Office of Evidence Based Practice (EBP) – Critically Appraised Topic: Nasogastric (NG)/Orogastric (OG) Tube Length Estimation/Verification

Specific Care Question

Since 2012, what is the state of the science in estimating NG/OG tube insertion lengths and what bedside testing has been proven to verify NG/OG tube placement?

Recommendations Based on Current Literature

A strong recommendation is made to employ one of two insertion length predictors (age-related, height-based [ARHB] or the nose-ear-mid-umbilicus [NEMU]) for determining NG/OG tube length is based on the GRADE Evidence to Decision instrument[d]. The overall certainty in the evidence is very low[d].

A strong recommendation is made for the continued use of bedside pH testing, based on the GRADE Evidence to Decision instrument[d]. The overall certainty in the evidence is low[d].

Literature Summary

Background. Inserting naso- (NG) or oro-gastric (OG) tubes is viewed as a benign routine procedure performed typically by nursing staff. In a recent prevalence study in which 63 organizations participated, NG/OG tubes were reported in 24% of the inpatient neonatal/pediatric population (*n = 1991)*, with the range being reported from 22 to 68% (Lyman et al., 2016). These tubes are usually inserted via a blind procedure; however, nurses have the responsibility to ensure the tube location is verified to be the correct position prior to use. Lyman et al. (2016) identified that the most common methods of tube verification was aspiration (33%), auscultation (29%) and pH testing (16%). In 2012, the Children's Hospital Association published a *Patient Safety Alert* identifying a call to action to: (a) immediately discontinue the use of auscultation to verify NG tube placement, (b) consider discontinuing the NG tube insertion measurement predictor of nose-ear-xiphoid, and (c) consider x-ray verification when indicated (Children's Hospital Association, 2012). This review will summarize literature that answers the PICOT question.

Study characteristics. The search for suitable studies was completed on April 12, 2019. After duplicates were removed, C. Kemper, PhD, RN, CPHQ, CPPS reviewed the 86 titles and/or abstracts found in the search and identified 25 single studies believed to answer the question. After an in-depth review of the articles, five articles answered the question (see Figure 1).

Estimating NG/OG tube length study characteristics. Since 2012 two studies, a randomized control trial (Ellett et al., 2012) and a cohort study (Nguyen, Fang, Saxton, & Holberton, 2016), were identified that estimated NG/OG tube lengths. Ellett et al. (2012) compared correct NG/OG tube insertion lengths of three existing methods (age-related, height-based [ARHB], nose-ear-xiphoid [NEX], and nose-ear-mid-umbilicus [NEMU] of predicting the correct gastric tube insertion length was employed. Nguyen et al. (2016) was a replication cohort study using a revised neonatal weight-based formula to estimate NG/OG tube lengths.

Bedside testing to verify NG/OG tube placement study characteristics. Three diagnostic studies were identified from the literature search that reported the use of bedside testing to verify NG/OG tube placement (Metheny, Pawluszka, Lulic, Hinyard, & Meert, 2017; Mizzi, Cozzi, Beretta, Greco, & Braga, 2017; Zatelli & Vezzali, 2017). One study (Metheny et al., 2017) reported the sensitivity, specificity, positive and negative predictive values associated with four different pH cut points (<4.0, <4.5, <5.0, and <5.5). While the two remaining studies reported two novel approaches to verify NG/OG tube placement: (a) use of IRIS technology (IRIS uses a camera to provide the visualization of anatomic landmarks) while inserting a Kangaroo Feeding Tube (Mizzi et al., 2017) and (b) use of four-point sonography to validate correct NG tube placement (Zatelli & Vezzali, 2017).

Summary by Outcome

Estimating NG/OG tube length. A randomized control trial (Ellett et al., 2012) and a cohort study (Nguyen, Fang, Saxton, & Holberton, 2016) used two different approaches to determine the insertion length for placing an NG or OG tube at the bedside. For both studies, the reference standard employed to validate correct NG/OG tube placement was a chest or abdominal radiograph (Ellett et al., 2012; Nguyen et al., 2016). Ellett et al. (2012)

tested NEX, NEMU, and ARHB for determining insertion NG/OG tube length for children between one month and 17 years (*n* = 103). When NEMU and ARHB were compared the odds ratio (OR) proved to be insignificant, OR 0.24, 95% Confidence Interval (CI) [0.02, 2.22] (see Figure 4). When NEX was compared to NEMU and ARHB, the odds were 23.26, 95% CI [2.82, 191.88] and 5.47, 95% CI [1.56, 19.22] times greater, respectively, that the NG or OG was misplaced on insertion (see Figures 5 and 6). Nguyen et al. (2016) tested a revised weight-based (rWB) formula to determine the NG/OG insertion length (*n* = 195) in neonates. Eighty-four percent of the NG or OG tubes were correctly placed (Nguyen et al., 2016). The data reported indicates that using NEMU and ARHB for children between one month and 17 years is favorable compared to the use of NEX for estimating the NG/OG tube length. In addition, the data supports the use of the rWB formula in estimating the NG/OG tube length in neonates.

Certainty of the evidence for estimating NG/OG tube lengths in neonates. The certainty of the evidence was very low based on very serious risk of bias, very serious inconsistency, and very serious imprecision. The risk of bias was very serious due to the employed study method. As only one study was identified to answer this question, the findings were considered inconsistent. Imprecision was serious due to the low number of participants in the study.

Certainty of the evidence for estimating NG/OG tube lengths in children > 1 month of age to 17 years of age. The certainty of the evidence was very low based on very serious risk of bias, very serious inconsistency, and serious imprecision. The risk of bias was very serious due as the sample size was not determined a priori. As only one study was identified to answer this question, the findings were very serious for inconsistency. Imprecision was serious due to the low number of participants in the study.

