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

**Worksheet author(s)**
Jonathan Wyllie

**Date Submitted for review:** 19.10.2009

**Clinical question.**
For neonates (P) following attempted endotracheal intubation, is CO2 detection (I) superior to clinical assessment (C) for confirming endotracheal location (O)?

**Is this question addressing an intervention/therapy, prognosis or diagnosis?**
Intervention for diagnosis

**State if this is a proposed new topic or revision of existing worksheet:** New topic for existing worksheet. Different phrasing.

**Conflict of interest specific to this question**
Do any of the authors listed above have conflict of interest disclosures relevant to this worksheet? I published previous evidence evaluation. I have no other conflict of interest and no financial interest.

**Search strategy (including electronic databases searched).**
Best results are listed.
These were used as MeSH headings but also in Title, Key Word and “Any Field” as below in combination
Accessed EMBASE, MEDLINE, PUBMED, CINAHL
Looking also through related articles on PUBMED

**State inclusion and exclusion criteria**
Included Newborn, Infant and Pediatric clinical studies. No abstracts. Reviewed and accepted some adult clinical data as potentially relevant. Some case studies and series included when demonstrating limitations of techniques.

**Number of articles/sources meeting criteria for further review:**
Using Keywords MeSH headings
Endotracheal intubation 26,424, Carbon dioxide 792, Neonate 77 all of which were reviewed.
Intubation 37,239, Carbon dioxide 904, Pediatric 9
Intubation 37,239, Carbon dioxide 904, infant 142 all of which were reviewed
Intubation 37,239, Carbon dioxide 904, Child 108 all of which were reviewed
Intubation 37,239, Carbon dioxide 904, Newborn 85 all of which were reviewed
Resuscitation 59,636, neonate 7330, capnography 17 all of which were reviewed
Resuscitation 59,636, carbon dioxide 2702, infant 394 all of which were reviewed.
Resuscitation 59,636, carbon dioxide 2702, endotracheal 21 all of which were reviewed.
Resuscitation 59,636, Infant 9,480, Capnography 19 all of which were reviewed
Resuscitation 59,636, Infant 9480, Carbon dioxide 394, Intubation 55 all of which were reviewed
Resuscitation 59,636, Child 5867, Carbon dioxide 203, Intubation 38 all of which were reviewed
Resuscitation 59,636, Newborn 7330, Carbon dioxide 325, intubation 39 all of which were reviewed
Title
Endotracheal tube position 53 all of which were reviewed
Endotracheal 4270, confirmation 22 all of which were reviewed
Intubation 8969, Capnography 166, Pediatric or neonate, child, newborn or infant 27 all of which were reviewed
Intubation 8965, neonate (key word) 519 all of which were reviewed this produced no useful papers.
Any field
Endotracheal, clinical assessment 271, infant 42 all of which were reviewed.
Endotracheal position, clinical assessment 31 all of which were reviewed
This left 79 papers to be reviewed in depth as of potential direct relevance of which 28 were included.
## Summary of evidence

### Evidence Supporting Clinical Question

<table>
<thead>
<tr>
<th>Level of evidence</th>
<th>1</th>
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<tr>
<td><strong>Good</strong></td>
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<td>Hosono 2009 E</td>
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<td><strong>Fair</strong></td>
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<td>Repetto 2001 E, Roberts 1995 E</td>
<td>Aziz 1999 E,</td>
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<td><strong>Poor</strong></td>
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<td>Salthe 2006 E</td>
<td>Bhende 1995b E,</td>
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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

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<td>Sutherland 1995 E,</td>
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<td>O'Donnell 2005 E</td>
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### Evidence Opposing Clinical Question

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<th>Good</th>
<th>Fair</th>
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<th>Siddik-Sayyid 2009 E</th>
<th>Kamlin 2005</th>
<th>Hughes 2007 E</th>
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**A** = Return of spontaneous circulation  
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**REVIEWER’S FINAL COMMENTS AND ASSESSMENT OF BENEFIT / RISK:**

