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[Diagnostic Test Accuracy Review]

Ultrasonography for confirmation of gastric tube placement

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ABSTRACT

Background

Gastric tubes are commonly used for the administration of drugs and tube feeding for people who are unable to swallow. Feeding via a tube misplaced in the trachea can result in severe pneumonia. Therefore, the confirmation of tube placement in the stomach after tube insertion is important. Recent studies have reported that ultrasonography provides good diagnostic accuracy estimates in the confirmation of appropriate tube placement. Hence, ultrasound could provide a promising alternative to X-rays in the confirmation of tube placement, especially in settings where X-ray facilities are unavailable or difficult to access.

Objectives

To assess the diagnostic accuracy of ultrasound for gastric tube placement confirmation.

Search methods

We searched the Cochrane Library (2016, Issue 3), MEDLINE (to March 2016), Embase (to March 2016), National Institute for Health Research (NIHR) PROSPERO Register (to May 2016), Aggressive Research Intelligence Facility Databases (to May 2016), ClinicalTrials.gov (to May 2016), ISRCTN registry (May 2016), World Health Organization International Clinical Trials Registry Platform (to May 2016) and reference lists of articles, and contacted study authors.

Selection criteria

We included studies that evaluated the diagnostic accuracy of naso- and orogastric tube placement confirmed by ultrasound visualization using X-ray visualization as the reference standard. We included cross-sectional studies, and case-control studies. We excluded case series or case reports. Studies were excluded if X-ray visualization was not the reference standard or if the tube being placed was a gastrostomy or enteric tube.

Data collection and analysis

Two review authors independently assessed the risk of bias and extracted data from each of the included studies. We contacted authors of the included studies to obtain missing data.

Main results

We identified 10 studies (545 participants and 560 tube insertions) which met our inclusion criteria.

No study was assigned low risk of bias or low concern in every QUADAS-2 domain. We judged only three (30%) studies to have low risk of bias in the participant selection domain because they performed ultrasound after they confirmed correct position by other methods.

Few data (43 participants) were available for misplacement detection (specificity) due to the low incidence of misplacement. We did not perform a meta-analysis because of considerable heterogeneity of the index test such as the difference of echo window, the combination of ultrasound with other confirmation methods (e.g. saline flush visualization by ultrasound) and ultrasound during the insertion of the tube. For all settings, sensitivity estimates for individual studies ranged from 0.50 to 1.00 and specificity estimates from 0.17 to 1.00. For settings where X-ray was not readily available and participants underwent gastric tube insertion for drainage (four studies, 305 participants), sensitivity estimates of ultrasound in combination with other confirmatory tests ranged from 0.86 to 0.98 and specificity estimates of 1.00 with wide confidence intervals.

For the studies using ultrasound alone (four studies, 314 participants), sensitivity estimates ranged from 0.91 to 0.98 and specificity estimates from 0.67 to 1.00.

Authors' conclusions

Of 10 studies that assessed the diagnostic accuracy of gastric tube placement, few studies had a low risk of bias. Based on limited evidence, ultrasound does not have sufficient accuracy as a single test to confirm gastric tube placement. However, in settings where X-ray is not readily available, ultrasound may be useful to detect misplaced gastric tubes. Larger studies are needed to determine the possibility of adverse events when ultrasound is used to confirm tube placement.

PLAIN LANGUAGE SUMMARY

Ultrasound scan for confirmation of gastric tube placement

Background

Each year approximately one million people receive a tube feeding (gastric tube) in the US. Gastric tubes are commonly used for giving drugs and nutrition directly into the gastrointestinal tract (tube that digests food) for people who are unable to swallow. Feeding via a tube that is misplaced in the trachea (wind pipe) can result in severe pneumonia (infection of the lungs). Therefore, confirmation of tube placement in the stomach after tube insertion is important. Gastric tubes are also used to reduce the pressure of the stomach after providing breathing assistance through masks, which is mainly used in resuscitation. Medical ultrasound is one of the diagnostic imaging techniques using sound waves to create images of the inside of the body. Recent studies suggest that ultrasound provides good diagnostic accuracy in the confirmation of appropriate tube placement. Hence, ultrasound could provide a promising alternative to X-rays in confirming tube placement, especially where X-ray facilities are unavailable or difficult to access.

Study characteristics

Studies included in this review are current to March 2016. We included 10 studies involving 545 participants for evaluation of the diagnostic accuracy of ultrasound for confirmation of gastric tube placement.

Key results

Most studies showed good performance for correct placement of the tube. However, few data were available for incorrect placement of the tube and the possible complications of a misplaced tube. Among the included studies, only 43 participants had a misplaced tube. None of the studies reported complications during ultrasound use. Three methods of ultrasound were reported: neck approach, upper abdominal (tummy) approach and a combination of both. No included studies indicated that ultrasound had sufficient accuracy as a single test for the confirmation of gastric tube placement for feeding. In contrast, ultrasound combined with other tests (e.g. saline flush visualization (pushing salt solution through the tube and seeing it inside the stomach by ultrasound)) might be useful for the confirmation of tubes used for gastric drainage.

Limitations of the review

Generally, the studies were of low or unclear methodological quality. We considered only three (30%) of the 10 included studies to be representative of patients in practice because they performed ultrasound after they confirmed correct position by other methods. The studies reported a variety of results for incorrect tube placement.

Future research

Larger studies are needed to investigate whether ultrasound could replace X-rays for confirming gastric tube placement, as well as whether ultrasound could decrease severe complications, such as pneumonia, from a misplaced tube.

Summary of findings 1. Accuracy of ultrasound for confirmation of gastric tube placement

Accuracy of ultrasound for confirmation of gastric tube placement									
Population	Adults in any settings (prehospital, ICU, EMS or unclear)								
Index test	Ultrasound (any methods)								
Reference standard	X-ray								
Studies	Cross-sectional study or unclear study design[a]								
Study ID	**TP[b]**	**FP[b]**	**FN[b]**	**TN[b]**	**Partici-pants**	**Sensitivity (95% CI)**	**Specificity (95% CI)**	**Method[c]**	**Echo win-dow[c]**
Basile 2015	17	10	17	2	46	0.50 (0.32 to 0.68)	0.17 (0.02 to 0.48)	Ultrasound + air injection after insertion	NR
Brun 2012 [a,d]	80	0	8	8	96	0.91 (0.83 to 0.96)	1.00 (0.63 to 1.00)	Ultrasound after insertion	Epigastric
Brun 2014 [d]	27	0	1	4	32	0.96 (0.82 to 1.00)	1.00 (0.40 to 1.00)	Ultrasound + air injection after insertion	Neck + epigastric
Chenaitia 2012 [d]	116	0	2	12	130	0.98 (0.94 to 1.00)	1.00 (0.74 to 1.00)	Ultrasound after insertion	Epigastric
Gok 2015	52	0	4	0	56	0.93 (0.83 to 0.98)	Not estimable	Ultrasound during insertion	Neck
Kim 2012	38	1	6	2	47	0.86 (0.73 to 0.95)	0.67 (0.09 to 0.99)	Ultrasound + saline and air injection	Neck + epigastric
Lock 2003 [a]	43	0	15	2	55 (60 measure-ments)[e]	0.74 (0.61 to 0.85)	1.00 (0.16 to 1.00)	Ultrasound + air injection after insertion	Epigastric
Nikandros 2006 [a]	15	0	1	0	16	0.94 (0.70 to 1.00)	Not estimable	Ultrasound + dextrose and air injection after insertion	NR

Radulescu 2015 [a]	28	0	2	2	32	0.93 (0.78 to 0.99)	1.00 (0.16 to 1.00)	Ultrasound after insertion	Neck + epigastric
Vigneau 2005	34	0	1	0	35	0.97 (0.85 to 1.00)	Not estimable	Ultrasound + saline injection after insertion	Epigastric

CI: confidence interval; EMS: emergency medical service; ICU: intensive care unit: FN: false negative; FP: false positive; NR: not reported; TN: true negative; TP: true positive.
[a] Unclear study design (either case-control or cross-sectional study).
[b] TP: correct gastric tube placement and correct visualization by ultrasound; FP: incorrect gastric tube placement but not visualized by ultrasound; FN: correct gastric tube placement but not visualized by ultrasound; TN: incorrect gastric tube placement and correct visualization by ultrasound.
[c] We found several methods of ultrasound to confirm gastric tubes using ultrasound.
[d] Reports from the same research group.
[e] 60 tube insertions to 55 participants.

Summary of findings 2. Accuracy of ultrasound for confirmation of gastric tube placement for drainage in settings where X-ray facilities are not readily available

Accuracy of ultrasound for confirmation of gastric tube placement for drainage in settings where X-ray facilities are not readily available									
Population	Adults underwent gastric tube insertion for drainage in settings where X-ray facilities are not readily available (prehospital or EMS)								
Index test	Ultrasound (any methods)								
Reference standard	X-ray								
Studies	Cross-sectional study or unclear study design[a]								
Study ID	**TP[b]**	**FP[b]**	**FN[b]**	**TN[b]**	**Participants**	**Sensitivity (95% CI)**	**Specificity (95% CI)**	**Method[c]**	**Echo window[c]**
Brun 2012 [c,d]	80	0	8	8	96	0.91 (0.83 to 0.96)	1.00 (0.63 to 1.00)	Ultrasound after insertion	Epigastric
Brun 2014 [d]	27	0	1	4	32	0.96 (0.82 to 1.00)	1.00 (0.40 to 1.00)	Ultrasound+ air injection after insertion	Neck + epigastric
Chenaitia 2012 [d]	116	0	2	12	130	0.98 (0.94 to 1.00)	1.00 (0.74 to 1.00)	Ultrasound after insertion	Epigastric

Kim 2012	38	1	6	2	47	0.86 (0.73 to 0.95)	0.67 (0.09 to 0.99)	Ultrasound + saline and air injection	Neck + epigastric

CI: confidence interval; EMS: emergency medical service; FN: false negative; FP: false positive; TN: true negative; TP: true positive.

[a] Unclear study design (either case-control or cross-sectional study).

[b] TP: correct gastric tube placement and correct visualization by ultrasound; FP: incorrect gastric tube placement but not visualized by ultrasound; FN: correct gastric tube placement but not visualized by ultrasound; TN: incorrect gastric tube placement and correct visualization by ultrasound.

[c] We found several methods of ultrasound to confirm gastric tubes using ultrasound.

[d] Reports from the same research group.

BACKGROUND

Gastric tubes are commonly used for the administration of drugs and delivery of nutrition directly into the gastrointestinal tract (enteral feeding) for people who are unable to swallow (e.g. people after stroke, or who need respirator support) (NICE 2006; Samuels 2013). Placement of a gastric tube is performed by inserting the tube through the nose (nasogastric tube) or mouth (oral gastric or orogastric tube), down the oesophagus and into the stomach (ENA 2015; Samuels 2013). Generally, doctors or nurses insert the tubes by pushing the tube into the nose or mouth. Gastrectomy tubes (G-tubes) are a type of gastric tube inserted into the stomach; however, they are inserted via the abdominal wall rather than the nose or mouth. This review will focus on nasogastric and orogastric tubes.

Each year approximately one million people receive tube feeding in the US (Metheny 1999). Gastric tubes are also used for the decompression of the gastrointestinal tract after the application of a bag valve mask, which is mainly used in resuscitation (Chenaitia 2012). Gastric tubes, made primarily from flexible polyurethane, and sometimes latex, silicone or polyurethane, require regular replacement if used for extended periods (Samuels 2013). In addition, tubes sometimes require unscheduled replacement due to dislodgement caused by vomiting or blockages (Thomson 2000). Gastric feeding tubes are associated with the recognised risk of misplacement into the trachea (airway) through the larynx due to the close proximity of the larynx to the oesophagus. During insertion, the tubes might enter the trachea through the larynx. Feeding via a tube misplaced in the trachea can result in severe pneumonia, pneumothorax, empyema and pulmonary haemorrhage. Therefore, the confirmation of tube placement in the stomach after insertion is important (Kawati 2005). Recommended methods to confirm correct tube placement are X-ray visualization and suction of gastric fluids (AACCN 2009). In a prehospital situation, a combination of the suction method and auscultation is used (Chenaitia 2012).

Medical ultrasound is one of the diagnostic imaging techniques using ultrasound wave. Studies from the same research group have demonstrated that ultrasonography provides good diagnostic accuracy estimates in the confirmation of appropriate tube placement (Brun 2014; Chenaitia 2012). These studies focused on tube placement for decompression of the stomach after the administration of a bag valve mask in a prehospital situation where X-ray was not available. Therefore, ultrasound could provide a promising alternative to X-rays in the confirmation of tube placement, especially in settings where X-ray facilities are unavailable or difficult to use.

Target condition being diagnosed

Appropriate gastric tube placement for any reason.

Index test(s)

Ultrasound test for gastric tube confirmation that visualizes the tubes via both the neck and abdomen, regardless of frequency of ultrasound, probe shape (linear or convex) or probe size. The test is performed in both prone and sitting position and can also be performed at the bedside. Visualization of the tubes is generally from the neck, abdomen, or both. Direct visualization of tubes in the oesophagus or stomach is interpreted as correct placement. During visualization, saline or air flush of the tube may help to visualize it by showing dynamic fogging in the stomach (Kim 2012).

Clinical pathway

People may need a gastric tube for the administration of drugs, enteral feeding or drainage. In these situations, the gastric tube is inserted via the nose or mouth, down the oesophagus and into the stomach.

After the gastric tube is inserted, its location should be promptly confirmed before proceeding with feeding or drug administration (AACCN 2009). This is by either suction of gastric fluids (visual inspection of aspirate contents or checking of pH) or the auscultation method (instillation of air in the tube with sounds heard simultaneously through a stethoscope placed over the stomach region) or both may be performed as prior tests (AACCN 2009; Chenaitia 2012). Tube placement is usually confirmed by X-ray visualization of the tube (e.g. chest X-ray).

Ultrasound may be used as a replacement test for X-ray. During the test, saline or air flush of the tube may help to visualize it.

In addition, if the person with the tube placement has vomited, retched or coughed, or if oropharyngeal suction was needed, the tube will require regular checking every four hours during daily feeding or in cases of suspected tube dislodgement (Holland 2013).

Prior test(s)

Either suction of gastric fluids (visual inspection of aspirate contents) or the auscultation method (instillation of air in the tube with sounds heard simultaneously through a stethoscope placed over the stomach region), or both are possibly performed as prior tests (AACCN 2009; Chenaitia 2012). In a prehospital situation, a combination of the suction and the auscultation method is possibly used (Chenaitia 2012). If one of these tests showed misplacement, reinsertion of the tube is needed.

