WORKSHEET for Evidence-Based Review of Science for Veterinary CPR

1. Basic Demographics

Worksheet author(s)

Worksheet author(s)	Date Submitted for review:
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[redacted]	

2. Clinical question:

In dogs and cats with cardiac arrest (P), does a ventilation ratio of 10 breaths per minute (I), as opposed to any other ventilation rate (C), improve outcome (eg. ROSC, survival) (O)?

3. Conflict of interest specific to this question:

None

4. Search strategy (including electronic databases searched):

4a. Databases

PUBMED (1967 to April 2011) (Performed on April 9, 2011)
1. Ventilation
2. CPR
3. Animals

1 and 2 and 3: 37 relevant hits out of 501 total hits

CAB (1981 to 2011) (Performed on April 10, 2011)
1. Ventilation
2. Cardiopulmonary resuscitation
3. Animals
4. CPR
5. CPCR
6. Resuscitation

1 and 2 and 3: 2 relevant hits out of 16 total hits
1 and 3 and 4: no additional relevant hits
1 and 3 and 5: no additional relevant hits
3 and 4: 2 additional hits
1 and 2 and 6: no additional relevant hits

4b. Other Sources

GOOGLE Scholar (Performed on April 10, 2011)
Report as for PUBMED search

4c. State inclusion and exclusion criteria for choosing studies and list number of studies excluded per criterion

Inclusion criteria
Ventilation rates during CPR in humans or animals
Ventilation strategies during CPR in humans or animals

Exclusion criteria
Conference proceedings, Reviews, Abstracts only, Editorials, Book chapters

4d. Number of articles/sources meeting criteria for further review: 13
LOE 3:
- 1 experimental canine study (Hwang et al 2008)

LOE 6:
- 2 combined human clinical observational studies and experimental pig studies (Aufderheide et al 2004; Yannopoulos et al 2006)
- 9 prospective randomized experimental studies (Cavus et al 2008; Dorph et al 2003; Berg et al 2001;Yannopoulos et al 2010; Yannopoulos et al 2005; Dorph et al 2004; Iglesias et al 2010; Lurie et al 2008; Wang et al 2010)

5. Summary of evidence

Evidence Supporting Clinical Question

Good						
Fair						***Lurie, 2008 E*** ***Yannopoulos, 2010 BDE*** ***Yannopoulos, 2005 E*** ***Cavus , 2008 E***
Poor						
	1	**2**	**3**	**4**	**5**	**6**
Level of evidence (P)						

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

Evidence Neutral to Clinical question

Good						
Fair			Hwang, 2008 AE			*Iglesias, 2010 E* *Dorph, 2004 ABE* *Dorph, 2003 E* *Yannopoulos, 2006 A* *Aufderheide, 2004 BE*
Poor						
	1	**2**	**3**	**4**	**5**	**6**
Level of evidence (P)						

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

Evidence Opposing Clinical Question

Good						
Fair						*Wang, 2010 ABE* *Berg, 2001 BD*
Poor						
	1	**2**	**3**	**4**	**5**	**6**
Level of evidence (P)						

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

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

The difficulty in defining the ideal ventilation ratio with cardiac arrest is the lack of clinically relevant models in dogs and cats. The majority of research studies evaluating different ventilation rates are experimental, randomized controlled ventricular fibrillation or asphyxia arrest models on healthy animals. This does not correlate to the veterinary clinical cardiac arrest presentation of animals with preexisting disease and/or pulseless arrest rhythms consisting of predominantly asystole and pulseless electrical activity. Additionally, an endpoint of intact neurological survival is vital when evaluating cardiopulmonary resuscitation outcomes in veterinary medicine due to the likelihood of humane euthanasia with a poor neurological outcome.

