WORKSHEET for Evidence-Based Review of Science for Emergency Cardiac Care

Worksheet author(s)

Douglas F. Kupas, MD and Ian Cash

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Clinical question.

In adult cardiac arrest (prehospital [OHCA], in-hospital [IHCA]) (P), does the use of devices (eg. CO2 detection device, CO2 analyzer or esophageal detector device) (I) compared with usual management (C), improve the accuracy of diagnosis of airway placement (O)?

Is this question addressing an intervention/therapy, prognosis or diagnosis? Diagnosis
State if this is a proposed new topic or revision of existing worksheet: New topic

Conflict of interest specific to this question

Do any of the authors listed above have conflict of interest disclosures relevant to this worksheet? No

Search strategy (including electronic databases searched).

OVID (Medline and Cochrane Library) and Embase
[(MeSH exp Colorimetry OR exp Capnography OR exp Carbon dioxide) OR (t.w. co2 detection OR co2 analyzer OR esophageal detector)] AND [MeSH. Heart Arrest OR Intubation, intratracheal]
AHA Endnote Master Library
[colorimetry, capnograpy, co2 detection, or co2 analyzer]
Last searched 10/09, but also OVID automatic monthly search occurs continuously to find any additional articles.
Manual search of additional references in articles identified by above.

- State inclusion and exclusion criteria

Includes: Human and animal studies, Adult and children

Excludes: Case reports, review articles, and mannequin simulations. Excludes studies of transthoracic impedance as the use of this device for confirmation of endotracheal tube placement is addressed by a separate worksheet (ALS-CPR&A-006).

- Number of articles/sources meeting criteria for further review:

Over 900 articles were found, and review of these abstracts identified 67 articles for more thorough review. After thorough review, 51 articles related to the question were identified, and 3 articles related to the accuracy of the usual management of auscultation to identify endotracheal tube placement were also identified.

Summary of evidence

Evidence Supporting Clinical Question

Good					**Knapp (1999) capnometer**
Fair		**Bozeman (1996) syringe asp. Grmec (2002) waveform**			**Trikha (1999) waveform Tong (2002) bulb EDD, waveform Schaller (1997) syringe EDD Zaleski (1993) bulb EDD, waveform Wolfe (2002) electronic EDD**
Poor		**Sanders (1994) colorimetric Silvestri (2005) waveform Vukmir (1991) capnometer**			**Holland (1993) waveform Jenkins (1994) syringe EDD Ko (1993) waveform Linko (1983) waveform Oberly (1992) Bulb EDD Yao (2007) waveform**
	D1	**D2**	**D3**	**D4**	**D5**
Level of evidence					

A = Return of spontaneous circulation
B = Survival of event
C = Survival to hospital discharge
D = Intact neurological survival
E = Other endpoint
Italics = Animal studies

Evidence Neutral to Clinical question

Good					**Katz (2001) clinical** **Knapp (1997) bulb EDD, clinical**
Fair		**Grmec (2002) clinical**			**Jemmett (2003) clinical** **Weaver (2006) ultrasound**
Poor		**Campbell (1990) colorimetric** **Hayden (1995) colorimetric**		**Bair (2005) clinical**	**Chun (2004) ultrasound** **Bhende (1995) colorimetric, capnometer** **Bhende (1992) colorimetric** **Jones (2004) clinical** **Kapsner (1996) syringe EDD** **Kasper (1998) bulb** **McLeod (1992) capnometer** **Garnett (1987) capnography** **Werner (2007) ultrasound** **White (1994) waveform**
	D1	**D2**	**D3**	**D4**	**D5**
Level of evidence					

A = Return of spontaneous circulation
B = Survival of event
C = Survival to hospital discharge
D = Intact neurological survival
E = Other endpoint
Italics = Animal studies

Evidence Opposing Clinical Question

Good					**Knapp (1997) transillumination**
Fair		**Bozeman (1996) capnometer Grmec (2002) capnometer Ornato (1992) colorimetric Varon (1991) colorimetric**		**Anton (1991) colorimetric, capnometer MacLeod (1991) colorimetric Pelucio (1997) syringe EDD**	**Bhende (1995) colorimetric Trikha (1999) SCOTI**
Poor	**Takeda (2003) bulb EDD, waveform Tanigawa (2001) syringe EDD, bulb EDD, waveform Tanigawa (2000) bulb EDD, waveform**			**Schaller (1997) colorimetric**	**Li (2001) colorimetric, capnometer**
	D1	**D2**	**D3**	**D4**	**D5**
Level of evidence					

A = Return of spontaneous circulation
B = Survival of event
C = Survival to hospital discharge
D = Intact neurological survival
E = Other endpoint
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REVIEWER'S FINAL COMMENTS AND ASSESSMENT OF BENEFIT / RISK:

This question is complex, because it asks whether devices are better than usual management in identifying correct airway placement. It is impractical to place all "devices" into one group for comparison, so in this worksheet, each device has been separated in comparison to the usual management. The use of transthoracic impedance to identify proper placement of airway devices has been excluded from this worksheet since it is covered by a separate worksheet ALS-CPR&A-006). Furthermore, in this worksheet, "usual management" for the purpose of comparison to devices is defined as clinical assessment of airway placement – i.e. auscultation (gastric and breath sounds) and direct visualization when possible. Additionally, the question is related to "airway" placement in general, but virtually all available evidence studies the use of these confirmatory devices in their ability to identify tube position strictly for endotracheal tube placement.

Clinical auscultation and direct visualization (Clinical): Because most of the studies identified in this search are descriptive observational studies of the function of a device without direct comparison either to the usual management of clinical assessment or to other devices, it is important to describe the baseline accuracy of clinical assessment by auscultation. Several studies have been included, and all studies that determined an accuracy of airway placement identification using clinical assessment have been categorized as "Neutral". Because the study question asks that devices be compared with usual management, therefore the usual management must be neutral. This includes data from one LOE D2 study, one LOE D4, and four LOE D5 studies that were all published between 2001 and 2005. Clinical assessment of the correct placement of an advanced airway, specifically an endotracheal tube, leads to rates of unrecognized non-tracheal placement of endotracheal tubes between 0.5% and 25%. Grmec described the lowest rate of unrecognized placement, 0.5%, in a study of intubations by EMS physicians. In studies of intubations by paramedics, Jones, Jemmett, Silvestri, and Falk reported 6, 10, 23, and 25% rates of misplaced endotracheal tubes, respectively. In-hospital studies and descriptions of anesthesia incidents have identified unrecognized non-tracheal tube placement in these settings also. Knapp reported that experienced examiners were 100% accurate in identifying tube placement but inexperienced examiners were only 68% accurate. Although the rates vary widely, it is clear that with clinical assessment alone, there is delayed recognition of misplaced endotracheal tubes in both the in-hospital and out-of-hospital settings. Although not included in this worksheet because they did not address the question at hand, Kelly and Angelotti have both demonstrated that misting or fogging within the endotracheal tube is neither sensitive of specific for identification of tube placement.

Clinical Method : Auscultation				
Author	LOE	Sensitivity	Specificity	Population type / n =
Grmec (2002) 701	D2 fair	100	80	cardiac arrest
Takeda (2003) 153	D1 poor	92.6	88.9	cardiac arrest
Grmec (2004) 518	D5 fair	94	66	emergency
Takeda (2003) 153	D5 poor	89.3	100	emergency
Grmec (2002) 701	D5 fair	94	83	emergency
Yao (2007) 898	D5 good	90	86	anaesthetized
Knapp (1999) 766	D5 good	74	95	intubated stable ICU
Clinical Method : Tube Misting				
Angelotti (2006) 74		84	94	anaesthetized

Several devices have been suggested as means of rapidly identifying endotracheal tubes that are placed in non-tracheal positions. Because the accuracy of clinical assessment in identifying placement is relatively low, any device that is globally recommended for identification of tube placement must be more accurate than clinical assessment – or must be nearly perfect in identifying correct tube placement and misplacement. The value of each of these devices for identifying airway placement in both in-hospital and out-of-hospital cardiac arrest patients will be discussed separately in the following paragraphs.

Miscellaneous Detectors (Transillumination and SCOTI): In addition to the detection devices listed below, there is one study that considers a transillumination technique (Opposes LOE D5) and one that uses the SCOTI device (Opposes LOE D5). Neither of these provides enough evidence to consider these miscellaneous detectors as useful for detecting tracheal placement of endotracheal tubes in cardiac arrest. With transillumination, Knapp found that experienced providers were 84% accurate and inexperienced providers were 87% accurate in identifying correct tube position in 38 non-arrest patients. Trikha used a sonic confirmation of tracheal intubation (SCOTI) technique with a 72% sensitivity in identifying tubes placed in the trachea, but in this same study, auscultation was 99% sensitive and capnography was 100% sensitive. This evidence opposes any use of the SCOTI technique for confirmation of tube placement.

Colorimetric End-tidal Carbon Dioxide ($ETCO_2$) Detectors (Colorimetric): Disposable colorimetric $ETCO_2$ detectors use a litmus paper to detect CO2, and these devices generally give readings of purple ($ETCO_2$ <0.5%), tan ($ETCO_2$ 0.5 - 2%) and yellow ($ETCO_2$>2%) results. The studies vary on how they interpret the intermediate (tan) results, but most consider tan to verify tracheal placement of the tube if the tan result is persistent after a few ventilations. The usefulness of a colorimetric detector in verifying endotracheal tube position in cardiac arrest is opposed by 7 studies (2 LOE D2, 3 LOE D4 and 2 LOE D5) and supported by one (LOE D2) study. In cardiac arrest patients, these studies reveal 62-100% sensitivity in detecting tracheal placement of the endotracheal tube and an 86 -100% specificity in identifying non-tracheal position. Although colorimetric $ETCO_2$ detectors identify placement in patients with good perfusion quite well, these devices are less accurate than clinical assessment in poorly-perfusing cardiac arrest patients, and their use may cause confusion in this setting. When data was specifically available for the use of colorimetric devices in cardiac arrest, the colorimetric device continued to identify nearly 100% of the non-tracheal tubes, but only identified as few as 62% of the tracheal tubes. An additional concern is that most studies require about six ventilations before interpreting the color change on the detector. If the endotracheal tube is misplaced in the esophagus, six ventilations may lead to gastric distention, vomiting and aspiration.

