WORKSHEET for Evidence-Based Review of Science for Veterinary CPCR

1. Basic Demographics

Worksheet author(s)

[redacted]

2. Clinical question:

BLS01: In dogs and cats with cardiac arrest (P), does compression only CPCR (I) when compared with traditional CPCR (C) improve outcome (eg. 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 – 13 Relevant hits initially identified
-Hands-only CPR: 1 relevant hit from 23 responses
-Compression-only CPR: 12 relevant hits from 84 responses

GOOGLE SCHOLAR
-No additional relevant hits that were novel to those obtained via Medline (Pubmed)

VETERINARY JOURNAL INDEX v.1/31/11(including CAB abstracts)
-No additional relevant hits

4b. Other sources

References of the 13 articles were checked; particular attention was paid to mining the reference list from the recently published meta-analysis on this topic [Hupfl, M., H.F. Selig, et al (2010) ***Lancet*** 376(9752):1552-1557]
-29 additional relevant hits were identified

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: 42

- **Clinical/observational/retrospective studies (18): (**SOS-KANTO Study Group 2007), (Bobrow, B. J., L. L. Clark, et al. 2008), (Bobrow, B. J., D. W. Spaite, et al. 2010), (Bohm, K., M. Rosenqvist, et al. 2007), (Gundersen, K., J. T. Kvaloy, et al. 2009), (Hallstrom, A., L. Cobb, et al. 2000), (Hallstrom, A. P. 2000), (Iwami, T., T. Kawamura, et al. 2007), (Kellum, M. J., K. W. Kennedy, et al. 2006), (Kellum, M. J., K. W. Kennedy, et al. 2008), (Kellum, M. J., K. W. Kennedy, et al. 2006), (Kitamura, T., T. Iwami, et al. 2011), (Kitamura, T., T. Iwami, et al. 2010), (Kitamura, T., T. Iwami, et al. 2010), (Ogawa, T., M. Akahane, et al.

2011), (Olasveengen, T. M., L. Wik, et al. 2008), (Ong, M. E., F. S. Ng, et al. 2008), (Rea, T. D., C. Fahrenbruch, et al. 2010), (Svensson, L., K. Bohm, et al. 2010)

- **Prospective randomized animal study (23):** (Bendixen, H. H., M. B. Laver, et al. 1963), (Berg, R. A., R. W. Hilwig, et al. 1999), (Berg, R. A., R. W. Hilwig, et al. 2000), (Berg, R. A., K. B. Kern, et al. 1997a), (Berg, R. A., K. B. Kern, et al. 1997b), (Berg, R. A., K. B. Kern, et al. 1993), (Berg, R. A., A. B. Sanders, et al. 2001), (Chandra, N. C., K. G. Gruben, et al. 1994), (Dorph, E., L. Wik, et al. 2004), (Engoren, M., M. C. Plewa, et al. 1997), (Ewy, G. A., R. W. Hilwig, et al. 2010), (Ewy, G. A., M. Zuercher, et al. 2007), (Idris, A. H., L. B. Becker, et al. 1994), (Idris, A. H., V. Wenzel, et al. 1995), (Kern, K. B., R. W. Hilwig, et al. 1998), (Kern, K. B., R. W. Hilwig, et al. 2002), (Kill, C., A. Torossian, et al. 2009), (Sanders, A. B., K. B. Kern, et al. 2002), (Tang, W., M. H. Weil, et al. 1994), (von Planta, I., M. H. Weil, et al. 1991), (Wang, S., C. Li, et al. 2010), (Yakaitis, R. W., J. D. Thomas, et al. 1975), (Yannopoulos, D., T. Matsuura, et al. 2010)
- **Data Analysis (1):** (Hupfl, M., H.F. Selig, et al 2010)

