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

Worksheet author(s)

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Clinical question.

"In adult cardiac arrest (out-of-hospital and in-hospital) with either a protected and unprotected airway (P), does the monitoring and control of ventilatory parameters (eg. minute ventilation and/or peak pressures) (I) as opposed to standard care (without ventilatory monitoring) (C), improve outcome (O) (eg. ROSC, survival)?"

Is this question addressing an intervention/therapy, prognosis or diagnosis? Intervention / therapy
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).

(heart arrest OR cardiopulmonary resuscitation) AND ventilat*): 2238 hits

660 titles reviewed after exclusion criteria applied

17 studies given further consideration as below

Included

O'Neill JF, Deakin CD. Do we hyperventilate cardiac arrest patients?
Resuscitation. 2007 Apr;73(1):82-5. Epub 2007 Feb 7

Aufderheide TP, Sigurdsson G, Pirrallo RG, Yannopoulos D, McKnite S, von Briesen C, Sparks CW, Conrad CJ, Provo TA, Lurie KG. Hyperventilation-induced hypotension during cardiopulmonary resuscitation. Circulation. 2004 Apr 27;109(16):1960-5

Voelckel WG, Lurie KG, Zielinski T, McKnite S, Plaisance P, Wenzel V, Lindner KH. The effects of positive end-expiratory pressure during active compression decompression cardiopulmonary resuscitation with the inspiratory threshold valve. Anesth Analg. 2001 Apr;92(4):967-74

Losert H, Risdal M, Sterz F, Nysaether J, Köhler K, Eftestøl T, Wandaller C, Myklebust H, Uray T, Sodeck G, Laggner AN. Thoracic impedance changes measured via defibrillator pads can monitor ventilation in critically ill patients and during cardiopulmonary resuscitation. Crit Care Med. 2006 Sep;34(9):2399-405.

Kleinsasser A, Lindner KH, Schaefer A, Loeckinger A. Decompression-triggered positive-pressure ventilation during cardiopulmonary resuscitation improves pulmonary gas exchange and oxygen uptake. Circulation. 2002 Jul 16;106(3):373-8.

Abella BS, Edelson DP, Kim S, Retzer E, Myklebust H, Barry AM, O'Hearn N, Hoek TL, Becker LB. CPR quality improvement during in-hospital cardiac arrest using a real-time audiovisual feedback system. Resuscitation. 2007 Apr;73(1):54-61

No abstract / study available

Tian X, Fang WJ. [Study on regulation of some important parameters of ventilator during cardiopulmonary resuscitation]. Zhongguo Wei Zhong Bing Ji Jiu Yi Xue. 2008 Dec;20(12):750.

Not relevant to question

Herff H, Bowden K, Paal P, Mitterlechner T, von Goedecke A, Lindner KH, Wenzel V. Effect of decreased inspiratory times on tidal volume : Bench model simulating cardiopulmonary resuscitation. Anaesthesist. 2009 Jun 27

Kim HK, Pinsky MR. Effect of tidal volume, sampling duration, and cardiac contractility on pulse pressure and stroke volume variation during positive-pressure ventilation. Crit Care Med. 2008 Oct;36(10):2858-62.

Plaisance P, Soleil C, Lurie KG, Vicaut E, Ducros L, Payen D. Use of an inspiratory impedance threshold device on a facemask and endotracheal tube to reduce intrathoracic pressures during the decompression phase of active compression-decompression cardiopulmonary resuscitation. Crit Care Med. 2005 May;33(5):990-4

Steen S, Liao Q, Pierre L, Paskevicius A, Sjöberg T. Continuous intratracheal insufflation of oxygen improves the efficacy of mechanical chest compression-active decompression CPR. Resuscitation. 2004 Aug;62(2):219-27

Babbs CF, Kern KB. Optimum compression to ventilation ratios in CPR under realistic, practical conditions: a physiological and mathematical analysis. Resuscitation. 2002 Aug;54(2):147-57.

Yannopoulos D, Sigurdsson G, McKnite S, Benditt D, Lurie KG. Reducing ventilation frequency combined with an inspiratory impedance device improves CPR efficiency in swine model of cardiac arrest. Resuscitation. 2004 Apr;61(1):75-82

Stallinger A, Wenzel V, Oroszy S, Mayr VD, Idris AH, Lindner KH, Hörmann C. The effects of different mouth-to-mouth ventilation tidal volumes on gas exchange during simulated rescue breathing. Anesth Analg. 2001;93(5):1265-9

Abella BS, Alvarado JP, Myklebust H, Edelson DP, Barry A, O'Hearn N, Vanden Hoek TL, Becker LB. Quality of cardiopulmonary resuscitation during in-hospital cardiac arrest. JAMA. 2005 Jan 19;293(3):305-10.

