

## Confirming nasogastric tube position: Electromagnetic tracking versus pH or X-ray and tube radio-opacity.

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## 1 Abstract

Recent evidence suggests official statistics greatly underestimate the occurrence of complications from misplaced nasogastric (NG) tubes, even when detected. Current methods of confirming tube position may detect but not prevent misplacement, the main cause of complications. In addition, some tubes are inadequately radio-opaque.

We prospectively audited placement of Cortrak polyurethane tubes (PUTs) to determine: a) Accuracy of the electromagnetic (EM) trace in confirming tube position, b) Radio-opacity of PUTs compared with previously placed polyvinylchloride (PVC) Ryles tubes and whether 12F (F = French gauge = 0.33mm) PUTs can be used to aspirate gastric residual volumes (GRVs).

127 PUTs were placed in 113 patients. EM traces accurately confirmed tube position compared to X-ray (100% agreement). A 'gastric' EM trace has been defined for future use by other operators. PUTs were adequately radio-opaque with good agreement between interpreters ( $\geq 98\%$ ) whereas PVC Ryles tubes were insufficiently radio-opaque (57-73%), invisible in 23% of cases and with poor agreement between interpreters leaving risk of error. The alternative of using pH confirmation wasn't possible in 44%. In these cases subsequent X-ray incurred a 2h delay to feed and medications. In addition, neither post-placement pH nor X-ray pre-empt potential pneumonia or lung trauma cause by misplacement whereas the EM trace warned of lung placement prior to damage in 7% of placements. 12F, single-port PUTs appear adequate to aspirate large GRVs.

EM tracing may be considered a stand-alone method of confirming NG tube position. Cortrak/Corflo PUTs are adequately radio-opaque. We think use of PVC Ryles and other inadequately radio-opaque tubes should stop.

## 2 Key words

Cortrak, misplacement, nasogastric tube, radio-opacity, Ryles.

## 3 Key phrases

In terms of radio-opacity, using standard chest X-rays and viewing screens,  $\geq 98\%$  of Cortrak (Corflo) PUTs can be clearly seen along their entire length without the guide-wire. In contrast, only 57% and 73% of Ryles tubes could be seen in chest and abdominal compartments, respectively. Only tubes with adequate radio-opacity should be used. In contrast, EM traces were 100% accurate when measured against X-ray or CT; definitions of what constitutes a 'gastric' EM trace are offered for when using the EM trace as a standalone confirmation method. GRVs can be aspirated from 12F PUTs.

## 4 Conflict of interest

Stephen Taylor served on a Cortrak consultation committee once in 2007. Cortrak funded the time and equipment for this audit but played no part in study design, execution, analysis or reporting of results.

## 5 Introduction

 About 1.5% of feeding tubes are misplaced and commonly lead to pneumothorax or pneumonia (0.5%) and death (0.27%) [Taylor, 2014]. These figures suggest that official figures of undetected misplacement [National Patient Safety Association (NPSA), 2011] significantly under-estimate risk of misplacement [Taylor, 2013a; 2014]. Misinterpretation of the chest X-ray is the most common cause of undetected misplacement [NPSA, 2011]; inadequate radio-opacity of the tube appears to be an important predisposing factor. In addition, delays to feeding and medication while awaiting X-ray confirmation are common [NPSA, 2008] and may contribute to complications. Lastly, single X-ray confirmation is too late to prevent lung trauma [Marderstein et al, 2004] and low pH won't exclude oesophageal placement and subsequent

aspiration risk [Metheny et al, 1994].

The intensive care unit (ICU) is a major user of PVC Ryles tubes. This is because most ICU patients require NG feeding and a wide-bore tube facilitates aspiration of the gastric residual volume (GRV) to check for delayed gastric emptying. However, medics often report that these tubes are difficult to visualise on X-ray. Following an undetected misplacement of a 14F, PVC Ryles tube we prospectively audited the radio-opacity of Ryles tubes compared with an electromagnetically (EM)-guided version of the 12F Corflo (Cortrak) PUT. In addition, to determine whether EM traces are suitable as a standalone method of confirmation we compared accuracy with X-ray, CT or pH. Lastly we determined whether 12F PUTs could be used to check GRVs.

This study was submitted to the local Ethics committee and considered not to need approval because all procedures and data collection were part of routine patient management.

