WORKSHEET for Evidence-Based Review of Science for Veterinary CPCR

1. Basic Demographics

Worksheet author(s)

Deanna Purvis, VMD, DACVECC, CVA	**Date Submitted for review:** 7/24/11
[redacted]	

2. Clinical question:

BLS03 - In dogs and cats with cardiac arrest (P), does the use of a specific C: V ratio (I) compared with standard care (30:2) (C), improve outcome (e.g. ROSC, survival) (O)?

3. Conflict of interest specific to this question:

The author does not have any conflict of interest specific to the above clinical question.

4. Search strategy (including electronic databases searched):

4a. Databases

PUBMED – 17 Relevant hits
- Cardiopulmonary resuscitation basic life support - English language 9 relevant hits from 732 responses.
- Compression ventilation ratio – English language – 8 relevant hits from 212 responses.

GOOGLE SCHOLAR – 10 Relevant hits
- Compression ventilation ratio in BLS - 10 relevant hits from 7670 responses

4b. Other sources

References of the 27 articles were checked – no additional relevant hits.

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

Inclusion criteria – Articles in peer-reviewed literature; CPR (BLS) in all species and ages (to include human and pediatric); Clinical observation studies; Prospective randomized animal studies; data analysis articles.

Exclusion criteria – Abstracts only; Review articles; meta-analysis articles.

4d. Number of articles/sources meeting criteria for further review: 19

- **Clinical Observational Study** (Aufderheide, Sigurdsson et al. 2004) (Betz, Callaway et al. 2000) (Hallstrom, Cobb et al. 2000)(Greingor L, 2002)(Hostler, Guimond et al. 2004)(Eisenberger, Funk et al. 2007)(Dorph, Wik et al. 2002)
- **Prospective randomized animal study** (Wang, Li et al. 2010) (Sanders, Kern et al. 2002) (Yannopoulos, Aufderheide et al. 2006.)(Yannopoulos, McKnite et al. 2005)(Dorph, Wik et al. 2003) (Dorph, Wik, et al. 2004)(Berg, Sanders et al. 2001)(Kill, Torossian et al. 2009)(Hwang, Kim et al. 2008)(Cavus, Meybohm et al. 2008)(Hostler, Rittenberger et al. 2007)
- **Data Analysis** (Babbs, Kern 2002)

5. Summary of evidence

Evidence Supporting Clinical Question

Good						
Fair						***Wang 2010***; *E=CPP, Blood gases* ***Sanders 2002***; *B,D*
Poor						***Hallstrom 2000***; *C* ***Berg 2001***: *E=CPP, # chest compressions*
	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:*** *A, E=CPP, Blood gases*			
Poor						***Betz 2008***: *E=rescuer fatigue & chest compression depth* ***Dorph 2003***: *E=cerebral oxygenation & CPP* ***Cavus 2008:*** *A, E = Blood gases*
	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						***Yannopoulos 2006:*** *A, E=CPP, Blood gases* ***Dorph 2004:*** *A, E=cerebral O2 delivery, CPP* ***Kill 2009****:* *A, E=Blood gases*
Poor						***Babbs 2002****:* *E=mathematical calculations* ***Holster 2007****:* *E=# chest compressions*
	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 optimal compression:ventilation ratio during CPR has not yet been determined for the human or veterinary patient.

There is evidence that increased ventilation rates (lower C:V ratios) during CPR can negatively impact outcome. Aufderheide et al. has shown that with increasing respiratory rates there is increasing intrathoracic pressure and this is associated with decreased survival. Experimental pig studies report that continuous chest compressions are associated with higher coronary perfusion pressures, PaO_2 and global ventilation/perfusion parameters when compared to chest compressions that are interrupted by ventilations. (Wang 2010; Berg 2001) Another pig study reported that the neurologic status at 24 hours was better when a C:V ratio of 100:2 was used rather than a 15:2 ratio or continuous chest compressions, although there was no difference in survival between the groups in this study. (Sanders 2002) These findings are further supported by a human randomized clinical study which found that survival to hospital discharge was greater when bystanders were instructed to do continuous chest compressions instead of standard CPR (C:V of 15:2). (Hallstrom 2000) Utilizing mathematical analysis, oxygen delivery and oxygen delivery with blood flow were determined to be maximal at a compression:ventilation ratio near 60:2. (Babbs 2002) Overall these studies suggest that minimizing ventilation rate (increasing C:V ratio) during CPR maybe of benefit.