Bedside testing *to verify NG/OG tube placement*. One diagnostic study (Metheny et al., 2017) reported the sensitivity, specificity, and positive (PPV) and negative predictive values (NPV) associated with four different cut points (<4.0, <4.5, <5.0, and <5.5) for bedside pH testing (*N* = 212) to identify which pH differentiates between NG/OG tube placement in the stomach versus the trachea. Based on the study findings a pH cut point of less than 5.0 provides a PPV of 100% and the most reasonable sensitivities, specificities and NPV across the four acid inhibitor/recent feeding categories. Mizzi et al. (2017) performed a pilot study in which NGs were inserted in adult patients (*N* = 20) with the use of IRIS technology. Validation of NG placement occurred through the visualization of gastric mucosa in 18 patients (90%) with the median time for NG tube placement being 5 minutes with a range between 2 and 32 minutes (Mizzi et al., 2017). It is not clear if the IRIS technology is feasible in the pediatric population. Zatelli and Vezzali (2017) employed a cohort methodology (*N* = 114) in which an intensivist used sonography to visualize the NG in four different quadrants (esophagus, epigastrium, antrum, and gastric fundus). Four-point sonography validation occurred in 100% of the patients and was confirmed by radiography. The authors note the time for sonography validation was 10 minutes compared to 60 minutes for radiography validation (this timeframe began when the radiography request was sent to completion of the radiologic referral) (Zatelli & Vezzali, 2017).

Certainty of the evidence for using pH to verify NG/OG tube placement. The evidence was of low certainty based on serious inconsistency and imprecision. As only one study (Metheny et al., 2017) was identified to answer this question, the findings were considered inconsistent. Imprecision was serious due to the low number of participants in the study.

Certainty of the evidence for using IRIS technology to verify NG/OG tube placement. The evidence was of very low certainty based on serious risk of bias, indirectness, inconsistency and imprecision. Risk of bias was assessed as very serious for two reasons: (a) the index test was performed by medical staff; it is uncertain if this diagnostic test could be performed by staff nurses at Children's Mercy Kansas City; and (b) the study was a pilot study. Indirectness was serious as the patient population studied were adults. The IRIS technology was employed in only one study therefore the findings were considered serious for inconsistency. Imprecision was serious due to the low number of participants.

Certainty of the evidence for using sonography to verify NG/OG tube placement. The evidence was of very low quality based on serious risk of bias, indirectness, inconsistency and imprecision. Risk of bias was assessed as serious for the index test was performed by medical staff, it is uncertain if this diagnostic test could be performed by staff nurses at Children's Mercy Kansas City. Indirectness was serious as the patient population studied was primarily adults. The sonography was employed in only one study; therefore, the findings were considered serious for inconsistency. Imprecision was serious due to the low number of participants.

Identification of Studies

Search Strategy and Results (see Figure 1)

PubMed search:

("Intubation, Gastrointestinal/methods"[Mesh] OR "Intubation, Gastrointestinal/nursing"[Mesh] OR "Intubation, Gastrointestinal/standards"[Mesh]) AND ("gastric acid"[Mesh] OR "Gastric Acidity Determination"[Mesh] OR "Radiography"[MeSH] OR "Ultrasonography"[Mesh] OR "Auscultation"[MeSH] OR placement[tiab] OR verification[tiab] OR capnometry) AND (child OR children OR infant OR infancy OR adolescence OR pediatr* OR paediatr*) AND (("2012/01/01"[PDat] : "2019/12/31"[PDat]))

CINAHL search:

Monday, March 25, 2019

#	Query	Limiters/Expanders	Last Run Via	Results
S4	S1 AND S2	Limiters - Published Date: 20120101-20191231; Age Groups: Infant, Newborn: birth-1 month, Infant: 1-23 months, Child, Preschool: 2-5 years, Child: 6-12 years, All Infant, All Child Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	29
S3	S1 AND S2	Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	252
S2	(MH "Tube Placement Determination") OR (MH "Catheter Placement Determination") OR (MH "Gastric Acid") OR (MH "Gastric Acidity Determination") OR (MH "Radiography+") OR (MH "Ultrasonography+") OR (MH "Auscultation+") OR "capnometry" OR "placement" OR "verification"	Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	264,501
S1	(MH "Intubation, Gastrointestinal/MT/NU/ST")	Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	500

Records identified through database searching *n* = 101
Additional records identified through other sources *n* = 0

Studies Included in this Review

Citation	Study Type
Ellett et al. (2012)	Predictive study comparing correct NG/OG tube insertion lengths between ARHB, NEX, and NEMU
Metheny et al. (2017)	Diagnostic
Mizzi et al. (2017)	Diagnostic pilot project

Nguyen et al. (2016)	Replication cohort study comparing correct NG/OG tube insertion lengths for weight-based formula
Zatelli and Vezzali (2017)	Diagnostic

Studies Not Included in this Review with Exclusion Rationale

Citation	Reason for exclusion
Arora and Karody (2017)	Case report for diagnosing hiatal hernia
Barkholt and Fenger-Grøn (2017)	Unable to analyze, article in Danish
Beghetto, Anziliero, Leães, and de Mello (2015)	Substantiated that auscultation test showed little correlation with radiographic findings for enteral feeding tube location
Brown (2017)	Pre-post intervention study verifying postpyloric feeding tube
Clifford, Heimall, Brittingham, and Davis (2015)	Narrative review
Dias et al. (2017)	Narrative review
Ellett et al. (2014)	Cross sectional, descriptive study
Guerrero-Márquez, Martínez-Serrano, and Míguez-Navarro (2014)	Unable to analyze, article in Spanish
Irving et al. (2018)	Narrative review
Kemper, Northington, Wilder, and Visscher (2014)	Commentary
Lyman et al. (2016)	Prevalence study to determine how often enteral access devices are used in a hospital setting
Lyman (2017)	Q and A format
Northington, Lyman, Guenter, Irving, and Duesing (2017)	Survey of home NG placement practices
Northington, Lyman, Moore, and Guenter (2018)	Narrative review of home NG tube practices
Parker, Withers, and Talaga (2018)	Survey of RN practices
Tiancha, Jiyong, and Min (2015)	Postpyloric feeding tube placement
Rao et al. (2016)	Not specific to bedside NG placement
Rollins, Arnold-Jellis, and Taylor (2012)	Analyzed accuracy of radiologic reporting of NG placement
Wan Ibadullah et al. (2016)	Unable to analyze, article in Spanish
"Pediatric Feeding Tube Project" 2018)	Call for institutions supporting a feeding tube project

Methods Used for Appraisal and Synthesis

[a]Rayyan is a web-based software used for the initial screening of titles and / or abstracts for this analysis (Ouzzani, Hammady, Fedorowicz & Elmagarmid, 2017).