## 6 Methods



In consecutive ICU patients requiring a new or replacement nasogastric (NG) tube a 12F (Cortrak/Corflo) polyurethane tube (PUT) was guided into place using an EM trace. To get maximum information to confirm position from the EM trace the tube was placed as deeply as possible up to duodenum part-2, then withdrawn to the gastric body. Aspiration of fluid with a pH  $\leq 5.0$  or, failing that, X-ray were used to confirm gastric placement as per hospital policy. pH 2-9 sticks (Merck™) were read by authors (ST, KA or HM) and EM traces interpreted by ST.

PUTs and Ryles tubes were assessed for 'clear' radiological visibility in the chest and abdomen; a plain chest X-ray was viewed on a standard 'picture archiving communication system' (PACS) computer monitor, by a gastrointestinal radiographer (WR) blinded to the EM trace results. Where the tube tip was visible the exact position was noted. Gastric position was confirmed if aspirated fluid had a pH  $\leq 5.0$  or an X-ray or CT scan showed the tube within the stomach. These results were compared with those from ST to determine possible differences in interpretation when using the different tubes. Agreement was tested, where appropriate, using Cohen's kappa [Cohen, 1960] giving the level of agreement using Landis and Koch criteria [1977].

EM interpretation was compared to pH, X-ray and CT scan results. Early in the audit we aimed to place the tube in the gastric antrum because a 45° bedrest elevation (BRE) should drain the GRV to this position [Taylor, 2013c]. However, aspiration of GRV was generally better from the fundus or body, possibly because of failure to meet the BRE target. Subsequently, to enable GRV aspiration, avoid spontaneous transpyloric placement and slippage into the oesophagus, most tubes (87%) were deliberately placed in the gastric body approximating the '4-5 O'clock' position on the EM anterior-posterior (AP) trace. GRVs were recorded 4 hourly for up to 5 days together with episodes of and predisposing factors for vomiting to determine whether GRVs could be adequately removed via a 12F tube to pre-empt vomiting.

## 7 Results



We analysed 127 tube placements in 113 patients most of whom were sedated or unconscious and mechanically ventilated via an endotracheal tube or tracheostomy during placement (Table 4.1). The group included a high percentage of trauma patients; Frenchay hospital is a Major Trauma Centre.

Table 1 Patient demography, airway type and disease category.

Parameter		Median [IQR] or %
Age		53 [36, 66]
Gender (male)		66%
Height (cm) [measured or known]		174 [166, 180]
Weight (kg) [record, mostly estimated or from relatives]		80 [68, 90]
Conscious state:	Awake	20%
	Sedated	65%
	Unconscious	15%
Airway	Endotracheal tube	51%
	Tracheostomy	40%
	Normal	9%
Disease category	Medical	30%
	Neurosurgery	12%
	Surgery (general)	14%
	Trauma	44%

### Placement

Of 127 placements, 125 (98%) were successful and confirmed to be gastric. One placement was aborted when a gastroenterology review deemed it unsafe because of recent banding of oesophageal varices. A second placement was identified to be in a hiatus hernia by EM-trace and X-ray and later placed fluoroscopically. EM placement and confirmation of placement was rapid [median, 6.4 minutes: interquartile range, IQR: 4-10.4] and was completed in late morning (11:30: 11:00-12:24] during the 8:00-12:00 no feeding 'rest' period, whereas X-ray, when required, was completed later (14:00: 13:00-15:00]. Confirmation of position was immediate for EM tracing and pH but X-ray delayed feeding and medications [2h: 1.3-2.5: Range: 0.4-9.1].

Three operators led tube placement (ST: 73%; KA: 18%; HM: 9%). During placement, 17% of tubes required a 10mL water flush to activate lubricant and permit manipulation of the guide-wire to attain ideal position. During placement the chest level trace deviated significantly to the left and/ or right in 7%, suggesting placement into the left or right main bronchus. All tubes were withdrawn, without complication, and successfully positioned in the stomach as seen on a significantly different EM trace.

### Confirmation

Fluid could be aspirated from 83% of 12F PUT tubes with a median pH of 4.0 [range 3-6]. Of these, 60% of tubes were confirmed as gastric position with a pH of  $\leq 5.0$ . A further 37% of tubes required initial confirmation of gastric position by X-ray; the remaining 3% were inadvertently removed by patients before their position could be confirmed. Acid suppression was used in 56% (H2-blockers: 26%; PPI: 31%). However, failure to obtain an aspirate pH of  $\leq 5.0$  was not associated with time elapsed since feeding or use of H2-blockers but was strongly associated with PPI use (pH failure: PPI 43% vs non-PPI 10%, Pearson's chi-square with continuity correction = 9.3,  $p=0.002$ ) even when eliminating patients

undergoing multiple placements.