Device: Colorimetric ETCO2 Detectors

Author	LOE	Sensitivity	Specificity	Population type / n =
Anton (1991) 271	D4 fair	89	X	IHCA and other inpatients
Bhende (1995) 395	D5 fair	85	100	pediatric cardiac arrest
Li (2001) 223	D5 poor	93	97	OOH patients, 80% used colorimetric ETCO2 others used nonwaveform digital capnometer
MacLeod (1991) 267	D4 fair	72	86	cardiac arrest
		100	86	emergency
Ornato (1992) 518	D2 fair	69	100	cardiac arrest
		100	93*/100	emergency (if cuff down)
Sanders (1994) 771	D2 poor	100	100	emergency + cardiac arrest
Schaller (1997) 57	D5 fair	78	X	OOH patients, 77% OOHCA
Varon (1991) 289	D2 fair	62	100	cardiac arrest
		98	100	non-cardiac arrest

Syringe Aspiration Esophageal Detector Device (Syringe EDD): All EDDs, commercial and provider assembled, that use the technique of aspirating on a syringe plunger to obtain negative pressure are included in this section. The use of the syringe aspiration EDD technique for identification of endotracheal tube position in cardiac arrest is supported by three (1 LOE D2 and 2 LOE D5) and opposed by two (1 LOE D2 and 1 LOE D4) studies. These studies reveal a73 -

100% sensitivity in detecting tracheal placement of the endotracheal tube and a 50-100% specificity in identifying non-tracheal position.

Device : Esophageal (Oesophageal) Detector Device (EDD) - Syringe				
Author	LOE	Sensitivity	Specificity	Population type / n =
Bozeman (1996) 595	D2 fair	100	100	cardiac arrest
Jenkins (1994) 413	D5 fair	100	100	ED and OOH
Schaller (1997) 57	D5 fair	100	100	OOH patients, 77% OOHCA
Tanigawa (2001) 375	D1 good	73	100	cardiac arrest
Pelucio (1997) 563	D4 fair	99	50	cardiac arrest + resp. emergency

Self-inflating Bulb Aspiration Esophageal Detector Device (Bulb EDD): All EDDs that use a self-inflating bulb to provide negative airway pressure for the purpose of identifying tube position are included in this section. The use of the bulb-type aspiration EDD technique for identification of endotracheal tube position in cardiac arrest is supported by three (LOE D5) and opposed by three (LOE D2) studies. Two (LOE D5) studies were neutral. These studies reveal 71 - 100% sensitivity in detecting tracheal placement of the endotracheal tube and 89-100% specificity in identifying non-tracheal position.

Device : Esophageal (Oesophageal) Detector Device (EDD)- Bulb				
Author	LOE	Sensitivity	Specificity	Population type / n =
Kasper (1998) 898	D5 good	99	100	emergency (only 3 CA)
Knapp (1999) 766	D5 good	91	100	intubated stable ICU
Oberly (1992) 317	D5 poor	100	100	cadavers
Takeda (2003) 153	D1 good	75 95	89 100	cardiac arrest emergency
Tanigawa (2000) 1432	D1 good	72	100	cardiac arrest
Tanigawa (2001) 375	D1 good	71	100	cardiac arrest
Tong (2002) 159	D5 fair	100	100	not cardiac arrests
Zaleski (1993) 244 * (4% of tracheal intubations had slow bulb inflation of 15 - 30 seconds)	D5 fair	100*	100	anesthesia

Non-waveform Electronic Infrared Capnometry (Capnometer): Electronic digital $ETCO_2$ detectors are available in many devices that use varying technologies to measure and display the $ETCO_2$ results. This section includes all electronic digital $ETCO_2$ detectors or monitors that do not provide a waveform graphical display of the respiratory cycle on a capnograph. These devices generally measure $ETCO_2$ using infrared spectrometer and display the results with a number and possibly an LED “blip”. Some of the studies identified in the search did not provide full descriptions of the electronic $ETCO_2$ detectors, and some of these devices do not appear to be available on the market at this time. For the purpose of this evaluation, if an article did not identify an electronic $ETCO_2$ monitor as providing a waveform result, the device was included in this section as a capnometer. The use of a capnometer for identification of endotracheal tube position in cardiac arrest is supported by two (1 LOE D2 and 1 LOE D5) and opposed by four (2 LOE D2, 1 LOE D4 and

1 LOE D5) studies. These studies reveal 70-100% sensitivity in detecting tracheal placement of the endotracheal tube and a100% specificity in identifying non-tracheal position.

Device : Capnometry (infra red, no waveform display)				
Author	LOE	Sensitivity	Specificity	Population type / n =
Anton (1991) 271	D4 fair	89	X	cardiac arrest
Bozeman (1996) 595	D2 fair	70	100	cardiac arrest
Grmec (2002) 701	D2 fair	88 100	100 100	cardiac arrest emergency
Grmec (2004) 518	D5 fair	100	100	emergency
Knapp (1999) 766	D5 good	91	100	intubated stable ICU
Li (2001) 223	D5 poor	93	97	OOH patients, 80% used colorimetric ETCO2 others used nonwaveform digital capnometer
Vukmir (1991) 726	D2 poor	100	100	21% traumatic CA

Waveform Capnography (Capnograph): All studies that use electronic $ETCO_2$ detectors or monitors that provide results in waveform graphical display are referred to as capnographs and are included in this section. The use of a waveform capnograph for identification of endotracheal tube position in cardiac arrest is supported by nine (2 LOE D2 and 7 LOE D5) and opposed by three (LOE D2) studies. These studies reveal 60-100% sensitivity in detecting tracheal placement of the endotracheal tube and a100% specificity in identifying non-tracheal position. A preponderance of the study results support waveform $ETCO_2$ as being nearly 100% accurate in identifying both tracheal and non-tracheal positions of endotracheal tube placement. The 3 studies that provide opposing evidence warrant specific review. These three studies were done in Japan, and all have overlapping authors with three individuals listed as authors on all three papers. Takeda (2003), Tanigawa (2001), and Tanigawa (2000) described the confirmation of endotracheal tube placement in OOH cardiac arrest patients who were transported to the emergency department by EMS, and endotracheal intubation was delayed until arrival in the ED. When reported, the CPR time prior to ED arrival averaged 32-37 minutes, and many of these individuals had prolonged ventilation with bag-valve-mask or dual lumen airway prior to the intubation. In a personal communication with one of the authors, he noted that the EMS system in this area of Japan required the transport of all cardiac arrest victims, even those with “very prolonged”/ “hopeless” resuscitation attempts. It can be argued that $ETCO_2$ production will eventually be nonexistent in victims that have been dead for a prolonged time, and therefore this systems confounding factors of extremely long times from initiation of resuscitation to intubation and the requirement that all cardiac arrest patients be transported lead to the use of capnography in some patients who would not be expected to produce carbon dioxide, because they have no possibility of resuscitation. If these three confounding opposing studies are ignored for these reasons, the remaining ten supportive studies describe a near 100% sensitivity and specificity for capnography when identifying endotracheal tube position. Aside from these three confounding studies, the only misidentified tubes in all other studies and case reports identified by the search are 1) a case report of a single negative capnography result in a patient with an endotracheal tube placed in the trachea but blocked with a one-way valve type obstruction (Zar LOE D5 – excluded single case report), 2) a single nasotracheally placed endotracheal tube with the tip in the esophagus and positive capnography in a patient that was also spontaneously breathing around the tube (Katz LOE D5), and 3) a single unrecognized esophageal intubation from 1657 consecutive OOH intubations with succinylcholine, but the error occurred when the paramedic ignored the zero reading on the capnograph (Wayne LOE D5). In a LOE D2 study with good methods by Grmec, the waveform capnograph was the only confirmation method tested that was 100% accurate in identifying both tracheal and non-tracheal placements of an endotracheal tube in 345 patients (246 in cardiac arrest). Silvestri (LOE D2) demonstrated that the addition of waveform capnography to EMS protocols led to a difference between 0 and 23% misidentified tube placements in services that used or did not use capnography, respectively. Lastly, in an analysis of 2000 anesthesia incident reports (LOE D5), Holland reported that “auscultation is an unreliable test” and that of the cases where capnography was used, there were no false positives.

Device : Capnography - Waveform				
Author	LOE	Sensitivity	Specificity	Population type / n =
Grmec (2002) 701	D2 fair	100	100	cardiac arrest
Grmec (2004) 518	D5 fair	100	100	emergency
Holland (1993)	D5 poor	X	100	anesthesia incident reports
Knapp (1999) 766	D5 fair	100	100	intubated stable ICU
Ko (1993)	D5 poor	100	100	pediatrics, no cardiac arrests
Linko (1983)	D5 poor	100	100	anesthesia
Silvestri (2005) 497	D2 poor	100	100	cardiac arrest emergency
Takeda (2003) 153 **very prolonged time from OOHCA to in-hospital intubation	D1 good	68* 98	100 100	cardiac arrest emergency
Tanigawa (2000) 1432 **very prolonged time from OOHCA to in-hospital intubation	D1 poor	60*	100	cardiac arrest
Tanigawa (2001) 375 **very prolonged time from OOHCA to in-hospital intubation	D1 poor	65*	100	cardiac arrest
Tong (2002) 159	D5 fair	100	100	not cardiac arrests
Trikha (1999)	D5 fair	100	X	not cardiac arrests
Yao (2007) 898	D5 good	100	100	anesthesia
Zaleski (1993) 244	D5 fair	100	100	anesthesia

The current availability of portable electronic waveform capnographs now makes it feasible to suggest that these monitors should be used in all cases where providers perform endotracheal intubation. The current portable monitors make capnographic initial confirmation and continuous monitoring of endotracheal tube position feasible in almost all settings, including OOH, emergency department, and in-hospital locations where intubation is performed. One could argue that in the settings where cost prohibits maintaining a waveform capnograph, these settings may also lack the experiences that providers need to justify maintaining this skill, and in these situations it may be preferable to use an alternative non-tracheal airway when advanced airway management is indicated.

