Integrated real-time imaging system, ‘IRIS’, Kangaroo feeding tube: a guide to placement and image interpretation

Stephen Taylor, Kaylee Sayer, Danielle Milne, Jules Brown, Zeino Zeino

ABSTRACT
Background Lung complications occur in 0.5% of the millions of blind tube placements. This represents a major health burden. Use of a Kangaroo feeding tubes with an ‘integrated real-time imaging system’ (‘IRIS’ tube) may pre-empt such complications. We aimed to produce a preliminary operator guide to IRIS tube placement and interpretation of position.

Methods In a single centre, IRIS tubes were prospectively placed in intensive care unit patients. Characteristics of tube placement and visualised anatomy were recorded in each organ to produce a guide.

Results Of 45 patients having one tube placement, 3 were aborted due to refusal (n=1) or inability to enter the oesophagus (n=2). Of 43 tubes placed beyond 30 cm, 12 (28%) initially entered the respiratory tract but all were withdrawn before reaching the main carina. We identified anatomical markers for the nasal or oral cavity (97.8%), respiratory tract (100%), oesophagus (97.6%), stomach (100%) and intestine (100%). Organ differentiation was possible in 100%: trachea-oesophagus, oesophagus-stomach and stomach-intestine. Gastric tube position was confirmed by aspiration of fluid with a pH ≤ 4.0 and/or X-ray. Trauma was avoided in 13.6% by identifying that the tube remained in the nasal lumen in the presence of a base of skull fracture (n=3) and in the stomach in the presence of recently bleeding polyps or mucosa (n=3). A systematic guide was produced from records of tube placement and interpretation of anatomical images.

Conclusion By permitting real-time confirmation of tube position, direct vision may reduce risk of lung complications. The preliminary operator guide requires validation in larger studies.

INTRODUCTION
An estimated 27 million nasogastric or orogastric and intestinal tubes are placed each year.1 End-of-procedure aspiration of fluid to check for a pH ≤ 5.5 or X-ray2 cannot prevent 0.5%, resulting in pneumothorax or pneumonia due to misplacement per se, despite tube removal before use.3 CO2 detection or X-ray can be done at a 30 cm or 40 cm tube depth, respectively. However, CO2 detection can fail4 and cannot warn of oesophageal misplacement, whereas a further X-ray adds delay to tube use.

In contrast, guided placement can potentially detect misplacement in real-time before damage is done, permit repositioning of the tube and confirming the tube position without delay. Fluoroscopy and endoscopy facilitate accurate placement but use is precluded by expense, risks from off-ward transport, invasive procedure, irradiation and delays to placement.5 Conversely, bedside ultrasound, electromagnet (EM) or direct vision-guided placement offers a solution.6–8 All require expert training but expertise in ultrasound may be the hardest to attain and requires a second operator. EM placement has a lower rate of undetected lung misplacement than blind placement in high-use centres (0.006% vs 0.01%), but it is higher than blind placement in low-use centres (0.35% vs 0.01%).3–12 Most errors were due to misinterpretation of the EM traces13–14 through insufficient training.15 In addition, interpretation based on manufacturer guidance may be inaccurate in about 25%–30% of cases.11–16 Finally, guided tube placement has been achieved by direct vision,6–7 However, there are

Summary box
What is already known about this subject?
► Tube misplacement is common but bedside guided tube placement can differentiate respiratory from gastrointestinal tract anatomy.

What are the new findings?
► From observations we developed a systematic, evidence-based operator guide to integrated real-time imaging system tube placement and identification of tube position using objective anatomical criteria.

How might it impact on clinical practice in the foreseeable future?
► The guide may facilitate operator training in use of a tube that permits early warning of tube misplacement to pre-empt complications.
Figure 1  IRIS console, cable link and tube. IRIS, integrated real-time imaging system.

insufficient data to determine safety and no evidence-based guide on which to train operators.

We documented a preliminary guide to integrated real-time imaging system (IRIS) tube placement from anatomical structures that were reliably visible.

METHODS
Preparation
Cardinal Health trained author ST for 2 hours in the use of IRIS equipment, including during a tube placement. In addition, ST studied both Cardinal’s and online written and video training materials regarding IRIS and recognition of endoscopic images for approximately 8 hours. This included feedback on the accuracy of ST’s image interpretation by ZZ, a consultant gastroenterologist (endoscopist). To date, these materials do not provide a new operator with an adequately evidence based, systematic or comprehensive guide to IRIS tube placement.

Equipment and tube placement
An IRIS tube incorporates a 3 mm camera within the tip to display an endoscope-like image via a cable link on a console (figure 1). Anatomical features can be identified in real time.

The external tube tip lubricant was activated in warm water before insertion via the nostril or mouth. A head tilt chin-down, jaw thrust manoeuvre or laryngoscopy were used, where necessary and safe to do so, to enable the tube to enter the oesophagus. Air insufflation and 5 cm tube retractions to clear the camera lens of mucus and slow tube advancement permitted recognition of anatomical features used to guide placement. Images were saved at noted tube lengths. When possible, nasogastric (NG) tubes were advanced into duodenum part 1 then withdrawn into the stomach to maximise recognition of anatomy and chance of aspirating fluid for a pH test.