[b]Review Manager (Higgins & Green, 2011) is a Cochrane Collaborative computer program used to assess the study characteristics as well as the risk of bias and create the forest plots found in this analysis.

[c]The GRADEpro Guideline Development Tool (GDT) is the tool used to create the Summary of Findings table(s) for this analysis (see Tables 1 and 3).

[d]The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram depicts the process in which literature is searched, screened, and eligibility criteria is applied (Moher, Liberati, Tetzlaff, & Altman, 2009).

[a]Ouzzani, M., Hammady, H., Fedorowicz, Z., & Elmagarmid, A. (2016). Rayyan-a web and mobile app for systematic reviews. *Systematic Reviews, 5*(1), 210. doi:10.1186/s13643-016-0384-4

[b]Higgins, J. P. T., & Green, S. e. (2011). *Cochrane Handbook for Systematic Reviews of Interventions [updated March 2011]* (Version 5.1.0 ed.): The Cochrane Collaboration, 2011.
[c]GRADEpro GDT: GRADEpro Guideline Development Tool (2015). McMaster University, (developed by Evidence Prime, Inc.). [Software]. Available from gradepro.org.
[d]Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). *P*referred *R*eporting *I*tems for *S*ystematic Reviews and *M*eta-*A*nalyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097 **For more information, visit www.prisma-statement.org.**

Question Originator
Carol Kemper, PhD, RN, CPHQ, CPPS
Medical Librarian Responsible for the Search Strategy
Keri Swaggart, MLIS, AHIP
EBP Scholar's Responsible for Analyzing the Literature
Teresa Bontrager, MSN, RN, CPEN
Justine Edwards, RN, MSN, CPEN
Rebecca Frederick, PharmD
Kori Hess, PharmD
Linda Martin, RN, BSN, CPAN
Hope Scott, RN, BSN, CPEN
EBP Team Member Responsible for Reviewing, Synthesizing, and Developing this Document
Jacqueline A. Bartlett, PhD, RN

Acronyms Used in this Document

Acronym	Explanation
NG	Nasogastric
OG	Orogastric
ARHB	Age-related height-based
NEMU	Nose-ear-mid-umbilicus
NEX	Nose-ear-xiphoid
OR	Odds ratio
CI	Confidence Interval
rWB	Revised weight based
PPV	Positive predictive value
NPV	Negative predictive value