Wik L, Kramer-Johansen J, Myklebust H, Sørebø H, Svensson L, Fellows B, Steen PA. Quality of cardiopulmonary resuscitation during out-of-hospital cardiac arrest. JAMA. 2005 Jan 19;293(3):299-304.

(heart arrest OR cardiopulmonary resuscitation) AND (hyperventilation OR hypoventilation OR minute volume): 283 hits

Exclusion criteria as above

113 titles reviewed after exclusion criteria applied

9 titles given further consideration

Included

O'Neill JF, Deakin CD. Do we hyperventilate cardiac arrest patients?
Resuscitation. 2007 Apr;73(1):82-5. Epub 2007 Feb 7.

Aufderheide TP, Sigurdsson G, Pirrallo RG, Yannopoulos D, McKnite S, von Briesen C, Sparks CW, Conrad CJ, Provo TA, Lurie KG. Hyperventilation-induced hypotension during cardiopulmonary resuscitation. Circulation. 2004 Apr 27;109(16):1960-5.

Not relevant

Geddes LA, Rundell A, Otlewski M, Pargett M. How much lung ventilation is obtained with only chest-compression CPR? Cardiovasc Eng. 2008 Sep;8(3):145-8.

Noc M, Weil MH, Tang W, Turner T, Fukui M. Mechanical ventilation may not be essential for initial cardiopulmonary resuscitation. Chest. 1995 Sep;108(3):821-7

Wenzel V, Lindner KH, Prengel AW. [Ventilation during cardiopulmonary resuscitation (CPR). A literature study and analysis of ventilation strategies]. Anaesthesist. 1997 Feb;46(2):133-41.

Busko JM, Blackwell TH. Impact of a pressure-responsive flow-limiting valve on bag-valve-mask ventilation in an airway model. CJEM. 2006 May;8(3):158-63.

Sainsbury DA, Davis R, Walker MC. Artificial ventilation for cardiopulmonary resuscitation. Med J Aust. 1984 Oct 13;141(8):509-11.

Hayes MM, Ewy GA, Anavy ND, Hilwig RW, Sanders AB, Berg RA, Otto CW, Kern KB. Continuous passive oxygen insufflation results in a similar outcome to positive pressure ventilation in a swine model of out-of-hospital ventricular fibrillation. Resuscitation. 2007 Aug;74(2):357-65. Epub 2007 Mar 26.

Hevesi ZG, Thrush DN, Downs JB, Smith RA. Cardiopulmonary resuscitation: effect of CPAP on gas exchange during chest compressions. Anesthesiology. 1999 Apr;90(4):1078-83.

Engoren M, Plewa MC, Buderer NF, Hymel G, Brookfield L. Effects of simulated mouth-to-mouth ventilation during external cardiac compression or active compression-decompression in a swine model of witnessed cardiac arrest. Ann Emerg Med. 1997 May;29(5):607-15.

Idris AH, Banner MJ, Wenzel V, Fuerst RS, Becker LB, Melker RJ. Ventilation caused by external chest compression is unable to sustain effective gas exchange during CPR: a comparison with mechanical ventilation. Resuscitation. 1994 Oct;28(2):143-50.

(heart arrest OR cardiopulmonary resuscitation) AND (peak pressure OR airway pressure): 463 hits

Exclusion criteria as above

204 titles reviewed after exclusion criteria applied

12 titles given further consideration

Included

Kleinsasser A, Lindner KH, Schaefer A, Loeckinger A. Decompression-triggered positive-pressure ventilation during cardiopulmonary resuscitation improves pulmonary gas exchange and oxygen uptake. Circulation. 2002 Jul 16;106(3):373-8.

Not relevant

Woda RP, Dzwonczyk R, Bernacki BL, Cannon M, Lynn L. The ventilatory effects of auto-positive end-expiratory pressure development during cardiopulmonary resuscitation. Crit Care Med. 1999 Oct;27(10):2212-7.

Plaisance P, Soleil C, Lurie KG, Vicaut E, Ducros L, Payen D. Use of an inspiratory impedance threshold device on a facemask and endotracheal tube to reduce intrathoracic pressures during the decompression phase of active compression-decompression cardiopulmonary resuscitation. Crit Care Med. 2005 May;33(5):990-4.

Herff H, Raedler C, Zander R, Wenzel V, Schmittinger CA, Brenner E, Rieger M, Lindner KH. Use of an inspiratory impedance threshold valve during chest compressions without assisted ventilation may result in hypoxaemia. Resuscitation. 2007 Mar;72(3):466-76. Epub 2006 Dec 5.

Gabrielli A, Layon AJ, Wenzel V, Dorges V, Idris AH. Alternative ventilation strategies in cardiopulmonary resuscitation. Curr Opin Crit Care. 2002 Jun;8(3):199-211.

Otto CW. Airway management and ventilation during CPR. Acta Anaesthesiol Scand Suppl. 1997;111:52-4.