Kate Hopper 8/7/11 8:09 PM
Comment [1]: I am not sure we need this statement – although it is probably true its relevant to every worksheet and might be more appropriate in the overall comments for the BLS section

There is some evidence supporting a specific ventilation rate of 10 breaths per minute during cardiopulmonary resuscitation (CPR) (Yannopoulos 2010; Lurie, 2008; Yannopoulos, 2004; Cavus 2008), in ventricular fibrillation cardiac arrest models on healthy pigs. In a comparison between chest compressions only, or 10 breaths per minute of positive pressure ventilation, the ventilated control group showed a statistically significantly improved 24 hour neurologic outcome (Yannopoulos, 2010). All other studies demonstrated improved cerebral and myocardial perfusion pressures resulting in increased vital organ blood flow achieving shorter duration to ROSC in the 10 breaths per minute groups compared to other controls.

Several studies evaluated various ventilation rates other than 10 breaths per minute compared to chest compressions alone and found ventilated patients to have significantly shorter time to ROSC (Dorph, 2004), increased myocardial and cerebral perfusion pressures, increased end tidal CO_2, and a significantly higher pH (Iglesias, 2010). Comparison of several ventilation rates consistently found in favor of avoidance of hyperventilation (20-30 breaths per minute), however, extreme hypoventilation (about 3 breaths per minute) resulted in inferior pulmonary gas exchange and poor neurologic outcome suggesting a balance between achieving vital organ blood flow but not at the expense of progressive arterial hypoxemia (Dorph, 2003; Aufderheide, 2004). One neutral study in a canine model mimicking simulated, witnessed ventricular fibrillation induced cardiac arrest showed improved hemodynamics with lower ventilation rates (Hwang, 2008).

Another issue identified in studies evaluating variable ventilation rates in CPR is that in a single rescuer scenario, increasing respiratory rates is associated with less time for chest compressions. (Hwang, 2008; Berg, 2001) This may not be a relevant concern to veterinary clinical patients where CPR is most commonly performed with more than one rescuer.

Two studies demonstrated advantages with chest compressions alone compared to ventilations plus compressions in ventricular fibrillation pig models (Wang, 2010; Berg, 2001). Although both of these studies showed improved hemodynamic parameters, arterial oxygen values were decreased in the compression only groups.

There is limited evidence to support the specific ventilation rate of 10 breaths per minute in dogs and cats, but there is some evidence supporting this rate in ventricular fibrillation cardiac arrest models in pigs (Yannopoulos 2010; Lurie, 2008; Yannopoulos, 2004; Cavus, 2008; Lurie, 2008). Given there is evidence to suggest that rates faster than 10 breaths per minute may have detrimental effects and the absence of evidence to support an alternative ventilation rate, it is reasonable to continue to recommend a ventilation rate of 10 breaths per minute during CPR in dogs and cats at this time.

7. Conclusion

DISCLAIMER: Potential possible wording for a Consensus on Science Statement. Final wording will differ due to other input and discussion.
CONSENSUS ON SCIENCE: Four randomized trials in pigs supported a ventilation rate of 10 breaths per minute (LOE 6) (Yannopoulos, 2010; Lurie, 2008; Yannopoulos, 2004; Cavus, 2008; Lurie, 2008) after ventricular fibrillation cardiac arrest which is not the most common cardiac arrest rhythm in dogs and cats. One randomized trial (LOE 1) (Hwang, 2008) showed improved hemodynamic parameters with lower ventilation rates in a canine ventricular fibrillation model but did not evaluate a rate of 10 breaths per minute. Five randomized trials supported ventilation during CPR in pigs, humans, and manikins but did not evaluate the rate of 10 breaths per minute (LOE 6) ((Dorph, 2004; Iglesias, 2010; Dorph, 2003; Aufderheide, 2004; Yannopoulos, 2006). Two pig studies demonstrated the negative hemodynamic effects of ventilation during resuscitation (LOE 6) (Wang, 2010; Berg, 2001) after ventricular fibrillation cardiac arrest. There is some evidence to support a ventilation rate of 10 breaths per minute in pigs with ventricular fibrillation-induced arrest. In the absence of evidence to support an alternative ventilation rate, it is reasonable to continue to recommend a ventilation rate of 10 breaths per minute during CPR in dogs and cats at this time.