Patients
The tube was placed in a convenience sample of 45 adults (≥18 years) who required gastric or intestinal tube placement. This includes the unpublished anatomical data of 15 patients from a previous study.18 Exclusion was based on contraindication to enteral tube placement: Moribund, surgery or trauma to the nose or upper gastrointestinal (GI) tract contraindicating safe tube placement and patient consent refusal. A neurosurgeon and intensive care unit (ICU) consultant assessed the risk: benefit of nasal versus oral tube passage in the presence of a base of skull fracture, where use of direct vision may reduce risk.

Aim, objectives, data collection and analysis
The aim was to produce a preliminary guide to IRIS tube placement based on the objectives of describing: (1) problems and solutions to placement and (2) anatomy from captured images. These images were interpreted by a non-endoscopist (ST, research dietitian) and compared against interpretation by ZZ (consultant gastroenterologist) and standard pH (gastric threshold ≤4.0) or X-ray (JB—consultant intensivist) confirmation of tube position.19 Patient demographics, clinical status and adverse events were recorded. Analysis was only intended to be descriptive but will inform future studies on how operators can best use the IRIS system.

Statistics
Parameters were tested for normal distribution using the Shapiro-Wilk test using ‘R Studio V.1.4’. Because several parameters were not normally distributed, descriptive statistics are presented as median (IQR) and percentage (%). Wilcoxon ranksum and Fishers exact tests were used to test continuous and binary variables, respectively. A p value <0.05 was considered significant.

RESULTS
Baseline characteristics
One tube was placed by ST (n=44) or KS (n=1) in each of 45 patients (table 1). Most were medical patients, mechanically ventilated via an artificial airway and sedated.

Tube and position
Placement was done on a median of day 2 (IQR: 2–5), via the nose (n=43) or mouth (n=2) using 12 Fr, 109 cm (n=38) or 10 Fr, 140 cm (n=7) tubes. Twelve tubes initially entered the respiratory tract (28%). Four tubes were removed when they reached the nostril (n=1) due to patient refusal, pharynx (n=2) due to inability to enter the oesophagus and upper stomach due to failure to achieve intestinal placement (n=1). Of 41 tubes left in situ, 30 remained in the upper stomach and 11 were pulled back from duodenum part 1 into the lower stomach. Gastric fluid was aspirated from 33 of 41 tubes (78%) and had a pH of ≤4.0 in 22 (54%). Of the 33 aspirates, the use of proton-pump inhibitors (PPI) led to a higher gastric pH (6 (5.75–6.5)) compared with non-PPI use (2.5 [2–4], p<0.0001). Three tubes were inadvertently removed preconfirmation. Of the 38 used for feeding, all were confirmed to be within the GI tract by a

pH of ≤4.0 and/or an X-ray (84%). X-rayed tubes were at least in the upper stomach (63%), lower stomach (34%) or duodenum part 1 (3%). However, 41% of tubes will have been more distal because the tip was below the X-ray frame.

Ease of placement
Placement of the large tube tip via the nose was relatively easy, but 68% of placements were difficult at the pharyngeal level, with most requiring a head tilt (86.7%) and/or jaw thrust (46.7%) manoeuvre to enter the oesophagus (Appendix: Section 3.1). Also because we did not water activate the tube’s internal lubricant, to ensure accurate pH assessment, manoeuvring the guide-wire and tube only succeeded in reaching the lower stomach and intestine in 34% of attempts.

Anatomical identification (figure 2: detail in online supplemental appendix: section 3.2 and 4)
Identification of the oral or nostril cavities or oesophageal lumen ( collapsible, fluted, pulsing mucosa) was possible in >97%, excepting one blood-filled nostril (online supplemental appendix 4.1) and one mucous-filled oesophagus (online supplemental appendix 4.4). However, we identified 100% of placements into respiratory tract (bronchi, carina, tracheal rings) (online supplemental appendix 4.3), stomach ( cavernous space, folds/ rugae, freckle patterned mucosa) (online supplemental appendix 4.5) or intestine (villi) (online supplemental appendix 4.6). Differentiation was possible in 100% between trachea-oesophagus, oesophagus-stomach and stomach-intestine.

Advantages and problems
There were specific advantages to IRIS tube guidance. The respiratory tract was avoided by manoeuvring the tube away from the identified airway in 6.8%. Tracheal placement was identified in 28%; one tube was removed and all the remainder repositioned in the GI tract. In addition, trauma was avoided in 13.6% by identifying that the tube remained in the nasal lumen in the presence of a base of skull fracture (n=3) and in the gastric lumen in the presence of recently bleeding polyps or mucosa (n=3).