Date Developed/Updated
10/2019; 01/2020

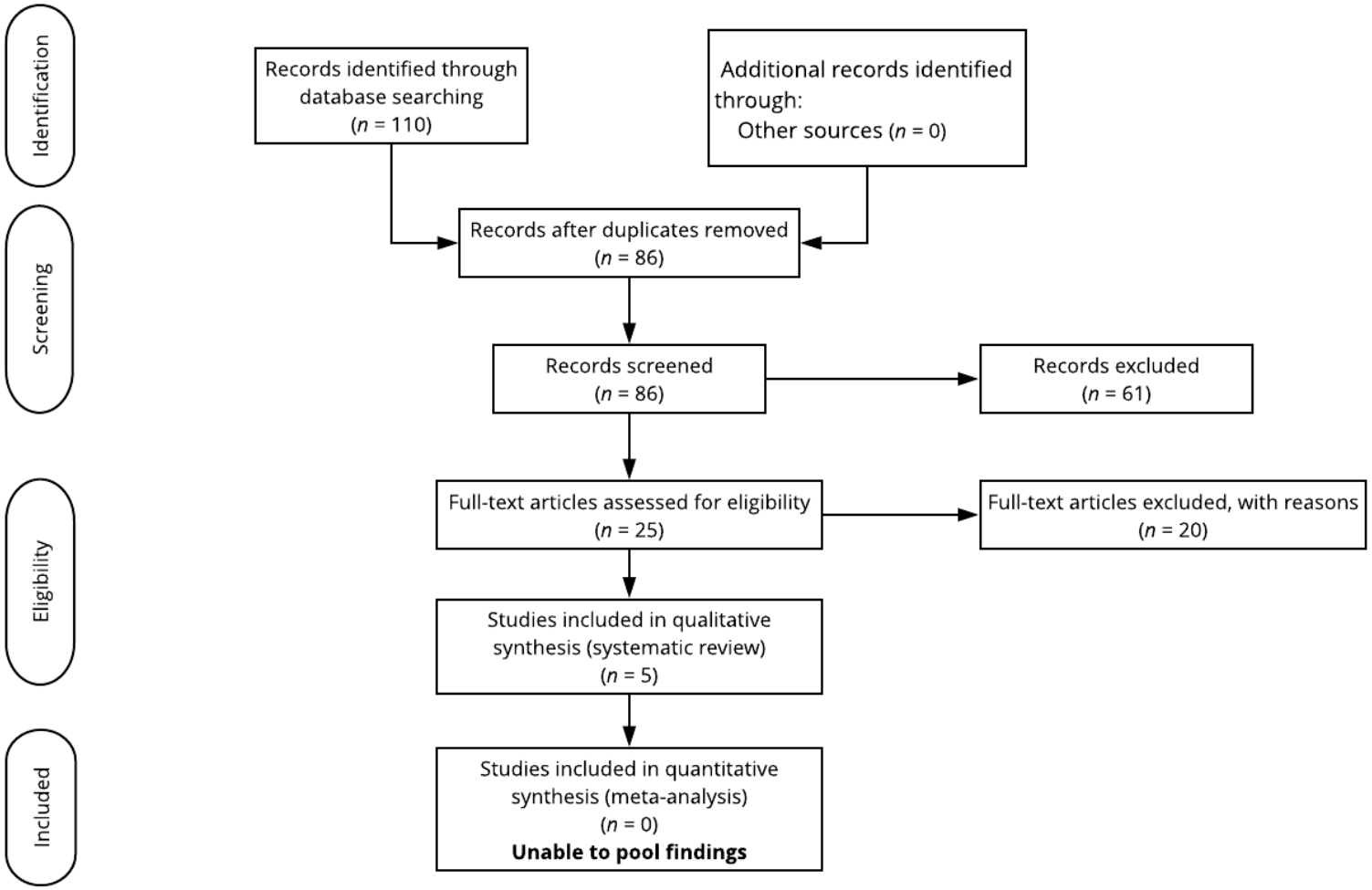

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRIMSA)[e]

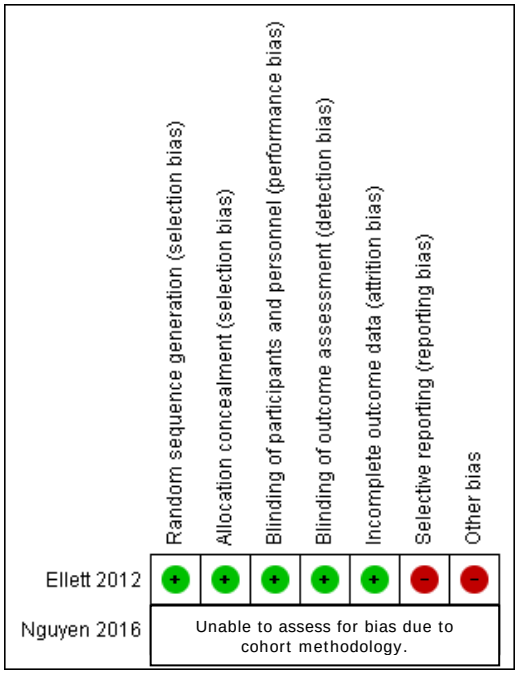

Figure 2. Risk of Bias Summary for NG Insertion Length Literature

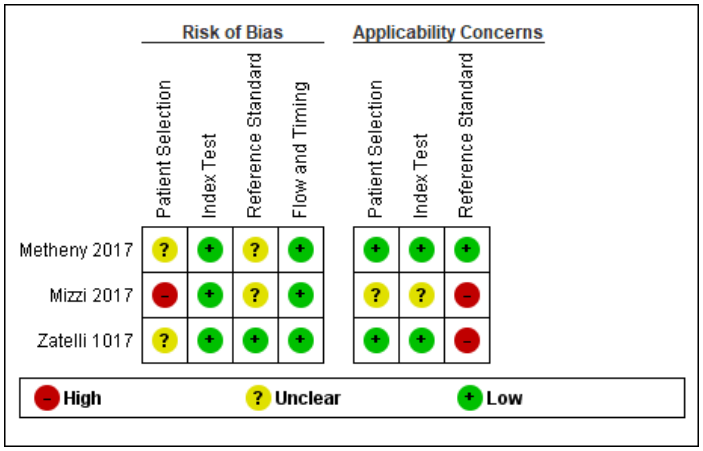

Figure 3. Risk of Bias Summary for Diagnostic Verification of NG/OG Placement

Summary of Findings Tables

Table 1. Estimating NG/OG tube length study characteristics. Ellett et al. (2012)

Certainty assessment							Summary of findings			
№ of participants (studies) Follow-up	**Risk of bias**	**Inconsistency**	**Indirectness**	**Imprecision**	**Publication bias**	**Overall certainty of evidence**	**Study event rates (%)**	**Relative effect (95% CI)**	**Anticipated absolute effects**	
									Risk with NEMU	**Risk difference with ARHB**
ARHB compared to NEMU for NG tube insertion length Outcome: Incorrect Tube Placement										
71 (1 observational study)	very serious [a]	not serious [b]	not serious	serious [c]	none	⨁◯◯◯ VERY LOW	**With NEMU** 4/36 (11.1%)	**With ARHB** 1/35 (2.9%)	**OR 0.24** (0.02 to 2.22)	111 per 1,000	**82 fewer per 1,000** (from 109 fewer to 106 more)
ARHB compared to NEX for health problem or population Outcome: Incorrect Tube Placement										
68 (1 observational study)	very serious [a]	not serious [b]	not serious	very serious [c]	none	⨁◯◯◯ VERY LOW	**With NEX** 13/32 (40.6%)	**With ARHB** 4/36 (11.1%)	**OR 5.47** (1.56 to 19.22)	406 per 1,000	**383 more per 1,000** (from 110 more to 523 more)
NEMU compared to NEX for health problem or population Outcome: Incorrect Tube Placement										
67 (1 observational study)	very serious [a]	not serious [b]	not serious	very serious [c]	none	⨁◯◯◯ VERY LOW	**With NEX** 13/32 (40.6%)	**With NEMU** 1/35 (2.9%)	**OR 23.26** (2.82 to 191.88)	406 per 1,000	**535 more per 1,000** (from 252 more to 586 more)

Explanations

a. This is a sub-group analysis report from a larger RCT. A total of 1,087 children met inclusion criteria but only 55.2% were approached based on physician's agreement to have the patient in the study (ARHB, n = 36; NEMU, n = 35; NEX, n = 32).

b. Only one study was included in the analysis; therefore, inconsistency could not be assessed.

c. Small sample size (NEX, n = 32; NEMU, n = 35) and the low number of incorrect tube placement events.