Some studies have found no superiority of a C:V ratio of 30:2 over other ratios during CPR. Two experimental animal studies found no difference in ROSC between a C:V ratio of 30:2 compared to other C:V ratios. (Cavus 2008; Hwang 2008) In addition, a manikin study found that rescuer fatigue was no different between a 15:1 and 30:2 C:V ratio. (Betz 2008)

A C:V ratio of 30:2 has been found to be superior in several studies. When a C:V ratio of 15:2 was compared to that of 30:2 in human clinical patients the patients that had a 30:2 ratio received more chest compressions per minute. (Hostler 2007) In an experimental pig study the hemodynamics, blood gases and ROSC was better in the group resuscitated with a 30:2 ratio compared to a 15:2 ratio. (Yannopoulos 2006) Comparing continuous chest compressions to CPR with a C:V ratio of 30:2 in pigs, it was found that hemodynamic performance was similar but cerebral oxygen delivery was better when ventilations were included. (Dorph 2004) When a higher C:V ratio of 100:5 was compared to a C:V ratio of 30:2 there was no difference in ROSC or arterial blood gases in an experimental pig study. Continuous chest compressions or a C:V ratio of 100:2 had lower ROSC and blood gases compared to the 30:2 or 100:5 groups in this study. (Kill 2009)

There is substantial evidence to suggest C:V ratios less than 30:2 should be avoided during CPR. Although there is some evidence that C:V ratios higher than 30:2 maybe superior during CPR, this evidence is not conclusive. No studies evaluating higher C:V ratios could be identified in dogs or cats and the majority of the studies that were identified evaluate single rescuer CPR. The relevance of these results to clinical veterinary patients is unknown. There is insufficient evidence at this time to change the current recommendation of a C:V ratio of 30:2 for CPR in dogs and cats.

7. Conclusion

Can you add a summary paragraph here – the template has a good example of this.

8. Acknowledgement

9. Citation list

Crit Care Med 2010 Oct; 38(10):2024-30
Effect of continuous compressions and 30:2 cardiopulmonary resuscitation on global ventilation/perfusion values during resuscitation in a porcine model.
Wang S, Li C et al.

OBJECTIVE:
Rescue ventilations during bystander resuscitation, although previously considered essential, interrupt the continuity of chest compressions and might have deleterious effects in basic life support. This study was undertaken to analyze the global ventilation/perfusion values of continuous compressions and 30:2 cardiopulmonary resuscitation to determine the effectiveness for each approach in a porcine model of prolonged bystander cardiopulmonary resuscitation for ventricular fibrillation.
DESIGN:
Prospective, randomized animal study.
SUBJECTS:
Twenty-four male domestic pigs (n = 12/group) weighing 30 ± 2 kg.
INTERVENTIONS:
All animals had ventricular fibrillation induced by programmed electrical stimulation instruments and were randomized into two groups. Continuous compressions or 30:2 compression/rescue ventilation cardiopulmonary resuscitation was performed in each group.
MEASUREMENTS AND MAIN RESULTS:
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 cardiopulmonary resuscitation group after 9 mins of cardiopulmonary resuscitation ($p < .05$). Values for pH and Pao2 progressively decreased, but there were no significant differences between the two groups, except for pH at 12 mins of cardiopulmonary resuscitation and Paco2 after 3 mins of cardiopulmonary resuscitation.
CONCLUSIONS:
In the first 12 mins of cardiopulmonary resuscitation, continuous compressions could maintain relatively better coronary perfusion pressure, Pao2, 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.
Key points:

Crit Care Med 2006 May; 34(5):1444-9

Clinical and hemodynamic comparison of 15:2 and 30:2 compression-to-ventilation ratios for cardiopulmonary resuscitation.
Yannopoulos D, Aufderheide TP, et al.

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).
DESIGN:
Prospective randomized animal and manikin study.

SUBJECTS:
Twenty female pigs and 20 Basic Life Support (BLS)-certified rescuers.
INTERVENTIONS, MEASUREMENTS, AND MAIN RESULTS:
ANIMALS:
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). HUMANS: Fatigue and quality of CPR performance were evaluated in 20 BLS-certified rescuers randomized to perform CPR for 5 mins at **15**:**2** or **30**:**2** on a recording CPR manikin. There were no significant differences in the quality of CPR performance or measurement of fatigue. Significantly more compressions per minute were delivered with **30**:**2** in both the animal and human studies.
CONCLUSIONS:
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.

Resuscitation 2008 Nov;79(2):278-82.
Work of CPR during two different compression to ventilation ratios with real-time feedback.
Betz AE, Callaway CW et al.