Role of index test(s)

The role of ultrasound is assumed as a replacement test for X-ray visualization. The downstream consequences according to the four test accuracy categories are as follows:

- no need for further testing for TP (true positive) = correct gastric tube placement and correct visualization by ultrasound;
- serious accidents of feeding via a tube misplaced in the trachea or no effective drainage of gastric contents via a tube misplaced in the trachea for FP (false positive) = incorrect gastric tube placement but not visualized by ultrasound;
- useless reinsertion of the tube and retesting for FN (false negative) = correct gastric tube placement but not visualized by ultrasound;
- safe feeding or effective drainage of gastric contents for TN (true negative) = incorrect gastric tube placement and correct visualization by ultrasound.

Alternative test(s)

X-ray visualization is generally used to assess appropriate tube placement (Bourgault 2009). Although the risk of cancer from X-rays is not conclusive, concerns regarding the risks associated with frequent exposure to X-rays exist (Berrington 2004).

In addition, pH test of aspirate is used. The National Patient Safety Agency reported if pH is between 1 and 5.5, it is safe to start feeding (Lamont 2011; National Patient Safety Agency 2011). If pH is between 5 and 6, it is recommended that checking of the pH with a competent colleague (double checking is needed because misinterpretations of pH is possible) (Lamont 2011).

Rationale

The use of ultrasonography to assess appropriate tube placement has the potential to reduce patient discomfort. Confirmation by X-ray visualization can be difficult for people with tube placement because they have to change their body position to have a hard film plate placed on their back, or stand up for scanning while dealing with uncomfortable tubes hanging from their nose or mouth. An ultrasound test, by comparison, can be performed at the bedside without the need for the person to sit up or change position, and can, therefore, reduce the discomfort of the procedure for the patient (Vigneau 2005).

Ultrasonography can also widen accessibility to confirmatory testing outside of the hospital environment. As some ultrasound devices are portable, medical care providers who visit patients in the home can use ultrasound to check appropriate tube placement. Patients need not visit the hospital for insertion and confirmation of nasogastric or orogastric feeding tubes, which is an important consideration in the primary care setting (Mariani 2010).

The National Patient Safety Agency recommends that before using feeding tubes, repeated placement checks should be performed by X-ray or pH of aspirate measured at least once daily (National Patient Safety Agency 2011). X-rays should be avoided for children as much as possible due to concerns about the risk of irradiation (Frush 2003). Although the dose of irradiation by chest or abdominal X-rays is small according to the linear non-threshold model used in risk assumption, reducing irradiation as much as possible is of value to people of all ages (Berrington 2004; CNSC 2013).

We hypothesized that ultrasound could be a beneficial alternative to X-ray visualization since ultrasound devices have become common not only in critical care but also in primary care or prehospital settings.

OBJECTIVES

To assess the diagnostic accuracy of ultrasound for gastric tube placement confirmation.

Secondary objectives

To assess the diagnostic accuracy of ultrasound for gastric tube placement confirmation in children (aged 16 years or less).

To investigate the potential sources of heterogeneity, we planned to assess the effects of the following factors on the diagnostic accuracy of ultrasound: body mass index (BMI), clinical setting (emergency setting or not), tube diameter and area of visualization (the neck, abdomen, or both).

METHODS

Criteria for considering studies for this review

Types of studies

We included studies that evaluated the diagnostic accuracy of naso- and orogastric tube placement confirmed by ultrasound visualization and using X-ray visualization as the reference standard. We included cross-sectional studies and case-control studies. We excluded case series or case reports (Bossuyt 2008). We excluded studies where X-ray visualization was not the reference standard or if the tube being placed was a gastrostomy or enteric tube. We defined gastrostomy tubes as tubes for percutaneous enteric access and enteric tubes as both nasal or oral gastrojejunal tubes and small bowel tubes (Schattner 1997). We excluded studies if we could not extract TP, FN, FP and TN values.

Participants

Both adults (aged greater than 16 years) and children (aged 16 years or less) who needed gastric tube placement.

Index tests

Ultrasonographic confirmation of gastric tube placement. We included all studies regardless of where the ultrasound test was performed (e.g. bedside or X-ray department) or who performed and interpreted the test (e.g. ultrasonographer or physician).

Target conditions

The target condition was appropriate gastric tube placement for any reason.

Reference standards

The reference standard was X-ray of the chest or abdomen (X-ray visualization). If misinterpretation of the X-ray was not reported in the included studies, we considered X-ray of the chest or abdomen to have 100% sensitivity and 100% specificity.

Search methods for identification of studies

Electronic searches

We systematically searched the following databases:

- the Cochrane Library databases (Cochrane Reviews and other reviews, the Cochrane Central Register of Controlled Trials (CENTRAL) and technology assessments) (2016, issue 2) (Appendix 2)
- MEDLINE (Ovid MEDLINE(R) In-Process & Other Non-Indexed Citations and Ovid MEDLINE(R) 1946 to 2016 February) (Appendix 3);
- Embase (OvidSP) (1974 to 2016 February) (Appendix 4);
- National Institute for Health Research (NIHR) PROSPERO Register (up to 2016 May) (www.crd.york.ac.uk/prospero/);
- Aggressive Research Intelligence Facility Databases (ARIF) (up to 2016 May) (www.arif.bham.ac.uk/databases.shtml);
- ClinicalTrials.gov (up to 2016 May) (clinicaltrials.gov/);
- the International Clinical Trials Registry Platform (ISRCTN) registry (up to 2016 May) (www.isrctn.com/);

- World Health Organization (WHO) International Clinical Trials Registry Platform (ICTRP) (up to 2016 May) (www.who.int/ictrp/en/).

We used controlled indexing terms and free-text terms as well as variations of root words. Key terms related to 'ultrasound' were combined using the set operator "AND" with key terms related to 'stomach tube'. We excluded animal studies.

We applied no language restrictions.

Searching other resources

We searched for additional references by cross-checking bibliographies of retrieved full-text papers. We searched citations and references using Scopus (www.elsevier.com/solutions/scopus). We contacted common manufacturers of ultrasound devices to seek additional or unpublished studies.

We contacted the top five manufacturing companies according to their global market share in ultrasound devices: GE Healthcare, Philips, Hitachi-Aloka, Toshiba and Siemens (Ministry of Economy, Trade and Industry 2013).

Data collection and analysis

Selection of studies

We undertook the systematic review using the methods outlined in the *Cochrane Handbook for Systematic Reviews of Interventions* (Higgins 2011) and the *Cochrane Handbook for Reviews of Diagnostic Test Accuracy* (Deeks 2010). Two review authors (HT and YK or MU) independently reviewed titles and abstracts identified by the search strategy. HT and YT retrieved the full text of potentially relevant studies and independently assessed the full text against the eligibility criteria outlined in the Criteria for considering studies for this review section. We resolved differences by consensus. We provided details of both included and excluded studies in the Characteristics of included studies and Characteristics of excluded studies tables.

Data extraction and management

The two review authors (HT and YK) independently extracted data on study characteristics, participant demographics, sample size, test methods, methodological quality, sensitivity and specificity. Then, both review authors extracted data to construct a 2 × 2 contingency table including TP = correct gastric tube placement and correct visualization by ultrasound; FP = incorrect gastric tube placement but failure to visualize by ultrasound; FN = correct gastric tube placement but failure to visualize by ultrasound; TN = incorrect gastric tube placement and correct visualization by ultrasound. We resolved disagreements by consensus and with the help of the other investigator (YT).

Assessment of methodological quality

We used the QUADAS-2 tool to assess the quality of studies (Whiting 2011). We recorded the assessment on in the Characteristics of included studies table. The qualities assessed were described in detail in Appendix 5. For each item in the quality assessment form, we included a description of how the study addressed the issue and entered a judgement of 'low', 'high' or 'unclear' for an overall risk of bias for each of the four domains. In addition, we added a judgement of 'low', 'high' and 'unclear' for the overall concern of applicability to the review question for domains one, two and three. We presented an Assessment of methodological quality, which showed all judgements made for all included studies. Two review authors (HT and YK or YT) independently assessed methodological quality. We resolved disagreements by discussion between the review authors, with a further review author acting as an arbiter (YT or YK).

Statistical analysis and data synthesis

We planned to analyze data using the methods recommended in the *Cochrane Handbook for Systematic Reviews of Diagnostic Test Accuracy* (Deeks 2010). We assumed that the data were binary (either appropriate placement, or not). Therefore, no threshold or cut-off value for positivity was required. For each study, the sensitivity, specificity, positive and negative likelihood ratios, and diagnostic odds ratio (Glas 2003) for the detection of appropriate gastric tube placement were calculated from the 2 × 2 contingency table. If these counts were unavailable, we contacted the original authors of the study.

If any misinterpretation of the X-ray was reported, we planned to construct another 2 × 2 contingency table that took the misinterpretation into account. For the table, if misplacement of the tubes was interpreted as correct placement by X-ray, we planned to ignore the X-ray result and treat the outcome as misplacement. If appropriate placement of the tubes was interpreted as misplacement by X-ray, we planned to ignore the X-ray result and treat the outcome as appropriate placement. In addition, we planned to perform sensitivity analyses.

For the meta-analysis, if quantitative data synthesis was acceptable, we planned to use a bivariate random-effects model to determine summary estimates of sensitivity and specificity with 95% confidence and prediction regions (Reitsma 2005). We planned to create a summary receiver-operator curve (sROC).

We planned to present the bivariate mean estimates of sensitivity and specificity graphically along with their corresponding 95% confidence ellipses.

All analyses were to be undertaken using Review Manager 5 (RevMan 2014), or STATA software, version 13.0 (Stata).

Investigations of heterogeneity

If sufficient studies were available, we planned to investigate the following potential sources of heterogeneity by adding variables to the meta-regression model and using the command xtmelogit in Stata (Harbord 2009; Takwoingi 2013): effects of obesity (BMI over 30 or not), effects of tube diameter (up to 14 Fr or 16 Fr and above) and area of visualization (the neck, abdomen, or both).

Sensitivity analyses

We planned to perform sensitivity analyses stratified by methodological quality as per the QUADAS-2 tool domain and planned to carry out the following sensitivity analyses to explore the robustness of the results:

- excluding studies of non-sedated people;
- excluding studies of intubated people;
- excluding studies of orogastric tubes;
- excluding studies including reported X-ray misinterpretation.

The reason for excluding non-sedated people was because the gag reflex of non-sedated people may suggest tracheal insertion of the gastric tube which may affect the diagnostic accuracy of the ultrasound. For intubated people, the tube may be difficult to visualize in the oesophagus behind the trachea, or the tracheal tube itself may block the gastric tube from entering the trachea. We anticipated that there were no differences between the diagnostic accuracy of the nasogastric and orogastric tubes and confirmed the assumption using sensitivity analysis. In addition, we anticipated that we would identify other relevant factors to include in the sensitivity analyses as we went through the process of reviewing the identified studies. We specified the criteria for the sensitivity analyses in the review rather than to predefine them at the protocol stage.

Assessment of reporting bias

We did not explore reporting bias due to a lack of suitable statistical methods (Deeks 2013).

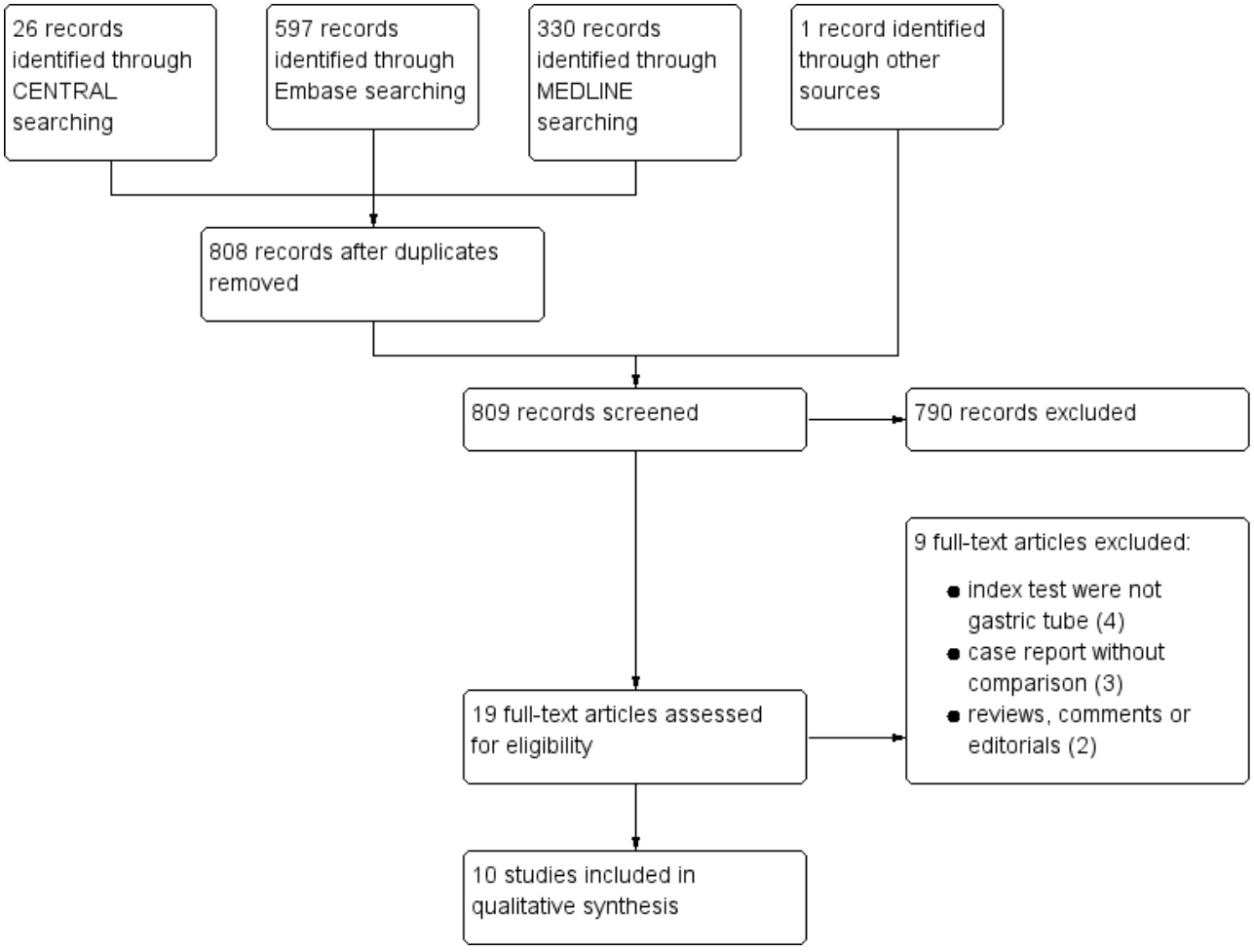
RESULTS

Results of the search

We identified 953 references through the electronic searches of CENTRAL (26 records), MEDLINE (330), and Embase (597). One record was identified through other sources (citation search of relevant guidelines). No additional reports were identified through NIHR Prospero Register, ARIF, ClinicalTrials.gov, ISRCTN registry or WHO ICTRP.