Acknowledgements:
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Citation List

(1) Ahrens T, Schallom L, Bettorf K, Ellner S, Hurt G, O'Mara V, et al. End-tidal carbon dioxide measurements as a prognostic indicator of outcome in cardiac arrest. Am.J.Crit.Care 2001 Nov;10(6):391-398

LOE D5 - Not related to confirmation of tube placement.
Prospective study of capnography for prediction of death as an outcome of cardiac arrest. In 127 cases, there is no

mention of any with initial capnography reading of "0", but only averages are reported, so it is impossible to determine whether there was a waveform reading in each of the cases..

(2) Anton WR, Gordon RW, Jordan TM, Posner KL, Cheney FW. A disposable end-tidal CO2 detector to verify endotracheal intubation. Ann.Emerg.Med. 1991 Mar;20(3):271-275

LOE D4 - Opposes - Fair [Colorimetric and infrared capnometry]
Study of intubations in hospitalized patients comparing colorimetric ECTO2 with an electronic capnometer (not waveform). 60 intubated patients included.
Device: colorimetric $ETCO_2$ monitor and TRIMED electronic infrared capnometer (not waveform)
Gold standard for indentifying endotracheal tube position not described.
Tracheal placement was identified by colorimetric monitor in 3/9 (33%) of cardiac arrests if yellow color change was considered positive and in 8/9 (89%) if tan color change was considered positive.
Tracheal placement was identified by infrared capnometer in 8/9 (89%) of cardiac arrests.
No esophageal placements were recorded.
Authors caution against using these devices to confirm placement in cardiac arrest.

(3) Asplin BR, White RD. Prognostic value of end-tidal carbon dioxide pressures during out-of-hospital cardiac arrest. Ann.Emerg.Med. 1995 Jun;25(6):756-761

LOE D5 - Not related to endotracheal tube placement
Prospective observational study using convenience sample of OOH cardiac arrest patients
Patients= adult nontraumatic cardiac arrests. 65 OHCA patients included, but capnograph was only available for 27 patients.
Device= mainstream infrared capnograph
No description of standard for identifying tube placement or of any capnograph readings that were 0.

(4) Bair AE, Smith D, Lichty L. Intubation confirmation techniques associated with unrecognized non-tracheal intubations by pre-hospital providers. J.Emerg.Med. 2005 May;28(4):403-407

LOE D4 - Neutral - Poor [Auscultation and Visualization]
Retrospective review of reported non-tracheal placement of endotracheal tubes where intubations occurred in the prehospital setting. Review of EMS QI documents and records from a single hospital that received the patients.
Patients: During the study period there were 1643 patient intubations, of which 35 (2%) were discovered to be non-tracheal. Of these 35 cases, 80% were adults > 10 y/o. 15 (43%) were OHCA.
Device: This was a descriptive study of methods used to confirm placement, and no confirmatory device was used in most of these cases. Colorimetric $ETCO_2$ was only used selectively (9/20) in patients that were not in cardiac arrest. No aspiration technique used.
Gold Standard: ED physician identification of misplaced tubes was the standard, but methods used were not defined. In 15 cases of non-tracheal placement of ETTs in cardiac arrest, prehospital personnel documented equal breath sounds in 5 cases, documented visualization of the tube through the cords in 2 cases, and documented both equal breath sounds and visualization in 2 cases.
In the 20 cases with pulse, 9 cases of non-tracheal ETT placement were not detected with colorimetric $ETCO_2$.
This study assists in identifying a baseline occurance rate of non-tracheal ETT placement of at least 2%, but due to the retrospective method of identifying misplaced tubes, the true rate of misplacement is expected to be >2%..

(5)

Article	An assessment of a tracheal tube introducer as an endotracheal tube placement confirmation device

Author(s)	Bair AE, Laurin EG, Schmitt BJ
Journal	Am J Emerg Med 2005; 23(6): 754-8
LOE	D5 Extrapolated – cadaver study
Methodological Quality	GOOD - RCT, blinded trial
Relevance to question asked	relevant
Relevance to outcome observed	relevant
Magnitude of observed event	Experienced operator – 98% specificity for tracheal intubation, 100% for esophageal intubation Novice operator – 88% specificity for tracheal intubation, 95% for esophageal intubation
Exclusion Log	
Study Finding (conclusion)	Supports hypothesis – lower specificity for novice operators **ETT Bougie – click and 'hang up' detection technique** Use of a bougie passed through a placed ETT to detect tracheal or esophageal placement by presence or absence of tracheal ring 'click's felt with insertion of bougie beyond ETT, and 'hang up' of the bougie with terminal resistance felt (small airway placement).

(6) Bhende MS, Karasic DG, Menegazzi JJ. Evaluation of an end-tidal CO2 detector during cardiopulmonary resuscitation in a canine model for pediatric cardiac arrest. Pediatr.Emerg.Care 1995 Dec;11(6):365-368

LOE D5 Neutral - Poor [colorimetric AND mainstream capnometric $ETCO_2$ detectors]
Canine model of cardiac arrest in 11 puppies. Asphyxial cardiac arrest induced by clamping ETT. CPR started either 5 or 10 minutes after cardiac arrest.
Devices - colorimetric $ETCO_2$ monitor and mainstream capnometer connected in series to ventilator circuit.
Gold standard - direct visualization of tube placement and bilateral breath sounds used to identify tube placement.
In tracheal placements of ETT and cardiac arrest, the capnometry reading was less than 5 mmHg in 4 readings, of these, the colorimetric $ETCO_2$ detector had readings of 2 in 50% and 3 in 50% (on a scale of 1-6 with 1= purple and 6 = yellow).
Although the colorimetric $ETCO_2$ detector correlated well with the capnometer in these cases, the short "down time" before CPR, and the subtle color change (2 on 1-6 scale) in several cases does not strongly support the usefulness of the colorimetric device..

(7) Bhende MS, Thompson AE. Evaluation of an end-tidal CO2 detector during pediatric cardiopulmonary resuscitation. Pediatrics 1995 Mar;95(3):395-399

LOE D5 - Opposes - Fair [colorimetric $ETCO_2$ detector]
Prospective observational study in 40 children in cardiac arrest.
Patients= pediatric (1 week/o - 10 y/o) patients in cardiac arrest intubated by paramedics as OHCA or in ED, but

colorimetric $ETCO_2$ done in ED.
Gold standard= clinical assessment including possible direct visualization, bilateral breath sounds, gastric sounds, and possible chest radiograph/ pulse oximetry.
In tracheal placements, colorimetric $ETCO_2$ was positive 33/39 (85%), but of these 25/39 (64%) had colorimetric readings in the "B/tan" range between purple and yellow.
In esophageal placements, colorimetric $ETCO_2$ was negative in 9/9 (100%)..

(8) Bhende MS, Thompson AE, Cook DR, Saville AL. Validity of a disposable end-tidal CO2 detector in verifying endotracheal tube placement in infants and children. Ann.Emerg.Med. 1992 Feb;21(2):142-145

LOE D5 - Neutral - Poor [Colorimetric $ETCO_2$ Detector]
Prospective convenience study of pediatric intubations in the OR, ICU and ED. 151 intubations in 137 patients (17 in cardiac arrest).
Patients= pediatric patients in the hospital.
Device= colorimetric $ETCO_2$ detector.
Gold Standard = Some combination of direct visualization, capnometry (in OR), chest rise, blood gas, and pulse oximetry.
In esophageal misplacements of tube during CPR, colorimetric $ETCO_2$ detector was negative in 6/6 (100%).
In tracheal placement during CPR, colorimetric $ETCO_2$ detector was positive in 15/17 (88%)..

(9) Bozeman WP, Hexter D, Liang HK, Kelen GD. Esophageal detector device versus detection of end-tidal carbon dioxide level in emergency intubation. Ann.Emerg.Med. 1996 May;27(5):595-599

LOE D2 - Supports - Fair [EDD] AND Opposes - Fair [Qualitative capnometer]
Prospective ED study of patients intubated by EMS or in the ED. 113 intubations, but 13 excluded for failure to follow protocol. 100 intubated patients included with one single esophageal placement. Intubations performed by various resident physicians and paramedics.
Patients= adult patients
Device= aspiration EDD AND spectrographic qualitative $ETCO_2$ capnometer.
Gold Standard= clinical exam, not further described.
In tracheal placement, the EDD identified 98/99(99%) and the $ETCO_2$ identified 86/98 (87%). Of the 37 patients in cardiac arrest, the EDD identified placement in 37/37 (100%) and the $ETCO_2$ identified 26/37 (70%).
In the single non-tracheal placement, the EDD identified 1/1 (100%) and the $ETCO_2$ identified 1/1 (100%)..

(10) Callaham M, Barton C. Prediction of outcome of cardiopulmonary resuscitation from end-tidal carbon dioxide concentration. Crit.Care Med. 1990 Apr;18(4):358-362

LOE D5 Not related to ETT confirmation
Article lists 2 patients with $ETCO_2$ readings of 0, but there is no description of methods to confirm tube placement in these or any patients in the study.
Prospective study of 55 adult nontraumatic prehospital cardiac arrest patients $ETCO_2$ monitored on ED arrival. Study focused on $ETCO_2$ for prognosis of cardiac arrest, but not for ETT placement. .

(11) Campbell RC, Boyd CR, Shields RO, Odom JW, Corse KM. Evaluation of an end-tidal carbon dioxide detector in the aeromedical setting. J.Air Med.Transp. 1990 Nov;9(11):13-15

LOE D2 - Neutral - Poor [Colorimetric $ETCO_2$ detector]
Air medical service study of intubated patients. 35 patients transported by air medical service were entered into study, and 1/35 had non-tracheal intubation. Only 3 patients were in cardiac arrest when presenting to the flight crew, and 1/3 of these had a non-tracheal tube placement.
Patients=
Device= colorimetric $ETCO_2$ detector
Gold Standard= direct laryngoscopy in ED by EM physician or trauma surgeon.