Kate Hopper 8/7/11 8:21 PM
Deleted: , however, there is insufficient scientific evidence to support this rate in dogs and cats.

8. Acknowledgement

9. Citation list

T. P. Aufderheide, et al. (2004). "Hyperventilation-Induced Hypotension During Cardiopulmonary Resuscitation." Circulation (2004);109:1960-1965.
Survival rates were studied in 3 groups of 7 pigs in cardiac arrest that were ventilated at 12 breaths per minute (100% O_2), 30 breaths per minute (100% O_2), or 30 breaths per minute (5% CO_2/95% O_2). In animals treated with 12, 20, and 30 breaths per minute, the mean intrathoracic pressure (mm Hg/min) and coronary perfusion pressure (mm Hg) were 7.1 +/- 0.7, 11.6+/- 0.7, 17.5+/- 1.0 ($P \leq 0.0001$), and 23.4+/- 1.0, 19.5+/- 1.8, and 16.9+/- 1.8 ($P \leq 0.03$), respectively. Survival rates were 6/7, 1/7, and 1/7 with 12, 30, and 30+ CO_2 breaths per minute, respectively ($P \leq 0.006$).
funding: NIH USA grant
Key points: LOE 6, supportive, fair: Professional rescuers are observed to excessively ventilate patients during out-of-hospital CPR. Subsequent animal studies demonstrated that similar excessive ventilation rates resulted in significantly increased intrathoracic pressure and markedly decreased coronary perfusion pressures and survival rates.

R. A. Berg, et al. (2001). "Adverse Hemodynamic Effects of Interrupting Chest Compressions for Rescue Breathing During Cardiopulmonary Resuscitation for Ventricular Fibrillation Cardiac Arrest" Circulation (2001); 104:2465-2470.
After 3 minutes of untreated VF, 14 swine were randomly assigned to receive chest compressions plus rescue breathing or chest compressions alone for 12 minutes, followed by advanced cardiac life support.
All 14 animals survived 24 hours, 13 with good neurological outcome.
For the chest compressions plus rescue breathing group, the mean coronary perfusion pressure of the first 2 compressions – those with simultaneous delivery of artificial breaths- was lower than those of the final 2 compressions – those without simultaneous delivery of artificial breaths- (14+/-1 versus 21 +/- 2 mm Hg, $P < 0.001$). During each minute of CPR, the number of chest compressions was also lower in the chest compressions plus rescue breathing group (62+/-1 versus 92+/-1 compressions, $P < 0.001$).

Because the arterial oxygen saturation was higher with the compressions plus rescue breathing group, the left ventricular myocardial oxygen delivery did not differ between groups.
funding: AHA Desert/Mountain Affiliate
Key points: LOE 6, opposing, fair: Interrupting chest compressions for rescue breathing can adversely affect hemodynamics during CPR for VF.