Table 2. Sensitivity, Specificity Based on Four Cut Points (<5.5, <5.0, < 4.5, <4.0)*

	pH cut-off							
	<5.5		<5.0		<4.5		< 4.0	
	Sensitivity*	*Specificity**	Sensitivity**	Specificity**	Sensitivity**	Specificity**	Sensitivity**	Specificity**
Acid inhibitor absent, recent feeding absent	100	98.3	94.1	100	88.2	100	66.7	100
Acid inhibitor present, recent feeding absent	94.0	98.3	70.0	100	56.0	100	34.0	100
Acid inhibitor absent, recent feeding present	100	98.3	60	100	28.3	100	13.3	100
Acid inhibitor present, recent feeding present	96.1	98.3	47.1	100	25.5	100	3.9	100

Metheny, Pawluszka, Lulic, Hinyard, & Meert (2017)95% CI not reported

Table 3. Summary of Findings For Using Bedside pH to Verify NG/OG tube placement

Outcome	Nº of studies (Nº of patients)	Study design	Factors that may decrease certainty of evidence					Test accuracy CoE*	Importance
			Risk of bias	Indirectness	Inconsistency	Imprecision	Publication bias		
True positives (patients with NG/OG placement)	1 studies (212 patients)	cohort & case-control type studies	not serious	serious [a]	not serious [b]	serious [c]	none	⨁⨁◯◯ LOW	CRITICAL
False negatives (patients incorrectly classified as not having NG/OG placement)									CRITICAL
True negatives (patients without NG/OG placement)	1 studies (212 patients)	cohort & case-control type studies	not serious	serious [d]	not serious [e]	serious [f]	none	⨁⨁◯◯ LOW	CRITICAL
False positives (patients incorrectly classified as having NG/OG placement)									CRITICAL

Explanations

* Confidence of Evidence

a. The study measuring the pH to diagnose NG/OG placement in children was performed in infants (median age, in weeks 12; range 0.5 -51) only and therefore it is unclear if this diagnostic test could be used in the entire pediatric population.

b. Only one study was included in the analysis; therefore, inconsistency could not be assessed.

c. Small sample size (*N* = 212); unable to verify calculations as true positives, true negatives, false positives, and false negatives values were not disclosed by the study authors.

d. The study measuring the pH to diagnose NG/OG placement in children was performed in infants (median age in weeks 12; range 0.5 -51) only and therefore it is unclear if this diagnostic test could be used in the entire pediatric population.

e. Only one study was included in the analysis; therefore, inconsistency could not be assessed.

f. Small sample size (*N* = 212); unable to verify calculations as true positives, true negatives, false positives, and false negatives values were not disclosed by the study authors.

Characteristics of Studies

Ellett et al. (2012)

<table>
<tr><td>Methods</td><td>Randomized Control Trial</td></tr>
<tr><td>Participants</td><td>
Participants: Hospitalized children aged 1 month to 17 years requiring nasogastric (NG) / orogastic (OG) tube placement
Setting: Three midwestern hospitals
Randomized into study: N = 103
• Group 1, age-related, height-based tube placement (ARHB): n = 36
• Group 2, nose-ear-mid-umbilicus tube placement (NEMU): n = 35
• Group 3, nose-ear-xiphoid tube placement (NEX): n = 32
Completed Study: N = 103
• Group 1: n = 36
• Group 2: n = 35
• Group 3: n = 32
Gender, males (as defined by researchers):
• Group 1: n = 20 (55.6%)
• Group 2: n = 19 (54.3%)
• Group 3: n = 14 (43.8%)
Race / ethnicity or nationality (as defined by researchers):
<table>
<tr><td>Race/Ethnicity</td><td>ARHB, n (%)</td><td>NEMU, n (%)</td><td>NEX, n (%)</td></tr>
<tr><td>Caucasian</td><td>29 (80.6)</td><td>28 (80.0)</td><td>29 (90.6)</td></tr>
<tr><td>Other</td><td>4 (11.1)</td><td>3 (8.6)</td><td>1 (3.1)</td></tr>
<tr><td>Hispanic</td><td>2 (5.6)</td><td>3 (8.6)</td><td>1 (3.1)</td></tr>
<tr><td>Non-Hispanic</td><td>34 (94.4)</td><td>32 (91.4)</td><td>31 (96.9)</td></tr>
</table>
Age
<table>
<tr><td>Age (months)</td><td>ARHB, n (%)</td><td>NEMU, n (%)</td><td>NEX, n (%)</td></tr>
<tr><td>1-28</td><td>16 (44.4)</td><td>15 (42.9)</td><td>15 (46.9)</td></tr>
<tr><td>29-100</td><td>15 (41.7)</td><td>14 (40.0)</td><td>11 (34.4)</td></tr>
<tr><td>101-215</td><td>5 (13.9)</td><td>6 (17.1)</td><td>6 (18.8)</td></tr>
</table>
Inclusion Criteria:
• Children hospitalized on one of the participating units who required an NG/OG tube to be inserted
Exclusion Criteria:
• Staff physician refused consent
• Medical condition could drastically affect their gastric acid-secreting ability
• Previous gastric surgery resulting in removal of part of stomach
• NG/OG tube ordered by physician, had orifices further than 3 cm from the tip of the tube
</td></tr>
</table>