In tracheal placement, the colorimetric $ETCO_2$ detector identified 32/34 (94%). Of these, the colorimetric $ETCO_2$ detector identified 2/2 (100%) tracheal intubations in cardiac arrest patients.
In the single reported non-tracheal placement (the only non-tracheal tube placement occurred in a cardiac arrest), the colorimetric $ETCO_2$ identified 1/1 (100%) of the non-tracheal placements..

(12) Cantineau JP, Lambert Y, Merckx P, Reynaud P, Porte F, Bertrand C, et al. End-tidal carbon dioxide during cardiopulmonary resuscitation in humans presenting mostly with asystole: a predictor of outcome. Crit.Care Med. 1996 May;24(5):791-796

LOE D5 – Not related to tube placement confirmation
Prospective study of 120 prehospital cardiac arrest patients.
Patients= nontraumatic cardiac arrest
Device= infrared sidestream absorption capnometer (non-waveform)
This study did not investigate ETT placement. There are no apparent cases with $ETCO_2$ = 0, but this is not specifically discussed..

(13)

Article	Where's the tube? Evaluation of hand-held ultrasound in confirming endotracheal tube placement
Author(s)	Chun R, Kirkpatrick AW, Sirois M, et al.
Journal	Prehospital and Disaster Medicine 2004; 19(4): 366-369
LOE	D5 Extrapolated – eg *different pt population group, animal study, mechanical*
Methodological Quality	POOR (=few but worthy of inclusion)
Relevance to question asked Relevance to outcome observed Magnitude of observed event	Observational study to confirm ultrasound identification of an ETT in a known correct placement
Exclusion Log	
Study Finding (conclusion)	Supports hypothesis. Noted 2 cases for mainstem intubation not diagnosed clinically. Whilst confirming that Ultrasound looking for visceral – parietal interface (sliding lung sign) can be seen when the trachea is intubated, did not compare for results when tube located in the esophagus

(14)

Article	An Evaluation of Out-of-hospital Advanced Airway Management in an Urban Setting

Author(s)	Colwell CB, McVaney KE, Haukoos JS, et al.
Journal	Academic Emergency Medicine 2005; 12(5): 417–422
LOE	D5 Extrapolated - eg *different pt population group, animal study, mechanical*
Methodological Quality	POOR (=some)
Relevance to question asked Relevance to outcome observed Magnitude of observed event	Includes malpositioning of tracheal tube in out of hospital context, where ETCO2 plus at least one other usual technique (eg direct visualisation, auscultation, epigastric sounds, oxygen saturation, observed clinical improvement) Only 3 tubes found to be incorrectly positioned at hospital ED. (2 x esophageal, 1 x hypopharangeal.) Study does not account for potential position loss during transport. One tube noted on xray 60 minutes after arrival to be hypopharyngeal. 22 patients had right mainstem intubation. Of the 278 studied patients, there was no documentation of patient numbers in cardiac arrest.
Exclusion Log	Does not sufficiently test hypothesis. ETCO2 detection device used for all patients after intubation attempt in field. Reported initial fail rate (at scene) does not differentiate whether fail determined by clinical means or by device. Of the two tubes detected as be esophageal o/a to ED, there was no method documented of esophageal placement finding.
Study Finding (conclusion)	

(15) Falk JL, Rackow EC, Weil MH. End-tidal carbon dioxide concentration during cardiopulmonary resuscitation. N.Engl.J.Med. 1988 Mar 10;318(10):607-611

LOE D5 – Study not related to endotracheal tube confirmation.
Study of quantitative $ETCO_2$ in 10 critically ill patients that had 13 cardiac arrest episodes. No specific study of the use of $ETCO_2$ for confirmation of tube placement..

(16) Garnett AR, Gervin CA, Gervin AS. Capnographic waveforms in esophageal intubation: effect of carbonated beverages. Ann.Emerg.Med. 1989 Apr;18(4):387-390

LOE D5 - Neutral - Poor [waveform capnograph]
Canine study of waveform $ETCO_2$ in 5 dogs after ingestion of carbonated beverages. Anesthetized dogs received carbonated beverage via gastric tube, and capnography via an ETT in the esophageal position at 10, 20, and 30 minutes.
Device= waveform capnograph
In esophageal intubation, 2/5 (40%) of cases had no wave correctly indicating esophageal placement, but 3/5 (60%) had a waveform indicating CO2 - of note, these false positive CO2 waves were not typical of normal capnographic waves from tracheal intubation, and these abnormal waves diminished over time from ingestion.

This animal study simulates ingestion of carbonated beverages within 10-30 minutes preceding intubation, not necessarily realistic to even most EMS situations..

(17) Garnett AR, Ornato JP, Gonzalez ER, Johnson EB. End-tidal carbon dioxide monitoring during cardiopulmonary resuscitation. JAMA 1987 Jan 23-30;257(4):512-515

LOE D5 - No study of $ETCO_2$ for confirmation of placement.
Assessment of relationship of $ETCO_2$ on outcome in cardiac arrest, but study does not specifically assess use of $ETCO_2$ monitoring for ETT placement..

(18) Grmec S. Comparison of three different methods to confirm tracheal tube placement in emergency intubation. Intensive Care Med. 2002 Jun;28(6):701-704

LOE D2 - Supportive - Fair [Capnography], Neutral - Fair [Auscultation], Opposes - Fair [Capnometry]
Prospective OOH study of confirmation of ETT position in intubations performed by EMS physicians. Auscultation (bilateral breath sounds in two locations on each side and absent epigastric sounds) was compared to capnography and capnometry for confirmation of tube placement. 345 intubated patients were included, 246 of these were in cardiac arrest. In addition, 33 patients were excluded for device malfunction or failure to follow protocol.
The study includes 9 (3%) initial esophageal placements, and 2 (0.5%) of these were not identified by clinical examination.
Patients= adults > 18 y/o
Devices= waveform capnography AND infrared electronic capnometry
Gold Standard= Final determination by repeated direct visualization.
Only capnography had 100% sensitivity, specificity, PPV, and NPV in all patients
In cardiac arrest (n=246), sensitivity/specificity/PPV/NPV for each method respectively were: auscultation (100,80,100,99), capnometry (88,100,13,100), and capnography (100,100,100,100).
In non-arrest patients (n=99), sensitivity, specificity, PPV, and NPV for each method respectively were: auscultation (94,83,56,97), capnometry (100,100,100,100), and capnography (100,100,100,100).
When using auscultation only, in cardiac arrest 1/246 (0.4%) of tubes was misdiagnosed and this tube was esophageal. In non-arrest patients, 5/99 (5%) of the tubes was misdiagnosed, including 1 esophageal and 4 tracheal tubes..

(19) Grmec S, Klemen P. Does the end-tidal carbon dioxide (EtCO2) concentration have prognostic value during out-of-hospital cardiac arrest?. Eur.J.Emerg.Med. 2001 Dec;8(4):263-269

LOE D5 No specific study of ETT confirmation techniques.
Prospective study of 139 prehospital cardiac arrest patients for outcome related to $ETCO_2$, but not a study of $ETCO_2$ for confirmation of ETT placement..

(20) Grmec S, Krizmaric M, Mally S, Kozelj A, Spindler M, Lesnik B. Utstein style analysis of out-of-hospital cardiac arrest--bystander CPR and end expired carbon dioxide. Resuscitation 2007 Mar;72(3):404-414

LOE D5 – Not applicable
Study of outcomes in relation to $ETCO_2$, but not of $ETCO_2$ for tube placement confirmation..

(21) Grmec S, Kupnik D. Does the Mainz Emergency Evaluation Scoring (MEES) in combination with capnometry (MEESc) help in the prognosis of outcome from cardiopulmonary resuscitation in a prehospital setting?. Resuscitation 2003 Jul;58(1):89-96

LOE D5 No study of $ETCO_2$- patients from this study included in Grmec study in Intens Care.
$ETCO_2$ of <10 used to predict nonsurvivability, but no study of $ETCO_2$ for tube confirmation.

(22) Grmec S, Lah K, Tusek-Bunc K. Difference in end-tidal CO2 between asphyxia cardiac arrest and ventricular fibrillation/pulseless ventricular tachycardia cardiac arrest in the prehospital setting. Crit.Care 2003 Dec;7(6):R139-

44

LOE D5 – Not applicable.

Study of outcome of cardiac arrest in relation to $ETCO_2$, but not of $ETCO_2$ for tube lacement confirmation.
(23)

Article	Prehospital determination of tracheal tube placement in severe head injury
Author(s)	Grmec S, Mally S.
Journal	Emergency Medicine Journal 2004; 21(4):518-520
LOE	D5 Extrapolated - eg *different pt population group – head trauma, not cardiac arrest,*
Methodological Quality	FAIR (control of direct tube visualisation)
Relevance to question asked	Emergency (pre hospital) intubation of adult patients with head trauma performed by emergency physicians
Relevance to outcome observed	Detection devices – two forms of ETCO2 detection were 100% specific and sensitive for detection of correct tube placement, versus auscultation (sensitivity 94%, specificity 66%)
Magnitude of observed event	81 patients, initial tube placement 73 tracheal and 8 esophageal
Exclusion Log	
Study Finding (conclusion)	Supports hypothesis for capnographic devices over usual management of (chest) auscultation.

(24) Hayden SR, Sciammarella J, Viccellio P, Thode H, Delagi R. Colorimetric end-tidal CO2 detector for verification of endotracheal tube placement in out-of-hospital cardiac arrest. Acad.Emerg.Med. 1995 Jun;2(6):499-502

LOE D2 - Neutral - Poor [colorimetric $ETCO_2$ detector]
Prospective observational study of convenience sample of colorimetric $ETCO_2$ device for confirmation of ETT placement in OHCA. 566 victims included from 571 cardiac arrests (5 detectors contaminated with secretions). Prior to this protocol, 1% of intubation attempts were reported to have non-tracheal placements.
Patients= all cardiac arrests
Device= colorimetric $ETCO_2$ detector.
Gold Standard = clinical exam of EMS personnel, but some (e.g. the tubes without colorimetric $ETCO_2$ color change) were verified in ED on arrival. Method of clinical verification not described.