E. Cavus, et. al. (2008). "Impact of different compression—ventilation ratios during basic life support cardiopulmonary resuscitation" Resuscitation (2008) 79, 118—124
After 4 min of untreated ventricular fibrillation (VF), 24 pigs were randomly assigned to 6 min of basic-life support (BLS) CPR with 21% oxygen, and either (1) chest compressions only (''CC'' group, n = 8), or (2) cycles of 30 compressions followed by two breaths with a self-inflating bag (FiO_2 0.21, C:V ratio 30:2; ''30:2'' group, n = 8), or (3) 15 compressions followed by two breaths (C:V ratio 15:2; ''15:2'' group, n = 8), all followed by advanced life support. Results: Arterial PO_2 during BLS-CPR was higher in the 15:2 group compared to the 30:2 and CC groups (74±3 vs. 59±2 and 33±4 mmHg, respectively; $p < 0.05$). Both mixed-venous PO_2 and SO_2 were higher in the 15:2 and 30:2 groups, compared to the CC group (PO_2: 23±2 and 25±1 vs. 17±1 mmHg; SO_2: 21±6 and 19±3 vs. 8±1 %, respectively; $p < 0.05$). Arterial pH decreased in the 30:2 and CC groups compared to the 15:2 group (7.33±0.03 and 7.25±0.02 vs.7.51±0.04, respectively; $p < 0.001$). 4/8, 2/8, and 0/8 animals in the 15:2, 30:2, and CC groups, respectively, had ROSC at the end of the study period (p = ns).
funding: restricted to institutional and departmental sources
Key point: LOE 6, supportive, fair: Increasing the chest compression ratio from 15:2 to 30:2 resulted in changes in arterial, but not mixed-venous, blood gases; therefore, the advantages of more chest compressions may outweigh a decrease in gas exchange.

E. Dorph, et. al. (2003) "Quality of CPR with three different ventilation: compression ratios. "Resuscitation 58 (2003) 193- 201
This study was designed to compare arterial and mixed venous blood gas changes and cerebral circulation and oxygen delivery with ventilation: compression ratios of 2:15, 2:50 and 5:50 in a model of basic CPR. Ventricular fibrillation (VF) was induced in 12 anaesthetized pigs, and satisfactory recordings were obtained from 9 of them. A non-intervention interval of 3 min was followed by CPR with pauses in compressions for ventilation with 17% oxygen and 4% carbon dioxide in a randomized, crossover design with each method being used for 5 min.
Pulmonary gas exchange was clearly superior with a ventilation: compression ratio of 2:15. While the arterial oxygen saturation stayed above 80% throughout CPR for 2:15, it dropped below 40% during part of the ventilation: compression cycle for both the other two ratios.
On the other hand, the ratio 2:50 produced 30% more chest compressions per minute than either of the two other methods. This resulted in a mean carotid flow that was significantly higher with the ratio of 2:50 than with 5:50 while 2:15 was not significantly different from either. The mean cerebrocortical microcirculation was approximately 37% of pre-VF levels during compression cycles alone with no significant differences between the methods.
The oxygen delivery to the brain was higher for the ratio of 2:15 than for either 5:50 or 2:50. In parallel the central venous oxygenation was higher for the ratio of 2:15 than for both 5:50 and 2:50.
funding: Laerdal Foundation, the Norwegian Air Ambulance and the Jahre Foundation.
Key points: LOE 6, neutral, fair: basic CPR by professionals should continue with ratio of 2:15 at present if it can be shown that brief (2 - 3 seconds per ventilation) pauses for ventilation can be achieved in clinical practice.

E. Dorph, et. al. (2004) "Oxygen delivery and return of spontaneous circulation with ventilation: compression ratio 2:30 versus chest compressions only CPR in pigs." Resuscitation 60 (2004) 309 – 318
The present study was designed to compare cerebral oxygen delivery during basic life support (BLS) by chest compressions only with chest compressions plus ventilation in pigs with an obstructed airway mimicked by an impedance threshold device connected to the external end of the tracheal tube. Resuscitability was then studied during the subsequent advanced life support (ALS) period. After 3 min of untreated ventricular fibrillation (VF), BLS as started. The animals were randomized into two groups. One group received chest compressions only. The other group received ventilations and chest compressions with a ratio of 2:30. A gas mixture of 17% oxygen and 4% carbon dioxide was used for ventilation during BLS. After 10 min of BLS, ALS was provided. All six pigs ventilated during BLS attained a return of spontaneous circulation (ROSC) within the first 2 min of advanced cardiopulmonary resuscitation (CPR) compared with only one of six compressions-only pigs. While all except one compressions-only animal achieved ROSC before the experiment was terminated, the median time to ROSC was shorter in the ventilated group. With a ventilation: compression ratio of 2:30 the arterial oxygen content stayed at 2/3 of normal, but with compressions-only, the arterial blood was virtually desaturated with no arterio-venous oxygen difference within 1.5-2 min. Hemodynamic data did not differ between the groups.
funding: Laerdal Foundation, the Norwegian Air Ambulance and the Jahre Foundation.
Key point: LOE 6, neutral, fair: In this model of BLS, ventilation improved arterial oxygenation and the median time to ROSC was shorter.