In two patients, the tube luer became damaged and there was signal failure in one tube, resulting in removal,

<table>
<thead>
<tr>
<th>Table 1 Patient demography, clinical state</th>
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<tbody>
<tr>
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</tr>
<tr>
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<td>Age</td>
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<td>BMI</td>
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<tr>
<td>Height</td>
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<tr>
<td>Weight</td>
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<tr>
<td>APACHE 2 Score</td>
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<tr>
<td>Disease</td>
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<tr>
<td></td>
</tr>
<tr>
<td>Consciousness</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Artificial airway</td>
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</table>

BMI, body mass index; ETT, endotracheal tube.
and one connector cable. The presence of an artificial airway in 9 (endotracheal tube; ETT, n=8; tracheostomy, n=1) of 12 tracheal misplacements was not significantly more than in those without an artificial airway (32% vs 20%, p=0.5). However, an artificial airway was associated with a trend to greater difficulty entering the oesophagus (76% vs 53%, p=0.17). So, though a similar proportion of patients with an artificial airway needed a head tilt manoeuvre (62% vs 53%, p=0.74), more of these patients needed a jaw thrust manoeuvre (48% vs 0%, p=0.001) and could not be done in one of two patients whose placement failed due to spinal injury. The common requirement for a head tilt or jaw thrust may preclude use of an IRIS tube, where these manoeuvres cannot be performed. Swallowing was requested in those patients without artificial airways and conscious; this may reduce risk of tracheal placement. IRIS tube tip size (5.6 mm diameter) and its curvature pointing towards the epiglottis when it reaches the pharynx may predispose to tracheal placement. In later placements, the operator straightened the guide wire, while within the tube, to reduce the curvature, but numbers were insufficient to analyse the effect. There were no placement-related adverse events, but one patient who was having bradycardic episodes before and after tube placement experienced reversible bradycardia during the initial stage of placement.

DISCUSSION
Main findings

Direct vision using the IRIS tube facilitated placement by enabling recognition of the nasal or oral cavity (97.8%), respiratory tract (100%), oesophagus (97.6%), stomach (100%) and intestine (100%) and differentiated 100% of the trachea-oesophagus, oesophagustrachomach and stomach-intestine. Importantly, respiratory placement was detected pre-main carina, thus reducing risk of trauma or bacterial contamination. By comparison, blind and EM-guided placement is associated with the tube tip being a median or 18 cm (IQR: 16–23) and 12 cm (IQR: 9–15) beyond the carina, respectively. Blind placement is associated with a ~0.5% risk of pneumothorax or pneumonia.3 20 21 In addition, because IRIS has the potential to confirm position in real time, this would obviate the 2.1-hour delay for X-ray or, where the tube is misplaced would permit immediate repositioning rather than a 4.8-hour delay using X-ray.18

It was found important to advance slowly, sometimes with air insufflation to short withdrawal to permit identification of anatomy, particularly when differentiating the oesophagus from trachea, both of which can be mucous filled above the ETT or tracheostomy cuff. A head tilt and/or jaw thrust manoeuvre was commonly needed for the tube to enter the oesophagus. The large tube tip and possibly tube curvature appear to result in more tubes initially deflecting into the trachea (28%), similar to the 20–35% found in previous studies,8 17 but more than the 11.4% of smaller-tipped EM-guided tubes.18 However, IRIS tubes detect misplacement precarina and usually without inducing coughing. Conversely, blind and EM tube placements may enter more deeply into the lung and induce coughing that leads the tube being repositioned before the X-ray or EM trace can evidence respiratory placement. The latter methods may, therefore, underestimate misplacement but fail to prevent pneumothorax or pneumonia.19

Guidance for IRIS placement

From the findings and images captured during placement, a preliminary operator guide was written (online supplemental appendix section 4).

Nose, pharynx and respiratory tract

IRIS permits the operator to identify that the tube was safely within either the nose or oral cavity. Pharyngeal mucosa is pale and, close-up, contains blood vessels that Blanch when impacted. A head tilt and/or jaw thrust manoeuvre may then be needed to facilitate tube advancement into the oesophagus. To allow early differentiation of the oesophagus from trachea, 10–30 mL of air insufflation ±5 cm tube retraction cleared the lens and gave a good view of the oesophagus that is expected to collapse, have flutted walls and pulse. Identification of blood vessels and the z-line was less common. Mucus above an ETT or tracheostomy cuff usually obscured the tracheal wall’s cartilaginous rings and the cuff that is a translucent grey and may be bubble filled. However, beyond the cuff the trachea, carina and bronchi were clearly identifiable and the tube was carefully withdrawn.