There is good and fair evidence (LOE 4 for this statement but LOE 5 for the PICO assessed, O’Donnell 2006, Leone 2005) suggesting a significant rate of esophageal intubation when neonatal tracheal intubation is attempted. Also that success is related to experience (LOE 4 for this statement but LOE 5 for the PICO assessed, O’Donnell 2006, Leone 2005 638) but also that doctors may be overconfident of their skills (LOE 4 for this statement but LOE 5 for the PICO assessed Falke 2003). The rates of successful intubation at first attempt vary from 24% in junior trainees to 86% in consultants (LOE4 for this statement but LOE 5 for the PICO assessed O’Donnell 2006, Leone 2005). Therefore there is a need to be able to confirm accurate placement of the endotracheal tube and whilst experience is important it does not guarantee success.

Adult studies of good quality demonstrate both the inadequacy clinical assessment alone and the superiority of capnography. In a randomized, blinded, controlled experiment in adults listening to both lung fields and the stomach was the only reliable clinical method of assessment. Listening to the lung fields alone was incorrect in 15% of cases (LOE 5 Anderson 1989). In direct comparisons in adults, capnography was superior to clinical assessment but no single technique was perfect with capnography less accurate in cardiac arrest (LOE 5, Grmec 2002 Knapp 1999). A meta-analysis of all available adult studies found no randomised studies. Based on 2192 intubations , the sensitivity 93% (92-94), specificity 97% (93-99), false negative rate 7%, false positive rate 3% were found (LOE 5 Li 2001). Unfortunately there was no comparison with clinical assessment.

Paediatric studies confirm that detection of exhaled carbon dioxide is useful in identifying esophageal intubation in emergency situations but also that false negatives are possible in patients in cardiac arrest with correct tracheal intubation. (LOE 5 Bhende 1995c, Kelly 1992). In pediatric patients > 2 Kg, with a spontaneous circulation, detection of exhaled carbon dioxide confirms tracheal tube position in all cases (LOE 5 Bhende 1992) but during cardiac arrest the possibility of a false negative rate requires further confirmation of tracheal tube position.

There are four neonatal studies, all of which used infants as their own controls (LOE 2 Hosono 2009, Repetto 2001, Roberts 1995 , LOE4 Aziz 1999). All of these found that capnography identified tracheal tube position more rapidly than clinical assessment. A problem with each study was that direct visualization of tracheal tube position (or clinical assessment) was used as the final “gold standard. Hosono 2009 (LOE 2) delivered clear comparison with defined clinical assessments. Capnography was completely accurate in all babies studied all of whom had a spontaneous circulation and were less than 32 weeks gestation. This study also had a better defined method for defining tracheal tube position. All studies utilized a separate team to measure exhaled carbon dioxide with the clinical team blinded to the measurements. They were therefore not a true measurement of clinical practice. This has been provided by O’Donnell 2006 (LOE 4) in which 122 video recordings demonstrated that the time to determine ETT position in the DR was longer when clinical assessment alone was used. All four studies examined neonates with spontaneous circulations. Several reports of false negatives (Kamlin 2005, Hughes 2007) in the neonatal population as well as evidence that false negatives may occur in newborn, adult and pediatric cardiac standstill ( LOE 4 Aziz 1999, LOE 5 Bhende 1995c, Bhende 1992, Grmec 2002, Kelly 1992,) should caution the use of exhaled carbon dioxide in extremely small neonates (LOE 5 Kamlin 2005) or those in whom extensive resuscitation is required.

Two papers have addressed the use of devices down to a birth weight of 400g (LOE 5 Garey 2008, LOE 4 Sutherland 1995).

Detection of exhaled carbon dioxide confirms tracheal intubation in neonates with a cardiac output more rapidly and more accurately than clinical assessment alone (LOE 2 Hosono 2009 79, Repetto 2001, Roberts 1995, LOE4 Aziz 1999). There have been no clinical randomized trials. False negatives may occur in very low birth weight neonates 9LOE5 Kamlin 2005) and those in cardiac arrest ( LOE 4 Aziz 1999, LOE 5 Bhende 1995c, Bhende 1992, Grmec 2002, Kelly 1992,). False positives may occur in the presence of colorimetric devices contaminated with epinephrine (adrenaline), surfactant and atropine (LOE 5 Hughes2007). There is no comparative information to recommend any one method for detection of exhaled carbon dioxide in the neonatal population.