We excluded 147 duplicates from the electronic searches. We then excluded 791 records through reading the titles and abstracts. We retrieved 19 references for further assessment. Of the 19 references, we excluded nine for the reasons listed in the Characteristics of excluded studies table. This resulted in the inclusion of 10 references of 10 studies. Results of the search are displayed in Figure 1. We identified no additional reports through citation search of included studies or inquiry of manufacturing companies.

Figure 1. Study flow diagram.



Methodological quality of included studies

The methodological quality of the included studies is shown in the Characteristics of included studies table, Figure 2, and Figure 3.

Figure 2. Risk of bias and applicability concerns graph: review authors' judgements about each domain presented as percentages across included studies.

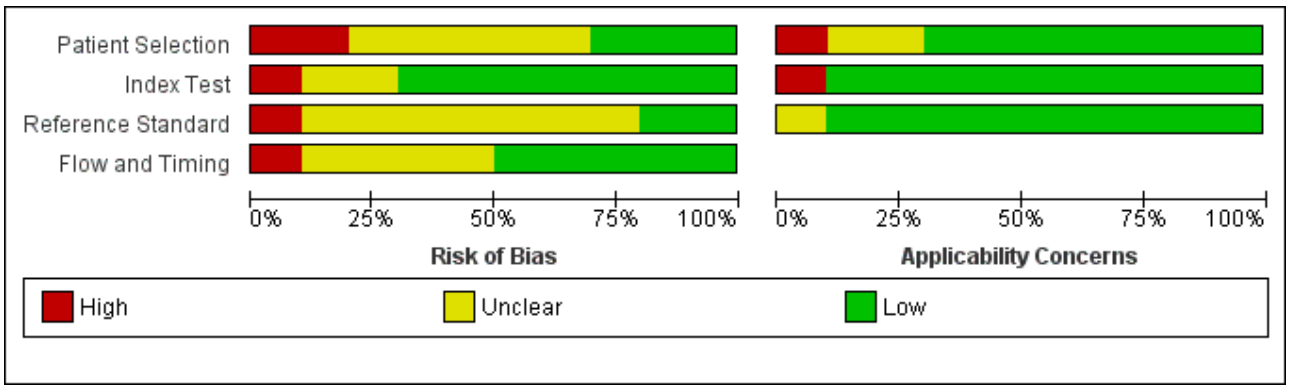
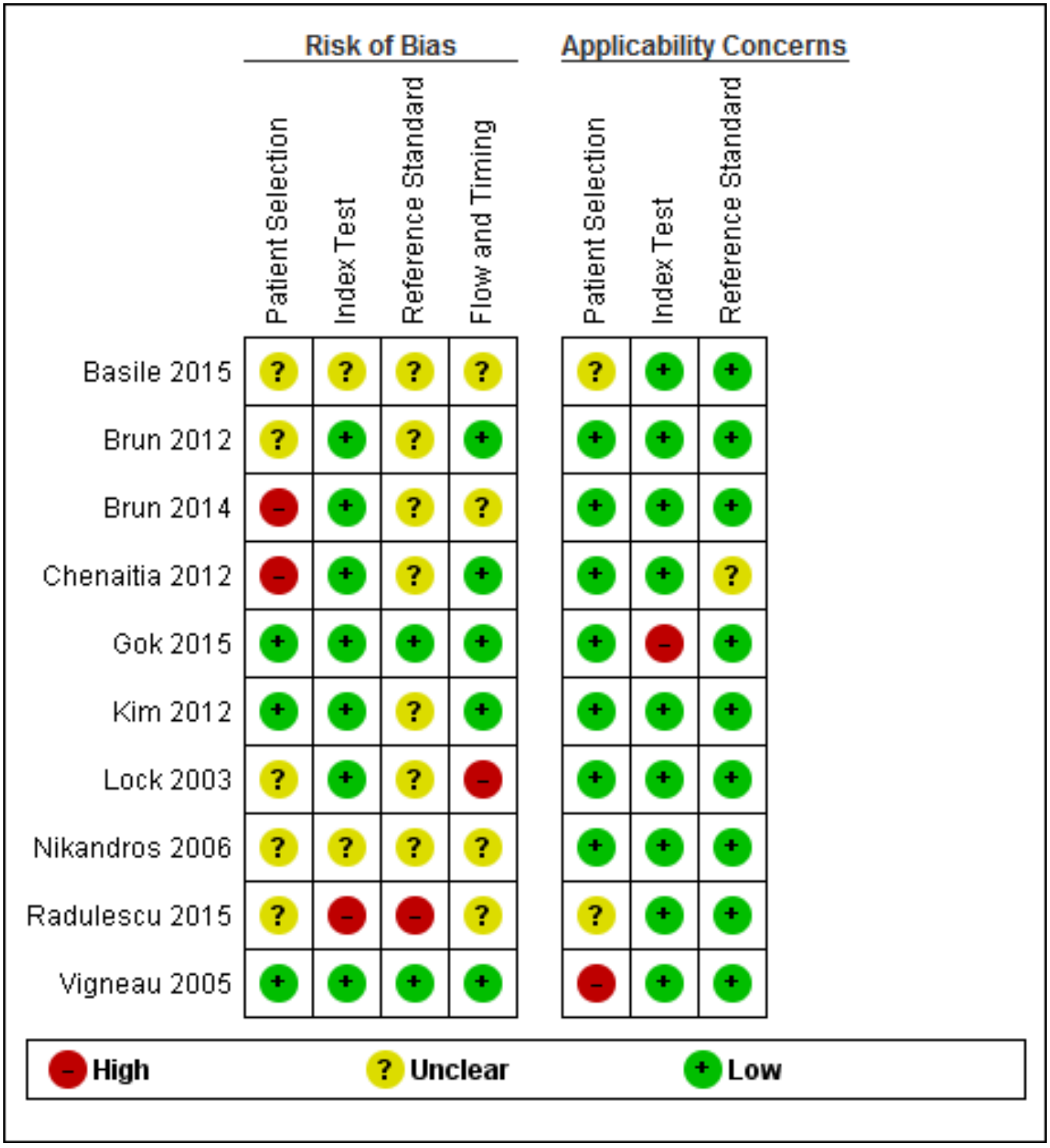


Figure 3. Risk of bias and applicability concerns summary: review authors' judgements about each domain for each included study.



No study was assigned low risk of bias or low concern in every QUADAS-2 domain assessed. Two studies presented high risk of participant selection bias because they performed the index test after they confirmed correct position by whoosh test or auscultation (Brun 2014; Chenaitia 2012), five had unclear risk (Basile 2015; Brun 2012; Lock 2003; Nikandros 2006; Radulescu 2015), and three demonstrated low risk (Gok 2015; Kim 2012; Vigneau 2005).

One study presented high risk of index test interpretation bias because a single examiner interpreted the index test and the reference standard (Radulescu 2015), two had unclear risk (Basile 2015; Nikandros 2006), and seven demonstrated low risk (Brun 2012; Brun 2014; Chenaitia 2012; Gok 2015; Kim 2012; Lock 2003; Vigneau 2005).

We considered that one study has high risk of bias in the reference standard because the use of prespecified criteria was unclear and

the same person interpreted all the results of X-ray and ultrasound (Radulescu 2015). Seven studies presented unclear risk of reference standard interpretation bias (Basile 2015; Brun 2012; Brun 2014; Chenaitia 2012; Kim 2012; Lock 2003; Nikandros 2006), and two demonstrated low risk (Gok 2015: Vigneau 2005).

One study presented high risk of bias in the 'flow and timing' domain because they reported the possibility of long time gap (greater than four hours) between the index test and the reference standard (Lock 2003), four had unclear risk (Basile 2015; Brun 2014; Nikandros 2006; Radulescu 2015), and five demonstrated low risk (Brun 2012; Chenaitia 2012; Gok 2015; Kim 2012; Vigneau 2005). In the 'flow and timing' domain, time gap presents a risk of bias because a person may feel uncomfortable when a tube remains in a misplaced position for a long time.

Findings

Characteristics of participants

Overall, we included 545 participants and 560 tube insertions for this review. The number of appropriate tube placements was 492 insertions (88%) and the number of misplacements was 68 insertions (12%). The mean age of participants in the included studies was about 50 to 60 years old (some studies did not report the range) (Table 1). None of the included studies assessed the diagnostic accuracy of ultrasound for gastric tube placement confirmation in children (aged 16 years or less).

Participants of five studies were all intubated (Brun 2012; Brun 2014; Chenaitia 2012; Gok 2015; Nikandros 2006). Over half of participants of two studies were intubated (78.8% of Vigneau 2005; 57.4% of Kim 2012). One study of 55 participants reported that 50 (83.3%) of 60 of tube insertions were performed in intubated participants (Lock 2003). The number of intubated participants in two studies was unclear (Basile 2015; Radulescu 2015). One study included 14 (42.4%) non-sedated participants (Vigneau 2005). One study of 55 participants reported that nine (15.0%) from 60 tube insertions were performed in non-sedated participants (Lock 2003). Participants of seven studies were either sedated or intubated (Brun 2012; Brun 2014; Chenaitia 2012; Gok 2015; Kim 2012; Lock 2003; Nikandros 2006). The number of non-sedated participants in two studies was unclear (Basile 2015; Radulescu 2015). Studies that provided demographic details of participants reported roughly equal numbers of males and females. Four studies were an intensive care unit (ICU) setting (Gok 2015; Lock 2003; Nikandros 2006; Vigneau 2005). Three studies were prehospital settings (Brun 2012; Brun 2014; Chenaitia 2012). One study was in the emergency medical service (EMS) (Kim 2012). It was considered that ultrasound was performed at the bedside in eight studies (Brun 2012; Brun 2014; Chenaitia 2012; Gok 2015; Kim 2012; Lock 2003; Nikandros 2006; Vigneau 2005). Two studies had an unknown setting (Basile 2015; Radulescu 2015). Two studies reported mean participant BMI of 27.1 (Gok 2015) and 24.8 (Vigneau 2005). Diameter of inserted tubes ranged from 10 Fr to 18 Fr.

Characteristics of the index test and the reference standard

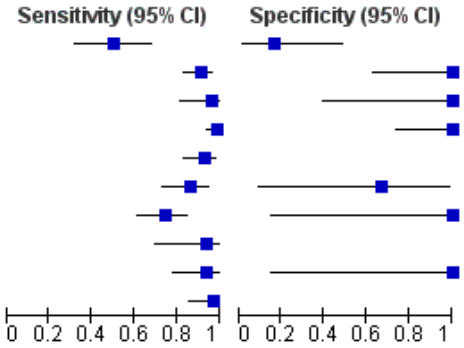
We found several methods of ultrasound to confirm gastric tubes using ultrasound (see Summary of findings 1). Four studies reported the diagnostic accuracy of ultrasound alone (Brun 2012; Chenaitia 2012; Gok 2015; Radulescu 2015), while the others reported the diagnostic accuracy of ultrasound combined with other confirmation method (Basile 2015; Brun 2014; Kim 2012; Lock 2003; Nikandros 2006; Vigneau 2005). One study reported the diagnostic accuracy of ultrasound during tube insertion (ultrasound-guide insertion) (Gok 2015). We found three visualization methods (echo window) of ultrasound: neck approach (Gok 2015), epigastric approach (Brun 2012; Chenaitia 2012; Kim 2012; Lock 2003; Vigneau 2005), and a combination of both (Brun 2014; Radulescu 2015). Two studies used air injection during ultrasound (Basile 2015; Brun 2014). One study used saline injection (Vigneau 2005). One study used both air and saline injection (Kim 2012). One study used dextrose and air injection (Nikandros 2006). Two studies did not report the echo window (Basile 2015; Nikandros 2006). None of the studies reported any complications related to ultrasound test. One study reported the performers of ultrasound were trained nurses (Basile 2015). In other studies, the performers of the ultrasound were emergency medicine specialists (Kim 2012), experienced examiners/practitioners (Lock 2003), emergency physicians (Brun 2014), intensive care physicians following two-hour training course (Vigneau 2005), emergency physician following a one-day training course (Chenaitia 2012), staff experienced in ultrasonography (Gok 2015), prehospital services doctors trained in extended Focused Assessment with Sonography for Trauma (eFAST) examination (Brun 2012), and unclear (Nikandros 2006; Radulescu 2015). It was considered that the performers interpreted the results. All included studies used X-ray as a reference standard. No misinterpretation of X-ray among gastric tube position (revealed by other reliable clinical tests) was reported.

Diagnostic accuracy estimates of included studies

We considered the studies to differ in important ways clinically, therefore, we did not perform a meta-analysis to determine summary diagnostic accuracy estimates of ultrasound. We described diagnostic accuracy estimates of the individual studies in any settings in Summary of findings 1 and Figure 4 . We separately described the diagnostic accuracy of ultrasound for confirmation of gastric tube placement for drainage in settings where X-ray facilities were not readily available for the clinical implications (Summary of findings 2). Three studies had lower accuracy estimates than those of the other studies (Basile 2015; Kim 2012; Lock 2003) (Summary of findings 1; Figure 4). Basile and colleagues reported a sensitivity of 0.50 (95% confidence interval (CI) 0.32 to 0.68) and specificity of 0.17 (95% CI 0.02 to 0.48) (Basile 2015). Kim and colleagues reported a sensitivity of 0.86 (95% CI 0.73 to 0.95) and specificity of 0.67 (95% CI 0.09 to 0.99) (Kim 2012). Lock and colleagues reported a sensitivity of 0.74 (95% CI 0.61 to 0.85) and specificity of 1.00 (95% CI 0.16 to 1.00) (Lock 2003).

Figure 4. Forest plot of diagnostic accuracy of ultrasound in different ways. Four studies reported the diagnostic accuracy of ultrasound (Brun 2012; Chenaitia 2012; Gok 2015; Radulescu 2015), while the others reported the diagnostic accuracy of ultrasound combined with other methods. Gok 2015 reported the diagnostic accuracy of ultrasound during tube insertion (ultrasound-guide insertion). We found three visualization methods (echo window) of ultrasound: neck (Gok 2015), epigastric (Brun 2012; Chenaitia 2012; Kim 2012; Lock 2003; Vigneau 2005), and a combination (Brun 2014; Radulescu 2015). Studies used air injection during ultrasound (Basile 2015; Brun 2014), saline injection (Vigneau 2005), both air and saline injection (Kim 2012), and dextrose and air injection (Nikandros 2006). Two studies did not report the echo window (Basile 2015; Nikandros 2006).