5. Summary of evidence

Evidence Supporting Clinical Question

Good						*SOS-Kanto Study Group (2007); D* *Bobrow, B. J., L. L. Clark, et al. 2008: C* *Bobrow, B. J., D. W. Spaite, et al. 2010: C* *Ewy, G. A., M. Zuercher, et al. 2007: D* *Hupfl, M., H.F. Selig, et al 2010: B & C*
Fair			*Chandra, N. C., K. G. Gruben, et al. 1994: E= blood gases*			*Berg, R. A., A. B. Sanders, et al. 2001: E=hemodynamics* *Ewy, G. A., R. W. Hilwig, et al. 2010: C & D* *Kellum, M. J., K. W. Kennedy, et al. 2006: C* *Kern, K. B., R. W. Hilwig, et al. 2002: C & D* *Sanders, A. B., K. B. Kern, et al. 2002: D* *Wang, S., C. Li, et al. 2010: E= hemodynamics, blood gases*
Poor						*Engoren, M., M. C. Plewa, et al. 1997: E=blood gases* *Gundersen, K., J. T. Kvaloy, et al. 2009: E= defib likelihood* *Kellum, M. J., K. W. Kennedy, et al. 2008: D*
	1	**2**	**3**	**4**	**5**	**6**

Level of evidence (P)						

A = Return of spontaneous circulation
B = Survival of event
species studies

C = Survival to hospital discharge
D = Intact neurological survival

E = Other endpoint
Italics = Non-target

Evidence Neutral to Clinical question

Good						*Bohm, K., M. Rosenqvist, et al. 2007: C* *Rea, T. D., C. Fahrenbruch, et al. 2010: C* *Svensson, L., K. Bohm, et al. 2010: C*
Fair						*Berg, R. A., K. B. Kern, et al. 1997a: C & D* *Berg, R. A., K. B. Kern, et al. 1997b: C* *Berg, R. A., K. B. Kern, et al. 1993: D* *Iwami, T., T. Kawamura, et al. 2007: C & D*
Poor			*Yakaitis, R. W., J. D. Thomas, et al. 1975: E= defib threshold*			*Hallstrom, A., L. Cobb, et al. 2000: C* *Hallstrom, A. P. 2000: C* *Kern, K. B., R. W. Hilwig, et al. 1998: C* *Olasveengen, T. M., L. Wik, et al. 2008: C* *Ong, M. E., F. S. Ng, et al. 2008: C* *Tang, W., M. H. Weil, et al. 1994: A & C*
	1	**2**	**3**	**4**	**5**	**6**
Level of evidence (P)						

A = Return of spontaneous circulation
B = Survival of event
species studies

C = Survival to hospital discharge
D = Intact neurological survival

E = Other endpoint
Italics = Non-target

Evidence Opposing Clinical Question

Good						
Fair			*Bendixen, H. H., M. B. Laver, et al. 1963: E= epi effects*			*Berg, R. A., R. W. Hilwig, et al. 1999: A & C* *Berg, R. A., R. W. Hilwig, et al. 2000: A & C* *Dorph, E., L. Wik, et al. 2004: A & E=blood gases* *Idris, A. H., L. B. Becker, et al. 1994: A* *Idris, A. H., V. Wenzel, et al. 1995: A* *Kill, C., A. Torossian, et al. 2009: A & E= hemodynamics*

						Kitamura, T., T. Iwami, et al. 2011: D *Kitamura, T., T. Iwami, et al. 2010: D* *Yannopoulos, D., T. Matsuura, et al. 2010: D* *Kitamura, T., T. Iwami, et al. 2010: D*
Poor						*Ogawa, T., M. Akahane, et al. 2011: C & D* *von Planta, I., M. H. Weil, et al. 1991:A*
	1	**2**	**3**	**4**	**5**	**6**
Level of evidence (P)						