Of tubes in the trachea, 540/565 (96%)were identified by the colorimetric device.
Of tubes in the esophagus, 0/1 (0%) was identified by the colorimetric device..

(25) Holland R, Webb RK, Runciman WB. The Australian Incident Monitoring Study. Oesophageal intubation: an analysis of 2000 incident reports. Anaesth.Intensive Care 1993 Oct;21(5):608-610

There were 35 oesophageal intubations in the first 2000 incidents reported to the Australian Incident Monitoring Study (AIMS). These reports confirm existing impressions that misplacement of the endotracheal tube can occur in trained as well as untrained hands, and that auscultation is an unreliable test. On the other hand, the value of capnography is emphasised, with no false positives in the 16 cases in which the instrument was used. There was one false negative. Over the 4 years of the AIMS study, reports have declined in frequency. It is possible that the early detection of oesophageal intubation by capnography has altered its status to the extent that anaesthetists no longer regard it as a "critical" incident. It is highly recommended that the presence of the expected concentration of carbon dioxide in expired air be confirmed by capnography immediately after any endotracheal intubation.

LOE D5 - Supports - Poor [Capnography]
Not specific to cardiac arrest patients. *Collection of 2000 self-reported anaesthesia incident reports that contains 35 esophageal misplaced ETTs.*
Device= capnograph
In 16 cases in which capnograph was used, there were no false positives and one false negative..

(26) Jemmett ME, Kendal KM, Fourre MW, Burton JH. Unrecognized misplacement of endotracheal tubes in a mixed urban to rural emergency medical services setting. Acad.Emerg.Med. 2003 Sep;10(9):961-965

LOE D5 Neutral - Fair [Auscultation]
Prospective observational study of ETIs by EMS personnel in urban/suburban/rural regions. 167 patients with ETI attempts led to 136 intubations (81%) that were believed to be successful by EMS personnel. Observational forms were completed in the ED on 109/136 intubations deemed to be successful by EMS provider.
Device = no protocol required device. Tube placement generally by direct visualization, vapor in tube, ease of ventilation, oxygen saturation, and auscultatation of lungs and epigastrium. Any use of additional devices was at the service level, but described as being sporatic.
Gold Standard = Receiving ED physician verified tube placement with infrared $ETCO_2$ detector and breath sounds. Questionable cases could also be verified by direct visualization, esophageal detector device and/or CXR.
Of the 109 patients in whom paramedics believed the ETT was in the trachea/mainstem bronchus, the tube was non-tracheal (esophageal or above the cords) in 11/109 (10%).

(27) Jenkins WA, Verdile VP, Paris PM. The syringe aspiration technique to verify endotracheal tube position. Am.J.Emerg.Med. 1994 Jul;12(4):413-416

LOE D5 - Supportive - Fair [syringe aspiration esophageal detector device]
Prospective study of 90 consecutive intubated patients encountered by 3 receiving emergency physicians.
Patients= patients in ED (57%) or OOH (43%), but treated by one of 3 EM physicians. Age 2 mo - 92 years. 45 (50%) of these patients were in non-traumatic cardiac arrest.
Device= syringe aspiration esophageal detector device.
Gold Standard = after test aspiration, placement confirmed by physician with a combination of direct visualization, breath sounds, epigastric sounds, colorimetric $ETCO_2$ device, and CXR as deemed necessary.
Of the tracheal intubations, the syringe aspirator identified 88/88 (100%).
Of the non-tracheal intubations, the syringe aspirator identified 2/2 (100%) - paramedics believed these 2 ETTs were in tracheal position based upon auscultation..

(28) Jones JH, Murphy MP, Dickson RL, Somerville GG, Brizendine EJ. Emergency physician-verified out-of-hospital intubation: miss rates by paramedics. Acad.Emerg.Med. 2004 Jun;11(6):707-709

LOE D5 - Neutral - Poor [Auscultation]
Prospective observational study of consecutive intubations for correct placement of ETTs by EMS personnel in OOH setting as determined by receiving EM physician. 208 paramedic intubations included.
Patients= OOH intubations
Device= No device studied, rather this is a study of all OOH intubations (unfortunately, the study does not describe the standard techniques used in these OOH intubations - some did have devices used in addition to clinical exam).
Gold standard= Receiving EM physician assessment of direct visualization, patient examination, colorimetric $ETCO_2$ detection, and syringe aspiration esophageal detector device.
12/208 (6%) OOH intubations were determined to be non-tracheal. In 3/12 misplaced ETTs, a confirmatory device ($ETCO_2$ or EDD) was used.

(29)

Article	Frova intubating catheter position can be determined with aspirating oesophageal detection device.
Author(s)	Kadry T, Harvey M, Wallace M, Imrie J.
Journal	Emergency Medicine Australasia 2007; 19(3): 203-206
LOE	D5 Extrapolated - eg *different pt population group, - elective anaethetised patients*
Methodological Quality	GOOD (=most or all)
Relevance to question asked Relevance to outcome observed Magnitude of observed event	RCT of using an esophageal detection device in combination with the insertion of a Frova intubating catheter placed in both trachea and esophagus. Patient group – elective, anaesthetised patients prior to surgery. 100% sensitivity and specificity for tube placement. Small study with 18 patients. However confounders typical of cardiac arrest patients where EDD's have been found not to be reliable, are not tested in this study.
Exclusion Log	
Study Finding (conclusion)	LOE 5 study supports hypothesis in a low risk patient group.

(30) Kapsner CE, Seaberg DC, Stengel C, Ilkhanipour K, Menegazzi J. The esophageal detector device: accuracy and reliability in difficult airway settings. Prehospital Disaster Med. 1996 Jan-Mar;11(1):60-62

LOE D5 - Neutral - Poor [Esophageal Detector Device]
Respiratory arrest model in swine. 100% accuracy in detecting tube placement using EDD for esophageal,

esophageal +air, trachea and right mainstem bronchus locations, but only 80% accurate (4/5) in detecting tracheal position when fluid in trachea.

(31)

Article	The self-inflating bulb to detect esophageal intubation during emergency airway management
Author(s)	Kasper CL, Deem S
Journal	Anesthesiology 1998; 88 (4): pp. 898-902.
LOE	D5 Extrapolated - eg *different pt population group – mostly non cardiac arrest patients, all emergency pts (only 3 pts with IHCA)*
Methodological Quality	GOOD (=most or all)
Relevance to question asked	Only 3 pts were undergoing CPR, therefore LOE 5 – different patient population.
Relevance to outcome observed	Relevant in determining tube placement
Magnitude of observed event	Good for extrapolated group, poor numbers for cardiac arrest group
Exclusion Log	
Study Finding (conclusion)	Supports hypothesis **IHCA or emergency - Self Inflating Bulb** (negative pressure test) Required 10 seconds wait for bulb to inflate – issue may relate to requiring a CPR hands off period. 300 consecutive pts requiring intubation. Only 3 pts were undergoing CPR, therefore LOE 5 – different patient population. 100% sensitivity for detecting esophageal intubation, 99% specificity for tracheal intubation (3 false positives) CO2 detection device used for secondary confirmation. The CO2 device failed to demonstrate CO2 in 2 of 3 patients receiving CPR

(32) Katz SH, Falk JL. Misplaced endotracheal tubes by paramedics in an urban emergency medical services system. Ann.Emerg.Med. 2001 Jan;37(1):32-37

LOE D5 - Neutral - Good [Auscultation]
Prospective observational study of OOH intubation by paramedics. Total of 108 intubations included.
Patients=OOH patients with ETI.
Device= Clinical methods
Gold Standard= Receiving EM physician auscultation, $ETCO_2$ monitoring, and direct visualization.
27/108 (25%) of OOH ETTs were non-tracheal (18/27 in esophagus, 9/27 above the cords).
Note, 17/18 esophageal tubes had no expired $ETCO_2$ in ED (the one with $ETCO_2$ was nasally intubated with ETT in esophagus, but the patient had spontaneous respirations)..

(33) Knapp S, Kofler J, Stoiser B, Thalhammer F, Burgmann H, Posch M, et al. The assessment of four different methods to verify tracheal tube placement in the critical care setting. Anesth.Analg. 1999 Apr;88(4):766-770

LOE D5 (does not include cardiac arrest patients) Supportive- Good [capnometer], Neutral-Good [auscultation and bulb EDD], Opposes-Good [Transillumination]
Prospective study of 38 consecutive intubated patients in an ICU setting comparing auscultation (bilateral breath sounds in two locations each side and epigastrium) with 3 devices. A second tube was placed into the esophagus of each patient, and the participant was blinded to the position of each tube. Participants were experienced ICU physicians and 4th year medical students.
Patients= Adult ICU patients, no cardiac arrest patients.
Device= infrared capnometer (Capnosat Drager), self-inflating bulb aspiration esophageal detector device, and transillumination with lighted stylet.
Gold Standard= ETTs in place in in chronically ventilated patients.
For auscultation- the experienced examiner was correct 100% and inexperienced 68%.
For $ETCO_2$- both examiners correct 100%.
For aspiration bulb- there were 3 errors (1 in experienced provider), and all errors were mistook tracheal position for esophageal.
For transillumination- the experienced examiners were correct in 84% and the inexperienced examiners were correct 87%.
$ETCO_2$ was statistically better at identifying tube position when compared with auscultation generally..

(34) Ko FY, Hsieh KS, Yu CK. Detection of airway CO2 partial pressure to avoid esophageal intubation. Chung Hua.Min.Kuo Hsiao Erh Ko.I.Hsueh Hui Tsa.Chih. 1993 Mar-Apr;34(2):91-97

LOE D5 Supportive- Poor [waveform capnography]
Noncardiac arrest PICU study of patients receiving emergency intubation. Inadvertent esophageal intubation was detected by $ETCO_2$ <5mm HG and no typical respiratory waveform.

(35) Levine RL, Wayne MA, Miller CC. End-tidal carbon dioxide and outcome of out-of-hospital cardiac arrest. N.Engl.J.Med. 1997 Jul 31;337(5):301-306

LOE D5 – Not applicable.

No specific info re $ETCO_2$ for ETT confirmation.