	Power Analysis (as reported by authors): Assuming the true percentages of correct placements in the stomach/duodenum/pylorus were as observed in this study, there was 97% power to detect an association between placement method and correct placement using a chi-square test (two-sided, level of significance .05). Conservatively using Fisher Exact tests (two-sided, level of significance .017) to estimate power for all pair-wise differences, there was 93% power when comparing NEX to NEMU, but only 57% power when comparing NEX to ARHB, and 4% power when comparing NEMU to ARHB.
Interventions	All groups had tubed placed by a research nurse according to standard practice in the unit where the child was admitted (NG vs. OG) • **Group 1:** ARHB tube placement • **Group 2:** NEMU tube placement • **Group 3:** NEX tube placement
Outcomes	**Primary outcome(s):** • Error rates of three existing methods of predicting the correct gastric tube insertion length o *For the primary analysis, only tubes that were placed too high with the tube tip in the esophagus or GEJ were considered to be placed incorrectly, and tubes placed in the stomach, pylorus, or duodenum were considered correctly placed o As a secondary analysis, a more strict definition of correctness was used whereby the tube tip was required to actually be in the stomach o Tube placement was confirmed by radiograph read by pediatric radiologist, physician, or pediatric nurse practitioner (based on unit policy) o All radiographs were reviewed at a later time by a single board-certified pediatric radiologist (second author) who was blinded as to the method used to estimate the required length of the tube **Covariates tested** o Adjusting for the two stratification factors did not substantially change the results: ▪ Use of acid inhibiting medications (p = .2935) ▪ Age group (p = .3270) *Outcomes of interest to the CMH CAT development team
Notes	Note "incorrect tube placement" refers to tip located outside of stomach/duodenum/pylorus Results being presented were part of a larger study examining gastric tube placement in 276 children including neonates.

Risk of bias table

Bias	Scholars' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	A computer-generated stratified block randomization strategy in which stratification was by use of acid-inhibiting medication (needed for a different aim of this trial) and age group (1–28 months, 29–100 months, and 101–204 months)
Allocation concealment (selection bias)	Low risk	Random assignments were delivered to the research nurses in sequentially numbered opaque sealed envelopes.
Blinding of participants and personnel (performance bias)	Low risk	Personnel taking measurements completed data collection prior to treatment assignment
Blinding of outcome assessment (detection bias)	Low risk	All radiographs were reviewed at a later time by a single board-certified pediatric radiologist (second author) who was blinded as to the method used to estimate the required length of the tube
Incomplete outcome data (attrition bias)	Low risk	No missing outcome data (intent-to-treat)
Selective reporting (reporting bias)	High risk	Although data was reported as specified; power analysis was not completed a-priori since the study was a sub-group analysis.
Other bias	High risk	They did not use the most reliable method to obtain length in children < 2 years of age. Recumbant stadiometers, especially for research, are the preferred length measurement devices.

Metheny et al. (2017)

Patient Selection	
A. Risk of Bias	
Patient Sampling	Not described
Was a consecutive or random sample of patients enrolled?	Unclear
Was a case-control design avoided?	Yes
Did the study avoid inappropriate exclusions?	Unclear
Could the selection of patients have introduced bias?	Unclear risk
B. Concerns regarding applicability	
Patient characteristics and setting	**Participants:** Critically ill children with a nasogastric or orogastric feeding tube who were receiving mechanical ventilation **Setting:** Pediatric intensive care unit at the Children's Hospital of Michigan in Detroit **Number enrolled into study:** *N* = 212 • **Group 1, Acid inhibitor absent, recent feeding absent:** *n* = 51 • **Group 2, Acid inhibitor present, recent feeding absent:** *n* = 50 • **Group 3, Acid inhibitor absent, recent feeding present:** *n* = 60 • **Group 4, Acid inhibitor present, recent feeding present:** *n* = 51 **Number completed:** *N* = 212 • **Group 1:** *n* = 51 • **Group 2:** *n* = 50 • **Group 3:** *n* = 60 • **Group 4:** *n* = 51 **Gender, males:** *n* = 120 (56.6%) • **Groups 1-4:** *n* = *N*ot reported **Race / ethnicity or nationality (as defined by researchers):** • Detroit, Michigan, United States **Age, median in weeks, range / IQR:** 12, 0.5 - 51.0 / 4.25 - 24.0 • **Groups 1-4:** *n* = Not reported **Gestational age, median in weeks, range / IQR:** 37, 24 - 40 / 34 - 40 • **Groups 1-4:** *n* = Not reported
Are there concerns that the included patients and setting do not match the review question?	Low concern
Index tests	pH of Gastric and tracheal aspirates were tested with plastic wide-range pH indicator strips that indicate pH values from 0 to 14 in increments of 1.0 pH unit • If the wide-range pH strip indicated a pH of 5.0 or less, a final pH reading was performed by using a narrow-range pH indicator paper calibrated for pH values from 2.9 to 5.2 in increments of 0.3 to 0.4 pH units

	• If the wide-range pH strip indicated a pH greater than 5.0, a final pH reading was performed by using a narrow-range pH indicator paper calibrated for pH values 4.9 to 6.9 in increments of 0.2 to 0.3 pH units
All tests	
A. Risk of Bias	
Were the index test results interpreted without knowledge of the results of the reference standard?	Yes
If a threshold was used, was it pre-specified?	Yes
Could the conduct or interpretation of the index test have introduced bias?	Low risk
B. Concerns regarding applicability	
Are there concerns that the index test, its conduct, or interpretation differ from the review question?	Low concern
Reference Standard	
A. Risk of Bias	
Target condition and reference standard(s)	**Target condition:** NG placement verification **Reference standard:** x-ray
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
Could the reference standard, its conduct, or its interpretation have introduced bias?	Unclear risk
B. Concerns regarding applicability	
Are there concerns that the target condition as defined by the reference standard does not match the question?	Low concern
Flow and Timing	
A. Risk of Bias	
Flow and timing	• Nasogastric feeding tube samples were collected in the mornings near the time of routine radiography that revealed tube position • Tracheal aspirates were obtained at the time of routine suctioning, without normal saline
Was there an appropriate interval between index test and reference standard?	Yes
Did all patients receive the same reference standard?	Yes
Were all patients included in the analysis?	Unclear
Could the patient flow have introduced bias?	Low risk
Study Notes	Unable to verify calculations as true positives, true negatives, false positives, and false negatives values were not disclosed by the study authors.