A = Return of spontaneous circulation
B = Survival of event
species studies

C = Survival to hospital discharge
D = Intact neurological survival

E = Other endpoint
Italics = *Non-target*

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

This reviewer's assessment of the clinical and scientific evidence relating to the relative superiority of either compression-only or standard CPCR resuscitation techniques is as follows: *nearly all of the published evidence is irrelevant to the veterinary clinical setting*. While one can find a moderate number of clinical trials in which human patients are randomly assigned to receive resuscitation by one of these two means, these studies model the veterinary clinical setting in only the poorest fashion. These studies are all of out-of-hospital arrests with emergency response system personnel giving instructions to lay-persons over the phone. Such studies might be relevant to guiding the veterinary profession in how to advise clients whose pets have arrested at home, but provide little insight into the optimal management of an arrested veterinary patient in the hospital environment. Equally concerning is the disparity in results amongst the published trials regarding outcomes. The meta-analysis by Hupfl and colleagues (Hupfl, M., H.F. Selig, et al 2010) concluded that in the three large published trials that had been performed there was evidence of improved outcomes with compression-only resuscitation techniques. This same meta-analysis found that no such finding was supported by pooling data from the many more numerous small published trials. Unfortunately, this meta-analysis was published prior to several more large trials coming out from Japan (Kitamura, T., T. Iwami, et al. 2011, Kitamura, T., T. Iwami, et al. 2010, Ogawa, T., M. Akahane, et al. 2011, and Kitamura, T., T. Iwami, et al. 2010) all of which concluded that compression-only approaches resulted in outcomes that were inferior (or rarely equivalent) to standard methods. Such results have been echoed in other smaller trials from other parts of the world (e.g. Singapore, Sweden, Norway) and do not seem to be inherent to the Japanese model of emergency medical provision (Olasveengen, T. M., L. Wik, et al. 2008, Ong, M. E., F. S. Ng, et al. 2008, and Svensson, L., K. Bohm, et al. 2010). Each of these three trials has concluded that compression-only or "hands-only" CPCR does not result in improved outcomes. To date, no veterinary clinical trials have been published (to this author's knowledge) comparing outcomes with the two approaches.

Unfortunately, the overwhelming majority of laboratory research has been performed in swine and may not be directly relevant to the resuscitation of canine and feline patients. Moreover, these studies almost exclusively utilize a ventricular fibrillation model of cardiac arrest which, while entirely relevant to human medicine, is less than ideal for veterinary patients. A minority of the swine models have used a hypoxic or asphyxia arrest approach with varied results regarding the superiority of compression-only resuscitation. The results from swine models of arrest regarding the superiority or inferiority of compression-only CPCR are mixed. Several studies have reported ***worse*** outcomes [e.g. ROSC, survival, neurologic outcomes] with compression-only resuscitation methods (Berg, R. A., R. W. Hilwig, et al. 1999, Berg, R. A., R. W. Hilwig, et al. 2000, Dorph, E., L. Wik, et al. 2004, Idris, A. H., L. B. Becker, et al. 1994, Idris, A. H., V. Wenzel, et al. 1995). Not surprisingly, one can find swine models in which it was shown that withholding IPPV during resuscitation leads to more severe derangement of blood gas values (Dorph, E., L. Wik, et al. 2004). One can also find a large number of published reports using swine models of cardiac arrest in which outcomes are ***not different*** using compression-only or standard resuscitation methods (Berg, R. A., K. B. Kern, et al. 1997a, Berg, R. A., K. B. Kern, et al. 1997b, Berg, R. A., K. B. Kern, et al. 1993). Interestingly, one study demonstrated similar results using the two methods even when airway

obstruction was created (Kern, K. B., R. W. Hilwig, et al. 1998) which conflicts with other findings in similar settings. Studies using swine models of cardiac arrest have also been published which report ***improved*** hemodynamics with compression-only resuscitation methods (Berg, R. A., A. B. Sanders, et al. 2001). Work by both Ewy and Kern with swine models of cardiac arrest have reported ***superior*** outcomes (survival, neurologic recovery) with compression-only resuscitation methods (Ewy, G. A., R. W. Hilwig, et al. 2010, Ewy, G. A., M. Zuercher, et al. 2007, Kern, K. B., R. W. Hilwig, et al. 2002, Sanders, A. B., K. B. Kern, et al. 2002).

There is much less published data using canine models that is relevant to the question at hand (and none whatsoever in feline models). Bendixen and colleagues did perform a study using a dog model which demonstrated that respiratory acidosis blunts the cardiovascular effects of epinephrine (Bendixen, H. H., M. B. Laver, et al. 1963) suggesting that compression-only CPCR in dogs for more than 4-5 minutes may reduce the effectiveness of one of the most widely used resuscitation drugs. Yakaitis and colleagues demonstrated in a canine model that respiratory acidosis does not alter the defibrillation threshold substantially which suggests that in an arrest due to ventricular fibrillation the use of compression-only methods would not inherently alter energy requirements for defibrillation in dogs (Yakaitis, R. W., J. D. Thomas, et al. 1975). Chandra, et al, did use a canine model to demonstrate that blood oxygenation can be maintained adequately for up to 4 minutes with a compression-only approach to initial resuscitation (Chandra, N. C., K. G. Gruben, et al. 1994).