Stomach to duodenum part 1

On gastric entry, air insufflation and tube insertion or retraction aided visualisation of the cavernous structure and rugae or folds at a distance or, close up, a freckle-patterned mucosa. Air insufflation and use of a flexible tube tip may have helped advancement, but use of any length of a flexible tip was difficult; use of a non-water-activated lubricant would facilitate guide wire manipulation and tube manoeuvres using a flexible tip. This limitation and possibly the long, stiff tube tip may explain the low success rate in reaching the lower stomach. However, once the tube reached the lower stomach, sometimes with the aid of further air insufflation, advancement to duodenum part 1 was always successful. The pylorus was mostly only observed on slow tube withdrawal back into the stomach, but duodenal villi were easily visible. Finally, there was some uncertainty between gastric and intestinal placement on two images, similar to previous findings.8

Limitations, recommendations and conclusion

This was a small, single centre, ICU study using operators already experienced in other guided tube placement techniques and only one non-gastroenterologist and one gastroenterologist interpreting images; therefore, generalisability may be limited. However, it was possible for a non-endoscopist to accurately identify major features of
the respiratory and alimentary tracts. These are described to
guide future users. To improve use of the IRIS tube, we
think that its tip must be reduced in diameter and length
and the angle removed. This would facilitate passage
through the nose, entry into the oesophagus and ability to
traverse GI flexures. The guide wire needs non-water-ac-
vorianted lubricant to both permit subsequent pH checks and
case withdrawal and replacement around bends, enabling
the tube to collapse into the lower stomach or traverse
flexures during advancement. The IRIS tube makes real-
time guided tube placement possible. This should reduce
the risk of lung damage during accidental respiratory
placement and its use in non-ventilated patients suggests
that non-ICU use is applicable. Improvements to the tube
should increase placement success rates. In the future,
training material should include video of external place-
ment alongside internal images and a photographic bank
to extend operators’ training experience.

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drafted or provided critical revision of the article, provided final approval of
the version submitted for publication (all authors).

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a clinical effectiveness study (CE10413) and therefore not requiring formal ethics
approval.

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protocol and electromagnetic technology eliminate feeding tube
Introduction

This is a preliminary guide based on the only study to systematically describe how to identify anatomy and thereby guide placement [Taylor et al, 2021]. This included 45 patients from one institution. It will undergo validation in future studies.

1.1 Aim

To enable IRIS tube operators to interpret screen image and thereby facilitate safe guided-tube placement.

1.2 Objectives

1.2.1 Image interpretation

Describe the sequence, characteristics and display images of specific anatomical points.

1.2.2 Tube and placement

Detail problems and solutions likely to be met during placement.

2 Guidance

This guidance is for adults (>18 years). Each anatomical area is described beside referenced images. Note that 'tube depth' per se, cannot be taken to indicate a specific anatomy due to differences in patient size, coiling within the GI tract and the possibility of being in the respiratory.

Supplemental material

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3 Background evidence

3.1 Ease of placement

Despite the large tube tip diameter, advancement through the nose (or mouth) was relatively easy. The patient who refused placement when the tip was 2cm into the nostril declined other treatments including pain relief. Lignocaine gel was applied pre-emptively to the noses of 5 conscious patients, to reduce discomfort, but it may also have reduced nasal swelling and facilitated tube passage (Table 4). However, 68% of placements were difficult at the pharyngeal level, predominantly in those with an artificial airway, most of whom required a head tilt or jaw thrust manoeuvre for the tube to enter the oesophagus. Two tubes could not be advanced beyond the pharynx, including one in which laryngoscopic placement failed and eventually required an airway to be directed into the oesophagus, through which a finer tube was placed. The IRIS tube tip appears to impact the pharyngeal mucosa and deflect towards the trachea.

Table 4 Techniques used during placement.

<table>
<thead>
<tr>
<th>Area</th>
<th>Difficult placement</th>
<th>Technique used to overcome difficulty</th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>N</td>
<td>%</td>
</tr>
<tr>
<td>Nose</td>
<td>2</td>
<td>Lignocaine*</td>
<td>2</td>
<td>100</td>
</tr>
<tr>
<td>Pharynx</td>
<td>30</td>
<td>Head tilt</td>
<td>26</td>
<td>86.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jaw thrust</td>
<td>14</td>
<td>46.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Laryngoscopy</td>
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<td>3.3</td>
</tr>
<tr>
<td>Stomach_upper*</td>
<td>27</td>
<td>Air insufflation</td>
<td>20</td>
<td>74.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10cm flexible tip</td>
<td>20</td>
<td>74.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≥20cm flexible tip</td>
<td>5</td>
<td>18.5</td>
</tr>
<tr>
<td>Stomach_lower*</td>
<td>3</td>
<td>Air insufflation</td>
<td>3</td>
<td>100</td>
</tr>
</tbody>
</table>

*Given pre-emptively in 5 patients to reduce discomfort; difficulty in only 2.

For clinical reasons of instability or comfort no attempt was made to advance some tubes beyond the upper stomach in 15 patients. In the remainder it was attempted to reach duodenum part-1, to help confirmation of tube position. The tube was then withdrawn and left in the lower stomach which, compared to upper stomach, reduces risk of the tube or feed regurgitating into the oesophagus. When attempting to reach duodenum part-1, 34% succeeded. However, where there was a difficulty moving from upper to lower stomach only 22% succeeded. We used air insufflation and withdrawing the guide-wire 10cm to create a flexible tip in 74% of attempts to advance into the lower stomach, but half the attempts failed. Use of a 20-30cm flexible tip was only used in 18.5% of attempts but was abandoned because the tube’s internal lubricant had not been activated and therefore the guide-wire could not be re-inserted. We purposely avoided water flush-activation of the lubricant because of national guidance [NHSI, 2016]\textsuperscript{2}. Guide-wires were wiped dry on removal and stored in their labelled original pack.
3.2 Anatomical identification

Identification of nasal or oral cavities and oesophagus (collapsible, fluted, pulsing mucosa) was possible in >97%. However, it was possible to identify 100% of placements into respiratory tract (bronchi, carina, tracheal rings), stomach (cavernous space, folds/rugae, freckle patterned mucosa) or intestine (villi). Differentiation was possible in 100% between respiratory trace-oesophagus, oesophagus-stomach, stomach-intestine.