(36) Li J. Capnography alone is imperfect for endotracheal tube placement confirmation during emergency intubation. J.Emerg.Med. 2001 Apr;20(3):223-229

LOE D5 - Opposes - Poor [Colorimetric devices AND Nonwaveform Capnometers]
Metaanalysis of studies of $ETCO_2$ detector use in OOH patients. Analysis of 10 articles with 2192 intubations and

compared the accuracy of $ETCO_2$ detector in identifying tracheal and esophageal tube placements. 80% of the intubations studied used colorimetric detectors, the others used infrared capnometers. Not specific to cardiac arrest patients.
Device= colorimetric and infrared capnometer
For tracheal tube placements, 1941/2088 (93%) identified by $ETCO_2$ device.
For esophageal tube placements, 101/104 (97%) identified by $ETCO_2$ device.
Note that the study uses capnography incorrectly, since capnography implies waveform detectors, when these detectors were colorimetric and infrared capnometer.

(37) Linko K, Paloheimo M, Tammisto T. Capnography for detection of accidental oesophageal intubation. Acta Anaesthesiol.Scand. 1983 Jun;27(3):199-202

LOE D5 - Supportive - Fair [Capnography]
20 anesthetized patients with both tracheal and esophageal placements of ETTs.
Not a cardiac arrest study, human study of patients with both tracheal and esophageal tubes tested using waveform $ETCO_2$. In some cases of patients that had BVM ventilation prior to esophageal tube placement, there was small $ETCO_2$ levels (from exhaled air blown into stomach during BVM ventilation) with intial ventilation of esophageal tube that quickly disappeared. Capnographic waves during esophageal intubation were reported as easy to distinguish from normal tracheal ventilation.

(38) MacLeod BA, Heller MB, Gerard J, Yealy DM, Menegazzi JJ. Verification of endotracheal tube placement with colorimetric end-tidal CO2 detection. Ann.Emerg.Med. 1991 Mar;20(3):267-270

LOE D4 - Opposes - Fair [colorimetric $ETCO_2$]
Prospective convenience study of confirmation of ETT placement in OOH, air medical and ED settings. 250 intubations (238 tracheal and 14 esophageal). 42% were in cardiac arrest.
Patient ages not described.
Device= disposable colorimetric $ETCO_2$ detector]
Gold standard= not described, presume clinical evaluation.
Tracheal ETT placement identified in 210/238 (88%), 73/101 (72%) of cardiac arrests.
Nontracheal ETT placement identified 11/12 (92%).

(39) McLeod GA, Inglis MD. The MiniCAP III CO2 Detector: assessment of a device to distinguish oesophageal from tracheal intubation. Arch.Emerg.Med. 1992 Dec;9(4):373-376

LOE D5 Neutral - Poor [capnometer]
Prospective study of capnometer readings in 50 patients undergoing anesthesia with ETTs placed simultaneously in both the trachea and esophagus. There are no cardiac arrest patients.
Device: infrared capnometer
In trachea, 50/50 (100%) identified by capnometer.
In esophagus, 50/50 (100%) identified by capnometer.
These were all perfusing patients, so this is not a reliable study of capnometer performance in cardiac arrest patients.

(40) Oberly D, Stein S, Hess D, Eitel D, Simmons M. An evaluation of the esophageal detector device using a cadaver model. Am.J.Emerg.Med. 1992 Jul;10(4):317-320

LOE D5 – Supports – Poor [bulb esophageal detector device]
Human cadaver (recently deceased) study in which ETTs were placed in both the trachea and esophagus without inflation of the distal ETT cuffs. 10 cadavers used. Physicians, nurses, paramedics and respiratory therapists confirmed the placement.
Device= bulb EDD.
EDD identified 100% of both tracheal and esophageal ETT placements (45/45 in each case). In the esophagus 44/45 did not reinflate, and 1/45 filled with vomitus on inflation.

(41)

Article	Identification of Endotracheal Tube Malpositions Using Computerized Analysis of Breath Sounds via Electronic Stethoscopes
Author(s)	O'Connor CJ, Mansy H, Balk RA, Tuman KJ, Sandler RH
Journal	Anesthesia and Analgesia 2005; 101(3): 735-739
LOE	D5 Other group – anaesthetised patients prior to surgery.
Methodological Quality	POOR (=few but worthy of inclusion)
Relevance to question asked	Assesses placement of an ET tube in the trachea, esophagus and R main stem bronchus. Bronchoscopic determine made of correct tube placement (control).
Relevance to outcome observed	100% sensitivity and specificity for tube placement when using computer analysed energy ratios of (filtered) breath sounds
Magnitude of observed event	Note – confounders: obese patients were excluded from study, and tested on general anaesthesia patients with a clear airway
Exclusion Log	
Study Finding (conclusion)	Supports hypothesis that computer analysis of breath sounds may determine misplacement of ET tube. Technique will rely on a readily available tool for clinical use, and confounders of obesity and airways with secretions providing similar strong results.

(42) Ornato JP, Shipley JB, Racht EM, Slovis CM, Wrenn KD, Pepe PE, et al. Multicenter study of a portable, hand-size, colorimetric end-tidal carbon dioxide detection device. Ann.Emerg.Med. 1992 May;21(5):518-523

LOE D2 - Opposes - Fair [colorimetric $ETCO_2$ detector]

Prospective multicenter study in 6 urban EMS systems. 227 intubated patients included. 144 of these were for cardiac arrest. Intubations occurred either OOH or in ED.

Patients= Adult patients

Device= colorimetric $ETCO_2$ detector

Gold Standard= In OOH intubations, placement confirmed by EMS personnel by present breath sounds, absent gastric sounds, good chest wall excursion, tube fogging, and improvement in patient color. On arrival to ED, physician assessment and, if necessary, capnography, pulse oximetry, and/or arterial blood gas results were used to verify tube placement.

In non=arrests: (n=83)

In tracheal position,69/69 (100%) identified correctly by $ETCO_2$ detector.

In esophageal position, 13/14 (93%) were correctly identified by $ETCO_2$ detector. The one misinterpretation was in an esophageally placed tube in a spontaneously breathing patient with the ETT cuff deflated - when the cuff was

inflated and several breaths were given, the $ETCO_2$ color change became negative.
In cardiac arrests:
In tracheal position, 91/132 (67%) correctly identified by $ETCO_2$ detector.
In esophageal position, 12/12 (100%) correctly identified by $ETCO_2$ detector.
1/227 intubations was reported to be an unrecognized esophageal intubation.

(43) Pelucio M, Halligan L, Dhindsa H. Out-of-hospital experience with the syringe esophageal detector device. Acad.Emerg.Med. 1997 Jun;4(6):563-568

LOE D4 Opposes -Fair [syringe aspirator esophageal detector device]
Cardiac arrest results not separated from non-arrest, even though the majority were for cardiac arrest. Prospective observational study of paramedic intubations in the OOH setting and transport to one of 8 participating urban hospitals. Initial tube placements verified by paramedics using breath sounds and tube fogging. During study, EDD used in 213 of 374 intubation attempts (347 cardiac arrests and 27 respiratory distress).
Patients= Adult patients over 18 y/o. Excluded if unsure of EDD interpretation (11) or if not verified by physician (32).
Device= Syringe aspiration EDD
Gold Standard= Tube placement ultimately confirmed by receiving physician using direct laryngoscopy and/or CXR.
In tracheal position, the EDD identified 156/158 (99%) of placements. The 2 misses were one with severe pulmonary edema and one with blood in oropharynx.
In esophageal position, the EDD identified 5/10 (50%) of placements.
EDD interpretation was indeterminate in 11 cases.
Physicians confirmed unrecognized esophageal intubations in 18/284 (6%) of intubations with physician confirmation.

(44) Petroianu G. [Confirmation of tube position using a non-quantitative CO2-detector. Initial results in an emergency service]. Anaesthesist 1993 May;42(5):324-325

Not included in analysis
German article, not available to worksheet author..

(45) Rozenberg A, Carli P, Bousquet M, Barrier G. [Capnography and pulse oximetry in resuscitation after cardiac arrest outside the hospital]. Ann.Fr.Anesth.Reanim. 1989;8(Suppl):R78

Not included
French article not available to worksheet author.

(46) Sanders KC, Clum WB,3rd, Nguyen SS, Balasubramaniam S. End-tidal carbon dioxide detection in emergency intubation in four groups of patients. J.Emerg.Med. 1994 Nov-Dec;12(6):771-777

LOE D2 – Supports- Poor [Colorimetric detector]
Observational study of emergent intubations in an urban ED. Tubes clinically evaluated with breath sounds, absent gastric sounds, chest rise, and tube fogging before application of device. 49 intubations in 43 patients (10 cardiac arrest).
Patients= adult patients between 18-89 y/o.
Device= colorimetric $ETCO_2$ detector.
Gold Standard= Vocal cord visualization, when possible - clinical exam when no direct visualization.
Results section is poorly written and mixes results for tracheal placements with those of esophageal placements. The article claims 100% sensitivity (true positives) and 100% specificity (true negatives). If the 43 patients were all eventually successfully intubated, then there would have been 43/43 tracheal placements verified and 6/6 esophageal placements verified. (And in cardiac arrest, 10/10 tracheal placements verified and 4/4 esophageal placements verified.).

(47) Sayah AJ, Peacock WF, Overton DT. End-tidal CO2 measurement in the detection of esophageal intubation during cardiac arrest. Ann.Emerg.Med. 1990 Aug;19(8):857-860

LOE D5 Study inadequate for inclusion.
Canine model of VF cardiac arrest in 16 dogs (4 animals excluded for failure to complete protocol for various reasons), animals were ventilated through ETT in either tracheal or esophageal position.
Concludes that this waveform $ETCO_2$ reliably distinguished between tracheal and esophageal intubations, but the protocol studied only $ETCO_2$ readings and not the type of wave-form.

