 1 13.1.1 Summary of EM interpretation: 1 13.1.2 Anatomy versus tra characteristics 1 13.1.3 Midline deviation 13.1.4 Differentiate lung from GI traces 13.1.5 GI flexures 13.1.6 EM artefacts: Confused traces 13.2 Anatomy in detail 13.2.1 Nose, upper oesophagus & trach	18 19 20 22 23 26 27 ea
74 lockwise 75 reverse 75 reverse 76 76 76 77 77 78	13.1 Tube position 1 13.1.1 Summary of EM interpretation: 1 13.1.2 Anatomy versus tra characteristics 1 13.1.3 Midline deviation 1 13.1.4 Differentiate lung from GI traces .1 13.1.5 GI flexures 1 13.1.6 EM artefacts: Confused traces 1 13.2 Anatomy in detail	18 18 19 20 22 23 26 27 26 27
74 lockwise 75 reverse 75 reverse 76 76 76 77 77 77 superior	13.1 Tube position	18 18 19 20 22 23 26 27 28
74 lockwise 75 reverse 75 reverse 76 76 76 77 77 78 superior 78	13.1 Tube position 1 13.1.1 Summary of EM interpretation: .1 13.1.2 Anatomy versus tra characteristics .1 13.1.3 Midline deviation .1 13.1.4 Differentiate lung from GI traces .1 13.1.5 GI flexures .1 13.1.6 EM artefacts: Confused traces .1 13.2 Anatomy in detail .1 13.2.1 Nose, upper oesophagus & trach .1 13.2.2 Lung .1 13.2.3 Oesophagus .1	18 18 20 22 23 26 27 28 27 28 29
74 lockwise 75 reverse 75 reverse 76 76 76 77 77 78 superior 78 superior 78	13.1 Tube position 1 13.1.1 Summary of EM interpretation: .1 13.1.2 Anatomy versus tra characteristics .1 13.1.3 Midline deviation .1 13.1.4 Differentiate lung from GI traces .1 13.1.5 GI flexures .1 13.1.6 EM artefacts: Confused traces .1 13.2 Anatomy in detail .1 13.2.1 Nose, upper oesophagus & trach .1 13.2.2 Lung .1 13.2.3 Oesophagus .1 13.2.4 Gastric flexures .1	18 18 20 22 23 26 27 28 27 28 29 30
74 lockwise 75 reverse 75 reverse 76 76 76 76 77 77 78 superior 78 superior 78	13.1 Tube position 1 13.1.1 Summary of EM interpretation: 1 13.1.2 Anatomy versus tra characteristics 1 13.1.3 Midline deviation 1 13.1.4 Differentiate lung from GI traces .1 13.1.5 GI flexures 1 13.1.6 EM artefacts: Confused traces 1 13.2.1 Nose, upper oesophagus & trach 1 13.2.2 Lung 1 13.2.3 Oesophagus 1 13.2.4 Gastric flexures 1 13.2.4.1 'Easy' placement 1	18 18 20 22 23 26 27 28 27 28 29 30 30
74 <u>lockwise</u> 75 <u>reverse</u> 75 <u>reverse</u> 76 76 76 77 77 78 <u>superior</u> 78 <u>superior</u> 78 <u>superior</u> 	13.1 Tube position 1 13.1.1 Summary of EM interpretation: .1 13.1.2 Anatomy versus tra characteristics .1 .1.1 .1.2 Anatomy versus tra characteristics .1 .1.3 Midline deviation .1 .1.3 .1.3 Midline deviation .1 13.1.3 Midline deviation .1 .1.3 .1.4 Differentiate lung from GI traces .1 13.1.4 Differentiate lung from GI traces .1 .1.3 .1.5 GI flexures .1 13.1.5 GI flexures .1 .1.1 .1.1 .1.1 .1.1 .1.1 13.2 Anatomy in detail .1 .1 .1.2 .1.1	18 18 19 20 22 23 26 27 28 29 30 30 31
74 lockwise 75 reverse 75 reverse 76 76 76 76 77 77 78 superior 78 superior 	13.1 Tube position 1 13.1.1 Summary of EM interpretation: 1 13.1.2 Anatomy versus tra characteristics 1 13.1.3 Midline deviation 1 13.1.3 Midline deviation 1 1 13.1.4 Differentiate lung from GI traces 1 13.1.4 Differentiate lung from GI traces 1 1 1.5 GI flexures 1 13.1.5 GI flexures 1 1.6 EM artefacts: Confused traces 1 13.2.6 Anatomy in detail 1 1 1.3.2.1 Nose, upper oesophagus & trach 13.2.1 Nose, upper oesophagus 1 1.3.2.3 Oesophagus 1 13.2.4 Gastric flexures 1 1.3.2.4.1 Teasy' placement 1 13.2.4.1 'Easy' placement 1 1.3.2.5 Duodenal flexures 1	18 19 20 22 23 26 27 28 29 30 31 32
74 lockwise 75 reverse 75 reverse 76 76 76 77 77 78 superior 78 superior 78 	13.1 Tube position 1 13.1.1 Summary of EM interpretation: .1 13.1.2 Anatomy versus tra characteristics .1 .1.1 .1.2 Anatomy versus tra characteristics .1 .1.3 Midline deviation .1 .1.1 .1.3 .1.1	18 19 20 22 23 26 27 27 29 30 31 32 33
74 lockwise 75 reverse 75 reverse 76 76 76 77 77 77 78 superior 78 superior 78 	13.1 Tube position 1 13.1.1 Summary of EM interpretation: 1 13.1.2 Anatomy versus tra characteristics 1 13.1.3 Midline deviation 1 13.1.4 Differentiate lung from GI traces 1 13.1.5 GI flexures 1 13.1.6 EM artefacts: Confused traces 1 13.2 Anatomy in detail 1 13.2.1 Nose, upper oesophagus & trach 1 13.2.2 Lung 1 13.2.3 Oesophagus 1 13.2.4 Gastric flexures 1 13.2.4.1 'Easy' placement 1 13.2.4.2 'Difficult' placement 1 13.2.5 Duodenal flexures 1 13.3.1 ENvue artefacts 1	18 18 19 20 22 23 26 27 29 30 31 32 33 33
74 lockwise 75 reverse 75 reverse 76 76 76 77 77 78 superior 78 superior 78 	13.1 Tube position 1 13.1.1 Summary of EM interpretation: .1 13.1.2 Anatomy versus tra characteristics .1 .1.1 .1.2 Anatomy versus tra characteristics .1 .1.3 Midline deviation .1 .1.1 .1.3 .1.1	18 18 19 20 22 23 26 27 29 30 31 32 33 33