Identification was done at placement by XX (dietitian) and confirmed by YY (gastroenterologist) either at placement or from a recorded screen image. Differentiation between respiratory versus GI tract and oesophagus versus stomach were always possible (Table 2). However, when examining four views of the dietitian’s identification the gastroenterologist thought: a) A ‘retroflex view of the pylorus’ was probably the superior flexure; b) An ‘antral view’ may have been duodenum part-2, although the tube had been retracted and should not have been long enough to reach the duodenum; c) When uncertain of tube position leading to withdrawal, the gastroenterologist glimpsed tracheal cartilage not initially recognised by the dietitian and d) The dietitian tentatively identified villi partially obscured by blood; the gastroenterologist confirmed this.

Except for one patient whose nostrils were blood filled prior to tube placement, the nasal or oral cavity was visible in all patients, including three with base of skull fracture. Mucus prevented visualisation of the pharyngeal mucosa in 3 patients and the airway (epiglottis, ETT) and early part of the trachea in most patients. However, when entering the respiratory tract, except when the ETT cuff was spotted first, the carina and bronchi were always observed in the distance, usually with the tracheal wall visible close to the tip. All respiratory misplacements were detected and the tube removed before reaching the main carina.

Table 2 Anatomical identification.

<table>
<thead>
<tr>
<th>Area</th>
<th>n*</th>
<th>Cases identified: Characteristic</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nostril/ mouth</td>
<td>45</td>
<td>Cavity</td>
<td>44</td>
<td>97.8</td>
</tr>
<tr>
<td>Pharynx</td>
<td>44</td>
<td>Blood vessels blanch; pale mucosa</td>
<td>41</td>
<td>93.2</td>
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<td>43</td>
<td>Endotracheal tube</td>
<td>3</td>
<td>7</td>
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<tr>
<td></td>
<td></td>
<td>Epiglottis</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Respiratory tract</td>
<td>12</td>
<td>All</td>
<td>12</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Carina and bronchi</td>
<td>10</td>
<td>83.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ETT cuff</td>
<td>3</td>
<td>25</td>
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<tr>
<td></td>
<td></td>
<td>Tracheal wall</td>
<td>9</td>
<td>75</td>
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<td>Oesophagus</td>
<td>42</td>
<td>All</td>
<td>41</td>
<td>97.6</td>
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<tr>
<td></td>
<td></td>
<td>Blood vessels</td>
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<td>14.3</td>
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<tr>
<td></td>
<td></td>
<td>Collapsible</td>
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</tr>
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<td>Fluted</td>
<td>31</td>
<td>78.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pulses</td>
<td>27</td>
<td>64.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Z-line</td>
<td>1</td>
<td>2.4</td>
</tr>
<tr>
<td>Stomach</td>
<td>42</td>
<td>All</td>
<td>42</td>
<td>100</td>
</tr>
</tbody>
</table>
Cavernous 41 97.6
Folds or rugae 39 92.9
Freckle pattern mucosa 32 76.2

<table>
<thead>
<tr>
<th>Intestine</th>
<th>11</th>
<th>All</th>
<th>11</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pylorus</td>
<td>5</td>
<td></td>
<td></td>
<td>45.5</td>
</tr>
<tr>
<td>Villi</td>
<td>11</td>
<td></td>
<td></td>
<td>100</td>
</tr>
</tbody>
</table>

*Tubes reaching point or in a parallel tract.

Except for one mucus-filled oesophagus, all were recognisable, mostly by the collapsible and/or fluted and/or pulsing appearance. Blood vessels were harder to identify and the Z-line was seen only in one patient by the gastroenterologist. A short (≤5cm) tube withdrawal ± 10-30mL air insufflation was usually employed to clear the lens of mucus and open the lumen. The stomach was always identifiable by these characteristics: Cavernous space > folds or rugae > gastric pits. Of the 11 tubes reaching the duodenum, the pylorus was seen in 46%, but almost always on withdrawal because entry occurred too quickly. Villi were always seen though in one case villi were only tentatively identified by the dietitian because of blood covered the mucosa.

Differentiation between the respiratory tract and oesophagus and oesophagus and stomach were always possible. However, there were 2 cases of uncertainty regarding differentiation between the stomach and intestine (Table 3).

Table 3 Accuracy of anatomical identification.