(48) Schaller RJ, Huff JS, Zahn A. Comparison of a colorimetric end-tidal CO2 detector and an esophageal aspiration device for verifying endotracheal tube placement in the prehospital setting: a six-month experience. Prehospital Disaster Med. 1997 Jan-Mar;12(1):57-63

LOE D5 - Supportive - Fair [syringe aspiration EDD], Opposes - Fair [colorimetric $ETCO_2$ detector]
Prospective OOH study alternating weekly between colorimetric $ETCO_2$ detector and syringe EDD. 49 patients met inclusion criteria, but only 43 had devices used on them. 33 (77%) were intubated for cardiac arrest. Results for cardiac arrest patients not reported specifically as a group, therefore LOE D5.
Patients= adults over 18 y/o
Devices= colorimetric $ETCO_2$ detector and syringe aspiration EDD
Gold Standard= Placement confirmed by receiving emergency physician. (Of the 2 misplaced intubations, one supraglottic placement found on CXR and one on direct visualization).
For EDD:
In tracheal placement, 23/23 (100%) identified by EDD
In non-tracheal position, 2/2 (100%) identified by EDD, but despite EDD findings, the tubes were left malpositioned as part of study protocol. In one of these, the patient was nasotracheally intubated above the cords, in the other the patient had vomitus on aspiration.
For $ETCO_2$:
In tracheal placement, 14/18 (78%) were correctly identified by $ETCO_2$.
Unrecognized misplaced intubations occurred in 2/25 of intubations in EDD group or 2/43 (5%) of all intubations in study.

(49) Silvestri S, Ralls GA, Krauss B, Thundiyil J, Rothrock SG, Senn A, et al. The effectiveness of out-of-hospital use of continuous end-tidal carbon dioxide monitoring on the rate of unrecognized misplaced intubation within a regional emergency medical services system. Ann.Emerg.Med. 2005 May;45(5):497-503

LOE D2 - Supportive - Poor [continuous capnography $ETCO_2$]
Prospective observational study of continuous $ETCO_2$ monitoring for ETI in OOH setting comparing confirmation of tube placement in several EMS services, some use continuous $ETCO_2$ monitoring and some do not. 153 intubations, 93 with continuous $ETCO_2$ and 60 without. One third of patients in cardiac arrest.
Adult and pediatric patients.
Device= continuous $ETCO_2$ capnography monitoring (device not specified).
Gold standard = ETT position verified by receiving EM physician using confirmation algorithm.
Tube in trachea identified in 93/93 (100%) with continuous $ETCO_2$ monitoring.
Tube misplaced (esophagus (13)or hypopharynx (1)) identified in 46/60 (76.7%) without continuous $ETCO_2$ monitoring.
Unrecognized misplaced intubations in 23.3% without $ETCO_2$ and 0% with $ETCO_2$.
Of note, 2 patients with misplaced ETTs without continuous $ETCO_2$ had colorimetric $ETCO_2$ used on scene.

(50) Takeda T, Tanigawa K, Tanaka H, Hayashi Y, Goto E, Tanaka K. The assessment of three methods to verify tracheal tube placement in the emergency setting. Resuscitation 2003 Feb;56(2):153-157

LOE D1 - Opposes - Poor [capnography AND self-inflating bulb EDD]
Prospective study of 137 consecutive patients (81 in cardiac arrest) transported by EMS to ED where they were intubated. There were a total of 150 ETI attempts.
Patients= Adult patients,

Device= Self-inflating bulb aspiration device AND infrared waveform capnograph
Gold Standard= confirmation by investigators by direct visualization, breath sounds, absence of gastric sounds, chest rise, and tube fogging.
For auscultation:
In non-tracheal position, 8/9 (89%) identified in cardiac arrest AND 4/4 (100%) identified in non-arrest by auscultation.
In tracheal position, 75/81(93%) identified in cardiac arrest AND 50/56 (89%) identified in non-arrest.
For capnography:
In esophageal position, 9/9 100% identified in cardiac arrest and 4/4 (100%) identified in non-arrest.
In tracheal position, 55/81 (68%) identified in cardiac arrest AND 55/56 (98%) identified in non-arrest.
For self-inflating bulb EDD:
In non-tracheal position, 8/9 (89%) identified in cardiac arrest AND 4/4 (100%) identified in non-arrest.
In tracheal position, 61/81 (75%) in cardiac arrest AND 54/56 (95%) identified in non-arrest.
NOTE: study done in Japan where patients were transported to ED by EMS (without report of prehospital time or any EMS intervention) with intubation delayed until arrival at ED. Personal communication with author determined that ambulance crews in the study region were required to transport all cardiac arrest, even those with "very prolonged, hopeless" resuscitation attempts.

(51) Tanigawa K, Takeda T, Goto E, Tanaka K. The efficacy of esophageal detector devices in verifying tracheal tube placement: a randomized cross-over study of out-of-hospital cardiac arrest patients. Anesth.Analg. 2001 Feb;92(2):375-378

LOE D1 Opposes - Poor [syringe EDD and bulb EDD and $ETCO_2$]
Prospective, randomized, cross-over study between bulb and syringe aspirators after ETI, 56 attempts at ETI.
Patients all had OOH cardiac arrests (transported with BVM or dual lumen airway) and were intubated after arrival in ED.
Patients= adult patients in cardiac arrest.
Device= self-inflating bulb aspiration device AND syringe aspiration device AND waveform capnograph.
Gold Standard= direct visualization, chest rise, breath sounds, absent gastric sounds and tube fogging.
In tracheal position (48), 34/48 (71%) identified by bulb and 35/48 (73%) identified by syringe. $ETCO_2$ detected in 31/48 (65%).
In the esophageal position (8), all three devices identified 8/8 (100%) of non-tracheal intubations.
NOTE: Japanese study of cardiac arrest patients with unreported, but probably extremely prolonged poor perfusion, because of transport during CPR without intubation until arrival in ED. Personal communication with author determined that ambulance crews in the study region were required to transport all cardiac arrest, even those with "very prolonged, hopeless" resuscitation attempts.

(52) Tanigawa K, Takeda T, Goto E, Tanaka K. Accuracy and reliability of the self-inflating bulb to verify tracheal intubation in out-of-hospital cardiac arrest patients. Anesthesiology 2000 Dec;93(6):1432-1436

LOE D1 - Opposes - Poor [self inflating bulb aspiration EDD AND waveform capnography]
65 consecutive OOH cardiac arrests, intubated in ED after average CPR time of 32-37 minutes and sometimes ventilation with dual lumen airway.
Patients= cardiac arrest
Device= Self-inflating bulb aspiration EDD AND waveform capnograph
5 esophageal intubations, 5/5 (100%) identified by both devices.
65 tracheal intubations, 47/65 (72%) identified with bulb and 39/65 (60%) identified by capnography.
Note: average CPR time in individuals who had tracheal intubations without $ETCO_2$ detected = 37 minutes. Personal communication with author determined that ambulance crews in the study region were required to transport all cardiac arrest, even those with "very prolonged, hopeless" resuscitation attempts.

(53)

Article	The Out-of-Hospital Esophageal and Endobronchial Intubations Performed by Emergency Physicians
Author(s)	Timmermann A, Russo SG, Eich C, Roessler M, Braun U, Rosenblatt WH, Quintel M,
Journal	Anesthesia & Analgesia 2007; 104(3):619-623
LOE	D4 No control group (case series)
Methodological Quality	FAIR (=some) - confounder of initial misplaced intubation by first physician not reported. Pts dead at scene with stop of resusc before arrival of second physician not assessed – may also have included misplaced tubes. Study results indicate both continuous and colorimetric ETCO2 detection used, but do not differentiate between the two techniques.
Relevance to question asked	OOHCA (21/149 pts)+ other patients requiring emergency intubation
Relevance to outcome observed	Clinical means missed one esophageal placement, and one R main bronchus placement.
Magnitude of observed event	Only 21 of 149 intubated patients in cardiac arrest when intubated. 1 pt with esophageal intubation (+ 1 with R main bronchus) – incorrect position determined by ETCO2 but not initially picked using sole clinical means by intubating emergency physician. EDD (syringe) used for 2 pts in CA – tube in correct position
Exclusion Log	
Study Finding (conclusion)	Supports hypothesis for ETCO2 over clinical means

(54) Tong YL, Sun M, Tang WH, Xia JY. The tracheal detecting-bulb: a new device to distinguish tracheal from esophageal intubation. Acta Anaesthesiol.Sin. 2002 Dec;40(4):159-163

LOE D5 – Supports – Fair [Bulb aspiration detector AND capnography]
400 patients in 3 groups
Study 1- 200 patients with bulb aspirator then capnography
Study 2- 100 patients with esophageal intubation with bulb aspirator then capnography.
Study 3- 100 patients double-blinded esoph or tracheal position
100% sensitivity and specificity in all cases.
Not cardiac arrest cases.

(55) Trikha A, Singh C, Rewari V, Arora MK. Evaluation of the SCOTI device for confirming blind nasal intubation. Anaesthesia 1999 Apr;54(4):347-349

LOE D5 - Supports - Fair [waveform capnography] and Opposes - Fair [SCOTI]

Prospective observational study of 132 patients undergoing general anesthesia and requiring nasotracheal intubation for dental/oromaxillofacial surgery.
Patients= None in cardiac arrest
Device= SCOTI (sonic) and capnograph and auscultation
In tracheal intubation, 86/120 (72%) identified by SCOTI AND 132/132 (100%) identified by capnography and 131/132 (99%) were identified by auscultation.

(56) Varon AJ, Morrina J, Civetta JM. Clinical utility of a colorimetric end-tidal CO2 detector in cardiopulmonary resuscitation and emergency intubation. J.Clin.Monit. 1991 Oct;7(4):289-293

LOE D2 - Opposes - Fair [Colorimetric $ETCO_2$ detector]
Convenience sample of all CPR team and emergency resuscitations where colorimetric $ETCO_2$ detector used. 110 patients total. A respiratory therapist attached the $ETCO_2$ detector and recorded the result. In-hospital setting in ED or hospital wards.
Patients= Patient ages unclear, 57 of patients were cardiac arrest.
Device= Colorimetric $ETCO_2$ detector
Gold Standard= exam by physician using auscultation and direct visualization.
In cardiac arrest (n=57):
For tubes in trachea, 32/52 (62%) identified.
For non-tracheal positioning, 5/5 (100%) identified.
In non-arrest patients (n=53):
For tubes in trachea, 47/48 (98%) identified.
For non-tracheal positioning, 5/5 (100%) identified.
Note: this study uses >2% CO2 to distinguish positive without any consideration for patients in the 0.5-2% intermediate range that other studies generally included as positive $ETCO_2$ if it was persistent..