alignment134	pneumonia (VAP)165
13.3.3 Patient prone142	15.2.4.1 <u>Tube placement depth</u> 165
14 Secure & document position143	15.2.4.2 Gastro-oesophageal reflux and
14.1 <u>Securement</u> 143	bedrest elevation (BRE)166
14.2 Documenting tube position145	15.2.4.3 Testing for aspiration
15 Appendices146	15.2.4.4 Acidification168
15.1 Background146	15.2.5 Gastric residual volumes (GRVs)
15.1.1 Routes of nutritional support146	and pH checks168
15.1.2 Rationale for NI feeding149	15.2.5.1 Effect of position168
15.1.2.1 DGE: Cause and effect149	15.2.5.2 GRV threshold170
15.1.2.2 Feed retention	15.2.6 Insertion techniques to enter the
15.1.3 Efficacy: Jejunal vs duodenal vs	oesophagus171
gastric feeding	15.3 Feeding, records and maintenance
15.1.4 Distance nose to stomach153	172
15.2 Tube misplacements and	15.3.1 <u>Choice of feed</u> 172
complications155	15.3.2 Enteral tube confirmation record &
15.2.1 Blind tube placement	<u>care plan</u> 173
15.2.2 Implications for safety158	15.3.3 Flushing and medicines, blockage
15.2.3 Guided tube misplacement159	and kinking173
15.2.3.1 Cortrak	15.3.3.1 Flushing173
15.2.3.2 IRIS	15.3.3.2 Blockage and kinking174
15.2.4 Reducing ventilator-associated	16 <u>References</u> 176

1 How to use

Table 1.1: Overview of use.

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

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

2 Glossary

Table 2.1: Glossary of terms.

ССК	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

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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

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4.1 Efficacy

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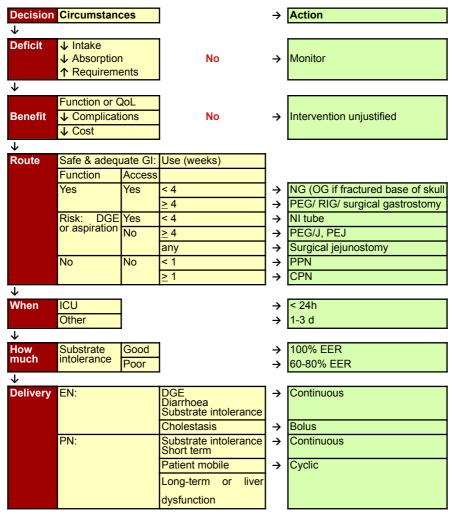
When oral intake fails to meet nutrition requirements, about 6% of hospital patients require invasive enteral nutrition (EN) [Elia, 2015]. EN is at least as effective as parenteral nutrition (PN) when the gut is accessible and has adequate function, but reduces infection risk and cost [CCN 1.0, 2021].

4.2 Choice of route

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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

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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

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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 \geq 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 followup 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

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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) endof-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 CO₂, pH and X-ray

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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 \leq 5.5 only gives an overall accuracy of 76-77%; 66% of oesophageal samples were \leq 5.5 [Rowat et al, 2018]. Conversely, while a pH threshold of \leq 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 rechecking 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 CO₂ 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 CO₂ 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

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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

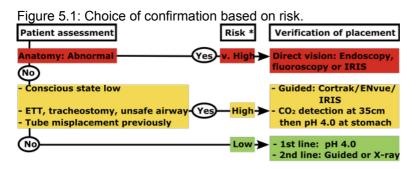
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This involves interpreting tube position from an EM trace. EM-guided placement warned of initial lung misplacement in ~5% and pre-empted trauma in most. In addition, confirming tube position by EM trace instead of X-ray would reduce the delay feeding 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

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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.



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

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

Attribute		Con	firm	atio	n of	ana	tom	ical I	poin	t			Logi	stics	
Technique		N o s e	P h a r y n x	R T r a c h e a	T L n g	O e s o p h a g u	S t o m a c h	 [1	In Duod	enur 3	Jejunu m	B d s i d	C h a p	Q u i c k	S i p l e
U n g u i d e d	Air insufflation CO2 detection Lipase Magnet_external pH ≤4.0 or 5.0 or 5.5 Ultrasound Vacuum test X-ray: 40cm end of procedure			3			2								
G u i d e d	-				4										

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 EMguidance (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. CO₂ 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 CO2 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 CO₂ from GI bacterial fermentation giving false positive readings, respectively [Mordiffi et al, 2016]. Until larger studies become available CO₂ 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 CO₂ 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 $pH \pm CO_2$ detection $\pm X$ 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 CO₂ 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

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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 \leq 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].

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