<table>
<thead>
<tr>
<th>Confirmation</th>
<th>Anatomy</th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Differentiation</td>
<td>Respiratory tract vs GI</td>
<td>11</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Oesophagus vs stomach</td>
<td>42</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Stomach vs intestine</td>
<td>11*</td>
<td>100*</td>
</tr>
</tbody>
</table>

* 1 was a tentative identification by XX because it was obscured by blood; confirmed by the gastroenterologist (YY). Another was thought by the gastroenterologist to be duodenum part-2, not gastric, but the tube had been retracted making intestinal placement unlikely.
4 Tube placement and image interpretation
4.1 Nose and mouth

Summary
As the tube is advanced, it should remain within the oral or nasal lumen and not cause trauma. Steady pressure and a change of direction may be needed to move through the nose and, in awake patient, ‘humming’ facilitates movement from nose to pharynx.

<table>
<thead>
<tr>
<th>Comment</th>
<th>Depth</th>
<th>Images</th>
</tr>
</thead>
<tbody>
<tr>
<td>The tube should be inserted 1cm up into the nostril then raised to an angle of 90° to the face (as shown). This directs the tube along the floor of the nostril, the widest and least sensitive channel. In an oral approach, direct the tube down the centre, taking care to prevent buckling in the large orifice. The proximal nostril will contain hairs. Protrusions of nasal concha may be seen and cause obstruction [1-3]. Mucus is present throughout [4]. Rotate the tube or change its angle and gently attempt to advance. The tube should be seen to remain in an, often darkened, orifice. Impaction against mucosa [5], ‘red out’ or new blood [6] require tube retraction and re-appraisal of the placement. In cases of high patient sensitivity, nasal obstruction or bleeding, topical lignocaine (lidocaine) gel, 'sniffed' into the nostril, will reduce swelling, discomfort and bleeding risk.</td>
<td>0-10cm</td>
<td><img src="1.png" alt="Image 1" /> <img src="2.png" alt="Image 2" /> <img src="3.png" alt="Image 3" /> <img src="4.png" alt="Image 4" /> <img src="5.png" alt="Image 5" /> <img src="6.png" alt="Image 6" /></td>
</tr>
</tbody>
</table>
### 4.2 Pharynx, epiglottis and endotracheal tube (ETT)

**Summary**

The advancing tube commonly impacts and deflects off the posterior pharynx. Visualisation of the epiglottis or an ETT warns that it may be moving towards the trachea. Placing the head in a 'chin-down' position, a jaw-thrust manoeuvre, active swallowing and a slow advance facilitate tube movement into the oesophagus.

<table>
<thead>
<tr>
<th>Comment</th>
<th>Depth</th>
<th>Images</th>
</tr>
</thead>
<tbody>
<tr>
<td>The lens often passes through mucus and sputum at the confluence of the nose and mouth before the pharynx becomes visible. Pharyngeal mucosa appears pale pink with obvious blood vessels close-up [1] but these are often blurred. [2-3]. Tubes often impact the mucosa before advancing into the oesophagus or trachea. Facilitate oesophageal placement, unless contraindicated, by tilting the head forward, chin down. A 'jaw thrust' is often more successful, because it moves the structures of the throat forward, making a channel for the tube to enter the oesophagus. In very difficult cases, in sedated patients, an anaesthetist may place the tube into the oesophagus using a laryngoscope. An endotracheal tube (ETT) is translucent grey with black numerals [4-5]. The epiglottis appears as a 'tongue' anteriorly, opening to the glottis, with the oesophagus collapsed, barely visible posteriorly [6]. Generally, if the ETT or epiglottis are visible the tube will need to be re-orientated, otherwise it will enter the trachea. This may necessitate removing the guidewire and putting a 30° bend on it, 2-3cm from the tip. The guidewire is then re-inserted and rotated to move the tube tip away from the airway towards the oesophageal entrance. Visibility of a feeding tube already in situ and confirmed as GI is a path to follow.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10-25cm</td>
<td>Pale mucosa &amp; blood vessels close-up</td>
<td>ETT &amp; markings visible</td>
</tr>
<tr>
<td></td>
<td>Distant mucosa &amp; blood vessels out of focus</td>
<td>Epiglottis &amp; tracheal entrance</td>
</tr>
</tbody>
</table>
### 4.3 Respiratory tract

**Summary**

Tube entry into the trachea may be 'silent', not eliciting a cough, change in O2 saturation or a ventilator alarm. Visualisation of the vocal cords, ETT or tracheostomy cuff, cartilaginous tracheal rings, carina or bronchi should prompt immediate and careful tube withdrawal.