Davis K Jr, Johannigman JA, Johnson RC Jr, Branson RD. Lung compliance following cardiac arrest. Acad Emerg Med. 1995 Oct;2(10):874-8.

von Goedecke A, Keller C, Wagner-Berger HG, Voelckel WG, Hörmann C, Zecha-Stallinger A, Wenzel V. Developing a strategy to improve ventilation in an unprotected airway with a modified mouth-to-bag resuscitator in apneic patients. Anesth Analg. 2004 Nov;99(5):1516-20

Lurie K, Zielinski T, McKnite S, Sukhum P. Improving the efficiency of cardiopulmonary resuscitation with an inspiratory impedance threshold valve. Crit Care Med. 2000 Nov;28(11 Suppl):N207-9.

Okamoto K, Kishi H, Choi H, Morioka T. Cardiopulmonary resuscitation without intermittent positive pressure ventilation. Resuscitation. 1993 Dec;26(3):251-60.

von Goedecke A, Paal P, Keller C, Voelckel WG, Herff H, Lindner KH, Wenzel V. [Ventilation of an unprotected airway: evaluation of a new peak-inspiratory-flow and airway-pressure-limiting bag-valve-mask]. Anaesthesist. 2006 Jun;55(6):629-34.

Databases searched: Medline, EMBASE, CINAHL (last searched 26 January 2010).

Search of the AHA Master EndNote Library (24 March 2008) using the terms (abstract) ventilation AND monitor NOT cerebral NOT children produced 61 hits – 3 of these were reviewed but subsequently found not to be relevant.

In addition the reference lists from the papers selected for further review were hand searched.

State inclusion and exclusion criteria

Excluded: Neonates / paediatrics
- Quality of cardiopulmonary resuscitation
- Compression only CPR
- Haemorrhagic shock
- BATLS / BLS / ALS / Acute Care Undergraduate Teaching Initiative / First responders
- Cardiopulmonary bypass
- Transoesophageal cardiac pacing
- Cor pulmonale / lung transplantation
- Cerebral oxygenation
- Metabolic derangement
- Hypothermia / cooling
- Vasopressors / inotropes
- End tidal carbon dioxide / capnography
- Reviews

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

6 papers.

Summary of evidence

Evidence Supporting Clinical Question

Good			**Abella 2007 (E)**	**Aufderheide 2004 (E)**	***Aufderheide 2004 (A)***
Fair					***Kleinsasser 2002 (A)***
Poor					
	1	**2**	**3**	**4**	**5**
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				**O'Neill 2006 (B, E)**	***Voelckel 2001 (A)***
Fair					**Losert 2006 (E)**
Poor					
	1	**2**	**3**	**4**	**5**
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					
Fair					
Poor					
	1	**2**	**3**	**4**	**5**
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

REVIEWER'S FINAL COMMENTS AND ASSESSMENT OF BENEFIT / RISK:

O'Neill & Deakin 2006 demonstrated that hyperventilation is common when resuscitating patients. This is due to excessive respiratory rates rather than excessive tidal volumes. During resuscitation attempts 11/12 (91.7%) patients had airway pressures that remained positive for more than 90% of the time.

Losert 2006 concluded that an impedence measurement system sensor of a defibrillator is likely to provide adequate monitoring of the presence or absence of ventilations, which would also allow quantification of ventilation rates and inspiration times.

Aufderheide 2004 found that rescuers persistently hyperventilate patients during CPR. Rapid-rate, short-duration ventilations and slow-rate, long-duration ventilations contributed to a high percentage of time that pressure in the chest was increased. Animal studies demonstrated that excessive ventilation rates during CPR resulted in increased positive intrathoracic pressures, decreased coronary perfusion, and decreased survival rates. VF was induced in pigs. The animals were resuscitated with standard CPR (5:1 compression:ventilation rate) for the first 2 minutes then randomized to receive 3 different ventilation rates (12, 30 breaths per minute with 100% O2, or 30 breaths per minute with 5% CO_2, 95% O_2) with each phase lasting for 2 minutes. 6 of 7 (86%) of pigs ventilated at a rate of 12 per minute survived, compared with a survival rate of 1 of 7 (17%) at a rate of 30 breaths per minute (100% O2), and 1/7 (17%) at a ventilation rate of 30 breaths per minute (5% CO2/95% O2).