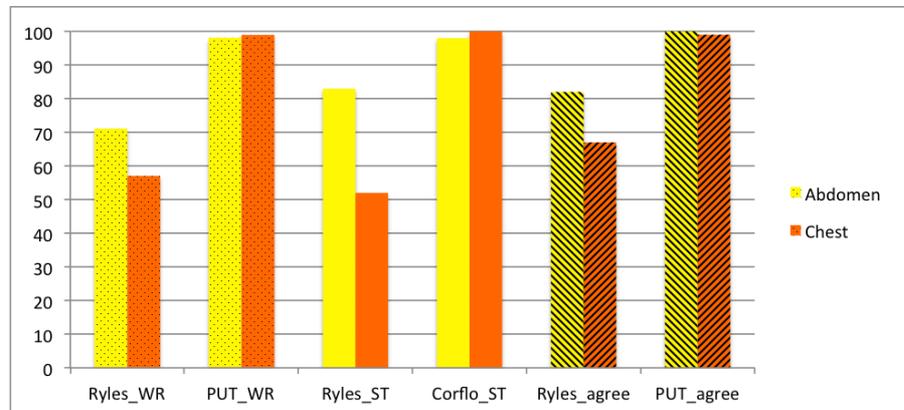
### Radio-opacity

X-rays were available for 106 12F PUTs with the guide-wire removed. Because agreement occurred in >95% of cases it paradoxically lowers inter-rater agreement values for Cohen's kappa test; the test was therefore not appropriate [Gwet, 2008]. Instead we present percentage agreement with the 95% confidence interval (%: 95%CI). WR (radiographer) could clearly see tubes in the chest (99%: 97%, 100%) and abdomen (98%: 95%, 100%) and usually

along the entire length. Similarly ST considered almost all tubes to be visible in both compartments (chest: 100%: 100%, 100%; abdomen: 98%: 95%, 100%) (Figure 1). WR and ST agreed visibility within the chest (99%: 97%, 100%), abdomen (100%: 100%, 100%), that of 106 tubes confirmed by X-ray or CT, 105 either entered or had its tip within the stomach and that one tube appeared to be within a hiatus hernia (100%: 100%, 100%). EM-trace interpretations (ST) agreed with X-ray or CT interpretations (WR, n=106) (100%: 100%, 100%).

X-rays were also obtained for 93 tubes placed prior to the 12F PUT tube placement. Most (97%) were 14F (12-16F), PVC Ryles tubes. WR found poor radio-opacity in both chest (57%: Kappa = 0.332; p=.002 [Fair Agreement]) and abdomen (71%: Kappa = 0.552; p<.001 [Moderate Agreement]). Better abdominal visibility is mostly explained by the presence of a steel tip, but particularly where this was absent or not captured by the X-ray, 23% were invisible along the entire length. Similarly ST found that radio-opacity was poor in both chest (52%) and abdomen (83%) components of the X-ray. Lastly, agreement on whether Ryles tubes were visible between WR and ST was poor (chest: 67%, abdomen: 82%), with clinically poor agreement of when a tube was invisible (81% agreement: 95%CI 73%, 89%, kappa=0.33). Adequacy or deficiency in radio-opacity becomes apparent in X-rays of misplaced tubes (Figure 2).

Figure 1 Percentage of tubes (Ryles vs PUT) that are clearly radio-opaque to WR, ST and both (agree) at the level of the chest or abdomen.



**Ryles stiffness**

Of note, many PVC Ryles tubes were beginning to stiffen from day 7 of use. Withdrawal was occasionally painful to the patient because the tube commonly retained a hook shape. The possibility of mucosal trauma was not investigated.