Study	TP	FP	FN	TN	Sensitivity (95% CI)	Specificity (95% CI)
Basile 2015	17	10	17	2	0.50 [0.32, 0.68]	0.17 [0.02, 0.48]
Brun 2012	80	0	8	8	0.91 [0.83, 0.96]	1.00 [0.63, 1.00]
Brun 2014	27	0	1	4	0.96 [0.82, 1.00]	1.00 [0.40, 1.00]
Chenaitia 2012	116	0	2	12	0.98 [0.94, 1.00]	1.00 [0.74, 1.00]
Gok 2015	52	0	4	0	0.93 [0.83, 0.98]	Not estimable
Kim 2012	38	1	6	2	0.86 [0.73, 0.95]	0.67 [0.09, 0.99]
Lock 2003	43	0	15	2	0.74 [0.61, 0.85]	1.00 [0.16, 1.00]
Nikandros 2006	15	0	1	0	0.94 [0.70, 1.00]	Not estimable
Radulescu 2015	28	0	2	2	0.93 [0.78, 0.99]	1.00 [0.16, 1.00]
Vigneau 2005	34	0	1	0	0.97 [0.85, 1.00]	Not estimable



DISCUSSION

Summary of main results

This review assessed the diagnostic accuracy of ultrasound for gastric tube placement confirmation. Most results showed high point estimates for correct tube detection (sensitivity) (Figure 4). However, there was a variety of point estimates for misplacement detection (specificity) and their CIs were wide due to the small sample of misplacement (Figure 4). We found considerable clinical heterogeneity among the included studies in terms of the difference of echo window, combination of ultrasound with other methods (e.g. saline flush visualization by ultrasound) and ultrasound during insertion of the tube. Thus, we could not obtain summary diagnostic accuracy (Summary of findings 1; Figure 4).

Among studies that evaluated the diagnostic accuracy of ultrasound on its own, we found three different visualization methods reported: neck approach (Gok 2015), epigastric approach (Brun 2012; Chenaitia 2012; Lock 2003), and a combination of both neck and epigastric approaches (Brun 2014; Radulescu 2015).

The authors of the studies reported mostly high sensitivity; however, the CIs of specificity were too wide to apply to clinical practice. We hypothesized that ultrasound could be an alternative to X-ray. However, studies included only a small number of participants for the purpose of determining tube misplacement (specificity) (Figure 4). In addition, there were limited data on the accuracy of tube placement in children.

Strengths and weaknesses of the review

Strengths and limitations of included studies

We contacted the authors of included studies and some authors provided us with unpublished details of studies for the review. The authors who provided additional information are presented in Acknowledgements. The weakness of our review is the inclusion of three studies from the same research group (see Table 1; Summary of findings 1) (Brun 2012; Brun 2014; Chenaitia 2012). In addition, we calculated diagnostic accuracy based on the number of tube insertions, rather than the number of participants, using 60 tube insertions among 55 participants.

Strengths and limitations of the search strategy

A strength of this review is that we placed no restrictions on the language of publication and we conducted a comprehensive search using both controlled term and free words (de Vet 2008). We avoided using search filters because of their limited sensitivity (Beynon 2013). We undertook additional searches to find related articles by inquiring major companies of ultrasound devises to obtain unpublished data. We also performed a citation search of included studies, major guidelines (ENA 2015; ESPEN Guidelines 2009; JSPEN Guideline 2013; SCCM and ASPEN Guidelines 2016), and previous related reviews (Irving 2014; Milsom 2015), regarding gastric tube placement or parenteral feeding. Therefore, we minimized the risk of missing relevant studies. Little is known about the mechanisms of publication bias for diagnostic accuracy studies and so it is not possible to estimate the impact of unpublished studies on our findings. Nevertheless, the studies included in this systematic review are likely to be the majority of studies that provided evidence on this topic.

We did not employ Web of Science (apps.webofknowledge.com/) for our citation search strategy, and acknowledge that we may have missed some studies despite the otherwise comprehensive search.

Quality assessment

Our review had several weaknesses in terms of the methodological quality of the included studies (Figure 2; Figure 3). Two studies presented high risk of participant selection bias because they performed the index test after they confirmed correct position by whoosh test or auscultation (Brun 2014; Chenaitia 2012); however, if the assumed prior test were whoosh test or auscultation, the risk of participant selection bias would be low. One study presented high risk of index test interpretation bias because a single examiner interpreted the index test and the reference standard (Radulescu

2015). We considered that one study had a high risk of bias in the reference standard because the use of prespecified criteria was unclear and the same person interpreted all the results of X-ray and ultrasound (Radulescu 2015).

Limitations in the review analyses

We could not synthesize the estimates of diagnostic accuracy (e.g. summary sensitivity, sROC curve) because of the heterogeneity of the included studies. This might make our findings relatively difficult to apply to clinical practice.

Within- and between-study comparisons

One study had extremely poor diagnostic performance with a sensitivity of 0.50 (95% CI 0.32 to 0.68) and specificity of 0.17 (95% CI 0.02 to 0.48) than those of the other studies (Basile 2015) (Summary of findings 1). The performers of ultrasound were trained personnel (nurses); however, they presented poor diagnostic accuracy. The reason was unclear; we inquired about the detailed information from the authors but we could not get sufficient information for this study.

Comparison with previous research

Milsom and colleagues systematically reviewed the methods to confirm the tube location regardless of gastric or enteric tubes and identified one study of gastric tubes. Their electronic search strategies were restricted publications to English language and they did not use controlled terms (Milsom 2015). In addition, they used a date filter for diagnostic accuracy studies restricting the search to 1985 to 2012. We could have identified additional studies by broadening the search methods but could not identify any relevant studies in children. Similarly, Irving and colleagues systematically reviewed ultrasound confirmation of gastric tube placement among children but found no studies of interest (Irving 2014).

Applicability of findings to the review question

Population and setting

Most included participants were unconscious, which may reduce the sensitivity to the tube being misplaced in the trachea. Misplaced tubes usually cause discomfort and conscious people may complain about it. Most included studies were in a prehospital setting (unconscious due to severe trauma), ICU setting (mechanical ventilated) or EMS setting. This is consistent with the population we expected to find; however, diagnostic accuracy may change according to the clinical setting, for example, clinicians may be able to perform the test more carefully in convalescent wards.

We considered that the mixture of gastric and transpyloric tube insertions had high concern regarding to applicability to the review question in 'patient selection domain' (Vigneau 2005). In addition, among include studies of 560 tube confirmations, misinterpretation of X-ray was not reported. In reality, misinterpretation of X-rays occurs especially when non-radiologists read the X-rays (ECRI and ISMP 2006; Lamont 2011).

Index test

We found various ultrasound methods regarding this review question. Brun 2014 used two-point ultrasound; they first observed the tube in the oesophagus through the neck and then confirmed the depth of the tube through the epigastric area. In contrast, Chenaitia 2012 only observed the tube through the epigastric area. Gok 2015 reported the diagnostic accuracy of real-time ultrasound during gastric tube insertion. Kim 2012 reported the diagnostic accuracy of ultrasound combined with saline and air insertion and Lock 2003 reported the accuracy of ultrasound combined with air injection. In addition, some studies did not report the method details (Basile 2015; Nikandros 2006). Such heterogeneity of the index test might be a concern for the applicability of the findings to clinical practice.

We considered that the diagnostic accuracy of real-time ultrasound during gastric tube insertion had high concern regarding to applicability to the review question (Gok 2015).

Reference standard

Most included studies used chest or abdominal X-rays. Some reported just "X-ray". No study reported misinterpretation or unclear results of X-ray; however, in clinical settings, misinterpretation of X-ray sometimes possible. Taking into account the misinterpretations, misplacement of tubes (especially in unconscious participants) might not be detected by X-ray. These differences of reference standard may affect the diagnostic accuracy of ultrasound in this review.

AUTHORS' CONCLUSIONS

Implications for practice

How is the test positioned in the clinical pathway?

For possible implication for practice, the gastric tube is first inserted into the patient via the nose or mouth, down the oesophagus and into the stomach. Next, tube placement is confirmed by ultrasound combined with other tests (whoosh test, auscultation, inflation of air, etc.) followed by X-ray visualization of the tube (e.g. chest X-ray). If a tube is misplaced and detected by X-ray visualization, the tubes would be reinserted and a second X-ray would confirm the position. If ultrasound detects obvious misplacement of the tube with this sensitivity, they would reinsert the tubes and confirm it by X-ray.

How does the index test perform in relation to its intended role (add, replace, triage)?

Available evidence suggests that ultrasound could play an important role in detecting gastric tube position combined with other confirmation methods (e.g. saline flush visualization by ultrasound). However, when we expect ultrasound to detect misplaced tubes, it is suggested that we could not use it alone as an alternative to X-rays for the feeding tube (Summary of findings 1). However, ultrasound could play an important role as one of the confirmation methods for gastric drainage tubes, especially in settings where X-ray facilities are not readily available (Summary of findings 2).

Implications for research

Additional research needed on aspects of tests beyond their accuracy

Available evidence suggests that ultrasound would mostly detect misplacement and possibly reduce repeated X-ray scan. Confirmation by X-ray scan can be difficult for people with tube placement because they have to change their body position to have a hard film plate placed on their back, or stand up for

scanning while dealing with uncomfortable tubes hanging from their nose or mouth. Further research is needed to investigate whether it would reduce repeated X-ray confirmations, patient's discomfort from the procedure and severe complications of tube feeding (e.g. feeding via a tube misplaced in the trachea resulting in severe pneumonia, pneumothorax, empyema or pulmonary haemorrhage). In addition, investigation into cost to healthcare is needed to determine if ultrasound could reduce expenditure on repeated X-rays. We consider research comparing X-ray and ultrasound considering diagnostic accuracy, patient outcome and cost is needed.

Further studies of test accuracy that need to be undertaken

Larger studies are needed to investigate whether ultrasound could replace X-rays for confirming gastric tube placement, as well as decrease severe complications, such as aspiration pneumonia, from a misplaced tube. Studies are also needed in children. We consider that investigation of the potential factors modifying the diagnostic accuracy of ultrasound is needed if data are obtained and acceptable for integration.

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CHARACTERISTICS OF STUDIES

Characteristics of included studies *[ordered by study ID]*

Basile 2015

Study characteristics	
Patient sampling	Consecutive enrolment, no information available regarding participant exclusion.
Patient characteristics and setting	No information available among participant characteristics and setting.
Index tests	Ultrasound (with and without 60 mL of air injected) by trained nurses. Blinded to whoosh test.
Target condition and reference standard(s)	No detailed information available.
Flow and timing	Participants were first tested with ultrasound (with and without 60 mL of air injected) as compared with whoosh test performed by other nurses. No information available regarding timing of reference standard or dropout of participants.
Comparative	
Notes	

Methodological quality

Item	**Authors' judgement**	**Risk of bias**	**Applicability concerns**
DOMAIN 1: Patient Selection			
Was a consecutive or random sample of patients enrolled?	Yes		
Was a case-control design avoided?	Yes		
How were participants' coughs managed? Did the study avoid reinsertion of the tube when participants coughed too much?	Unclear		
How were auscultation findings (e.g. bubbling sounds) dealt with? Did the study avoid reinsertion of the tube when auscultation was not found?	Unclear		
Did the study avoid inappropriate exclusions? Did the study avoid excluding participants for whom the GT was difficult to place?	Unclear		
Did the study avoid inappropriate exclusions? Did the study avoid excluding participants for whom tubes were difficult to visualize?	Unclear		
		Unclear	**Unclear**

Basile 2015 *(Continued)*

DOMAIN 2: Index Test Ultrasound			
Were the index test results interpreted without knowledge of the results of the reference standard?	Unclear		
		Unclear	**Low**
DOMAIN 3: Reference Standard			
Is the reference standards likely to correctly classify the target condition?	Yes		
Were the reference standard results interpreted without knowledge of the results of the index tests?	Unclear		
Were the criteria of reference standard for target condition prespecified?	Unclear		
		Unclear	**Low**
DOMAIN 4: Flow and Timing			
Did all patients receive the same reference standard?	Unclear		
Was there an appropriate interval between the index test and reference standard? We set an arbitrary 4 hours for this review	Unclear		
Were all participants included in the analysis? Consider withdrawals and withdrawals who were likely to impact on study results. Also consider the exclusion of 'difficult' participants	Unclear		
		Unclear	

Brun 2012

Study characteristics	
Patient sampling	No detailed information available regarding random or consecutive sampling. Inclusion criteria: people benefiting from the prehospital insertion of an NG tube after tracheal intubation. Exclusion criteria: aged < 18 years; supported during an interhospital transportation; presenting a suspected fracture of the bones of the skull base; and who absorbed detergents, oil or foam products.
Patient characteristics and setting	Aged ≥ 18 years, intubated in prehospital setting by EMS team which included a physician. Excluded people with suspicion of cranial base fracture and who had a history of caustic agent ingestion.
Index tests	Titan ultrasound machine in all ambulances. Physicians on board, who were e-FAST trained, received 1-day training for ultrasound verification of NG tube placement. Standardized method included

Brun 2012 *(Continued)*

	a left subcostal view with the ultrasound probe while NG tube inserted by EMS staff. If not initially seen on ultrasound, 50 mL of air injected through NG tube. X-ray control carried out at hospital and compared with prehospital results.
Target condition and reference standard(s)	Chest X-ray on arrival at the hospital.
Flow and timing	No exclusions described. Ultrasound test performed. If not initially seen on ultrasound, 50 mL of air was injected through the NG tube. X-ray control carried out at hospital and compared with the prehospital results.
Comparative	
Notes	2 review authors (HT and YT) assessed based on the extracted data.