J. M. Iglesias, et al. (2010) "Chest compressions versus ventilation plus chest compressions in a pediatric asphyxial cardiac arrest animal model" Intensive Care Med (2010) 36:712–716
This randomized experimental study compared the ventilation achieved with chest compressions (CC) or ventilation plus compressions (VC) in a pediatric animal model of cardiac arrest. Twelve infant pigs with asphyxial cardiac arrest underwent sequential 3-min periods of VC and CC for a total duration of 9 min. Tidal volume (TV), end-tidal CO_2 ($EtCO_2$), mean arterial pressure (MAP), central venous pressure (CVP), mean pulmonary arterial pressure (mPAP), and peripheral, cerebral, and renal saturations were recorded and arterial and venous blood gases were analyzed. Results: VC achieved a TV similar to the preset parameters on the ventilator, whilst the TV in CC was very low ($P < 0.001$). $EtCO_2$ with VC was significantly higher than with CC (14.0 vs. 3.9 mmHg, $P < 0.05$). Arterial pH was higher with VC than with CC (6.99 vs. 6.90 mmHg, $P < 0.05$). Arterial PCO2 was lower with VC than with CC (62.1 vs.97.0 mmHg, $P < 0.05$). There were no significant differences in the MAP; CVP; mPAP; peripheral, renal, and cerebral saturations; or lactate concentrations between the two techniques.
funding: Health Research Grant (Fondo de Investigaciones Sanitarias) of the Spanish Health Institute Carlos III
Key points: LOE 6, neutral, fair: VC achieves better ventilation than CC during cardiopulmonary resuscitation and has no negative effect on the hemodynamic situation.

K. G Lurie, et al. (2008) "Comparison of a 10-Breaths-Per-Minute Versus a 2-Breaths-Per-Minute Strategy During Cardiopulmonary Resuscitation in a Porcine Model of Cardiac Arrest" Respir Care 2008;53(7):862– 870
Female pigs (30.4 +/- 1.3 kg) anesthetized with propofol were subjected to 6 min of untreated ventricular fibrillation, followed by 5 min of CPR (100 compressions/min, compression depth of 25% of the anterior-posterior chest diameter), and ventilated with either 10 breaths/min or 2 breaths/min, while receiving 100% oxygen and a tidal volume of 12 mL/kg. An impedance threshold device was then used during 5 additional minutes of CPR. During CPR the mean +/- SD calculated coronary and cerebral perfusion pressures with 10 breaths/ min versus 2 breaths/min, respectively, were 17.6 +/- 9.3 mm Hg versus 14.3 +/- 6.5 mm Hg (p = 0.20) and 16.0 +/-9.5 mm Hg versus 9.3 +/- 12.5 mm Hg (p = 0.25). Carotid artery blood flow, which was prospectively designated as the primary end point, was 65.0 +/- 49.6 mL/min in the 10-breaths/min group,