BACKGROUND:
The 2005 Emergency Cardiac Care guidelines for basic life support (BLS) recommend compression to ventilation ratio of 30:2. The effect of the additional exertion required to deliver more chest compressions may present a considerable physical burden on the provider.
OBJECTIVE:
To compare cardiopulmonary resuscitation (CPR) performance and perceived exertion during compression to ventilation ratios of 15:2 and 30:2 with real-time feedback during two-rescuer CPR.
METHODS:
Eighteen BLS-certified healthcare providers each performed 5 min of chest compressions on a manikin with compression to ventilation ratios of 15:2 or 30:2 on two separate sessions. Heart rate, capillary lactate, and OMNI rate of perceived exertion (RPE) were recorded before and after each session. Subjects were given continuous, automated, feedback via an accelerometer that measured rate, depth, duration, and release of compressions. Compression measurements and feedback messages were recorded continuously during each 5-min session. Data were analyzed using descriptive statistics and t-test to compare groups. Repeated measures ANOVA were used to compare data over the 5-min epoch.
RESULTS:
After performing external chest compressions for 5 min, peak heart rate (102+/-24 vs. 106+/-27), capillary lactate (2.2+/-0.95 vs. 2.2+/-0.96), and OMNI RPE (4.3+/-1.2 vs. 4.6+/-1.1) were higher were higher than baseline, but did not differ between 15:2 and 30:2. Compression rate (102+/-24 vs.106+/-27) and depth (38.8+/-3.6 vs. 38.2+/-2.9) did not differ between 15:2 and 30:2 groups or at any minute. Total chest compressions delivered were higher (p<0.05) in the 30:2

group (457+/-43) compared to 15:2 (379+/-28). The average no flow time was lower (p<0.05) in the 30:2 group (22+/-3.03) compared to the 15:2 group (33+/-2.64). Number of correction prompts (48+/-55 vs. 64+/-70) did not differ significantly between the 15:2 and 30:2 groups.

CONCLUSIONS:

In a cohort of healthcare providers, increasing the CPR ratio from 15:2 to 30:2 did not change physical or perceived exertion during a 5-min bout of CPR when continuous, real-time feedback is provided. The 30:2 compression to ventilation ratio resulted in more chest compressions per minute without decreasing CPR quality.

Ann Emerg Med. 2002 Dec; 40(6):553-62.

Survival and neurologic outcome after cardiopulmonary resuscitation with four different chest compression-ventilation ratios.

Sanders AB, Kern KB et al.

STUDY OBJECTIVE:

The optimal ratio of chest compressions to ventilations during cardiopulmonary resuscitation (CPR) is unknown. We determine 24-hour survival and neurologic outcome, comparing 4 different chest compression-ventilation CPR ratios in a porcine model of prolonged cardiac arrest and bystander CPR.

METHODS:

Forty swine were instrumented and subjected to 3 minutes of ventricular fibrillation followed by 12 minutes of CPR by using 1 of 4 models of chest compression-ventilation ratios as follows: (1) standard CPR with a ratio of 15:2; (2) CC-CPR, chest compressions only with no ventilations for 12 minutes; (3) 50:5-CPR, CPR with a ratio of 50:5 compressions to ventilations, as advocated by authorities in Great Britain; and (4) 100:2-CPR, 4 minutes of chest compressions only followed by CPR with a ratio of 100:2 compressions to ventilations. CPR was followed by standard advanced cardiac life support, 1 hour of critical care, and 24 hours of observation, followed by a neurologic evaluation.

RESULTS:

There were no statistically significant differences in 24-hour survival among the 4 groups (standard CPR, 7/10; CC-CPR, 7/10; 50:5-CPR, 8/10; 100:2-CPR, 9/10). There were significant differences in 24-hour neurologic function, as evaluated by using the swine cerebral performance category scale. The animals receiving 100:2-CPR had significantly better neurologic function at 24 hours than the standard CPR group with a 15:2 ratio (1.5 versus 2.5; P =.007). The 100:2-CPR group also had better neurologic function than the CC-CPR group, which received chest compressions with no ventilations (1.5 versus 2.3; P =.027). Coronary perfusion pressures, aortic pressures, and myocardial and kidney blood flows were not significantly different among the groups. Coronary perfusion pressure as an integrated area under the curve was significantly better in the CC-CPR group than in the standard CPR group (P =.04). Minute ventilation and PaO (2) were significantly lower in the CC-CPR group.