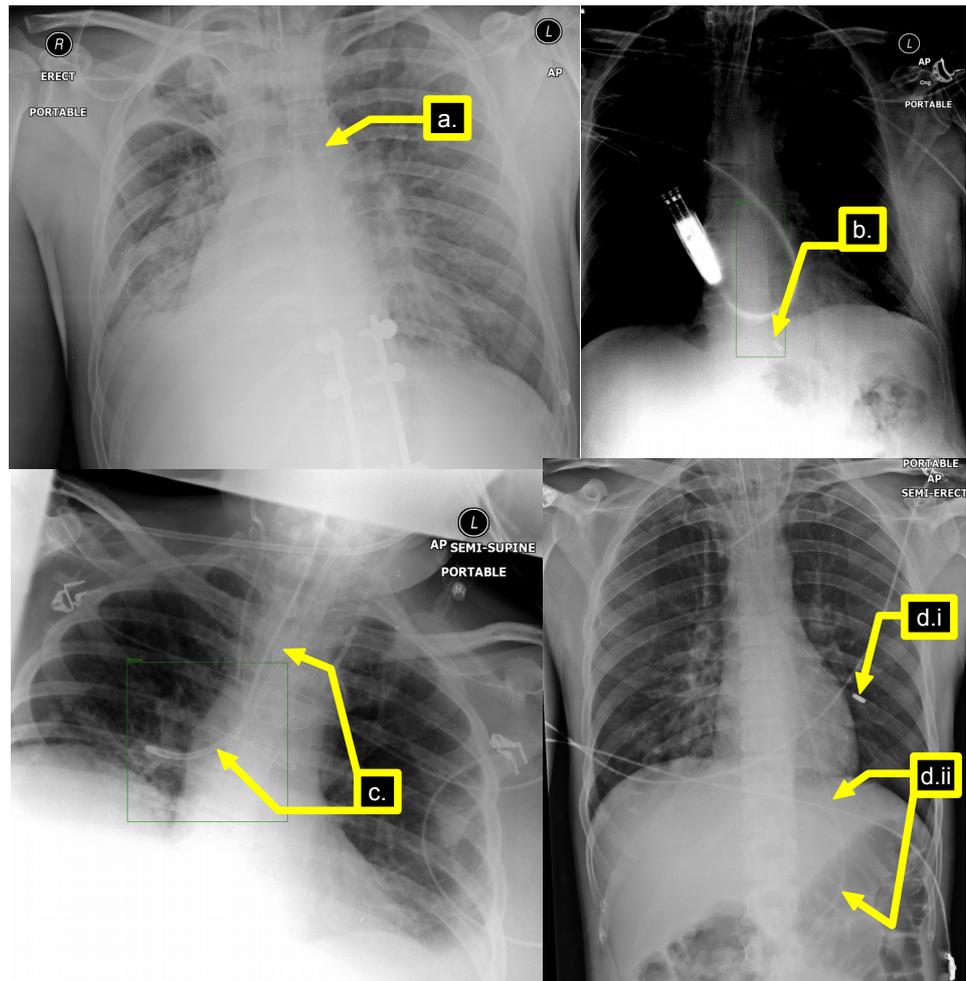
**Position & GRV**

EM trace indicated that 125 tubes were in the gastric fundus (6%), body (87%) or antrum (6%) from which 2915 attempts were made to measure GRV. Most GRVs were small (median: 5mL [IQR: 0, 25]) but the range was wide: 0-1240mL. Only 5% were  $\geq 250$ mL. Vomits occurred in 14% of feeding courses, but this reduced to 8.6% when pre-disposing factors were removed such as vomiting prior to the tube or directly related to physiotherapy or coughing.

**Tube use**

Tubes remained in situ a median of 10 days [IQR: 4, 19] reflecting a high rate of inadvertent removal (56%). In tubes requiring replacement most had been removed by the patient (39%) or slipped (4%).

Figure 2: Difference in radio-opacity when PUT or Ryles tubes are misplaced [Taylor, 2013b].



- a. 14FG Ryles tube in situ but barely visible and only in the upper chest.
- b. 14FG Ryles tube in situ: Only a steel tip shows, not the tube therefore placement is uncertain.
- c. The 8<sup>th</sup> attempted blind placement of a PUT misplaced in the right lung. It is clearly visible along the entire length. Subsequent EM-guided placement was successful.
- d. Patient fed through (i.) into the left lung; the steel tip clearly shows but the tube is faint compared to the VP shunt (ii) mistaken for an NG or duodenal tube.