versus 34.0 +/- 17.1 mL/min in the 2-breaths/min group ($p = 0.037$). Brain-tissue oxygen tension was 3.0 +/- 3.3 mm Hg in the 10-breaths/min group, versus 0.5+/- 0.5 mm Hg in the 2-breaths/min group ($p = 0.036$). After 5 min of CPR there were no significant differences in arterial pH, PO_2, or PCO_2 between the groups. During CPR with the impedance threshold device, the mean carotid blood flow and brain-tissue oxygen tension in the 10-breaths/min group and the 2-breaths/min group, respectively, were 102.5 +/- 67.9 mm Hg versus 38.8+/- 23.7 mm Hg ($p = 0.006$) and 4.5+/- 6.0 mm Hg versus 0.7 +/- 0.7 mm Hg ($p = 0.032$).
funding: Dwight Opperman Foundation, and by American Heart Association Postdoctoral Fellowship grant
Key points: LOE 6, supportive, fair: During the first 5 min of CPR, 2 breaths/min resulted in significantly lower carotid blood flow and brain-tissue oxygen tension than did 10 breaths/min. Subsequent addition of an impedance threshold device significantly enhanced carotid flow and brain-tissue oxygen tension, especially in the 10-breaths/min group.

S. O. Hwang, et al. (2008) "Comparison of 15:1, 15:2, and 30:2 Compression-to-Ventilation Ratios for Cardiopulmonary Resuscitation in a Canine Model of a Simulated, Witnessed Cardiac Arrest" Academic Emergency Medicine 2008; 15:183–189
Thirty healthy dogs, (mean ± SD, 19.2 ± 2.2 kg), were used in this study. A ventricular fibrillation (VF) arrest was induced. The dogs received cardiopulmonary resuscitation (CPR) and were divided into three groups based on the applied CV ratios of 15:1, 15:2, and 30:2. After 1 minute of untreated VF, 4 minutes of basic life support (BLS) was performed. At the end of the 4 minutes, the dogs were defibrillated with an automatic external defibrillator (AED) and advanced cardiac life support (ACLS) efforts were continued for 10 minutes or until restoration of spontaneous circulation (ROSC) was attained, whichever came first.
None of the hemodynamic parameters, and arterial oxygen profiles was significantly different between the three groups during BLS- and ACLS-CPR. Eight dogs (80%) from each group achieved ROSC during BLS and ACLS. The survival rate was not different between the three groups.
In the 15:1and 30:2 groups, the number of compressions delivered over 1 minute were significantly greater than in the 15:2 group (73.1 ± 8.1 and 69.0 ± 6.9 to 56.3 ± 6.8; $p < 0.01$). The time for ventilation during which compressions were stopped at each minute was significantly lower in the 15:1 and 30:2 groups than in the 15:2 group (15.4 ± 3.9 and 17.1 ± 2.7 to 25.2 ± 2.6 sec ⁄ min; $p < 0.01$).
Level 1, neutral, funding: Ministry of Health and Welfare, Republic of Korea grant
Key points: LOE 1, neutral, fair: In this canine model of witnessed VF using a simulated scenario, CPR with three CV ratios,
15:1, 15:2, and 30:2, did not result in any differences in hemodynamics, arterial oxygen profiles, and resuscitation outcome among the three groups. CPR with a CV ratio of 15:1 provided comparable chest compressions and shorter pauses for ventilation between each cycle compared to a CV ratio of 30:2.

S. Wang, et al. (2010) "Effect of continuous compressions and 30:2 cardiopulmonary resuscitation on global ventilation/perfusion values during resuscitation in a porcine model" Crit Care Med 2010; 38:2024 –2030
Twenty-four male domestic pigs (n = 12/group) weighing 30 +/- 2 kilograms were anesthetized and endotrachealy intubated before undergoing ventricular fibrillation. Following ventricular fibrillation, they were randomized into two groups: continuous compressions (CC) or 30:2 compression/rescue ventilation (VC) cardiopulmonary resuscitation groups. Continuous respiratory variables, hemodynamic parameters, and blood gas analysis outcomes were recorded, and global ventilation/perfusion values were calculated. Alveolar minute volume and global ventilation/perfusion values decreased progressively after ventricular fibrillation, but cardiac output was stable. The global ventilation/perfusion value was higher in the ventilation cardiopulmonary resuscitation group than that in the continuous compression group ($p < .0001$) and was higher than normal. Coronary perfusion pressure was progressively decreased after 6 mins of cardiopulmonary resuscitation and greatly fluctuated in the ventilation cardiopulmonary resuscitation group. Coronary perfusion pressure was