(57) Vukmir RB, Heller MB, Stein KL. Confirmation of endotracheal tube placement: a miniaturized infrared qualitative CO2 detector. Ann.Emerg.Med. 1991 Jul;20(7):726-729

LOE D2 - Supports - Poor [Infrared capnometer]
Prospective convenience sample study of endotracheal intubation confirmation by critical care physicians in ICU, hospital wards, and ED. Patient settings were ICU 79%, ED 11%, and med-surg ward 10%. 100 intubation attempts included in 88 patients.
Patients= 21% (17 medical, 4 trauma arrests) were intubated for cardiac arrest.
Device= electronic infrared spectrophotometric capnometer (sensitivity to 0.5%)
Gold Standard= Direct visualization, CXR, or both. Also used were auscultation (breath sounds and/or epigastric), chest expansion, tube fogging, or pulse oximetry.
Of tracheal placements, 96/96 (100%) were identified by device.
Of esophageal placements, 4/4 (100%) were identified by device.

(58) Wayne MA, Friedland E. Prehospital use of succinylcholine: a 20-year review. Prehosp.Emerg.Care 1999 Apr-Jun;3(2):107-109

LOE D5 - Supportive - Poor [waveform capnography]
Retrospective review of 1657 consecutive OOH intubations with succinylcholine by paramedics.
Patients= all patients 16 y/o or older intubated with succinylcholine by county EMS system.
Device = pre 1990 no device, post 1990 capnography or syringe aspiration device.
Gold standard= esophageal intubations identified by reports from ED or coroner (not comprehensive).
Esophageal intubations were reported in 5 cases (0.36%) before 1990 when no device was used.
Esophageal intubations were reported in 1 case (0.06%) and in this case a 0 reading on the capnograph was ignored.
This study only secondarily mentions misplaced esophageal intubation, and the method of identifying misplaced intubations is not robust, but there appears to be a reduction in reported esophageal intubations after using

waveform capnography or aspiration device, and the only reported esophageal misplacement after using the devices was reported to have a 0 capnograph reading that was ignored..

(59)

Article	Confirmation of Endotracheal Tube Placement after Intubation Using the Ultrasound Sliding Lung Sign
Author(s)	Weaver B, Lyon M, Blaivas M.
Journal	Academic Emergency Medicine 2006; 13(3): 239-244
LOE	D5 Extrapolated – eg *different pt population group, - cadaver study*
Methodological Quality	FAIR (=some) (randomised, blinded study, unable to control for some confounders)
Relevance to question asked	Compares ultrasound identification of tube placement by assessing sliding of visceral against parietal pleural (sliding lung sign).
Relevance to outcome observed	100% sensitivity not achieved (2 tubes falsely identified as esophageal), 100% specificity achieved. There was no time limit to time taken to perform test
Magnitude of observed event	Severe limiting factor is the requirement for qualification in emergency ultrasound imaging, and non portability of equipment, restricting availability of equipment to hospitals.
Exclusion Log	
Study Finding (conclusion)	100% specificity but less than 100% sensitivity for correct tracheal tube placement. Technique has limited general use due to requirement for ultrasound equipment and expertise in operation (study included 2 emergency physicians with credentialing in emergency ultrasonography).

(60)

Article	Pilot study to evaluate the accuracy of ultrasonography in confirming endotracheal tube placement.
Author(s)	Werner SL, Smith CE, Goldstein JR, et al
Journal	Annals of Emergency Medicine 2007; 49(1): 75-80
LOE	D5 Extrapolated - eg *different pt population group, - preoperative anaesthetised patients*
Methodological Quality	POOR (=some) – randomised, blinded study, unable to control for potential confounders likely to be present in cardiac arrest. Only one esophageal intubation included.

Relevance to question asked	Compares usual means of tube placement at routine anaesthetic intubation with ultrasound identification of the tube at the neck.
Relevance to outcome observed	100% sensitivity and specificity, including correct identification of one tube inadvertently placed by the anaesthetist during the trial. Procedure undertaken by emergency physicians with skill in emeregency ultrasonography.
Magnitude of observed event	Technique requires skill qualification and equipment availability to perform emergency ultrasonography
Exclusion Log	
Study Finding (conclusion)	100% sensitivity and specificity for correct tube placement when performed by persons with qualification or skills in emergency ultrasonography.

(61) White RD, Asplin BR. Out-of-hospital quantitative monitoring of end-tidal carbon dioxide pressure during CPR. Ann.Emerg.Med. 1994 Jan;23(1):25-30

LOE D5 - Neutral -Poor [waveform capnography]
Initial description of 4 case reports of OHCA patients that had capnography used during their resuscitation. Small case series that shows feasibility, but too small to prove effectiveness.

(62) Williamson JA, Webb RK, Cockings J, Morgan C. The Australian Incident Monitoring Study. The apnography: applications and limitations–an analysis of 2000 incident reports. Anaesth.Intensive Care 1993 Oct;21(5):551-557

LOE D5 – Supports – Poor [Capnography]
Case series of 2000 anesthesia incidents submitted to an incident monitoring study. Reported anesthesia incidents were analyzed related to the benefits and problems with capnography. Capnography was significantly useful, and when there was "failure" of capnography, this was often due to monitor checking and calibration.

(63)

Article	Unrecognized Misplacement of Endotracheal Tubes by Ground Prehospital Providers
Author(s)	Wirtz DD, Ortiz C, Newman DH, Zhitomirsky I.
Journal	Prehospital Emergency Care 2007; 11(2): 213 - 8
LOE	D5 No control group (case series)
Methodological Quality	FAIR (=some) - includes non arrest data , confounder of potential tube misplacement in transport not controlled for.

Relevance to question asked Relevance to outcome observed Magnitude of observed event	Assesses patients intubated prehospital and post admission to hospital. Unspecified ('only some') EMS units consistently using ETCO2 detectors. Does not discuss tube misplacement by emergency department staff for intubations carried out at ED 12 cases / 132 total out of hospital (EMS) intubations with misplacement of tube esophageal (11) or hypopharangeal (1). 6 cases were cardiac arrest at scene. No device used in any of the arrest pts with misplaced intubation. All identified on arrival @ ED as esophageal after ETCO2. (Data reported does not identify the hypopharyngeal intubation.) 11 of 12 patients arriving at the ED with misplaced ET tubes did not have device confirmation of tube placement post intubation in the field. Tube placement checked at ED by emergency physicians by laryngoscopy and / or **colorimetric ETCO2**.
Exclusion Log	
Study Finding (conclusion)	Supports hypothesis 6 cases of at scene cardiac arrest – intubated, assessed by clinical means only. On arrival to ED, esophageal placement confirmed by ETCO2 detection.

(64) Wolfe TR, Kimball EJ, Ogden LL, Schafer P, Hartsell SC, Richardson S, et al. Evaluation of an electronic esophageal detector device in patients with morbid obesity and pulmonary failure. Prehosp.Emerg.Care 2002 Jan-Mar;6(1):59-64

LOE D5 – Supports - Fair [electronic EDD, but maybe most supportive of capnography]
Gold Standard *=All confirmed with capnography and clinical judgment prior to study.*
Device= *Electronic EDD.*
27 morbidly obese and 37 pulmonary failure patients.
No false negatives in these tracheal intubations. No cardiac arrests.

(65)

Article	A clinical study of impedance graph in verifying tracheal intubation (Abstract only)
Author(s)	Yao Y.-X, Jiang Z, Lu X.-H, et aal
Journal	National Medical Journal of China 2007; 87(13): 898 -901
LOE	D5 Extrapolated - eg *different pt population group, animal study, mechanical*
Methodological Quality	GOOD (=most or all), RCT of anaesthetised patients tested

Relevance to question asked Relevance to outcome observed Magnitude of observed event	Impedance pneumography, capnography and auscultation (experienced and inexperienced observer) tested. 100% sensitivity and specificity for impedance pneumography and capnography, fail rate (17) recordings for auscultation
Exclusion Log	
Study Finding (conclusion)	Supports the hypothesis in an extrapolated population.

(66) Zaleski L, Abello D, Gold MI. The esophageal detector device. Does it work?. Anesthesiology 1993 Aug;79(2):244-247

LOE D5 - Fair - Supportive [self-inflating bulb aspirator EDD AND waveform capnography]
Operating room patients intubated electively in either the trachea or esophagus to review the accuracy of confirmation device. Capnograph used to validate intubation. Group 1 = 300 patients with tracheal intubation, Group #2 = 100 patients with esophageal tube placement, and Group #3 = 100 patients with either trachea or esophagus randomly intubated and blinded tester evaluating tube placement.
Patient= non-cardiac arrest patients
Device= bulb-type aspiration EDD, but capnography also checked on each patient.
Gold Standard = not well defined, but presumably clinical findings of intubating anesthetist.
Group 1 (300 attempted tracheal intubations) = 270/270 (100%) tracheal ETIs identified by EDD and 30/30 (100%) of inadvertent esophageal intubations detected. 100% identification by capnograph.
Group 2 = (100 attempted esophageal intubations) = 100/100 (100%) of esophageal intubations identified by EDD and capnograph.
Group 3 = (100 randomly assigned tracheal or esophageal intubations) = 49/49 (100%) tracheal and 51/51 (100%) esophageal placements identified.
Note that 5-10% of all tracheal intubations had delayed bulb inflation (5-30 seconds). Also note that all reintubations of initial esophageal intubations were also 100% identified by both the EDD and capnography.
Not a cardiac arrest study.

(67) Zar HA, Wu WW. The inability to detect expired carbon dioxide after endotracheal intubation as a result of one-way valve obstruction of the endotracheal tube. Anesth.Analg. 2001 table of contents; Oct;93(4):971-972

LOE D5 - Single case report does not meet inclusion criteria.
Single case report, included to reveal that there can be cases of misidentified trachal intubation with capnography.