Voelckel 2001 induced ventricular fibrillation in anaesthetized ventilated pigs and administered active compression – decompression CPR with an inspiratory threshold valve. After 4 minutes of cardiac arrest the pigs underwent CPR. During the first 8 minutes of CPR, all pigs received pressure controlled pure oxygen ventilation at constant flow rate, with a 5:1 compression:ventilation ratio. After 8 minutes animals were randomly assigned to receive either further IPPV alone or increasing levels of PEEP at 2.5, 5.0, 7.5, and 10 cm H_2O for 4 consecutive minutes.
The study demonstrated that PEEP significantly improved coronary perfusion pressure when compared to the IPPV alone group. Tidal volume decreased after the application of 7.5 and 10 cm H_2O of PEEP. If 10 cm H_2O of PEEP was applied, aortic and left ventricular pressures were significantly higher at maximal compression during CPR. Defibrillation was successful in 7 of 8 animals in PEEP + IPPV group after 28 minutes of cardiac arrest, compared to 5 of 8 animals in the IPPV alone group.

Kleinsasser induced VF arrest in 24 pigs who subsequently received CPR with either CPAP with pressure support ventilation, CPAP, or IPPV. Haemodynamics, blood gases, and inert gas measurements were performed before VF arrest was induced and at 10 and 20 minutes after induction.
CPAP PSV resulted in the highest blood flow to lung units with a normal $V^{\cdot}A/Q^{\cdot}$ ratio during CPR. Animals treated with CPAP, highest blood flow was to lung units with a low $V^{\cdot}A/Q^{\cdot}$ ratio, and in animals treated with IPPV, the highest blood flow to lung units with a high $V^{\cdot}$ $A/Q^{\cdot}$ ratio was recorded.
PaO2 was significantly higher in animals treated with CPAP PSV than in animals treated with CPAP (*P*_0.01) or IPPV (*P*_0.05). End-tidal carbon dioxide was higher in animals of the CPAP PSV group than in animals treated with CPAP or IPPV.
8 of 8 animals ventilated with CPAP PSV could be resuscitated, compared with 6 of 8 animals treated with CPAP and 3 of 8 treated in the IPPV group. The difference between CPAP PSV and IPPV was significant (*P*_0.025).

Abella 2007 evaluated quality of CPR using a defibrillator capable of monitoring chest compression rate and depth, and ventilation rate and volume, for patients in cardiac arrest receiving CPR. Two groups of patients are described in the study, the baseline group (no real-time feedback) and the (real-time) feedback group. The defibrillator was capable of providing real-time audiovisual feedback. Improvements were seen in the mean values of all four variables, though these improvements were not statistically significant. The study recorded a statistically significant reduction in distribution of chest compression depth and rate, and ventilation rate; demonstrated by a decrease in standard deviation. In addition, the fraction of time during which no compressions were administered was reduced in the feedback group. There was a small, statistically insignificant increase in the rate of ROSC between the baseline and feedback groups but no difference in survival to hospital discharge between the two groups.

Citation List

Abella BS, Edelson DP, et al. (2007) CPR quality improvement during in-hospital cardiac arrest using a real-time audiovisual feedback system. Resuscitation;73(1):54-61

Level 3 evidence which supports the clinical question. The study demonstrated that real-time feedback to personnel performing CPR resulted in closer correlation to current resuscitation guidelines.

Aufderheide, T. P., G. Sigurdsson, et al. (2004). "Hyperventilation-induced hypotension during cardiopulmonary resuscitation." Circulation **109**(16): 1960-1965.

Level 5 evidence which supports clinical question. Animal study which demonstrated that excessive ventilation rates during CPR resulted decreased survival rates.

Kleinsasser A, Lindner K et al (2002). Decompression-triggered positive-pressure ventilation during cardiopulmonary resuscitation improves pulmonary gas exchange and oxygen uptake. Circulation;106(3):373-8

Level 5 evidence which supports the clinical question.. Study demonstrated a higher rate of return of spontaneous circulation in animals resuscitated with CPAP pressure support ventilation compared to those resuscitated with either CPAP or IPPV alone.

Losert, H., M. Risdal, et al. (2006). "Thoracic impedance changes measured via defibrillator pads can monitor ventilation in critically ill patients and during cardiopulmonary resuscitation." Crit Care Med **34**(9): 2399-405.

Level 5 evidence, did not directly address clinical question (neutral). The study concluded that an impedence measurement system sensor of a defibrillator is likely to provide adequate monitoring of the presence or absence of ventilations

O'Neill, J. F. and C. D. Deakin (2007). Do we hyperventilate cardiac arrest patients? Resuscitation **73**(1): 82-5.

Level 4 evidence, did not directly address clinical question (neutral). Demonstrated that hyperventilation is common in CPR.

Voelckel, W. G., K. G. Lurie, et al. (2001). "The effects of positive end-expiratory pressure during active compression decompression cardiopulmonary resuscitation with the inspiratory threshold valve." Anesth Analg **92**(4): 967-974.

Level 5 evidence, neutral to clinical question. Study demonstrated that PEEP may improve oxygenation in CPR if used with a device designed to improve venous return.

(Voelckel 2001; Kleinsasser 2002)
(Aufderheide 2004; Losert 2006; O'Neill 2007; Abella 2007)