higher in the continuous compression group than that in the ventilation group after 9 mins of cardiopulmonary resuscitation ($p < .05$). Values for pH and PaO_2 progressively decreased, but there were no significant differences between the two groups, except for pH at 12 mins of cardiopulmonary resuscitation and $PaCO_2$ after 3 mins of cardiopulmonary resuscitation.
funding: National Natural Science Foundation of China grant
Key points: LOE 6, opposing, fair: In the first 12 mins of cardiopulmonary resuscitation, continuous compressions could maintain relatively better coronary perfusion pressure, PaO_2, and global ventilation/perfusion values than 30:2 cardiopulmonary resuscitation. Therefore, rescue ventilation during 12 mins of simulated bystander cardiopulmonary resuscitation did not improve hemodynamics or outcomes compared with compression-only cardiopulmonary resuscitation.

D. Yannopoulos, et al. (2005) "Reducing Ventilation Frequency During Cardiopulmonary Resuscitation in a Porcine Model of Cardiac Arrest"
The authors hypothesized that reducing the ventilation rate by increasing the C/V ratio from 15:2 to 15:1 would increase vital-organ perfusion pressures without compromising oxygenation and acid-base balance. Ventricular fibrillation was induced in 8 pigs. After 4 min of untreated VF without ventilation, all animals received 4 min of standard CPR with a C/V ratio of 15:2. Animals were then randomized to either (A) a C/V ratio of 15:1 and then 15:2, or (B) a C/V ratio of 15:2 and then 15:1, for 3 min each. During CPR, ventilations were delivered with an automatic transport ventilator, with 100% oxygen. RESULTS: The mean SEM values over 1min with either 15:2 or 15:1 C/V ratios were as follows: intratracheal pressure 0.93 +/- 0.3 mm Hg versus 0.3 +/- 0.28 mm Hg, p = 0.006; coronary perfusion pressure 10.1 +/- 4.5 mm Hg versus 19.3 +/- 3.2 mm Hg, p = 0.007; intracranial pressure 25.4 +/- 2.7 mm Hg versus 25.7 +/- 2.7 mm Hg, p = NS; mean arterial pressure 33.1 +/- 3.7 mm Hg versus 40.2 +/- 3.6 mm Hg, p = 0.007; cerebral perfusion pressure 7.7 +/- 6.2 mm Hg versus 14.5 +/- 5.5 mm Hg, p = 0.008. Minute area intratracheal pressure was 55 +/- 17 mm Hg versus 22.3 +/- 10 mm Hg, $p < 0.001$. End-tidal CO_2 with 15:2 versus 15:1 was 24 +/- 3.6 mm Hg versus 29 +/- 2.5 mm Hg, respectively, p = 0.001. Arterial blood gas values were not significantly changed with 15:2 versus 15:1 C/V ratios: pH 7.28 +/- 0.03 versus 7.3 +/- 0.03; $PaCO_2$ 37.7 +/- 2.9 mm Hg versus 37.6 +/- 3.5 mm Hg; and PaO_2 274 +/- 36 mm Hg versus 303 +/- 51 mm Hg.
funding: American Heart Association grant for postdoctoral fellowship
Key points: LOE 6, supportive, fair: In a porcine model of ventricular fibrillation cardiac arrest, reducing the ventilation frequency during CPR by increasing the C/V ratio from 15:2 to 15:1 resulted in improved vital-organ perfusion pressures, higher end-tidal CO2 levels, and no change in arterial oxygen content or acid-base balance.