**Acknowledgements:** Diane Atkins and Jeff Perlman
Citation List


   Comments: This was a good adult model demonstrating that the only reliable clinical assessment in adults was to listen to the stomach and both sides of the chest. Interestingly chest or stomach movement was not reliable. If these are unreliable in adults it is unlikely that they will be any better in neonates.
   (LOE 5 supportive)


   Comment: Prospective observational study demonstrating faster detection of both endotracheal and oesophageal intubation. Each patient was effectively its own control. Noted 3 false negatives with severe Cardiorespiratory depression. Only short term outcome measures, therefore presumed better for babies. Useful data: Study in 49 infants needing intubation of whom 21 were in the delivery room. Positive colour change indicates successful intubation. However, negative result in CPR may not be accurate as 4 who needed most resuscitation were excluded. Direct Intubation data: Yes. Faster time to deciding correct ETT position. Outcome data: Only as to intubation timing and success. No measure of success in resuscitation purely time to decision.
   (LOE 2 Supportive)


   Comment: This suggests that with a well placed ETT the quality of resuscitation using CPR in children might be assessed by carbon dioxide in exhaled breaths. However, does not suggest that this is better than clinical assessment in terms of intubation.
   (LOE 5 neutral)


   Comment: Prospective study in paediatric patients in non-traumatic cardiac arrest. Suggests that better CPR results in higher PETCO2. Therefore PETCO2 may be indicative of good CPR. However, does not suggest that this is better than clinical assessment in terms of intubation.
   (LOE 5 neutral)


   Comment: Capnography or colorimetric assay both indicate that the ETT is in the correct place and also relate to ROSC. This does not however show any advantage over clinical estimation in terms of intubation.
   (LOE 5 neutral)


   Comment: The paper suggests that this technique was better than clinical estimation for detecting ETTs which were esophageal or displaced. However, this was in children already ventilated.
   (LOE 5 supportive)

Comment: A prospective paediatric paper showing a sensitivity of 84.6%, specificity of 100%, positive predictive value of 100%, and negative predictive value of 60%. Interestingly both first and second readings of =0.5%CO2 correlated with short term survival. However, the final arbiter of correct ETT position for this study was visualisation of position. This is therefore supportive against most clinical measurements but cannot be said to have proved superior to visualisation.

LOE 5 supportive.


Comment: A prospective study in children showing that colorimetric test in children >2 kg with spontaneous circulation will correctly identify the site of the ETT. However, false negatives are possible in cardiac standstill. A concern is that this still uses visualization of the ETT as the gold standard.

LOE 5 supportive


Comment: Prospective study suggests that residents are over confident in their skills. Suggests the need for an objective measurement of intubation accuracy.

LOE 4 for over confidence in clinical skills, LOE 5 supportive for PICO


Comment: Neutral evidence for the PICO but offers some evidence that colorimetric devices can detect obstructed ventilation. Some indirect evidence therefore but overall neutral.


Comment: Model which looks at the likely tidal volume needed for colorimetric change with Pedi cap and Mini stat. It suggests viability of the technique to 400g despite the fact that they are only recommended for >1Kg.

LOE 5 neutral


Comment: A good prospective observational study assessing three different methods. In non-arrest situations the capnographic techniques were clearly superior. It also highlights the problems with false negatives in an arrest setting.

LOE 5 supportive


Comment: Clearly demonstrates that exhaled CO2 is faster at accurately detecting ETT position than clinical skills in 40 babies in the delivery room. Sensitivity and specificity for PETCO2 were both 100% in 54 intubations in babies all of whom had spontaneous circulations with heart rates of >100 per minute. The clinical sensitivity
was 92.5% and 82.4% for clinical assessments using: (i) chest movement with each breath, (ii) breath sounds audible over lung fields but decreased or absent over the stomach, (iii) no gastric distension with ventilation, (iv) changes in heart rate and color, and (v) vapour condensing on the inside of the tube during exhalation were used.

LOE 2 supportive


Comment: This document outlines epinephrine, surfactant, atropine and naloxone causing colour change to colorimetric devices which may mislead.

