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

Worksheet author(s)
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Clinical question.

“In adult cardiac arrest (prehospital [OHCA], in-hospital [IHCA]) (P), does the use of thoracic impedance (I) compared with usual management (C), improve the accuracy of diagnosis of airway placement and adequacy of ventilation (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?

Farley, H. -  Christiana Care Health System. No intellectual or commercial conflicts of interest.

García-Vega, FJ – Internal Medicine/Emergency Medicine Specialist. Secretary of the Executive Committee of the SRC (Spanish Resuscitation Council). No intellectual or commercial conflicts of interest.

Search strategy (including electronic databases searched).

\[((\text{thoracic impedance}) \text{ OR } (\text{Impedance, transthoracic}[\text{All Fields}]) \text{ OR } (\text{"cardiography, impedance"}[\text{MeSH Terms}]) \text{ OR } (\text{"cardiography"}[\text{All Fields}] \text{ AND } \text{"impedance"}[\text{All Fields}]) \text{ OR } (\text{"impedance cardiography"}[\text{All Fields}]) \text{ OR } (\text{"impedance"}[\text{All Fields}] \text{ AND } \text{"transthoracic"}[\text{All Fields}] \text{ AND } \text{cardiac arrest})\) \text{ AND } ((\text{"heart arrest"}[\text{MeSH Terms}]) \text{ OR } (\text{"cardiopulmonary resuscitation"}[\text{MeSH}]))

Medline (42), Cochrane Library (4), AHA EndNote X Master Library (35), Embase (6)

• State inclusion and exclusion criteria

Limits: All Adults: 18+ years (16 Medline) and pediatric patients.
Inclusion: RCT, CT, meta-analysis, systematic review, case-control studies, cohort studies, case series, case reports.
Exclusion: simple reviews, letters, editorials

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

9 articles selects, meet criteria for further review for two questions:
6 articles for Endotracheal Tube Placement, of these one were LOE D2, one LOE D3, one LOE D4, and three LOE D5 (not directly related) and
3 articles for Adequacy of Ventilation, of these two was LOE D2 and one LOE D5 (animal studie).
### Summary of evidence

#### Evidence Supporting Clinical Question

**Endotracheal Tube Placement**

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- Mehta, 2002, p1099, E
- Absolom, 2006, p1145, E
- Yong-xing, 2007, p898, E
- Kramer-Johansen, 2008, p11, E
- Pytte, 2007, p770, E
- Kramer-Johansen, 2006, p61, E

**Level of evidence**

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

### Adequacy of Ventilation

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- Risdal, 2007, p2237, E
- Losert, 2006, p2399, E
- Pellis, 2002, pS176, E

**Level of evidence**

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- *Italics* = Animal studies
### Evidence Neutral to Clinical question

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**Level of evidence**

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*Italicics = Animal studies*

### Evidence Opposing Clinical Question

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**Level of evidence**

A = Return of spontaneous circulation  
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*Italicics = Animal studies*
REVIEWER’S FINAL COMMENTS AND ASSESSMENT OF BENEFIT / RISK:

Discussion: There are few quality studies that examine the transthoracic/thoracic impedance (TTI). There are no definitive studies on the use of TTI compared with usual management to improve the accuracy of diagnosis of airway placement and adequacy of ventilation.

Airway Placement
The most methodologically sound studies on the use of TTI to confirm airway placement were conducted in operating room patients, not cardiac arrest patients. These studies were prospective randomized blinded studies investigating the sensitivity and specificity of TTI in diagnosing tracheal and esophageal intubations. One study (Absolom 2006) reported a sensitivity of 97.5% and a specificity of 92.5%, while two others reported sensitivities and specificities of 100% (Mehta 2002, Yong-xing 2007). Only one of these studies (Mehta 2002) also concurrently evaluated other methods of airway placement confirmation. The authors report a sensitivity and specificity of 100% for capnography and a sensitivity of 90% and specificity of 86% for auscultation. Two studies were conducted in cardiac arrest patients undergoing CPR and both were essentially case reports in which a disappearance of ventilation-induced changes in TTI was observed after suspected (Kramer-Johansen 2006) and confirmed (Pytte 2007) esophageal intubation. The power of this study (Pytte 2007), is limited by the number of patients included, but the cases, however, are well documented and they add weight to the arguments The most applicable study to date was performed on immediately post-mortem patients (Kramer-Johansen 2008). Patients underwent tracheal ventilation, followed by esophageal ventilation and the TTI changes and ETCO₂ for both scenarios were compared. There was a statistically significant difference in the mean change in TTI between tracheal and esophageal ventilations. In contrast, the difference in ETCO₂ between esophageal and tracheal intubations did not reach statistical significance, likely due to technical difficulties reported by the authors which prevented adequate collection of ETCO₂ data. TTI changes identified endotracheal tube position with a reported sensitivity of 99% and specificity of 97%.