CONCLUSION:

In this experimental model of bystander CPR, the group receiving compressions only for 4 minutes followed by a compression-ventilation ratio of 100:2 achieved better neurologic outcome than the group receiving standard CPR and CC-CPR. Consideration of alternative chest compression-ventilation ratios might be appropriate.

N Engl J Med 2000 May 25; 342(21):1546-53.

Cardiopulmonary resuscitation by chest compression alone or with mouth-to-mouth ventilation.

Hallstrom A, Cobb L, et al.

BACKGROUND:

Despite extensive training of citizens of Seattle in cardiopulmonary resuscitation (CPR), bystanders do not perform CPR in almost half of witnessed cardiac arrests. Instructions in chest compression plus mouth-to-mouth ventilation given by dispatchers over the telephone can require 2.4 minutes. In experimental studies, chest compression alone is associated with survival rates similar to those with chest compression plus mouth-to-mouth ventilation. We conducted a randomized study to compare CPR by chest compression alone with CPR by chest compression plus mouth-to-mouth ventilation.

METHODS:

The setting of the trial was an urban, fire-department-based, emergency-medical-care system with central dispatching. In a randomized manner, telephone dispatchers gave bystanders at the scene of apparent cardiac arrest instructions in either chest compression alone or chest compression plus mouth-to-mouth ventilation. The primary end point was survival to hospital discharge.

RESULTS:

Data were analyzed for 241 patients randomly assigned to receive chest compression alone and 279 assigned to chest compression plus mouth-to-mouth ventilation. Complete instructions were delivered in 62 percent of episodes for the group receiving chest compression plus mouth-to-mouth ventilation and 81 percent of episodes for the group receiving chest compression alone (P=0.005). Instructions for compression required 1.4 minutes less to complete than instructions for compression plus mouth-to-mouth ventilation. Survival to hospital discharge was better among patients assigned to chest compression alone than among those assigned to chest compression plus mouth-to-mouth ventilation (14.6 percent vs. 10.4 percent), but the difference was not statistically significant (P=0.18).

CONCLUSIONS:

The outcome after CPR with chest compression alone is similar to that after chest compression with mouth-to-mouth ventilation, and chest compression alone may be the preferred approach for bystanders inexperienced in CPR.

Resuscitation. 2004 Mar; 60(3):309-18.

Oxygen delivery and return of spontaneous circulation with ventilation: compression ratio 2:30 versus chest compressions only CPR in pigs.

Dorph E, Wik L, et al.

Abstract

The need for rescue breathing during the initial management of sudden cardiac arrest is currently being debated and reevaluated. 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 a valve hindering passive inhalation. Resuscitability was then studied during the subsequent advanced life support (ALS) period. After 3 min of untreated ventricular fibrillation (VF) BLS was started. The animals were randomised 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. Haemodynamic data did not differ between the groups. In this model of very ideal BLS, ventilation improved arterial oxygenation and the median time to ROSC was shorter. We believe that in cardiac arrest with an obstructed airway, pulmonary ventilation should still be strongly recommended.

Resuscitation 2008 Oct; 79(1):118-24.

Impact of different compression-ventilation ratios during basic life support cardiopulmonary resuscitation.

Cavus E, Meybohm P, et al.

BACKGROUND:

The 2005 revised guidelines for cardiopulmonary resuscitation (CPR) suggest a universal compression-to-ventilation (C:V) ratio of 30:2. The effects of this ratio in a realistic CPR scenario have not been investigated completely.

MATERIAL AND METHODS:

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 (Fio2 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 PO2 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 PO2 and SO2 were higher in the 15:2 and 30:2 groups, compared to the CC group (PO2 : 23+/-2 and 25+/-1 vs. 17+/-1 mmHg; SO2: 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).

CONCLUSIONS:

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.

Acad Emerg Med 2008 Feb; 15(2):183-9.
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.

Hwang SO, Kim SH, et al.

OBJECTIVES:

This experimental study compared the effect of compression-to-ventilation (CV) ratios of 15:1, 15:2, and 30:2 on hemodynamics and resuscitation outcome in a canine model of a simulated, witnessed ventricular fibrillation (VF) cardiac arrest.

METHODS:

Thirty healthy dogs, irrespective of species (mean +/- SD, 19.2 +/- 2.2 kg), were used in this study. A 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.

RESULTS:

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 15:1 and 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).

CONCLUSIONS:

In a 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.