LOE4/5 Opposing


Comment: Randomised study but really only addressing the position of the ETT in the trachea and did not assess whether the position was correct or not at intubation. Raises the possibility of another clinical tool which has not been assessed for determination of tracheal or oesophageal intubation.

LOE 4 Neutral


Comment: Case report detailing a misleading and incorrect result from colorimetric device in extremely premature baby.

LOE 4 Poor Opposing


Comments: Demonstrates the false negative rate in cardiac arrests in children; sensitivity 64.6%. Suggest the need for clinical judgement in situations of cardiac standstill (arrest). Most neonatal situations do not pertain to cardiac arrest. Therefore the evidence from this is balanced.

LOE 5 Neutral


Comment: Study in adults which again demonstrate that capnography was superior in terms of evaluation of ETT position in adults with a circulation. Clinical testing was poor and dependent on experience.

LOE 5 Positive


Comment: Demonstrates that the present system of using clinical assessments describes a low success rate for intubations in neonatal setting. There is therefore a need to be able to detect inaccurate placement.

LOE 4 for clinical assessment being poor, LOE 5 supportive for PICO


Comment: Meta-analysis of all available studies. No randomised studies available. Based on 2192 intubations -- Sensitivity 93% (92-94), Specificity 97% (93-99). False negative rate 7%, False positive rate 3%. Demonstrates
that within the adult literature no one system is perfect. This false negative rate was for all emergency intubations within the studies. Did not look at superiority to clinical assessment. Did look at the literature for other techniques and found no sole method to be foolproof.

LOE 5 Neutral


Comment: Demonstrates that even with recommendations for secondary confirmation of ETT position, ETCO2 is not necessarily being used.

LOE 4 Neutral


Comment: Observational study which found that in a clinical setting in the delivery room, ETT position was determined more quickly when ETCO2 detection was used with clinical assessment than when assessment was used alone. Also demonstrated that success varied from 24% for junior doctors to 86% for senior doctors. Overall the success rate was 62%.

LOE 4 for clinical assessment being poor, LOE 5supportive for PICO


Comments: Useful data: Capnography allowed more rapid determination of both tracheal and unintended esophageal intubation. This study occurred in the delivery room, however, there was a very high rate of esophageal intubation (11/27=40%). Direct intubation data: Yes. Small (16 infants) but useful information about time to confirmation Outcome data: Only as to intubation timing and success. No measure of success in resuscitation.

LOE 2 Supportive


Comment: Useful observational study but the intubating clinicians were blinded to the capnography. Therefore this was an experimental system and not a pragmatic assessment of “real life”. It was also within a neonatal unit and not in the delivery room. However, it clearly demonstrates that capnography is both faster to identify correct ETT placement and more accurate. It identified 39/40 oesophageal intubations in 1.6 sec as opposed to 97.1 seconds for clinical indicators. Capnography also correctly identified 59/60 tracheal intubations as opposed to 55/60 for clinical assessment.

LOE 2 Supportive


Comment: Case series of 4 premature babies below 1000g. Followed by institutional assessment of the literature and decision to institute capnography on all neonatal intubations.

LOE 4 Supportive

Comment: Single case of apparent failure of Exhaled carbon dioxide to detect correct endotracheal tube placement in this clinical situation. Reinforces evidence that there are clinical situations when false negatives occur.


Comment: No indication of comparison with clinical estimation and was used to confirm clinical findings. In fact direct visualization was the gold standard. However, it offers strong observational evidence that the detection of ETCO2 is useful with good accuracy when the ETT is in the trachea 57/58 and in the oesophagus 20/20. In this setting this techniques was useful within a weight range of 0.54-4.1 kg.

LOE 2 Neutral


Comment: In 57 adult patients with a circulation, ETCO2 was best at correctly detecting ETT position. However, it was least good in patients in cardiac arrest, with auscultation best. The comparison was made with direct visualization of the ETT. Therefore supports the premise for patients with a circulation but not for those in cardiac standstill.

LOE 5 supportive for patients with circulation and negative for those in cardiac arrest. Therefore Neutral