Methodological quality

Item	**Authors' judgement**	**Risk of bias**	**Applicability concerns**
DOMAIN 1: Patient Selection			
Was a consecutive or random sample of patients enrolled?	No		
Was a case-control design avoided?	Unclear		
How were participants' coughs managed? Did the study avoid reinsertion of the tube when participants coughed too much?	Yes		
How were auscultation findings (e.g. bubbling sounds) dealt with? Did the study avoid reinsertion of the tube when auscultation was not found?	No		
Did the study avoid inappropriate exclusions? Did the study avoid excluding participants for whom the GT was difficult to place?	Unclear		
Did the study avoid inappropriate exclusions? Did the study avoid excluding participants for whom tubes were difficult to visualize?	Unclear		
		Unclear	**Low**
DOMAIN 2: Index Test Ultrasound			
Were the index test results interpreted without knowledge of the results of the reference standard?	Yes		
		Low	**Low**
DOMAIN 3: Reference Standard			
Is the reference standards likely to correctly classify the target condition?	Yes		

Brun 2012 *(Continued)*

Were the reference standard results interpreted without knowledge of the results of the index tests?	Unclear		
Were the criteria of reference standard for target condition prespecified?	Unclear		
		Unclear	**Low**
DOMAIN 4: Flow and Timing			
Did all patients receive the same reference standard?	Yes		
Was there an appropriate interval between the index test and reference standard? We set an arbitrary 4 hours for this review	Yes		
Were all participants included in the analysis? Consider withdrawals and withdrawals who were likely to impact on study results. Also consider the exclusion of 'difficult' participants	Yes		
		Low	

Brun 2014

Study characteristics	
Patient sampling	Prospective single-centre observational study performed between November 2012 and May 2013 in mobile emergency and resuscitation service. Inclusion criteria: aged ≥ 18 years receiving prehospital care and requiring GT insertion. Exclusion criteria: aged ≤ 18 years, pregnant women, contraindication at GT insertion, interhospital transfers and absence of X-ray control. After verification of correct GT placement by the auscultation method or whoosh test (instillation of air in the tube with sounds heard simultaneously through a stethoscope placed over the stomach region) combined with the aspirate method (visual inspection of aspirate contents), ultrasound test was performed.
Patient characteristics and setting	Prior test: auscultation method or whoosh test (instillation of air in tube with sounds heard simultaneously through stethoscope placed over stomach region) combined with aspirate method (visual inspection of aspirate contents). Presentation: in prehospital setting, emergency physician checked GT placement using ultrasonography during GT insertion by nurse or just after epigastric auscultation and aspirate method was realized. Intended use of index test: to determine whether or not the GT could be viewed in the oesophagus, stomach, or both.
Index tests	Probe placed transversely on the anterior neck just superior to the suprasternal notch midline at level of thyroid gland and focused on visible part of oesophagus, with longitudinal and transversal viewing, then probe placed in subxiphoid area and oriented towards left upper abdominal quadrant to visualize stomach, with transverse and longitudinal viewing. Antrum imaged in a transversal plane in epigastric area using left lobe of liver as an internal landmark, angling transducer towards left subcostal area imaged the gastric body. Ultrasound examination considered positive when GT was visualized, appearing

Brun 2014 *(Continued)*

	as an hyperechogenic circle posterior to the thyroid tissue adjacent to trachea, and as a hyperechogenic line in stomach. When GT was seen in oesophagus and not in stomach, 50 mL of air injected through GT, if ultrasonography showed dynamic fogging in stomach, GT considered in stomach.
Target condition and reference standard(s)	X-ray on arrival at hospital. Details of interpretation: unclear.
Flow and timing	No participants excluded. After verification of correct GT placement by auscultation method or whoosh test (instillation of air in tube with sounds heard simultaneously through stethoscope placed over stomach region) combined with the aspirate method (visual inspection of aspirate contents), ultrasound test was performed. If not initially seen on ultrasound, 50 mL of air injected through NG tube. X-ray control carried out at hospital and compared with prehospital results. Unclear time interval. No information comparing index test and reference standard.
Comparative	
Notes	

Methodological quality

Item	Authors' judgement	Risk of bias	Applicability concerns
DOMAIN 1: Patient Selection			
Was a consecutive or random sample of patients enrolled?	Yes		
Was a case-control design avoided?	Yes		
How were participants' coughs managed? Did the study avoid reinsertion of the tube when participants coughed too much?	Unclear		
How were auscultation findings (e.g. bubbling sounds) dealt with? Did the study avoid reinsertion of the tube when auscultation was not found?	No		
Did the study avoid inappropriate exclusions? Did the study avoid excluding participants for whom the GT was difficult to place?	Yes		
Did the study avoid inappropriate exclusions? Did the study avoid excluding participants for whom tubes were difficult to visualize?	Yes		
		High	**Low**

Brun 2014 *(Continued)*

DOMAIN 2: Index Test Ultrasound			
Were the index test results interpreted without knowledge of the results of the reference standard?	Yes		
		Low	**Low**
DOMAIN 3: Reference Standard			
Is the reference standards likely to correctly classify the target condition?	Yes		
Were the reference standard results interpreted without knowledge of the results of the index tests?	Unclear		
Were the criteria of reference standard for target condition prespecified?	Unclear		
		Unclear	**Low**
DOMAIN 4: Flow and Timing			
Did all patients receive the same reference standard?	Yes		
Was there an appropriate interval between the index test and reference standard? We set an arbitrary 4 hours for this review	Unclear		
Were all participants included in the analysis? Consider withdrawals and withdrawals who were likely to impact on study results. Also consider the exclusion of 'difficult' participants	Yes		
		Unclear	

Chenaitia 2012

Study characteristics	
Patient sampling	Prospective multicentre study in people undergoing GT insertion in prehospital setting conducted in 2 French towns (Marseille and Grasse) over 1-year period from May 2010 to May 2011. Inclusion criteria: aged ≥ 18 years, prehospital settings and requiring GT insertion. Exclusion criteria: aged < 18 years, pregnant, interhospital transfers and absence of X-ray control. After insertion and securing of GT by auscultation or whoosh test, emergency physician verified correct placement of GT by ultrasound.

Chenaitia 2012 *(Continued)*

Patient characteristics and setting	Prior test: auscultation method or whoosh test (instillation of air in tube with sounds heard simultaneously through stethoscope placed over stomach region) combined with aspirate method (visual inspection of aspirate contents). Presentation: after insertion and securing of GT, emergency physician verified correct placement of GT by ultrasound. Intended use of index and setting: confirming accurate GT placement. Setting: prehospital.
Index tests	After insertion and securing of GT, emergency physician verified correct placement of GT by ultrasound. Technique standardized; probe placed in the subxiphoid area then oriented towards left upper abdominal quadrant to visualize stomach, with transverse viewing, antrum imaged in a transversal plane in epigastric area using left lobe of liver as internal landmark, gastric body imaged by angling transducer towards left subcostal area. Ultrasound examination considered positive when GT appeared as a hyperechogenic line in stomach. Videorecorded showing GT tip; 2 radiologists reviewed each video to confirm results.
Target condition and reference standard(s)	Final confirmation of GT placement was X-ray on arrival at hospital.
Flow and timing	No participants excluded. Time interval and interventions between index tests and reference standard not described.
Comparative	
Notes	

Methodological quality

Item	Authors' judgement	Risk of bias	Applicability concerns
DOMAIN 1: Patient Selection			
Was a consecutive or random sample of patients enrolled?	Yes		
Was a case-control design avoided?	Yes		
How were participants' coughs managed? Did the study avoid reinsertion of the tube when participants coughed too much?	Unclear		
How were auscultation findings (e.g. bubbling sounds) dealt with? Did the study avoid reinsertion of the tube when auscultation was not found?	No		

Chenaitia 2012 *(Continued)*

Did the study avoid inappropriate exclusions? Did the study avoid excluding participants for whom the GT was difficult to place?	Yes		
Did the study avoid inappropriate exclusions? Did the study avoid excluding participants for whom tubes were difficult to visualize?	Yes		
		High	**Low**
DOMAIN 2: Index Test Ultrasound			
Were the index test results interpreted without knowledge of the results of the reference standard?	Yes		
		Low	**Low**
DOMAIN 3: Reference Standard			
Is the reference standards likely to correctly classify the target condition?	Yes		
Were the reference standard results interpreted without knowledge of the results of the index tests?	Unclear		
Were the criteria of reference standard for target condition prespecified?	Unclear		
		Unclear	**Unclear**
DOMAIN 4: Flow and Timing			
Did all patients receive the same reference standard?	Yes		
Was there an appropriate interval between the index test and reference standard? We set an arbitrary 4 hours for this review	Unclear		
Were all participants included in the analysis? Consider withdrawals and withdrawals who were likely to impact on study results. Also consider the exclusion of 'difficult' participants	Yes		
		Low	

Gok 2015

Study characteristics	
Patient sampling	Inclusion criteria: mechanically ventilated participants monitored in ICU between February and July 2014 who received ultrasound-guided NG tube placement. Exclusion criteria: history of neck surgery (e.g. tracheotomy), anatomic deformity, nasal fracture or severe coagulopathy; aged < 16 years.

Gok 2015 *(Continued)*

	Tube removed if coughing and dyspnoea occurred during placement.
Patient characteristics and setting	Prior test: none. Presentation: 56 mechanically ventilated participants monitored in ICU between February and July 2014 who received ultrasound-guided NG tube placement. Intended use of index test: 'real-time' imaging of passage of NG tube through oesophagus. Setting: ICU.
Index tests	Image of empty oesophagus obtained, then inserted NG tube 10-14 Fr in thickness from appropriate nostril by adjusting nasal passage. Subsequently, NG tube gently advanced, and passage visualized with ultrasound. Oesophagus primarily viewed in transverse plain then attempt made to obtain a longitudinal view. Ultrasound performed to obtain sonographic image of oesophagus before removing guidewire of NG tube.
Target condition and reference standard(s)	After ultrasound-guided tube insertion, gastric placement of the NG tube tip confirmed with abdominal X-ray. All reference standard results interpreted by a single person. Used prespecified criteria of correct position, i.e. NG tube tip below the diaphragm; should follow straight course down midline of chest to a point below diaphragm.
Flow and timing	No participants excluded. Unclear time interval. No test performed between index tests and reference standard.
Comparative	
Notes	

Methodological quality

Item	**Authors' judgement**	**Risk of bias**	**Applicability concerns**
DOMAIN 1: Patient Selection			
Was a consecutive or random sample of patients enrolled?	Yes		
Was a case-control design avoided?	Yes		
How were participants' coughs managed? Did the study avoid reinsertion of the tube when participants coughed too much?	No		
How were auscultation findings (e.g. bubbling sounds) dealt with? Did the study avoid reinsertion of the tube when auscultation was not found?	Unclear		

Gok 2015 *(Continued)*

Did the study avoid inappropriate exclusions? Did the study avoid excluding participants for whom the GT was difficult to place?	Yes		
Did the study avoid inappropriate exclusions? Did the study avoid excluding participants for whom tubes were difficult to visualize?	Yes		
		Low	**Low**
DOMAIN 2: Index Test Ultrasound			
Were the index test results interpreted without knowledge of the results of the reference standard?	Yes		
		Low	**High**
DOMAIN 3: Reference Standard			
Is the reference standards likely to correctly classify the target condition?	Yes		
Were the reference standard results interpreted without knowledge of the results of the index tests?	No		
Were the criteria of reference standard for target condition prespecified?	Yes		
		Low	**Low**
DOMAIN 4: Flow and Timing			
Did all patients receive the same reference standard?	Yes		
Was there an appropriate interval between the index test and reference standard? We set an arbitrary 4 hours for this review	Unclear		
Were all participants included in the analysis? Consider withdrawals and withdrawals who were likely to impact on study results. Also consider the exclusion of 'difficult' participants	Yes		
		Low	

Kim 2012

Study characteristics	
Patient sampling	Prospective study performed between May and September 2011 in a local emergency centre. Included participants with low consciousness in whom correct placement of NG tube was ultimately verified by chest X-ray. Inclusion criteria: aged > 18 years, undergoing NG tube insertions for reasons including drug overdose, suspicion of gastric bleeding, endotracheal intubation and others.

Kim 2012 *(Continued)*

	10 participants excluded because they did not receive X-ray confirmation.
Patient characteristics and setting	Prior test: auscultation, pH testing and ultrasound performed in random order. Presentation: participants with low consciousness in whom correct placement of NG tube was ultimately verified by chest X-ray. Intended use of index test: to verify gastric intubation. Setting: EMS.
Index tests	Ultrasound examinations included a transversal scan performed prior to tube insertion from either right or left side of the participant's neck to verify that oesophagus was located behind respiratory tract. Attempted visualization of NG tube in separate scans of fundus and antrum of stomach. Used linear probe for study of neck and convex probe for stomach. If visualization not possible, 40 mL of normal saline and 10 mL of air were injected through NG tube and if ultrasonography showed dynamic fogging in stomach, gastric placement of tube was verified.
Target condition and reference standard(s)	Chest X-rays interpreted by emergency medicine specialist who did not perform ultrasound examinations.
Flow and timing	10 participants excluded because they did not receive X-ray confirmation; no other participants excluded from analysis. Auscultation, pH testing and ultrasound performed in random order. If ultrasound visualization not possible, 40 mL of normal saline and 10 mL of air were injected through NG tube and if ultrasonography showed dynamic fogging in stomach, gastric placement of tube was verified. After these tests, an emergency medicine specialist who did not perform ultrasound examinations interpreted chest X-rays. Unclear time interval.
Comparative	
Notes	

Methodological quality

Item	Authors' judgement	Risk of bias	Applicability concerns
DOMAIN 1: Patient Selection			
Was a consecutive or random sample of patients enrolled?	Yes		
Was a case-control design avoided?	Yes		
How were participants' coughs managed? Did the study avoid reinsertion of the tube when participants coughed too much?	Unclear		
How were auscultation findings (e.g. bubbling sounds) dealt with? Did the study avoid reinsertion of the tube when auscultation was not found?	Unclear		

Kim 2012 *(Continued)*

Did the study avoid inappropriate exclusions? Did the study avoid excluding participants for whom the GT was difficult to place?	Unclear		
Did the study avoid inappropriate exclusions? Did the study avoid excluding participants for whom tubes were difficult to visualize?	Unclear		
		Low	**Low**
DOMAIN 2: Index Test Ultrasound			
Were the index test results interpreted without knowledge of the results of the reference standard?	Yes		
		Low	**Low**
DOMAIN 3: Reference Standard			
Is the reference standards likely to correctly classify the target condition?	Yes		
Were the reference standard results interpreted without knowledge of the results of the index tests?	Unclear		
Were the criteria of reference standard for target condition prespecified?	Unclear		
		Unclear	**Low**
DOMAIN 4: Flow and Timing			
Did all patients receive the same reference standard?	Yes		
Was there an appropriate interval between the index test and reference standard? We set an arbitrary 4 hours for this review	Unclear		
Were all participants included in the analysis? Consider withdrawals and withdrawals who were likely to impact on study results. Also consider the exclusion of 'difficult' participants	Yes		
		Low	

Lock 2003

Study characteristics	
Patient sampling	Inclusion criteria: people in ICU, endotracheal intubation and ventilation or independent breathing. Exclusion criteria: percutaneous endoscopic gastrostomy tube.