<table>
<thead>
<tr>
<th>Comment</th>
<th>Depth</th>
<th>Images</th>
</tr>
</thead>
<tbody>
<tr>
<td>During respiratory placement mucus, particularly that which collects above the cuff of an artificial airway, frequently blocks visibility. However, the ETT cuff may contain air bubbles [1], appear translucent [2] or grey-white [3]. Mucus may prevent visualisation of the cuff or respiratory anatomy when advancing between the ETT and the tracheal wall. But, beyond the cuff the respiratory tract is clearly visible:</td>
<td>&gt;25cm</td>
<td>[Diagram of respiratory tract]</td>
</tr>
<tr>
<td>■ Trachea: Rigid tube with cartilaginous rings [4].</td>
<td></td>
<td>![Image of trachea: Rigid tube with cartilaginous rings]</td>
</tr>
<tr>
<td>■ Main carina: Point of Left-Right bifurcation [6].</td>
<td></td>
<td>![Image of main carina: Point of Left-Right bifurcation]</td>
</tr>
<tr>
<td>■ Bronchi: Smaller rigid tubes, with sub-bronchi distally [5].</td>
<td></td>
<td>![Image of bronchi: Smaller rigid tubes]</td>
</tr>
<tr>
<td>If any of the above features are seen or there are clinical signs of respiratory placement, slowly withdraw the tube to the pharynx. Assess whether it is safe to retry.</td>
<td></td>
<td>![Image of trachea: Circular rings - Main carina]</td>
</tr>
</tbody>
</table>
### 4.4 Oesophagus

**Summary**

Entry into the oesophagus is commonly obscured by mucus. Once entered, it is recognisable by its collapsible, fluted, pulsing wall allowing an easy advance. A 10-30mL air insufflation clears the lens, sometimes with a 5cm tube withdrawal. Only perform the latter when at least 10cm into the oesophagus to avoid returning to the pharynx.

<table>
<thead>
<tr>
<th>Comment</th>
<th>Depth</th>
<th>Images</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mucus and the collapsed oesophageal walls usually obscure entry [1].</td>
<td>25-45 cm</td>
<td><img src="image1.png" alt="Image 1" /> <img src="image2.png" alt="Image 2" /> <img src="image3.png" alt="Image 3" /></td>
</tr>
<tr>
<td>Food or feed debris may be visible [2]. Poor focus or soot (burn) blur features [3-4].</td>
<td></td>
<td><img src="image4.png" alt="Image 4" /> <img src="image5.png" alt="Image 5" /> <img src="image6.png" alt="Image 6" /></td>
</tr>
<tr>
<td>When oesophagus is collapsed and/or the lens it may require a 10-30mL air insufflation ± 5cm tube retraction to open the view [5-6]. Avoid a long tube retraction that otherwise might pull the tube back into the pharynx, thus risk tracheal placement when re-advancing.</td>
<td></td>
<td><img src="image7.png" alt="Image 7" /> <img src="image8.png" alt="Image 8" /></td>
</tr>
<tr>
<td>It should be possible to view the collapsible, fluted, pulsing oesophageal wall [7-8]. Blood vessels and the Z-line are harder to observe.</td>
<td></td>
<td><img src="image9.png" alt="Image 9" /> <img src="image10.png" alt="Image 10" /></td>
</tr>
</tbody>
</table>
4.5 Stomach

Summary

Recognisable by the dark cavernous space, folds or rugae and, close-up, mucosal freckling. Failure of the tube to advance may require use of manoeuvres. Antral mucosa is smoother and paler and the pylorus may be briefly seen as an orifice before passing into duodenum part-1.

<table>
<thead>
<tr>
<th>Comment</th>
<th>Depth</th>
<th>Images</th>
</tr>
</thead>
<tbody>
<tr>
<td>The tube enters the stomach angled left and may quickly about the greater curvature. If necessary, retract the tube a short distance. The most common gastric identifiers are that it is a cavernous (large) space [1-2] with folds and rugae distant [3] close-up [4]. Sometimes there is a cobbled or paved appearance [5-6]. Pulsing and peristaltic movements may be visible.</td>
<td>45-75 cm</td>
<td><img src="image1.png" alt="Image 1" /> <img src="image2.png" alt="Image 2" /> <img src="image3.png" alt="Image 3" /> <img src="image4.png" alt="Image 4" /></td>
</tr>
<tr>
<td>Close to the mucosa gastric pits may be visible [7-8]. Bile or feed or food debris may obscure vision [9-10].</td>
<td></td>
<td><img src="image5.png" alt="Image 5" /> <img src="image6.png" alt="Image 6" /></td>
</tr>
<tr>
<td>Close to the antrum, the mucosa is pale [11] and smoother. Pyloric approach and entry may be masked by bile or mucus [12]. Passages into the intestine may occur so quickly that the pylorus is only visualised on exiting the intestine.</td>
<td></td>
<td><img src="image7.png" alt="Image 7" /> <img src="image8.png" alt="Image 8" /></td>
</tr>
<tr>
<td>During placement the tube may coil, retroflex, back towards the oesophagus. First, withdraw close to the oesophagus. A slow advance, air insufflation (250-500mL) and use of a flexible tube tip mitigate risk of coiling and encourage the tip to advance down the greater curvature.</td>
<td></td>
<td><img src="image9.png" alt="Image 9" /> <img src="image10.png" alt="Image 10" /></td>
</tr>
</tbody>
</table>

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## 4.6 Intestine

### Summary
Duodenal entry is sudden. Intestinal walls are close, covered in finger-like villi, often undergoing active peristalsis.