Ventilation
Very few studies have been performed on the use of TTI to improve the accuracy of diagnosis of adequate ventilation in cardiac arrest. One exploratory study (Risdal 2007) performed in 30 cardiac arrest episodes with CPR conclude that the proposed impedance-based ventilation detection system has a detection accuracy comparable to human experts. One study (Pellis 2002) was performed in swine, and demonstrated that variations in respiratory impedance were time coincident with changes in ETCO₂ and that the intensity of the impedance signal was proportional to the observed tidal volumes. The only applicable study performed in humans (Losert 2006) was conducted in mechanically ventilated patients, cardiac arrest patients, and patients after restoration of spontaneous circulation (ROSC). The authors report a strong correlation between impedance changes and tidal volume changes, but also report large variations in the measured impedance coefficients. In addition, the authors only analyzed ventilation segments captured in the absence of chest compressions, further limiting the applicability of this measure to CPR patients undergoing continuous chest compressions.


Summary of Risdal 2007:
• Study performed in 30 cardiac arrest patients
• The impedance-based ventilation detection system (Heartstart 4000SP Laerdal) detects 90.4% of the annotated ventilations in a test set with 95.5% positive predictive value.
• This system has a detection accuracy comparable to human experts and its performance is not degraded by chest compressions.

Summary of Kramer-Johansen 2008:
• 123 esophageal and 178 tracheal ventilations in nine patients were assessed and included. ETCO₂ values were not available for three patients.
• Transthoracic impedance changes associated with tracheal ventilations were larger than those associated with esophageal ventilations (mean difference 1.3Ω (95% CI 1.0, 1.5), p<0.001).
• All changes above 1.2Ω were associated with tracheal ventilations, while all changes below 0.4Ω were associated with esophageal ventilations.
• Tube position was predicted with a sensitivity of 99% and a specificity of 97%.

Summary of Losert 2006:
• 138 assessed, 73 enrolled (20 cardiac arrest patients, 31 ROSC patients, 32 reference group patients; + overlap between the cardiac arrest and ROSC patient groups). 60 cardiac arrest/ROSC patients were excluded due to a
lack of ventilation recordings (ventilation recordings only available for ventilator patients, not patients ventilated via bag valve system). Five patients in the reference group were excluded due to data transfer problems.

- The mean (SD) correlations between the impedance waveform and the tidal volume waveform were as follows: 0.971 (0.027) in the mechanically ventilated reference group, 0.969 (0.032) in the cardiac arrest group, and 0.967 (0.035) in the ROSC group.
- The mean (SD) impedance coefficient for all patients in the study was 0.00194 (0.0078) Ω/ml, and the mean (SD) specific (weight-corrected) impedance coefficient was 0.152 (0.048) Ω/kg/ml.
- The measured thorax impedance change for different tidal volumes (400-1000 ml) was approximately linear.

Obviously, this determination (TTI) is relatively new, technological speaking. Studies are needed to compare different devices to verify proper ventilation.

**Acknowledgements:**

**Citation List**


*Comments: Performed in the OR in children.*

*LOE D5, Good.*


*Comments: There are some limitations in this study (after the end CPR patients; tube in the trachea first; regurgitation, aspiration or pulmonary edema were excluded). The TTI changes observed during esophageal and tracheal ventilations were compared and it was determined that esophageal ventilations demonstrated smaller changes than tracheal ventilations. This study was conducted immediately post-mortem. "Some" chest compressions were performed during the observations, but it is unclear how consistently or effectively they were performed.*

*LOE D2; Fair.*


*Comments: Esophageal intubation was suspected, but not confirmed, when the disappearance of ventilation induced changes in thoracic impedance after intubation was noticed upon retrospective analysis.*

*LOE D4, Poor.*


*Comments: This study examined cardiac arrest and ROSC patients, utilizing hemodynamically stable, mechanically ventilated patients under controlled conditions as a reference group. All patients were ventilated with Servor Ventilated system. The TTI was recorded by Heartstart 4000SP Laerdal. There are three groups of patients critically ill, in cardiac arrest and ROSC. The sample is fair. There is good agreement in the TTI records in three groups. Accurate tidal volumes are difficult to estimate. While a strong correlation between impedance changes and tidal volume changes was demonstrated, the authors point out that the observed large variation in measured impedance coefficients limits the utility of impedance as an accurate measure of tidal volume. In addition, no measurements were carried out during chest compressions, limiting the applicability of this measure to CPR patients undergoing continuous compressions.*

*LOE D2; Fair.*

Comments: only patients undergoing general anaesthesia.
LOE D5, Good.


Comments: experimental animals study with few cases, but fairly good design and good results. This study demonstrated that variations in respiratory impedance were time coincident with changes in end-tidal PCO$_2$ and that the intensity of the respiratory impedance signal was proportional to the tidal volumes observed.
LOE D5, fair. Animals study.


Comments: This was a case report in which differences in TTI ventilation changes were observed between proper and improper tube placement when tracings were analyzed retrospectively. Actual location of the endotracheal tube was confirmed by direct visualization. The cases, are well documented and they add weight to the argument.
LOE D3, Poor.


Comments: The impedance-based ventilation detection system (Heartstart 4000SP Laerdal) detects 90.4% of the annotated ventilations in a test set with 95.5% positive predictive value. This system has a detection accuracy comparable to human experts and its performance is not degraded by ongoing chest compressions.
LOE D2, Good.


Comments: Performed in OR patients.
LOE D5, Good.