Lock 2003 *(Continued)*

	How were participants' coughs managed: not reported.
Patient characteristics and setting	Adults aged 16-84 years. In 50/60 procedures, participants were endotracheally intubated and ventilated. In 10/60 procedures, participants were breathing spontaneously, none had a tracheostomy. Prior test: not reported. Presentation: people in ICU, endotracheal intubation and ventilation or independent breathing. Intended use of index test: to replace X-ray for verification of GTs. Setting: ICU.
Index tests	Correct placement of tip of tube in stomach ascertained by ultrasound by detecting a 50 mL air jet applied with a syringe via the GT. Ultrasound performed by 10 experienced examiners/practitioners. Reference standard test (radiological control) done after index test (ultrasound). Results of ultrasound and other control methods compared to radiological control of tube.
Target condition and reference standard(s)	X-ray of the lower thorax or upper abdomen. Incorrect localization of tube defined as localization of tube in oesophagus or lungs.
Flow and timing	In 60 GT insertions (with 50 participants on artificial ventilation) performed on a medical ICU, correct placement of tube was controlled by auscultation, pH measurement of aspirate and ultrasound. In ultrasound, correct placement of tip of tube in stomach ascertained by detecting a 50 mL air jet applied with a syringe via GT. Results of ultrasound and other control methods compared to radiological control of tube. Period between placement of GT and radiological control was within 24 hours.
Comparative	
Notes	

Methodological quality

Item	**Authors' judgement**	**Risk of bias**	**Applicability concerns**
DOMAIN 1: Patient Selection			
Was a consecutive or random sample of patients enrolled?	Unclear		
Was a case-control design avoided?	Unclear		

Lock 2003 *(Continued)*

How were participants' coughs managed? Did the study avoid reinsertion of the tube when participants coughed too much?	Unclear		
How were auscultation findings (e.g. bubbling sounds) dealt with? Did the study avoid reinsertion of the tube when auscultation was not found?	Unclear		
Did the study avoid inappropriate exclusions? Did the study avoid excluding participants for whom the GT was difficult to place?	No		
Did the study avoid inappropriate exclusions? Did the study avoid excluding participants for whom tubes were difficult to visualize?	No		
		Unclear	**Low**
DOMAIN 2: Index Test Ultrasound			
Were the index test results interpreted without knowledge of the results of the reference standard?	Yes		
		Low	**Low**
DOMAIN 3: Reference Standard			
Is the reference standards likely to correctly classify the target condition?	Yes		
Were the reference standard results interpreted without knowledge of the results of the index tests?	Unclear		
Were the criteria of reference standard for target condition prespecified?	Unclear		
		Unclear	**Low**
DOMAIN 4: Flow and Timing			
Did all patients receive the same reference standard?	Yes		
Was there an appropriate interval between the index test and reference standard? We set an arbitrary 4 hours for this review	No		
Were all participants included in the analysis? Consider withdrawals and withdrawals who were likely to impact on study results. Also consider the exclusion of 'difficult' participants	Yes		
		High	

Nikandros 2006

Study characteristics	
Patient sampling	Prospective study in a 5-bed ICU performed between May and September 2005.
Patient characteristics and setting	Included 16 participants, 9 men and 7 women, mean (± SD) age 66.3 ± 7.1 years, mean (± SD) APACHE II score 21 ± 5.2. All participants intubated and mechanically ventilated. Prior test: not reported. Presentation: people in ICU over 5-month period. Intended use of index test: to replace radiology for verification of GTs. Setting: ICU.
Index tests	Ultrasound confirmation of NG tube position by identifying air bubbles after injecting a 10 mL mixture of 5% dextrose and air and by standard X-ray. No detailed information available regarding interpretation of results.
Target condition and reference standard(s)	NG tube position also confirmed by X-ray. No detailed information available.
Flow and timing	Median (± SD) procedure time 14.93 ± 1.71 minutes for ultrasound and 84 ± 30.64 minutes for X-ray (P < 0.001). No detailed information regarding timing, time gap, withdrawals and any intervention between index test and reference standard available.
Comparative	
Notes	

Methodological quality

Item	**Authors' judgement**	**Risk of bias**	**Applicability concerns**
DOMAIN 1: Patient Selection			
Was a consecutive or random sample of patients enrolled?	Unclear		
Was a case-control design avoided?	Yes		
How were participants' coughs managed? Did the study avoid reinsertion of the tube when participants coughed too much?	Unclear		
How were auscultation findings (e.g. bubbling sounds) dealt with? Did the study avoid reinsertion of the tube when auscultation was not found?	Unclear		

Nikandros 2006 *(Continued)*

Did the study avoid inappropriate exclusions? Did the study avoid excluding participants for whom the GT was difficult to place?	Unclear		
Did the study avoid inappropriate exclusions? Did the study avoid excluding participants for whom tubes were difficult to visualize?	Unclear		
		Unclear	**Low**
DOMAIN 2: Index Test Ultrasound			
Were the index test results interpreted without knowledge of the results of the reference standard?	Unclear		
		Unclear	**Low**
DOMAIN 3: Reference Standard			
Is the reference standards likely to correctly classify the target condition?	Yes		
Were the reference standard results interpreted without knowledge of the results of the index tests?	Unclear		
Were the criteria of reference standard for target condition prespecified?	Unclear		
		Unclear	**Low**
DOMAIN 4: Flow and Timing			
Did all patients receive the same reference standard?	Yes		
Was there an appropriate interval between the index test and reference standard? We set an arbitrary 4 hours for this review	Unclear		
Were all participants included in the analysis? Consider withdrawals and withdrawals who were likely to impact on study results. Also consider the exclusion of 'difficult' participants	Unclear		
		Unclear	

Radulescu 2015

Study characteristics	
Patient sampling	No detailed information available.
Patient characteristics and setting	No detailed information available.
Index tests	Anterolateral neck scanned in high frequency to visualize GT tube's characteristic echogenic surface with posterior anechoic shadow in oesophagus. Then, right diaphragm location identified by low-frequency imaging. Comparisons of ultrasound findings

Radulescu 2015 *(Continued)*

	made to chest X-ray findings. Data collected by a single internal medicine resident.
Target condition and reference standard(s)	No detailed information available. Data collected by a single internal medicine resident.
Flow and timing	No detailed information regarding timing, time gap, withdrawals and any intervention between index test and reference standard.
Comparative	
Notes	

Methodological quality

Item	**Authors' judgement**	**Risk of bias**	**Applicability concerns**
DOMAIN 1: Patient Selection			
Was a consecutive or random sample of patients enrolled?	Unclear		
Was a case-control design avoided?	Unclear		
How were participants' coughs managed? Did the study avoid reinsertion of the tube when participants coughed too much?	Unclear		
How were auscultation findings (e.g. bubbling sounds) dealt with? Did the study avoid reinsertion of the tube when auscultation was not found?	Unclear		
Did the study avoid inappropriate exclusions? Did the study avoid excluding participants for whom the GT was difficult to place?	Unclear		
Did the study avoid inappropriate exclusions? Did the study avoid excluding participants for whom tubes were difficult to visualize?	Unclear		
		Unclear	**Unclear**
DOMAIN 2: Index Test Ultrasound			
Were the index test results interpreted without knowledge of the results of the reference standard?	No		
		High	**Low**
DOMAIN 3: Reference Standard			
Is the reference standards likely to correctly classify the target condition?	Yes		
Were the reference standard results interpreted without knowledge of the results of the index tests?	No		

Radulescu 2015 *(Continued)*

Were the criteria of reference standard for target condition pre-specified?	Unclear		
		High	**Low**
DOMAIN 4: Flow and Timing			
Did all patients receive the same reference standard?	Unclear		
Was there an appropriate interval between the index test and reference standard? We set an arbitrary 4 hours for this review	Unclear		
Were all participants included in the analysis? Consider withdrawals and withdrawals who were likely to impact on study results. Also consider the exclusion of 'difficult' participants	Unclear		
		Unclear	

Vigneau 2005

Study characteristics	
Patient sampling	Consecutive participants during a 2-month period who received a weighted tip NG tube (12CH, Cair, France) for enteral feeding between 8:30 a.m. and 8:00 p.m. Exclusion criteria: NG tubes inserted during other periods, when only 1 physician was on duty. When participants coughed too much, tube removed and reinserted (author's reply). Examiner did not reinsert the tube when there was no auscultation (author's reply).
Patient characteristics and setting	35 weighted tip NG tubes inserted in 33 participants (18 men, 15 women; mean (± SD) age 62.2 ± 19.8 years; mean (± SD) Simplified Acute Physiology Score II score 48 ± 20.7; mean (± SD) body mass index 24.8 ± 5.8). 26 (79%) participants mechanically ventilated at the time tube insertion and 19 (73%) sedated. Main diagnoses on ICU admission were acute aggravation of chronic respiratory failure (n = 8), community-acquired pneumonia (n = 4), pulmonary pneumocystosis (n = 1), acute respiratory distress syndrome (n = 3), septic shock (n = 6), myasthenia gravis (n = 1), stroke (n = 3) and other disorders (n = 5). Prior test: none described. Presentation: daytime weighted NG tube insertion. Intended use of index: ensuring correct tube placement. Setting: ICU. Did not differentiate gastric or enteric tube (i.e. possibly passing through pyloric ring to the duodenum).
Index tests	Duodenum examined in middle epigastric area; if duodenum or NG tip (or both) not visualized, probe oriented towards left upper abdominal quadrant to visualize gastric area. If NG tip still not visible, 5 mL normal saline mixed with 5 mL air injected into tube to visualize the hyperechogenic 'fog' exiting tip. NG tube tip considered cor-

Vigneau 2005 *(Continued)*

	rectly located when surrounded by hydric and echogenic moving formations (related to peristalsis). Did not specifically record cases of pneumothorax or intrabronchial NG tube location or precise gastric/duodenal location of tip. Examiner did not use prespecified criteria of ultrasound (author's reply).
Target condition and reference standard(s)	As soon as tube was correctly inserted, radiology department performed confirmatory X-ray. Blinded design of study required NG tube tip verification by 2 physicians, 1 to interpret X-rays and 1 to perform ultrasound examination. Each physician was unaware of the other's findings. Examiner did not use prespecified criteria of X-ray (author's reply).
Flow and timing	No detailed information regarding timing, withdrawals and any intervention between index test and reference standard. Time gap between index test and reference standard not recorded (author's response).
Comparative	
Notes	

Methodological quality

Item	Authors' judgement	Risk of bias	Applicability concerns
DOMAIN 1: Patient Selection			
Was a consecutive or random sample of patients enrolled?	Yes		
Was a case-control design avoided?	Yes		
How were participants' coughs managed? Did the study avoid reinsertion of the tube when participants coughed too much?	No		
How were auscultation findings (e.g. bubbling sounds) dealt with? Did the study avoid reinsertion of the tube when auscultation was not found?	Yes		
Did the study avoid inappropriate exclusions? Did the study avoid excluding participants for whom the GT was difficult to place?	Yes		
Did the study avoid inappropriate exclusions? Did the study avoid excluding participants for whom tubes were difficult to visualize?	Yes		
		Low	**High**
DOMAIN 2: Index Test Ultrasound			
Were the index test results interpreted without knowledge of the results of the reference standard?	Yes		

Vigneau 2005 *(Continued)*

		Low	**Low**
DOMAIN 3: Reference Standard			
Is the reference standards likely to correctly classify the target condition?	Yes		
Were the reference standard results interpreted without knowledge of the results of the index tests?	Yes		
Were the criteria of reference standard for target condition prespecified?	No		
		Low	**Low**
DOMAIN 4: Flow and Timing			
Did all patients receive the same reference standard?	Yes		
Was there an appropriate interval between the index test and reference standard? We set an arbitrary 4 hours for this review	Yes		
Were all participants included in the analysis? Consider withdrawals and withdrawals who were likely to impact on study results. Also consider the exclusion of 'difficult' participants	Yes		
		Low	

APACHE II: Acute Physiology and Chronic Health Evaluation II; eFAST: extended Focused Assessment with Sonography for Trauma; EMS: emergency medical service; GT: gastric tube; ICU: intensive care unit; n: number of participants; NG: nasogastric; SD: standard deviation.

Characteristics of excluded studies *[ordered by study ID]*

Study	Reason for exclusion
Blaivas 2012	Editorial.
Dagli 2015	Nasoenteric tubes inserted into the postpyloric area.
Greenberg 1993	Transpyloric tube.
Hernandez-Socorro 1996	Not a diagnostic test accuracy study. Compared method for placing feeding tubes.
Kerforne 2013	Case report.
Lock 1997	Letter.
Tamhne 2006	pH-specific paper used as reference standard.
Wagai 1981	Case series.

Study	Reason for exclusion
Xiao-feng 2015	Nasal-jejunal tube.

DATA

Presented below are all the data for all of the tests entered into the review.

Table Tests. Data tables by test

Test	No. of studies	No. of participants
1 Ultrasound	10	550

Test 1. Ultrasound.

ADDITIONAL TABLES

Table 1. Baseline characteristics of included studies

Study ID	Male:female	Age (mean ± SD)	BMI (mean ± SD)	Children	Non-sedated	Sedated	Intubated	Diameter of tube (Fr)	Setting
Basile 2015	NR	NR	NR	NR	NR	NR	NR	NR	NR
Brun 2012 [a]	56:24	52 ± 23	NR	0	0	96	96	14 or 16	Prehospital
Brun 2014 [a]	18:14	57 ± 17	NR	0	22	10	32	14 or 16	Prehospital
Chenaitia 2012 [a]	77:53	55.7 ± 19.8	NR	0	0	130	130	14-18	Prehospital
Gok 2015	32:24	48.4 ± 28.9	27.1 ± 6.4	0	0	56	56	10-14	ICU
Kim 2012	28:19	57.6 ± 17.2	NR	0	0	47	27	16	EMS
Lock 2003	NR	59.2 ± 16.2	NR	NR	NR	NR	50	14 or 16	ICU
Nikandros 2006	9:7	66.3 ± 7.1	NR	NR	0	16	16	NR	ICU
Radulescu 2015	NR	N/R	NR	NR	NR	NR	NR	NR	NR
Vigneau 2005	18:16	62.2 ± 19.8	24.8 ± 5.8	0	14	19	26	12	ICU

BMI: body mass index; EMS: emergency medical service; ICU: intensive care unit; NR: not reported; SD: standard deviation.
[a] Reports from the same research group.