Mizzi et al. (2017)

Patient Selection	
A. Risk of Bias	
Patient Sampling	Consecutive patients hospitalized in a neurosurgical ICU requiring enteral nutrition
Was a consecutive or random sample of patients enrolled?	Yes
Was a case-control design avoided?	Yes
Did the study avoid inappropriate exclusions?	Yes
Could the selection of patients have introduced bias?	Low risk
B. Concerns regarding applicability	
Patient characteristics and setting	This was a pilot study **Participants:** Adult patients admitted to a neurosurgical intensive care unit **Setting:** San Raffaele University Hospital, Milan, Italy **Number enrolled into study:** *N* = 20 **Number completed:** *N* = 20 **Gender, males:** Twenty one patients were approached with n = 11 being male. The authors did not provide the gender of the patient declining the invitation to participate. **Race / ethnicity or nationality:** • The study occurred in Milan, Italy. The authors did not identify the participants race / ethnicity or nationalities of the subjects. **Age, median in years, range:** 63, 22 - 83
Are there concerns that the included patients and setting do not match the review question?	Unclear concern
Index Test	
Index tests	Two medical staff experienced in gastric feeding tube placement placed the Kangaroo feeding tube using the IRIS device. • Bedside placement of a gastric tube using The Kangaroo Feeding Tube with IRIS Technology made by Medtronic. • The IRIS tube was inserted following the institutional protocol for nasoenteric feeding tube (EFT) in short-term enteral feeding. • Once the rugal folds of the gastric mucosa appeared on the screen, the insertion was considered complete and the time was recorded.
All tests	
A. Risk of Bias	

Were the index test results interpreted without knowledge of the results of the reference standard?	Yes
If a threshold was used, was it pre-specified?	Unclear
Could the conduct or interpretation of the index test have introduced bias?	Low risk
B. Concerns regarding applicability	
Are there concerns that the index test, its conduct, or interpretation differ from the review question?	Unclear concern
Reference Standard	
A. Risk of Bias	
Target condition and reference standard(s)	**Target condition:** NG tube verification **Reference standard:** Abdominal x-ray
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
Could the reference standard, its conduct, or its interpretation have introduced bias?	Low risk
B. Concerns regarding applicability	
Are there concerns that the target condition as defined by the reference standard does not match the question?	Unclear concerns
Flow and Timing	
A. Risk of Bias	
Flow and timing	Immediately after tube placement, a contrast-enhanced abdominal X-ray, including the diaphragm, was performed and interpreted by an in-house radiologist to confirm the distal tip of the IRIS device was located in the stomach. Once confirmed, the time was recorded, the stylet was removed, and enteral feeding was started.
Was there an appropriate interval between index test and reference standard?	Yes
Did all patients receive the same reference standard?	Yes
Were all patients included in the analysis?	Yes
Could the patient flow have introduced bias?	Low risk
Study Notes	Medical staff experienced in gastric feeding tube placement placed the Kangaroo feeding tube using the IRIS device.

Nguyen et al. (2016)

Methods	A prospective cohort study performed over 6 months.
Participants	**Participants:** Infants with nasogastric or orogastric tubes **Setting:** Melbourne, Australia **Number enrolled into study:** *N* = 195 • **Group 1, Orogastric Tubes:** *n* = 124 • **Group 2, Nasogastric Tubes**: *n* = 71 **Number completed:** *N* = 195 • **Group 1:** *n* = 124 • **Group 2:** *n* = 71 **Gender, males:** Not reported **Race / ethnicity or nationality (as defined by researchers):** • Not reported **Age, mean/median in months/years, range/IQR:** • Mean (SD): 30 weeks 6 days (5 weeks 1 day) • Median: 30 weeks 2 days, IQR: 26 weeks 4 days to 35 weeks **Inclusion criteria:** • Nasogastric tube requiring chest/abdominal radiograph • Orogastric tube requiring chest/abdominal radiograph **Exclusion criteria:** • None listed **Covariates identified:** Not reported
Interventions	**Both groups:** • Bedside nurse inserted all tubes, position was verified using pH paper to confirm an acidic aspirate (pH < 5.5) and by single radiologist reading the patient's chest/abdominal radiograph • Tube insertion length was determined by NEMU (nose-ear-mid-umbilicus) and checked by the weight based formula o Estimated orogastric length = 3 x weight (kg) + 12cm o Estimated nasogastric length = 3 x weight (kg) + 13cm • **Group 1:** Nasogastric tube placed • **Group 2:** Orogastric tube placed
Outcomes	**Primary outcome(s):** • Correctly placed gastric tubes using weight-based formula to determine length of gastric tube
Results	Gastric tube placement was identified as: • Appropriate in 84% (164) of patients • Borderline in 12.3% (24) of patients • High in 3.6% (7) of patients

Zatelli and Vezzali (2017)

Patient Selection	
A. Risk of Bias	
Patient Sampling	Patients hospitalized in an ICU
Was a consecutive or random sample of patients enrolled?	Unclear
Was a case-control design avoided?	Yes
Did the study avoid inappropriate exclusions?	Yes
Could the selection of patients have introduced bias?	Unclear risk
B. Concerns regarding applicability	
Patient characteristics and setting	**Participants:** Intensive care unit patients (ICU) with nasogastric feeding tubes (NG) **Setting:** Department of Intensive Care, Regional Hospital of Bolzano, Bolzano, Italy **Number enrolled into study:** *N* = 114 **Number completed:** *N* = 114 **Gender, males:** • *n* = 80 (70%) **Age, years (mean, [range]):** • 52 [14 - 89] **Race / ethnicity or nationality (as defined by researchers):** • Not reported **Inclusion criteria:** • Received a feeding tube upon admission to ICU or during stay **Exclusion criteria:** • Patients not requiring parenteral feedings
Are there concerns that the included patients and setting do not match the review question?	Low concern
Index Test	
Index tests	NG tubes were placed by nursing staff using the NEX (earlobe to tip of patient nose to xiphoid process) method of measurement. Medical staff experienced in sonography performed the index test. The ultrasound (US) exam was performed in real time using a four-step verification procedure. • Sonography from either left or right of neck to visualize esophagus • Sonography of the epigastrium to confirm passage through the esophagogastric junction • Position in the antrum • Sonography of fundus
All tests	
A. Risk of Bias	
Were the index test results interpreted without knowledge of the results of the reference standard?	Yes