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

Babbs CF, Kern KB

OBJECTIVE: To develop and evaluate a practical formula for the optimum ratio of compressions to ventilations in cardiopulmonary resuscitation (CPR). The optimum value of a variable is that for which a desired result is maximized. Here the desired result is assumed to be either oxygen delivery to peripheral tissues or a combination of oxygen delivery and waste product removal.

METHOD:

Equations describing oxygen delivery and blood flow during CPR as functions of the number of compressions and the number of ventilations delivered over time were developed from principles of classical physiology. These equations were solved explicitly in terms of the compression/ventilation ratio and evaluated for a wide range of conditions using Monte Carlo simulations.

RESULTS:

As the compression to ventilation ratio was increased from 0 to 50 or more, both oxygen delivery and the combination of oxygen delivery with blood flow increased to maximum values and then gradually declined. For variables typical of standard CPR as taught and specified in international guidelines, maximum values occurred at compression/ventilation ratios near 30:2. For variables typical of actual lay rescuer performance in the field, maximal values occurred at compression/ventilation ratios near 60:2.

CONCLUSION:

Current guidelines overestimate the need for ventilation during standard CPR by two to four-fold. Blood flow and oxygen delivery to the periphery can be improved by eliminating interruptions of chest compression for these unnecessary ventilations.

Circulation 2001; 104:2465

Adverse Hemodynamic Effects of Interrupting Chest Compressions for Rescue Breathing During Cardiopulmonary Resuscitation for Ventricular Fibrillation Cardiac Arrest

Robert A. Berg, MD; Arthur B. Sanders, MD; Karl B. Kern, MD; Ronald W. Hilwig, DVM, PhD; Joseph W. Heidenreich, BA; Matthew E. Porter, BA; Gordon A. Ewy, MD

Background— Despite improving arterial oxygen saturation and pH, bystander cardiopulmonary resuscitation (CPR) with chest compressions plus rescue breathing (CC+RB) has not improved survival from ventricular fibrillation (VF) compared with chest compressions alone (CC) in numerous animal models and 2 clinical investigations.

Methods and Results— After 3 minutes of untreated VF, 14 swine (32±1 kg) were randomly assigned to receive CC+RB or CC for 12 minutes, followed by advanced cardiac life support. All 14 animals survived 24 hours, 13 with good neurological outcome. For the CC+RB group, the aortic relaxation pressures routinely decreased during the 2 rescue breaths. Therefore, the mean coronary perfusion pressure of the first 2 compressions in each compression cycle was lower than those of the final 2 compressions (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 CC+RB group (62±1 versus 92±1 compressions, $P<0.001$). Consequently, the integrated coronary perfusion pressure was lower with CC+RB during each minute of CPR ($P<0.05$ for the first 8 minutes). Moreover, at 2 to 5 minutes of CPR, the median left ventricular blood flow by fluorescent microsphere technique was 60 mL · 100 g^{-1} · min^{-1} with CC+RB versus 96 mL · 100 g^{-1} · min^{-1} with CC, $P<0.05$. Because the arterial oxygen saturation was higher with CC+RB, the left ventricular myocardial oxygen delivery did not differ.

Conclusions— Interrupting chest compressions for rescue breathing can adversely affect hemodynamics during CPR for VF.

Resuscitation 2009 80(9): 1060-1065

Basic life support with four different compression/ventilation ratios in a pig model: The need for ventilation

Kill C, Torossian A et al.

Background: During cardiac arrest the paramount goal of basic life support (BLS) is the oxygenation of vital organs. Current recommendations are to combine chest compressions with ventilation in a fixed ratio of 30:2; however the optimum compression/ventilation ratio is still debatable. In our study we compared four different compression/ventilation ratios and documented their effects on the return of spontaneous circulation (ROSC), gas exchange, cerebral tissue oxygenation and haemodynamics in a pig model.

Methods: Study was performed on 32 pigs under general anaesthesia with endotracheal intubation. Arterial and central venous lines were inserted. For continuous cerebral tissue oxygenation a Licox® $PtiO_2$ probe was implanted.

After 3 min of cardiac arrest (ventricular fibrillation) animals were randomized to a compression/ventilation-ratio 30:2, 100:5, 100:2 or compressions-only. Subsequently 10 min BLS, Advanced Life Support (ALS) was performed (100%O_2, 3 defibrillations, 1 mg adrenaline i.v.). Data were analyzed with 2-factorial ANOVA.