APPENDICES

Appendix 1. Additional characteristics of included studies

Study ID	Basile 2015
Report ID	2-26
Review author name	HT and YK
Authors	Basile V, Cresci A, Brondi D, Solinas D, Cei M, Mumoli N
Contact address	Department of Internal Medicine, Ospedale Civile Livorno, Livorno, Italy
Country of the study	Italy
Language of publication	English

Participants	
Age (mean, median, range)	Unclear
Sex (male numbers/%)	Unclear
BMI	Unclear
Study characteristics	
Single or multicentre?	Single
Inclusion criteria of participants	Consecutive
Total number of participants	46
Total number of adults	Unclear
Total number of children	Unclear
Total number of non-sedated participants	Unclear
Total number of intubated participants	Unclear
Types of tubes (nasogastric or orogastric)	Nasogastric
Diameter of gastric tube	Unclear
Reference standard (chest or abdominal X-ray visualization)	Chest X-ray
Detail reference standard process (if available)	Blind
Index test (where was the echo window of the tube?)	Unclear

(Continued)

Index test (where the ultrasound test was performed)	Unclear
Index test (who performed the test)	Nurses
Time gap between index test and reference standard	Unclear
Study outcome (number of people)	
Correct gastric tube placement and correct visualization by ultrasound (i.e. true-positive test)	17
Incorrect gastric tube placement but failure to visualize by ultrasound (i.e. false-positive test)	10
Correct gastric tube placement but failure to visualize by ultrasound (i.e. false-negative test)	17
Incorrect gastric tube placement and correct visualization by ultrasound (i.e. true-negative test)	2
Number of X-ray misinterpretation	Not reported
Additional information	-
Conflict of interest	Unclear

Study ID	Brun 2012
Report ID	2-21
Review author name	Dr Laurie Dontigny-Duplain, Dr Mbah Okwen Patrick (for data extraction of the French article)
Authors	Brun PM, Chenaitia H, Bessereau J, Leyral J, Barberis C, Pradel-Thierry AL, Stephan J, Benner P, Querellou E, Topin F
Contact address	E-mail: brunpierremarie@voila.fr
Country of the study	France
Language of publication	France

Participants	
Age (mean, median, range)	Mean: 52 years; median: 53.5 years; SD: 23 years
Sex (male numbers/%)	56/58.3%
BMI	Not available
Study characteristics	

(Continued)

Single or multicentre?	Single
Inclusion criteria of participants	People intubated by prehospital services that required an NG tube
Total number of participants	96
Total number of adults	96
Total number of children	0
Total number of non-sedated participants	0
Total number of intubated participants	96
Types of tubes (nasogastric or orogastric)	NG
Diameter of gastric tube	14 or 16 Fr
Reference standard (chest or abdominal X-ray visualization)	Chest X-ray on arrival at hospital
Detail reference standard process (if available)	-
Index test (where was the echo window of the tube?)	Transverse left subcostal
Index test (where the ultrasound test was performed)	Prehospital setting
Index test (who performed the test)	Prehospital services doctor trained in eFAST examination
Time gap between index test and reference standard	Not available
Study outcome (number of people)	
Correct gastric tube placement and correct visualization by ultrasound (i.e. true-positive test)	80
Incorrect gastric tube placement but failure to visualize by ultrasound (i.e. false-positive test)	0
Correct gastric tube placement but failure to visualize by ultrasound (i.e. false-negative test)	8
Incorrect gastric tube placement and correct visualization by ultrasound (i.e. true-negative test)	8
Number of X-ray misinterpretation	0
Additional information	-
Conflict of interest	None

Study ID	Brun 2014

(Continued)

Report ID	2-01
Review author name	HT and YK
Authors	Brun PM, Chenaitia H, Lablanche C, Pradel AL, Deniel C, Bessereau J, Melaine R
Contact address	Department of Emergency Medicine and Intensive Care, Desgenettes Military Hospital, Lyon, France
Country of the study	France
Language of publication	English

Participants	
Age (mean, median, range)	mean: 57 years, median: 59 years, range unclear
Sex (male numbers/%)	18/56.3%
BMI	Unclear
Study characteristics	
Single or multicentre?	Single
Inclusion criteria of participants	Aged ≥ 18 years receiving prehospital care and requiring GT insertion. Exclusion criteria: aged < 18 years, pregnant, contraindication at GT insertion, interhospital transfers and absence of X-ray control.
Total number of participants	32
Total number of adults	32
Total number of children	0
Total number of non-sedated participants	0
Total number of intubated participants	32
Types of tubes (nasogastric or orogastric)	Either nasogastric or orogastric tubes used
Diameter of gastric tube	14 Fr: 12, 16 Fr: 20
Reference standard (chest or abdominal X-ray visualization)	X-ray
Detail reference standard process (if available)	Protocol also required final confirmation of GT placement by X-ray on arrival at hospital, X-ray was the test method reference to confirm correct GT placement.
Index test (where was the echo window of the tube?)	Portable ultrasound system (Titan, Sonosite, Bothell, WA) with a microconvex probe (2-A MHz). Technique standardized; probe placed transversely on anterior neck just superior to suprasternal notch in midline at level of thyroid gland and fo-

(Continued)

	cused on visible part of the oesophagus (Figure 1 of publication), with longitudinal and transversal viewing, then probe placed in subxiphoid area and oriented towards left upper abdominal quadrant to visualize stomach (Figure 2 of publication), with transverse and longitudinal viewing. The antrum was imaged in transversal plane in epigastric area using left lobe of liver as an internal landmark, angling the transducer towards left subcostal area to image gastric body. Ultrasound examination was considered as positive when GT was visualized, appearing as an hyperechogenic circle posterior to the thyroid tissue adjacent to the trachea (Figure 1 of publication), and as a hyperechogenic line in stomach (Figure 2 of publication). When GT was seen in oesophagus and not in stomach, 50 mL of air were injected through the GT, if ultrasonography showed dynamic fogging in the stomach, GT was considered in stomach.
Index test (where the ultrasound test was performed)	Prehospital setting
Index test (who performed the test)	Emergency physician
Time gap between index test and reference standard	Unclear
Study outcome (number of people)	
Correct gastric tube placement and correct visualization by ultrasound (i.e. true-positive test)	Echo + fogging 28 Echo only 27
Incorrect gastric tube placement but failure to visualize by ultrasound (i.e. false-positive test)	Echo + fogging 0 Echo only 0
Correct gastric tube placement but failure to visualize by ultrasound (i.e. false-negative test)	Echo + fogging 0 Echo only 1
Incorrect gastric tube placement and correct visualization by ultrasound (i.e. true-negative test)	Echo + fogging 4 Echo only 4
Number of X-ray misinterpretation	0
Additional information	-
Conflict of interest	Unclear

Study ID	Chenaitia 2012
Report ID	2-05,11
Review author name	HT and YK
Authors	Chenaitia H, Brun PM, Querellou E, Leyral J, Bessereaud J, Aimée C, Bouazize R, Georgesf A, Louisf F; WINFOCUS (World Interactive Network Focused On Critical Ultrasound) Group France

(Continued)

Contact address	Service de Médecine d'Urgence et de Radiologie, Centre Hospitalier General de Clavary, Grasse, France Tel.: +33 4 91499191; fax: +33 4 91386943
Country of the study	France
Language of publication	English

Participants	
Age (mean, median, range)	Mean ± SD: 55.7 ± 19.8 years
Sex (male numbers/%)	77/59%
BMI	Unclear
Study characteristics	
Single or multicentre?	Multicentre
Inclusion criteria of participants	Inclusion criteria: aged ≥ 18 years in prehospital settings and requiring GT insertion Exclusion criteria: aged < 18 years, pregnant, interhospital transfers and absence of X-ray control
Total number of participants	130
Total number of adults	130
Total number of children	0
Total number of non-sedated participants	0
Total number of intubated participants	130
Types of tubes (nasogastric or orogastric)	Both
Diameter of gastric tube	7 × 18-Fr GTs were inserted and all were visible, 94 × 16-Fr GTs were inserted and 98% were visible, and 29 × 14-Fr GTs were inserted and 81% were visible.
Reference standard (chest or abdominal X-ray visualization)	X-ray
Detail reference standard process (if available)	X-ray on arrival at hospital
Index test (where was the echo window of the tube?)	Subxiphoid area
Index test (where the ultrasound test was performed)	Prehospital
Index test (who performed the test)	2 emergency physicians who performed ultrasound examination were experienced and certi-

(Continued)

	fied in emergency ultrasound, had 1-day of training dedicated to study the specificities of this type of ultrasound examination.
Time gap between index test and reference standard	Unclear
Study outcome (number of people)	
Correct gastric tube placement and correct visualization by ultrasound (i.e. true-positive test)	116
Incorrect gastric tube placement but failure to visualize by ultrasound (i.e. false-positive test)	0
Correct gastric tube placement but failure to visualize by ultrasound (i.e. false-negative test)	2
Incorrect gastric tube placement and correct visualization by ultrasound (i.e. true-negative test)	12
Number of X-ray misinterpretation	0
Additional information	-
Conflict of interest	None

Study ID	Gok 2015
Report ID	2-06,07,09
Review author name	HT and YK
Authors	Gok F, Kilicaslan A, Yosunkaya A
Contact address	Necmettin Erbakan University, Meram Faculty of Medicine, Department of Anesthesiology and Reanimation, Intensive Care Unit, Konya 42080, Turkey Email: fundagok@gmail.com
Country of the study	Turkey
Language of publication	English

Participants	
Age (mean, median, range)	Mean ± SD: 48.4 ± 28.9 years
Sex (male numbers/%)	32/57.1%

(Continued)

BMI	Mean ± SD: 27.1 ± 6.4
Study characteristics	
Single or multicentre?	Single
Inclusion criteria of participants	56 mechanically ventilated participants monitored in the ICU between February and July 2014 who received ultrasound-guided NG tube placement were included in the study. Exclusion criteria: histories of neck surgery (e.g. tracheotomy), anatomic deformity, nasal fracture or severe coagulopathy.
Total number of participants	56
Total number of adults	56 (author's reply)
Total number of children	0 (author's reply)
Total number of non-sedated participants	0
Total number of intubated participants	56
Types of tubes (nasogastric or orogastric)	Nasogastric, guidewire
Diameter of gastric tube	10-14 Fr
Reference standard (chest or abdominal X-ray visualization)	After ultrasound-guided tube insertion, gastric placement of the NG tube tip confirmed with abdominal X-ray (author's reply). All reference standard results interpreted by a single person (author's reply). Used prespecified criteria of the correct position; i.e. NG tube tip below the diaphragm; should follow straight course down midline of chest to a point below diaphragm (author's reply).
Detail reference standard process (if available)	-
Index test (where was the echo window of the tube?)	Transversely placed over the suprasternal notch. Images obtained of isthmus and 2 lobes of thyroid gland. By shifting the probe to the left, the concentric layers of the oesophagus under thyroid lobe left to trachea were attempted to be viewed.
Index test (where the ultrasound test was performed)	ICU
Index test (who performed the test)	Ultrasound examination performed by the same operator, experienced in ultrasonography.
Time gap between index test and reference standard	10 minutes to 1 hour (author's reply)
Study outcome (number of people)	
Correct gastric tube placement and correct visualization by ultrasound (i.e. true-positive test)	52
Incorrect gastric tube placement but failure to visualize by ultrasound (i.e. false-positive test)	0

(Continued)

Correct gastric tube placement but failure to visualize by ultrasound (i.e. false-negative test)	4
Incorrect gastric tube placement and correct visualization by ultrasound (i.e. true-negative test)	0
Number of X-ray misinterpretation	0
Additional information	4 unclear result of ultrasound
Conflict of interest	None reported

Study ID	Kim 2012
Report ID	2-12,13,14
Review author name	HT and YK
Authors	Kim HM, So BH, Jeong WJ, Choi SM, Park KN
Contact address	Department of Emergency Medicine, College of Medicine, The Catholic University of Korea, St. Mary's Hospital, Seoul, South Korea. Email: emsky@catholic.ac.kr
Country of the study	Korea
Language of publication	English

Participants	
Age (mean, median, range)	Mean ± SD: 57.6 ± 17.2 years
Sex (male numbers/%)	28/59.6%
BMI	Unclear
Study characteristics	
Single or multicentre?	Single
Inclusion criteria of participants	Unclear criteria Prospective study performed between May and September 2011 in a local emergency centre. Included participants with low consciousness in whom correct placement of NG tube was ultimately verified by chest X-ray.

(Continued)

	Aged > 18 years, undergoing NG tube insertions for reasons including drug overdose, suspicion of gastric bleeding, endotracheal intubation and others. 17 patients with normal levels of consciousness were excluded. 10 participants did not undergo X-ray examination.
Total number of participants	47
Total number of adults	47
Total number of children	0
Total number of non-sedated participants	0
Total number of intubated participants	27
Types of tubes (nasogastric or orogastric)	Nasogastric
Diameter of gastric tube	16 Fr
Reference standard (chest or abdominal X-ray visualization)	Chest X-ray
Detail reference standard process (if available)	Final confirmation of gastric placement of tube by chest X-ray, i.e. test method reference standard to confirm correct NG tube placement. Chest X-rays interpreted by emergency medicine specialist who did not perform ultrasound examinations.
Index test (where was the echo window of the tube?)	In oesophagogastric junction, NG tube directly visualized with longitudinal and angled scans of the epigastrium. Visualization of NG tube in separate scans of fundus and antrum of stomach.
Index test (where the ultrasound test was performed)	EMS
Index test (who performed the test)	Ultrasound examinations conducted by 2 emergency medicine specialists.
Time gap between index test and reference standard	Unclear
Study outcome (number of people)	-
Correct gastric tube placement and correct visualization by ultrasound (i.e. true-positive test)	38
Incorrect gastric tube placement but failure to visualize by ultrasound (i.e. false-positive test)	1
Correct gastric tube placement but failure to visualize by ultrasound (i.e. false-negative test)	6
Incorrect gastric tube placement and correct visualization by ultrasound (i.e. true-negative test)	2
Number of X-ray misinterpretation	0

(Continued)

Additional information	-
Conflict of interest	None reported

Study ID	Lock 2003
Report ID	2-08
Review author name	Ms Katharina Kunzweiler, Dr Matthias Rinderknecht (translation and data extraction of the German article)
Authors	Lock G, Reng CM, Köllinger M, Rogler G, Schölmerich J, Schlottmann K
Contact address	Medizinische Klinik Albertinenkrankenhaus Süntelstr. 11a, 22457 Hamburg, Germany Tel.: 040/5588-2262, Email: guntram.lock@albertinen.de
Country of the study	Germany
Language of publication	Germany

Participants	
Age (mean, median, range)	Mean ± SD: 59.2 ± 16.2 years; range: 16-84 years
Sex (male numbers/%)	Not reported
BMI	Not reported
Study characteristics	
Single or multicentre?	Single (internal ICU of a university hospital)
Inclusion criteria of participants	Inclusion criteria: people in ICU, endotracheal intubation and ventilation or independent breathing Exclusion criteria: percutaneous endoscopic gastrostomy How were participants' coughs managed: not reported. How were auscultation findings dealt with: auscultation in the epigastrium after insufflation of 50 mL of air by a bladder syringe; localization counted as correct if sound of incoming air in epigastrium could clearly be auscultated. Prior testing: not reported. Presentation: in 50/60 procedures, participants were endotracheally intubated and ventilated; in 10/60 procedures, participants were breathing spontaneously, none had a tracheostomy.