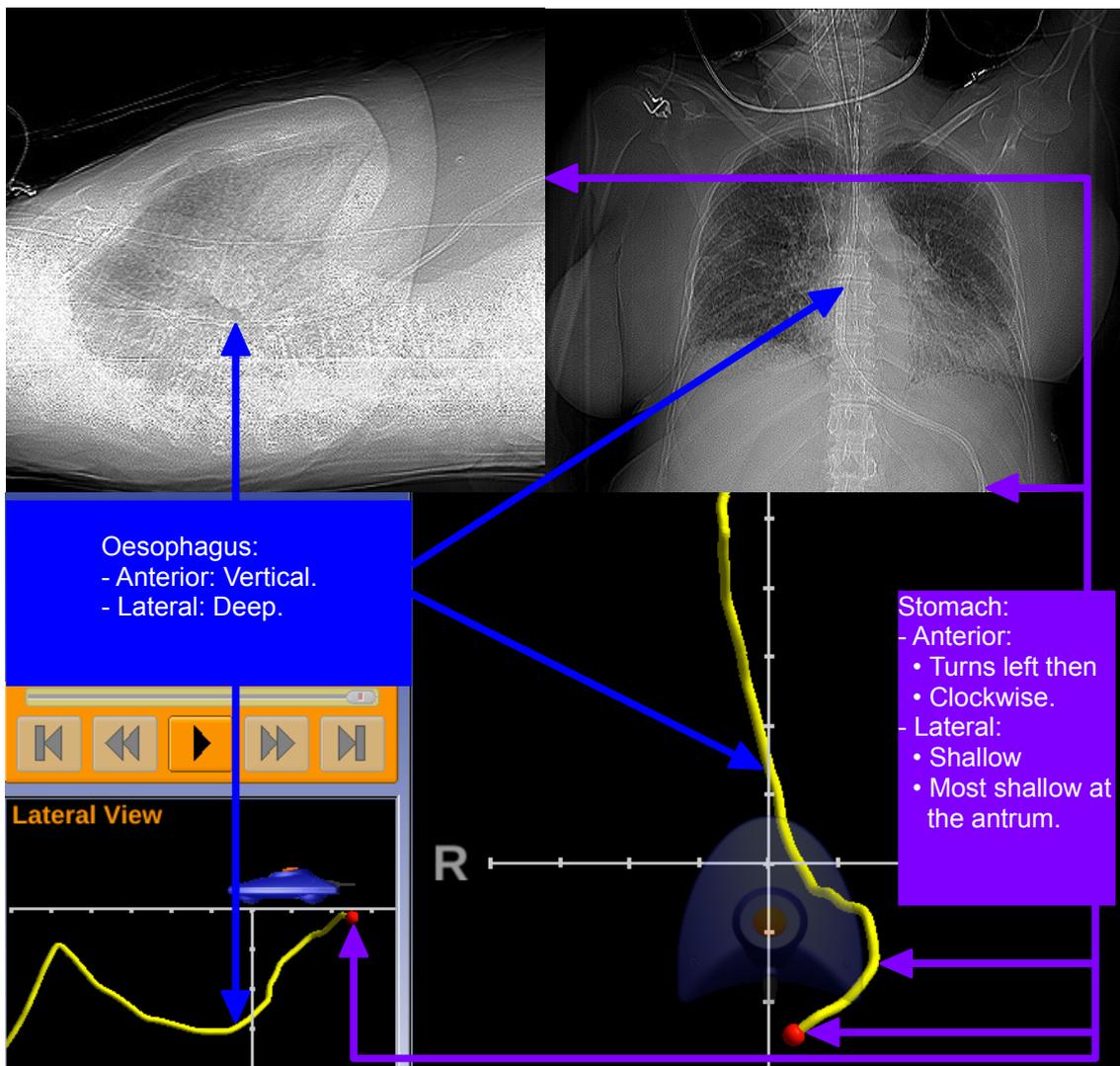
**EM trace interpretation versus X-ray**

X-ray comparison confirmed that EM trace interpretation of position was correct (100% agreement). Anatomical position matched the following criteria from the anterior-posterior (AP) and cross-section (CS) depth traces (Figure 3) [Taylor, 2013b]:

1. Oesophagus: Vertical (AP) and deep (CS) with no significant left/right deviation at chest level.
2. Gastric fundus: Moves left (AP) and shallow (CS) below the xiphisternum.
3. Gastric body: Clockwise trace, belly's out in a curve to the left (AP), increasingly shallow (CS).
4. Gastric antrum: Clockwise trace continues back to the midline (AP), close to the shallowest point (CS).
5. Duodenum parts 1 and 2: Trace begins an anti-clockwise (AP), deepening trace (CS).