D. Yannopoulos, et al. (2006) "Clinical and hemodynamic comparison of 15:2 and 30:2 compression-to-ventilation ratios for cardiopulmonary resuscitation" Crit Care Med 2006 Vol. 34, No. 5
Objective: To compare cardiopulmonary resuscitation (CPR) with a compression to ventilation (C:V) ratio of 15:2 vs. 30:2, with and without use of an impedance threshold device (ITD). Acid-base status, cerebral, and cardiovascular hemodynamics were evaluated in 18 pigs in cardiac arrest randomized to a C:V ratio of 15:2 or 30:2. After 6 mins of cardiac arrest and 6 mins of CPR, an ITD was added. Compared to 15:2, 30:2 significantly increased diastolic blood pressure (20 + /- 1 to 26 +/ -1; p < .01); coronary perfusion pressure (18 +/- 1 to 25 +/- 2; p = 04); cerebral perfusion pressure (16 +/- 3 to 18 +/- 3; p = .07); common carotid blood flow (48 +/- 5 to 82 +/- 5 mL/min; p < .001); end-tidal CO2 (7.7 +/- 0.9 to 15.7 +/- 2.4; p < .0001); and mixed venous oxygen saturation (26 +/- 5 to 36 +/- 5, p < .05). Hemodynamics improved further with the ITD. Oxygenation and arterial pH were similar. Only one of nine pigs had return of spontaneous circulation with 15:2, vs. six of nine with 30:2 (p < 0.03).
funding: American Heart Association Postdoctoral Fellowship (grant 0425714Z) and a research gift from the Dwight Opperman Foundation

Key points: LOE 6, neutral, fair: These data strongly support the contention that a ratio of 30:2 is superior to 15:2 during manual CPR and that the ITD further enhances circulation with both C:V ratios.

D. Yannopoulos, et al. (2010) "No assisted ventilation cardiopulmonary resuscitation and 24-hour neurological outcomes in a porcine model of cardiac arrest"
Objectives: To evaluate the effect of no assisted ventilation cardiopulmonary resuscitation on neurologically intact survival compared with ten positive pressure ventilations/minute cardiopulmonary resuscitation in a pig model of cardiac arrest. After 8 mins of untreated ventricular fibrillation, sixteen female intubated pigs were randomized to 8 mins of continuous chest compressions (100/min) and either no assisted ventilation (n = 9) or 10 positive pressure ventilations/min (Smart Resuscitator Bag with 100% O2 flow at 10 L/min) (n = 7). The primary end point, neurologically intact 24-hr survival, was evaluated using a pig cerebral performance category score by a veterinarian blinded to the cardiopulmonary resuscitation method. During cardiopulmonary resuscitation, aortic and coronary perfusion pressure were similar between groups but cerebral perfusion pressure was significantly higher in the positive pressure ventilation group (33 ± 15 vs. 14 ± 14, p = .04). After 7.5 mins of cardiopulmonary resuscitation, arterial pO2 (mm Hg) and mixed venous O2 saturation (%) were significantly higher in the positive pressure ventilation compared with the no assisted ventilation group (117 ± 29 and 41 ± 21 vs. 40 ± 24 and 10.8 ± 7; p = .01 for both). $PaCO_2$ was significantly lower in the positive pressure ventilation group (48 ± 10 vs. 77 ± 26, p = .01). After 24 hrs, four of nine no assisted ventilation pigs were alive with a mean cerebral performance category score of 3 ± 0 vs. five of seven alive and neurologically intact positive pressure ventilation pigs with a cerebral performance category score of 1 ± 0.3 ($p < .001$ for cerebral performance category score). In this scale, a lower number represents better outcome.
funding: none reported
Key points: LOE 6, supportive, fair: No assisted ventilation cardiopulmonary resuscitation results in profound hypoxemia, respiratory acidosis, and significantly worse 24-hr neurologic outcomes compared with positive pressure ventilation cardiopulmonary resuscitation in pigs.