If a threshold was used, was it pre-specified?	Yes
Could the conduct or interpretation of the index test have introduced bias?	Low risk
B. Concerns regarding applicability	
Are there concerns that the index test, its conduct, or interpretation differ from the review question?	Low concern
Reference Standard	
A. Risk of Bias	
Target condition and reference standard(s)	**Target condition:** NG tube verification **Reference standard:** Thorax x-ray
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
Could the reference standard, its conduct, or its interpretation have introduced bias?	Low risk
B. Concerns regarding applicability	
Are there concerns that the target condition as defined by the reference standard does not match the question?	Low concern
Flow and Timing	
A. Risk of Bias	
Flow and timing	Not described
Was there an appropriate interval between index test and reference standard?	Unclear
Did all patients receive the same reference standard?	Yes
Were all patients included in the analysis?	Yes
Could the patient flow have introduced bias?	Low risk

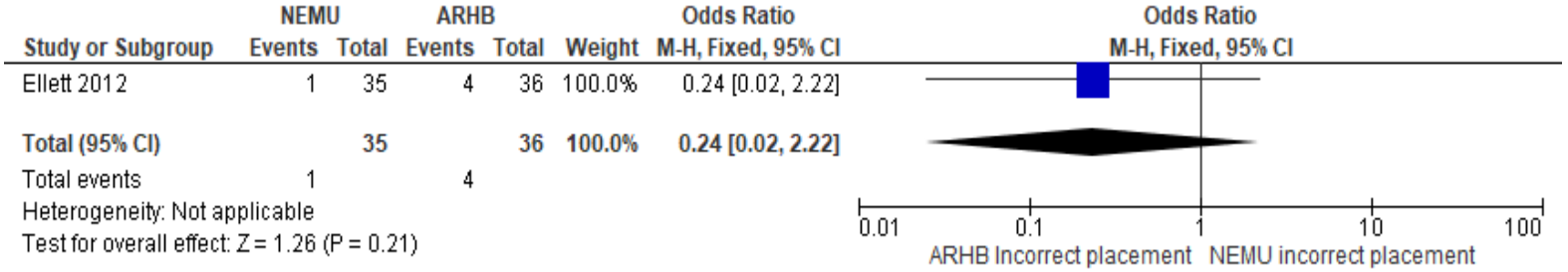

Figure 4. ***Comparison: NEMU vx. ARHB, Outcome: Incorrect Tube Placement***

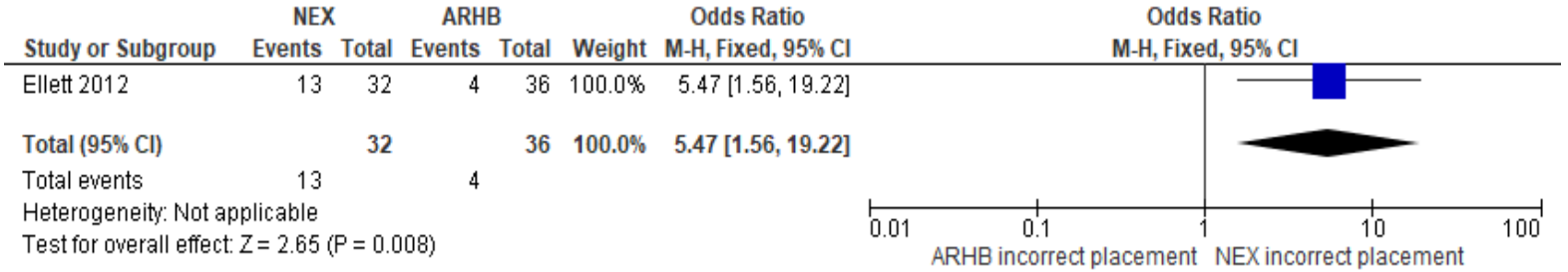

Figure 5. ***Comparison: NEX vx. ARHB, Outcome: Incorrect Tube Placement***

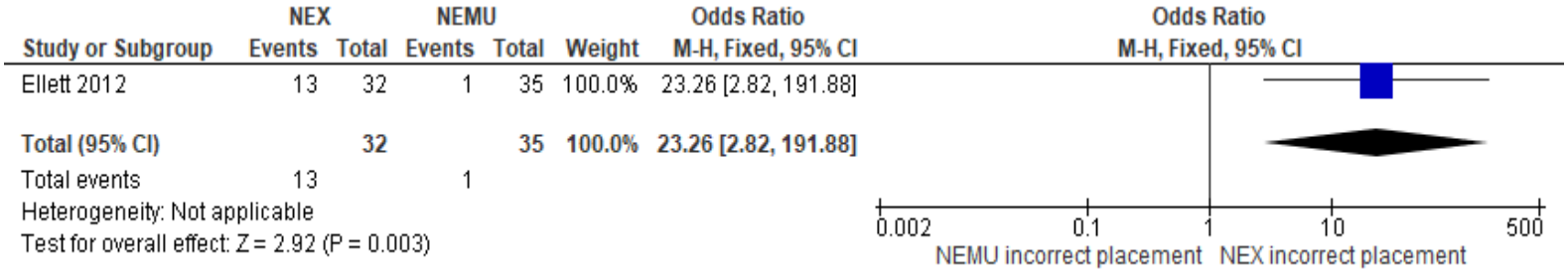

Figure 6. ***Comparison: NEX vx. NEMU, Outcome: Incorrect Tube Placement***

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