All placements except one were gastric. The one exception described an anti-clockwise trace (AP) mostly above the xiphisternum. Because the operator (ST) suspected this was a hiatus hernia, the tube was withdrawn and a duodenal tube placed under fluoroscopic guidance. A minimum of criteria 1+2 must be met to confirm gastric position. Excluding 5 placements where the tube was deliberately not placed as deeply as possible to avoid displacing a nasointestinal tube already in situ, most traces were initially deeper than the gastric body (>fundus: 96%, >body: 87%, >antrum: 57%, duodenum part-1: 12%, >superior duodenal flexure: 6%).

Figure 3: Anatomical position seen on X-ray versus EM trace [Taylor, 2014].



## 8 Discussion



### Placement

EM-guidance results in quick and successful placement of most tubes (98%), gives timely warning of impending misplacement (7%) and immediate confirmation of position that is 100% accurate when compared to X-ray, CT and/ or aspiration of fluid with a pH  $\leq 5.0$ . Others have found similar rates of initial lung misplacement (7.5-7.7%) and safe re-positioning along with 100% agreement between EM traces and X-ray with contrast [Powers et al, 2011; 2013]. Because X-ray without contrast only found 87% agreement, Powers et al [2013] suggest that the EM trace is more accurate because it includes a depth trace. In contrast, in the current study, pH could not confirm position in 44% because fluid could not be aspirated or pH was  $>5.0$ , whereas X-ray confirmation delayed feeding and medications by 2h. It is noteworthy that the radiology department is  $<30\text{m}$  from ICU therefore this figure may be greater in other units depending on staffing, priorities and distance. X-ray was required by 37% because of failure to obtain a pH  $\leq 5.0$ . This would have been higher, but three tubes were removed by patients pre-confirmation and several tubes were initially only used for drainage, confirmation of position being done later.

A practical point is that 17% of PUTs required injection of water to permit guide-wire manipulation to facilitate tube placement to an adequate depth within the stomach. NPSA guidelines ban water injection prior to placement because sterile water and NaCl solution is acidic and can falsely indicate gastric pH. However, gastric pH can be safely differentiated from that of water injected down the tube by using tap-water checked as pH  $\geq 6.0$  or pH sticks buffered against water. Water injection prior to insertion facilitates guide-wire manipulation whereas, inability to manipulate the guide-wire to attain deeper placement or placing tubes equivalent to the nose-ear-xiphisternum distance, as per NPSA guideline [NPSA, 2011], leaves many tubes barely within the stomach [Taylor et al, 2014]. It would require minimal slippage to leave the port(s) within the oesophagus and risk aspiration.

Because EM traces indicating lung placement were significantly different to subsequent EM traces, later independently X-ray confirmed to be gastric, it appears that EM-tracking can pre-empt lung damage. This is important because official data appears to underestimate complications. NEVER events (undetected misplacement causing serious harm) are only reported as averaging 20 per year, including 4 deaths [NPSA, 2011]. However, pooling 6628 patients having 11414 tube placements from seven studies, misplacement occurred in 1.5%, major complications (pneumonia or pneumothorax) in 0.5% and death in 0.27% [Taylor, 2014]. Applied to UK tube usage (275,000) [NPSA, 2008] this would equate to 3989 misplacements, 1353 pneumothoraces and 732 deaths [Taylor, 2014].

Specifically, risk of placement-related pneumothorax is 0.38% in ICU patients [Marderstein et al, 2004]. However, this group is disproportionately at risk from subsequent misplacement (32%) and risk of pneumothorax rises from 5% after a single misplacement to 36% after  $\geq 3$  misplacements [Marderstein et al, 2004]. When regarded as discrete misplacements, risk of pneumothorax increases from daytime (4.7%) to night (16%). 67.8% of misplacements occur when an endotracheal tube or tracheostomy was present. These complications can only be reduced by using real-time confirmation or a 2-stage placement (0.09% risk equivalent to reducing from 26.9% to 3.3% of those with intrabronchial placement) [Marderstein et al, 2004]. The latter involves placing the tube via the nose to 35cm (30cm if oral) and excluding lung placement using X-ray or capnography, then, if safe, completing placement and confirming gastric

placement with pH or X-ray. Combining canography with pH would significantly reduce delay to feeding and cost compared to the traditional 2-stage X-ray [Roubenoff and Ravich, 1989], but 44% (current data) would still require a final X-ray. Alternatively, EM tracking permits pre-emption of pneumothorax and confirmation of final position.