Taken as a whole, both the clinical and experimental evidence provide conflicting results. In addition, these studies model cardiac arrest in a means that is largely irrelevant to veterinary medicine. Recommendations for resuscitation techniques in regards to compression-only or standard methodology will need to be based on consensus rather than superior evidence at this time.

7. Conclusion

After a review of the evidence regarding the relative merits of compression-only versus standard resuscitation methods, this author would conclude that no true evidence-based recommendation can be made. Nearly all the evidence is from other species (swine, humans) and is almost exclusively modeled in a setting of acute ventricular fibrillation. Moreover, the quantity and quality of the evidence supporting one approach versus the other is roughly similar in its weight. However, the following conclusions might be reached without overstating the evidence:

a) Compression-only CPCR is easier for lay-persons to perform and easier to teach. Thus, when veterinarians are instructing lay-persons over the phone as to how to resuscitate an arrested dog or cat, it would appear appropriate to instruct them to perform chest compressions alone until helps arrives or resuscitation efforts are terminated.
b) Compression-only CPCR often results in improved hemodynamics and results in generally acceptable blood gas values for at least the first 4 minutes following cardiac arrest. In cases of witnessed arrest of presumed cardiac origin the immediate provision of chest compressions should be the priority. Intubation and ventilation can be attempted for the first 4 minutes *while compressions are being performed*.

c) In primary respiratory arrests or prolonged arrests (> 4-5 min) of any origin, *intubation and ventilation should be a priority* and performed in as timely a manner as is possible.

8. Acknowledgement

I acknowledge that my Fauxstralian Domain Chair is the most patient and understanding human being I have ever known. The great thing about being me is that I never have to work with me. What a relief.

9. Citation list

1) SOS-KANTO Study Group (2007). "Cardiopulmonary resuscitation by bystanders with chest compression only (SOS-KANTO): an observational study." Lancet **369**(9565): 920-926.

BACKGROUND: Mouth-to-mouth ventilation is a barrier to bystanders doing cardiopulmonary resuscitation (CPR), but few clinical studies have investigated the efficacy of bystander resuscitation by chest compressions without mouth-to-mouth ventilation (cardiac-only resuscitation). METHODS: We did a prospective, multicentre, observational study of patients who had out-of-hospital cardiac arrest. On arrival at the scene, paramedics assessed the technique of bystander resuscitation. The primary endpoint was favourable neurological outcome 30 days after cardiac arrest. FINDINGS: 4068 adult patients who had out-of-hospital cardiac arrest witnessed by bystanders were included; 439 (11%) received cardiac-only resuscitation from bystanders, 712 (18%) conventional CPR, and 2917 (72%) received no bystander CPR. Any resuscitation attempt was associated with a higher proportion having favourable neurological outcomes than no resuscitation (5.0%vs 2.2%, p<0.0001). Cardiac-only resuscitation resulted in a higher proportion of patients with favourable neurological outcomes than conventional CPR in patients with apnoea (6.2%vs 3.1%; p=0.0195), with shockable rhythm (19.4%vs 11.2%, p=0.041), and with resuscitation that started within 4 min of arrest (10.1%vs 5.1%, p=0.0221). However, there was no evidence for any benefit from the addition of mouth-to-mouth ventilation in any subgroup. The adjusted odds ratio for a favourable neurological outcome after cardiac-only resuscitation was 2.2 (95% CI 1.2-4.2) in patients who received any resuscitation from bystanders. INTERPRETATION: Cardiac-only resuscitation by bystanders is the preferable approach to resuscitation for adult patients with witnessed out-of-hospital cardiac arrest, especially those with apnoea, shockable rhythm, or short periods of untreated arrest.

2) Bendixen, H. H., M. B. Laver, et al. (1963). "Influence of Respiratory Acidosis on Circulatory Effect of Epinephrine in Dogs." Circ Res **13**: 64-70.