<table>
<thead>
<tr>
<th>Comment</th>
<th>Depth</th>
<th>Images</th>
</tr>
</thead>
<tbody>
<tr>
<td>The pylorus may be clearly seen when very slowly retracting the tube</td>
<td>&gt;75cm</td>
<td><img src="image1.png" alt="Image 1: Bubble over pylorus after tube retraction" /></td>
</tr>
<tr>
<td>Bile appears yellow-brown [2]. Feed and food debris may be present.</td>
<td></td>
<td><img src="image2.png" alt="Image 2: Villi obscured by" /></td>
</tr>
<tr>
<td>Villi appear as pink-white finger-like projections [3-4]. They have a</td>
<td></td>
<td><img src="image3.png" alt="Image 3: Poor focus" /></td>
</tr>
<tr>
<td>carpet-like appearance. Peristalsis may be visible.</td>
<td></td>
<td><img src="image4.png" alt="Image 4: Carpet-like appearance &amp; duodenum often actively peristalsing" /></td>
</tr>
</tbody>
</table>
### 5 Self-evaluation
This section presents scenarios of tube placement and image interpretation:
1. Read the question, examine the images compared to those presented above & note your answers.
2. Open a new window showing 5.2 to view answers. Re-examine previous sections when necessary.

#### 5.1 Scenarios
NB. Scenarios may be from different tube placements, not necessarily linked.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><img src="image1.png" alt="Image" /></td>
</tr>
<tr>
<td>The tube has been inserted 5cm into the nostril. What indication does this image give that the tube advance is safe?</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td><img src="image2.png" alt="Image" /></td>
</tr>
</tbody>
</table>
| In a mechanically ventilated patient with an endotracheal tube in situ, 3 images are seen at distances from the nose:  
  - 18cm  
  - 25cm  
  - 30cm  
  There are no clinical signs or ventilator alarms to that the tube is misplaced.  
  a) Where is the tube at 30cm?  
  b) State what anatomy is seen and the characteristics used to identify it for each of the 3 images. |
### Scenario

#### Image

<table>
<thead>
<tr>
<th>Scenario</th>
</tr>
</thead>
</table>
| **3** Following scenario 2 the:  
  - NG tube was carefully withdrawn into the pharynx and  
  - Patient's head was tilted chin down and a jaw thrust manoeuvre done while slowly advancing the tube.  
  The following images were obtained.  
  a) Image 1 (29cm) shows mucus and no clear anatomy. If the IRIS lens does not clear spontaneously, how was the 2nd image obtained?  
  b) Identify the organ shown in image 2 (36cm)?  
  c) What characteristics can you identify that enabled you to answer b) and what characteristics might have been present when watching a continuous real-time placement?  
| ![Image 1](image1.png) ![Image 2](image2.png)  
| **4** As the tube was advanced images were obtained at 60cm and 66cm.  
  a) Which organ is the tube in?  
  b) What 3 characteristics indicate this?  
| ![Image 3](image3.png) ![Image 4](image4.png)  
| **5** A tube advanced beyond 70cm from the nose, underwent a sudden advance and reached 80cm.  
  1. What techniques may help advance the tube from the upper to lower stomach?  
  2. Where is the tube in the image?  
  3. What characteristics indicate this?  
| ![Image 5](image5.png)  

```
### 5.2 Answers

<table>
<thead>
<tr>
<th>Q</th>
<th>Area</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Nose</td>
<td>The tube is clearly in the nasal lumen (a darkened orifice). There is no blood or tube impaction against mucosa.</td>
</tr>
</tbody>
</table>
| 2 | Pharynx and respiratory tract | a) Trachea  
                      b)  
                          i. Pharynx: Poorly focused, but the pale mucosa and visible blood vessels is typical.  
                          ii. ETT cuff: The IRIS tube is passing the grey-white cuff; sometimes air bubbles are seen in the cuff fluid.  
                          iii. The trachea has an open lumen and concentric cartilaginous rings. Distally it would show a carina and bronchi. |
| 3 | Oesophagus | a) A 10-30mL air insufflation, sometimes with a 5cm tube withdrawal clears the lens. Ensure the tube is 10cm into the oesophagus before withdrawing to avoid re-entering the pharynx.  
                      b) Oesophagus  
                      c) The lumen is fluted and in real-time collapses and pulses. It is not rigid and does not have cartilaginous rings. |
| 4 | Stomach | a) Stomach.  
                      b) i. Gastric folds in a cavernous space. ii. A 'freckle' patterned mucosa. |
| 5 | Duodenum part-1 | a) Slow advance, 250-500mL air insufflation (adult), 10cm guide-wire withdrawal to create a flexible tip. If the tube becomes retroflex, withdraw to remove the coil and repeat the advance.  
                      b) Intestine. Because the tube has only just past the pylorus it will be duodenum part-1.  
                      c) Finger-like villi and a smaller lumen. The gold-brown bile, partially obscuring the centre-screen, can also be seen in the stomach so does not help differentiate position. |

### Reference