Results: ROSC was achieved in 4/8 (30:2), 5/8 (100:5), 2/8 (100:2) and 0/8 (compr-only) pigs. During BLS, $PaCO_2$ increased to 55 mmHg (30:2), 68 mmHg (100:5; $p = 0.0001$), 66 mmHg (100:2; $p = 0.002$) and 72 mmHg (compr-only; $p < 0.0001$). PaO_2 decreased to 58 mmg (30:2), 40 mmHg (100:5; $p = 0.15$), 43 mmHg (100:2; $p = 0.04$) and 26 mmHg (compr-only; $p < 0.0001$). $PtiO_2$ baseline values were 12.7, 12.0, 11.1 and 10.0 mmHg and decreased to 8.1 mmHg (30:2), 4.1 mmHg (100:5; $p = 0.08$), 4.3 mmHg (100:2; $p = 0.04$), and 4.5 mmHg (compr-only; $p = 0.69$).

Conclusions: During BLS, a compression/ventilation-ratio of 100:5 seems to be equivalent to 30:2, while ratios of 100:2 or compressions-only detoriate peripheral arterial oxygenation and reduce the chance for ROSC.

Circulation. 2004; 109:1960-1965

Hyperventilation-Induced Hypotension during Cardiopulmonary Resuscitation

Tom P. Aufderheide, MD; Gardar Sigurdsson, MD; Ronald G. Pirrallo, MD, MHSA; Demetris Yannopoulos, MD; Scott McKnite, BA; Chris von Briesen, BA, EMT; Christopher W. Sparks, EMT; Craig J. Conrad, RN; Terry A. Provo, BA, EMT-P; Keith G. Lurie, MD

Background— A clinical observational study revealed that rescuers consistently hyperventilated patients during out-of-hospital cardiopulmonary resuscitation (CPR). The objective of this study was to quantify the degree of excessive ventilation in humans and determine if comparable excessive ventilation rates during CPR in animals significantly decrease coronary perfusion pressure and survival.

Methods and Results— In humans, ventilation rate and duration during CPR was electronically recorded by professional rescuers. In 13 consecutive adults (average age, 63±5.8 years) receiving CPR (7 men), average ventilation rate was 30±3.2 per minute (range, 15 to 49). Average duration per breath was 1.0±0.07 per second. No patient survived. Hemodynamics were studied in 9 pigs in cardiac arrest ventilated in random order with 12, 20, or 30 breaths per minute. Survival rates were then 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<0.0001), and 23.4±1.0, 19.5±1.8, and 16.9±1.8 (P=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=0.006).

Conclusions— Professional rescuers were 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.

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Increased chest compression to ventilation ratio improves delivery of CPR.

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OBJECTIVE:

Chest compressions are interrupted during cardiopulmonary resuscitation (CPR) due to human error, for ventilation, for rhythm analysis and for rescue shocks. Earlier data suggest that the recommended 15:2 compression to ventilation (C:V) ratio results in frequent interruptions of compressions during CPR. We evaluated a protocol change from the recommended C:V ratio of 15:2-30:2 during CPR in our municipal emergency medical system.

METHODS:

Municipal firefighters (N=875) from a single city received didactic and practical training emphasizing the importance of continuous **chest** compressions and recommending a 30:2 C: V **ratio**. Both before and after the training, digital ECG and voice records from all first-responder cases of out-of-hospital cardiac arrest were examined off-line to quantify **chest** compressions. The number of **chest** compressions delivered and the number and duration of pauses in **chest** compressions were compared by t-test for the first three 1min intervals when **CPR** was recommended.

RESULTS:

More compressions were delivered during minutes 1, 2, and 3 during **CPR** with the 30:2 C: V **ratio** (78+/-29, 80+/-30, 74+/-26) than with the 15:2C:V **ratio** (53+/-24, 57+/-24, 51+/-26) (p<0.001). Fewer pauses for **ventilation** occurred during each minute with the 30:2 C: V **ratio** (1.7+/-1.2, 2.2+/-1.2, 1.8+/-1.0) than with the 15:2C: V **ratio** (3.4+/-2.6, 4.7+/-7.2, 4.0+/-2.9) (p< or =0.01). Degradation of the final ECG to asystole occurred less frequently after the protocol change (asystole pre 67.1%, post 56.8%, p<0.05). The incidence of return of spontaneous circulation was not altered following the protocol change.

CONCLUSIONS:

Retraining first responders to use a C: V **ratio** of 30:2 instead of the traditional 15:2 during out-of-hospital cardiac arrest **increased** the number of compressions delivered per minute and decreased the number of pauses for **ventilation**. These data are new as they produced persistent and quantifiable changes in practitioner behavior during actual resuscitations.