(Continued)

	In 51/60 procedures, participants were unable to co-operate; in 8/60 procedures, participants were partly able to co-operate and in 1 procedure fully able to co-operate. In 49/60 procedures, tube placed for feeding, in 11/60 procedures, for drainage.
Total number of participants	55 participants with in 60 gastric tube insertions
Total number of adults	Not reported
Total number of children	Not reported
Total number of non-sedated participants	9 procedures
Total number of intubated participants	Participants were intubated in 50 gastric tube insertions
Types of tubes (nasogastric or orogastric)	Nasogastric (in exceptional cases orogastric)
Diameter of gastric tube	58 times soft silicon tube, diameter 14.6 Charrière 2 times drainage tube, diameter not reported
Reference standard (chest or abdominal X-ray visualization)	Reference standard: X-ray X-ray of lower thorax or upper abdomen. Incorrect localization of tube defined as localization of tube in oesophagus or lungs. X-ray usually carried out routinely on next morning after procedure or because of another medical indication. Period between placement of gastric tube and radiological control was within 24 hours.
Detail reference standard process (if available)	Not reported
Index test (where was the echo window of the tube?)	In ultrasound, correct placement of tip of tube in stomach was ascertained by detecting a 50 mL air jet applied with a syringe via the gastric tube.
Index test (where the ultrasound test was performed)	ICU
Index test (who performed the test)	Ultrasound performed by 10 experienced examiners/practitioners.
Time gap between index test and reference standard	After auscultation in the epigastrium, pH measurement of aspirate or ultrasound, examiner decided, if correct placement of gastric tube was documented by these methods. Period between placement of gastric tube and radiological control always within 24 hours.
Study outcome (number of people)	
Correct gastric tube placement and correct visualization by ultrasound (i.e. true-positive test)	43
Incorrect gastric tube placement but failure to visualize by ultrasound (i.e. false-positive test)	0
Correct gastric tube placement but failure to visualize by ultrasound (i.e. false-negative test)	15

(Continued)

Incorrect gastric tube placement and correct visualization by ultrasound (i.e. true-negative test)	2
Number of X-ray misinterpretation	-
Additional information	-
Conflict of interest	Not reported

Study ID	Nikandros 2006
Report ID	3-01
Review author name	HT and YK
Authors	Nikandros M, Skampas N, Theodorakopoulou M, Ioannidou S, Theotokas M, Armaganidis A
Contact address	Not reported (we contacted the journal *Critical Care* and Prof Armaganidis Apostles)
Country of the study	Greece
Language of publication	English

Participants	
Age (mean, median, range)	Mean ± SD: 66.3 ± 7.1 years
Sex (male numbers/%)	9/56%
BMI	Unclear
Study characteristics	
Single or multicentre?	Single
Inclusion criteria of participants	Unclear
Total number of participants	16
Total number of adults	Unclear
Total number of children	Unclear
Total number of non-sedated participants	0
Total number of intubated participants	16

(Continued)

Types of tubes (nasogastric or orogastric)	NG tube
Diameter of gastric tube	Unclear
Reference standard (chest or abdominal X-ray visualization)	X-ray
Detail reference standard process (if available)	-
Index test (where was the echo window of the tube?)	Unclear
Index test (where the ultrasound test was performed)	ICU
Index test (who performed the test)	Unclear
Time gap between index test and reference standard	Unclear
Study outcome (number of people)	
Correct gastric tube placement and correct visualization by ultrasound (i.e. true-positive test)	15
Incorrect gastric tube placement but failure to visualize by ultrasound (i.e. false-positive test)	0
Correct gastric tube placement but failure to visualize by ultrasound (i.e. false-negative test)	1
Incorrect gastric tube placement and correct visualization by ultrasound (i.e. true-negative test)	0
Number of X-ray misinterpretation	0
Additional information	-
Conflict of interest	Unclear

Study ID	Radulescu 2015
Report ID	2-27
Review author name	HT and YK
Authors	Radulescu V, Ahmad S
Contact address	Stony Brook University Hospital, St James, NY
Country of the study	US
Language of publication	English

Participants

(Continued)

Age (mean, median, range)	Unclear
Sex (male numbers/%)	Unclear
BMI	Unclear
Study characteristics	
Single or multicentre?	Unclear
Inclusion criteria of participants	Unclear
Total number of participants	32
Total number of adults	Unclear
Total number of children	Unclear
Total number of non-sedated participants	Unclear
Total number of intubated participants	Unclear
Types of tubes (nasogastric or orogastric)	Gastric tube
Diameter of gastric tube	Unclear
Reference standard (chest or abdominal X-ray visualization)	Chest X-ray
Detail reference standard process (if available)	Unclear
Index test (where was the echo window of the tube?)	Anterolateral neck scanned in high frequency to visualize the gastric tube's characteristic echogenic surface with posterior anechoic shadow in oesophagus. Then, right diaphragm location identified by low-frequency imaging.
Index test (where the ultrasound test was performed)	Unclear
Index test (who performed the test)	Unclear
Time gap between index test and reference standard	Unclear
Study outcome (number of people)	
Correct gastric tube placement and correct visualization by ultrasound (i.e. true-positive test)	28
Incorrect gastric tube placement but failure to visualize by ultrasound (i.e. false-positive test)	0
Correct gastric tube placement but failure to visualize by ultrasound (i.e. false-negative test)	2
Incorrect gastric tube placement and correct visualization by ultrasound (i.e. true-negative test)	2
Number of X-ray misinterpretation	0

(Continued)

Additional information	-
Conflict of interest	Unclear

Study ID	Vigneau 2004
Report ID	2-3,28
Review author name	HT and YK
Authors	Vigneau C, Baudel JL, Guidet B, Offenstadt G, Maury E
Contact address	Service de Reanimation Medicale, Hôpital Saint -Antoine, Assistance Publique-Hôpitaux de Paris, 184 rue du Faubourg Saint-Antoine, 75571 Paris Cedex 12, France
Country of the study	France
Language of publication	English

Participants	
Age (mean, median, range)	Mean ± SD: 62.2 ± 19.8 years
Sex (male numbers/%)	18/54.5%
BMI	Mean 24.8 ± 5.8
Study characteristics	
Single or multicentre?	Single
Inclusion criteria of participants	All consecutive participants during a 2-month period who received a weighted NG tube (12CH, Cair, France) for enteral feeding between 8:30 a.m. and 8:00 p.m.
Total number of participants	33
Total number of adults	Unclear
Total number of children	Unclear
Total number of non-sedated participants	14
Total number of intubated participants	26
Types of tubes (nasogastric or orogastric)	NG (weighted-tip NG tube)
Diameter of gastric tube	12 Fr

(Continued)

Reference standard (chest or abdominal X-ray visualization)	X-ray
Detail reference standard process (if available)	As soon as tube was correctly inserted, radiology department performed confirmatory X-ray. Times required to obtain the X-ray and ultrasound results were recorded.
Index test (where was the echo window of the tube?)	Epigastric area
Index test (where the ultrasound test was performed)	ICU
Index test (who performed the test)	Principal investigator (CV) was an intensive care physician who had not graduated in sonography, and who therefore followed a specific 2-hour training course with a radiologist.
Time gap between index test and reference standard	Not recorded
Study outcome (number of people)	
Correct gastric tube placement and correct visualization by ultrasound (i.e. true-positive test)	Echo only 26 Echo + saline injection 8
Incorrect gastric tube placement but failure to visualize by ultrasound (i.e. false-positive test)	0
Correct gastric tube placement but failure to visualize by ultrasound (i.e. false-negative test)	1 unclear result of ultrasound, but successful insertion (author's response)
Incorrect gastric tube placement and correct visualization by ultrasound (i.e. true-negative test)	0
Number of X-ray misinterpretation	0
Additional information	1 unclear result of ultrasound (gas interposition)
Conflict of interest	None (author's response)

BMI: body mass index; eFAST: extended Focused Assessment with Sonography for Trauma; GT: gastric tube; ICU: intensive care unit; NG: nasogastric; SD: standard deviation.

Appendix 2. CENTRAL search strategy

1. MeSH descriptor: [Ultrasonography] explode all trees
2. (ultrason* or ultrasound* or echotomograph* or echo tomograph* or echograph* or sonograph* or ultra sound or acoustic):ti,ab,kw (Word variations have been searched)
3. #1 or #2
4. MeSH descriptor: [Intubation, Gastrointestinal] explode all trees
5. ((stomach or gastric or gastro* or nasogastric or feeding or fine bore or Ryles) near/3 (tube* or intubat*)):ti,ab,kw (Word variations have been searched)
6. #4 or #5
7. #3 and #6

Appendix 3. MEDLINE search strategy

1. exp Ultrasonography/

2. (ultrason* or ultrasound* or echotomograph* or echo tomograph* or echograph* or sonograph* or ultra sound or acoustic).ti,ab,kw.
3. 1 or 2
4. exp Intubation, Gastrointestinal/
5. ((stomach or gastric or gastro* or nasogastric or feeding or fine bore or Ryles) adj3 (tube* or intubat*)).ti,ab,kw.
6. 4 or 5
7. 3 and 6
8. animals/ not human/s
9. 7 not 8

Appendix 4. Embase search strategy

1. exp ultrasound/
2. (ultrason* or ultrasound* or echotomograph* or echo tomograph* or echograph* or sonograph* or ultra sound or acoustic).ti,ab,kw.
3. 1 or 2
4. exp stomach tube/
5. exp nasogastric tube/
6. ((stomach or gastric or gastro* or nasogastric or feeding or fine bore or Ryles) adj3 (tube* or intubat*)).ti,ab,kw.
7. 4 or 5 or 6
8. 3 and 7
9. animal/not human/
10. 8 not 9

Appendix 5. Study quality assessment details

Domain 1: participant selection

Risk of bias: could the selection of participants have introduced bias?

Signalling question 1: was a consecutive or random sample of participants enrolled?

Signalling question 2: was a case-control design avoided?

Signalling question 3: did the study avoid reinsertion of the tube when participants coughed too much?

Signalling question 4: did the study avoid reinsertion of the tube when participants did not make a bubbling sound?

Signalling question 5 and 6: did the study avoid inappropriate exclusions?

Coughing or the absence of bubbling sounds indicates misplacement of tubes into the airway. If participants experience these tests and receive reinsertion based on the results, referral bias is suspected. In addition, anatomical variation of the neck structure (e.g. larynx, pharynx) may make insertion of gastric tubes more difficult (Der Kureghian 2011; Holland 2013). This point may also affect the difficulty of visualizing the tubes by ultrasound. We classified as 'yes' those studies that excluded people who had difficulties with nasogastric tube insertion or visualization, 'no' for those studies where people did not experience such difficulties and 'unclear' where this information was not clear.

Applicability: were there concerns that the included participants and the setting did not match the review question?

The inclusion criteria for this review specified studies in which the participants were considered to require gastric tube insertion (not including transpyloric tube) for any reason. Therefore, we anticipated that all the studies in the review were judged as 'low' concern.

Domain 2: index test

Risk of bias: could the conduct or interpretation of the index test have introduced bias?

Signalling question 1: were the index test results interpreted without knowledge of the results of the reference standard?

We classified the study as 'yes' if ultrasound test results were interpreted without knowledge of the reference standard or if ultrasound test results were interpreted before the X-ray test, 'no' if the ultrasound tests were interpreted with knowledge of the reference standard results and 'unclear' if this information was not clear.

Applicability: were there concerns that the index test, its conduct or interpretation differed from the review question?

Confirmation of gastric tube placement by ultrasound was an inclusion criterion for this review, so we anticipated that all studies were classified as 'low' concern.

Domain 3: reference standard

Risk of bias: could the reference standard, its conduct or its interpretation have introduced bias?

Signalling question 1: is the reference standard likely to correctly classify the target condition?

Signalling question 2: were the reference standard results interpreted without knowledge of the results of the index test?

Signalling question 3: were the criteria of reference standard for target condition prespecified?

We classified the studies as 'yes' if the criteria for appropriate gastric tube placement were checked by X-ray visualization, 'no' if the criteria for verification of placement were by any other methods and 'unclear' if this information was not clear. We classified the study as 'yes' if X-ray visualization results were interpreted without knowledge of the index test, 'no' if the X-ray visualization was interpreted with knowledge of the index test results and 'unclear' if this information was not clear. We classified the study as 'yes' if the criteria of reference standard for target condition were prespecified, 'no' if the criteria of reference standard for target condition were not prespecified and 'unclear' if this information was not clear.

Applicability: were there concerns that the target condition as defined by the reference standard did not match the review question?

The target condition is the appropriate placement of a gastric tube in the stomach via the nose or mouth, which may be improved by the use of prespecified diagnostic criteria for chest X-ray interpretation (Lamont 2011). We evaluated those studies that used clear diagnostic criteria for X-ray visualization interpretation as 'low' concern, those that did not use any criteria or where the interpretation was based on an individual clinician's interpretation as 'high' concern and 'unclear' concern if this information was not clear.

Domain 4: flow and timing

Risk of bias: could the participant flow have introduced bias?

Signalling question 1: did all participants receive the same reference standard?

Signalling question 2: was there an appropriate interval between the index test and reference standard?

Signalling question 3: were all participants included in the analysis?

We classified the study as 'yes' if all participants had the same reference standard, 'no' if the reference standard was different from chest or abdominal X-ray and 'unclear' if this information was not clear. If a gastric tube was correctly inserted and initial gastric tube placement was confirmed, continual assessment is still required because some routine activities (e.g. vomiting, coughing, retching) may cause tube displacement (Simons 2012). Therefore, any delay in testing may influence results. However, we set an arbitrary time delay between tests in line with the AACCN 2009, which recommends tube location to be checked at four-hourly intervals (Simons 2012). We classified the study as 'yes' if the delay was less than four hours, 'no' if the delay was four hours or more and 'unclear' if the information was not clear.

Uninterpretable results may be present (e.g. unclear chest X-ray or ultrasound). Additionally, withdrawals from the study may be present. We classified the study as 'yes' if uninterpretable results were reported and the study had no withdrawals or the withdrawals were unlikely to affect the results, 'no' if uninterpretable results were not reported or there were withdrawals that were likely to affect the results, or both, and 'unclear' if this information was not clear.

CONTRIBUTIONS OF AUTHORS

HT drafted the protocol and review with contributions from YK and Emma Barber (from the National Center for Child Health and Development).

HT and YK devised the study selection criteria.

HT, YK, YT, MA and Yuhong (Cathy) Yuan (Trials Search Co-ordinator) undertook the search strategy.

HT, YK and YT developed the study design and research question.

HT, YK and YN developed the statistical analysis/synthesis of data plan.

HT and Yuhong (Cathy) Yuan ran the search strategy.

HT, YK and MA screened the search results.

HT and YK extracted the data and assessed the methodological quality.

All review authors contributed to revising the manuscript, reviewed all drafts and agreed on the final version.

DECLARATIONS OF INTEREST

HT: none known.

YT: none known.

YN: none known.

MA: none known.

YK: none known.

SOURCES OF SUPPORT

Internal sources

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External sources

- No sources of support supplied

DIFFERENCES BETWEEN PROTOCOL AND REVIEW

We planned to present the sensitivity, specificity, positive and negative likelihood ratios, and diagnostic odds ratio for the detection of appropriate gastric tube placement (Glas 2003); however, we did not calculate the positive predictive value or negative predictive value because these values of individual studies were profoundly affected by the incidence of their studies and might cause confusion for readers when they apply the findings to their own setting. We did not calculate the diagnostic odds ratio because of the sparse data. We did not synthesize the diagnostic accuracy estimates of included studies because of the heterogeneity of the index test (the difference of echo window, combined with other confirmation methods and ultrasound during insertion of the tube). Alternatively, we presented true positive = correct gastric tube placement and correct visualization by ultrasound; false positive = incorrect gastric tube placement but failure to visualize by ultrasound; false negative = correct gastric tube placement but failure to visualize by ultrasound; true negative = incorrect gastric tube placement and correct visualization by ultrasound in Summary of findings 1. We tailored the QUADAS-2 tool before application to all included studies in our published protocol for the review because the agreement had been poor and we considered further refinement of the tool was needed (e.g. omitted unimportant signalling questions) (Whiting 2011).

INDEX TERMS

Medical Subject Headings (MeSH)

*Ultrasonography, Interventional; Case-Control Studies; Cross-Sectional Studies; Intubation, Gastrointestinal [*instrumentation]; Radiography, Abdominal; Stomach [*diagnostic imaging]

MeSH check words

Adolescent; Adult; Child; Humans; Middle Aged