### **Radio-opacity**

PUTs were almost always visible in both the chest and abdomen ( $\geq 98\%$ ) with good agreement between those interpreting results ( $\geq 99\%$ ). In contrast, PVC Ryles tubes could not be clearly seen in the chest (57%) or abdomen (71%) were invisible in 23% and interpretations differed between WR and ST in 18-33%; this would leave room for doubt as to tube position based on X-ray. Tubes used for feeding or wherever radiological confirmation may be necessary should have radio-opacity proven in vivo. In contrast, Ryles tubes cannot be considered safe for radiological confirmation of position and, additionally, their stiffness after 7 days use may pose a risk for mucosal damage whereas replacement and use of multiple X-rays to confirm position would increase cost. PUTs don't appear to stiffen but there was no systematic study of this aspect of care.

### **Position & GRV**

Large ( $\geq 250\text{mL}$ ) GRVs occurred in 5% though are usually more common at the beginning of ICU stay [Taylor et al, 2010b]. GRV checks, 4 hourly did not prevent vomits in the 8.6% who had no predisposing factors to vomiting. It is possible that a single port PUT can fail to detect a GRV where a multi-port tube might succeed. Nurses reported occasionally 'finding' a large GRV following a positional change, presumably because the GRV moved onto the port. Multi-port tubes have been reported better in obtaining GRVs [Metheny et al, 2005]. However, this has to be weighed against the risk that while some ports may be gastric, others may risk aspiration if they are in the oesophagus or dumping (if using boluses) in the intestine. Since there was no direct comparison between tubes, it is not known whether single-port PUTs result in excess vomiting compared to GRV checks with multi-port tubes. However, 12F PUTs effectively aspirated a single GRV up to 1240mL.

### **Tube use**

Most tubes were lost inadvertently (56%). A total of 43% required replacement, were lost due to patient removal or slippage and therefore could have been saved by use of a nasal bridle [Seder and Janczyk, 2008]. Bridle cost would be offset by reduced patient trauma, complications of misplacement, lost feeding and medication time and tube and X-ray cost.

### **EM trace criteria for gastric confirmation**

While gastric placement may be safely confirmed by EM trace criteria 1+2 (defined in Results), criteria 3 means that the tube has reached the gastric body therefore slight slippage would not risk oesophageal placement. Based on current evidence an EM trace indicating placement into the gastric body is sufficient 'standalone' confirmation when the operator is trained in interpretation, watched the whole trace and, preferably, placed the tube in order to have the full information. Where possible and safe, we recommend placing the tube up to duodenum part-2, to get extra information, then withdraw to the lower gastric body (~4 O'Clock).

It is noteworthy that in a historical single case, an EM trace indicated duodenum part 1 when the tube was intra-peritoneal. This occurred because of an oesophageal weakness and the tube following the exact anterior and depth EM trace expected of a correctly placed tube. It indicates extra care is needed if the GI tract is friable but such a 'false trace' is likely to be very rare. To our knowledge no tube has ever been misplaced in the lung or outside the GI tract when an EM trace indicates duodenum part 2 or beyond. While only 6% of 12F tubes reached this depth, it is probably because they won't easily go around the superior duodenal flexure; >90% of 10F tubes are successfully placed into the small intestine in circumstances where such placement is more difficult due to reduced gastric tone.

## 9 Conclusion



EM tracing warned of lung misplacement before trauma occurred in addition to accurately confirming gastric placement in all patients. Conversely, pH confirmation failed in nearly half of patients and subsequent X-ray delayed feeding and medicines by 2h compared to EM tracing. Cortrak/Corflo PUTs appear adequately radio-opaque for X-ray confirmation and a 12FG tube permits GRV checks. Systematic criteria for gastric confirmation by EM trace are proposed. These should be tested and re-evaluated in future studies.

Delay from daytime tube placement to X-ray for initial position check was similar between our ICU population (2h) and our hospital's ward population (1.5h) [Law et al, 2013]. However, this may underestimate the delay because hospital-wide X-ray checks outside 8.00-17.00 took a median of 4h. Later in the study the out of hours radiology review extended to 21.00 with a ban on non-urgent tube placements beyond this time. The consequent delayed medication and cumulative nutritional deficit require urgent study.

We think our findings justify use of an EM trace to place and confirm placement of NG tubes. Further research is required to determine how much guided tube placement can reduce risk and cost compared with blind tube placement.

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