No abstract (paper is not in that format)

3) Berg, R. A., R. W. Hilwig, et al. (1999). "Simulated mouth-to-mouth ventilation and chest compressions (bystander cardiopulmonary resuscitation) improves outcome in a swine model of prehospital pediatric asphyxial cardiac arrest." Crit Care Med **27**(9): 1893-1899.

OBJECTIVE: To compare the efficacy of four methods of simulated single-rescuer bystander cardiopulmonary resuscitation (CPR) in a clinically relevant swine model of prehospital pediatric asphyxial cardiac arrest. DESIGN: Prospective, randomized study. SUBJECTS: Thirty-nine anesthetized domestic piglets. INTERVENTIONS: Asphyxial cardiac arrest was produced by clamping the endotracheal tubes of the piglets. For 8 mins of simulated bystander CPR, animals were randomly assigned to the following groups: group 1, chest compressions and simulated mouth-to-mouth ventilation (FI(O2) = 0.17, FI(CO2) = 0.04) (CC+V); group 2, chest compressions only (CC); group 3, simulated mouth-to-mouth ventilation only (V); and group 4, no CPR (control group). Standard advanced life

support was then provided, simulating paramedic arrival. Animals that were successfully resuscitated received 1 hr of intensive care support and were observed for 24 hrs. MEASUREMENTS AND MAIN RESULTS: Electrocardiogram, aortic blood pressure, right atrial blood pressure, and end-tidal CO2 were monitored continuously until the intensive care period ended. Arterial and mixed venous blood gases were measured at baseline, 1 min after cardiac arrest, and 7 mins after cardiac arrest. Minute ventilation was determined during each minute of bystander CPR. Survival and neurologic outcome were determined. Twenty-four-hour survival was attained in eight of 10 group 1 (CC+V) piglets vs. three of 14 group 2 (CC) piglets ($p < or = .01$), one of seven group 3 (V) piglets ($p < or = .05$), and two of eight group 4 (control) piglets ($p < or = .05$). Twenty-four-hour neurologically normal survival occurred in seven of 10 group 1 (CC+V) piglets vs. one of 14 group 2 (CC) piglets ($p < or = .01$), one of seven group 3 (V) piglets ($p < or = .05$), and none of eight group 4 (control) piglets ($p < or = .01$). Arterial oxygenation and pH were markedly better during CPR in group 1 than in group 2. Within 5 mins of bystander CPR, six of 10 group 1 (CC+V) piglets attained sustained return of spontaneous circulation vs. only two of 14 group 2 (CC) piglets and none of the piglets in the other two groups ($p < or = .05$ for all groups). CONCLUSIONS: In this pediatric asphyxial model of prehospital single-rescuer bystander CPR, chest compressions plus simulated mouth-to-mouth ventilation improved systemic oxygenation, coronary perfusion pressures, early return of spontaneous circulation, and 24-hr survival compared with the other three approaches.

4) Berg, R. A., R. W. Hilwig, et al. (2000). ""Bystander" chest compressions and assisted ventilation independently improve outcome from piglet asphyxial pulseless "cardiac arrest"." Circulation **101**(14): 1743-1748.

BACKGROUND: Bystander cardiopulmonary resuscitation (CPR) without assisted ventilation may be as effective as CPR with assisted ventilation for ventricular fibrillatory cardiac arrests. However, chest compressions alone or ventilation alone is not effective for complete asphyxial cardiac arrests (loss of aortic pulsations). The objective of this investigation was to determine whether these techniques can independently improve outcome at an earlier stage of the asphyxial process. METHODS AND RESULTS: After induction of anesthesia, 40 piglets (11.5+/-0.3 kg) underwent endotracheal tube clamping (6.8+/-0.3 minutes) until simulated pulselessness, defined as aortic systolic pressure <50 mm Hg. For the 8-minute "bystander CPR" period, animals were randomly assigned to chest compressions and assisted ventilation (CC+V), chest compressions only (CC), assisted ventilation only (V), or no bystander CPR (control group). Return of spontaneous circulation occurred during the first 2 minutes of bystander CPR in 10 of 10 CC+V piglets, 6 of 10 V piglets, 4 of 10 CC piglets, and none of the controls (CC+V or V versus controls, $P<0.01$; CC+V versus CC and V combined, $P=0.01$). During the first minute of CPR, arterial and mixed venous blood gases were superior in the 3 experimental groups compared with the controls. Twenty-four-hour survival was similarly superior in the 3 experimental groups compared with the controls (8 of 10, 6 of 10, 5 of 10, and 0 of 10, $P<0.05$ each). CONCLUSIONS: Bystander CPR with CC+V improves outcome in the early stages of apparent pulseless asphyxial cardiac arrest. In addition, this study establishes that bystander CPR with CC or V can independently improve outcome.

5) Berg, R. A., K. B. Kern, et al. (1997). "Assisted ventilation does not improve outcome in a porcine model of single-rescuer bystander cardiopulmonary resuscitation." Circulation **95**(6): 1635-1641.

BACKGROUND: Mouth-to-mouth rescue breathing is a barrier to the performance of bystander cardiopulmonary resuscitation (CPR). We evaluated the need for assisted ventilation during simulated single-rescuer bystander CPR in a swine model of prehospital cardiac arrest. METHODS AND RESULTS: Five minutes after ventricular fibrillation, swine were randomly assigned to 8 minutes of hand-bag-valve ventilation with 17% oxygen and 4% carbon dioxide plus chest compressions (CC + V), chest compressions only (CC), or no CPR (control group). Standard advanced life support was then provided. Animals successfully resuscitated received 1 hour of intensive care support and were observed for 24 hours. All 10 CC animals, 9 of the 10 CC + V animals, and 4 of the 6 control animals attained return of spontaneous circulation. Five of the 10 CC animals, 6 of the 10 CC + V animals, and none of the 6 control animals survived for 24 hours (CC versus controls, $P = .058$; CC + V versus controls, $P < .03$). All 24-hour survivors were normal or nearly normal neurologically. CONCLUSIONS: In this model

of prehospital single-rescuer bystander CPR, successful initial resuscitation, 24-hour survival, and neurological outcome were similar after chest compressions only or chest compressions plus assisted ventilation. Both techniques tended to improve outcome compared with no bystander CPR.

6) Berg, R. A., K. B. Kern, et al. (1997). "Assisted ventilation during 'bystander' CPR in a swine acute myocardial infarction model does not improve outcome." Circulation **96**(12): 4364-4371.

BACKGROUND: Mouth-to-mouth rescue breathing is a barrier to the performance of bystander cardiopulmonary resuscitation (CPR). We evaluated the need for assisted ventilation during simulated single-rescuer bystander CPR in a swine myocardial infarction model of prehospital cardiac arrest. METHODS AND RESULTS: Steel cylinders were placed in the mid left anterior descending coronary arteries of 43 swine. Two minutes after ventricular fibrillation, animals were randomly assigned to 10 minutes of hand-bag-valve ventilation with 17% oxygen and 4% carbon dioxide plus chest compressions (CC+V), chest compressions only (CC), or no CPR (control group). Standard advanced life support was then provided. Animals successfully resuscitated received 1 hour of intensive care support and were observed for 24 hours. Five of 14 CC animals, 3 of 15 CC+V animals, and 1 of 14 controls survived for 24 hours (CC versus controls, P=.07). Myocardial oxygen delivery and consumption were greater among surviving animals than nonsurvivors but did not differ between CC and CC+V animals. CONCLUSIONS: In this acute myocardial infarction model of prehospital single-rescuer bystander CPR, assisted ventilation did not improve outcome.

7) Berg, R. A., K. B. Kern, et al. (1993). "Bystander cardiopulmonary resuscitation. Is ventilation necessary?" Circulation **88**(4 Pt 1): 1907-1915.

BACKGROUND: Prompt initiation of bystander cardiopulmonary resuscitation (CPR) improves survival. Basic life support with mouth-to-mouth ventilation and chest compressions is intimidating, difficult to remember, and difficult to perform. Chest compressions alone can be easily taught, easily remembered, easily performed, adequately taught by dispatcher-delivered telephone instruction, and more readily accepted by the public. The principal objective of this study was to evaluate the need for ventilation during CPR in a clinically relevant swine model of prehospital witnessed cardiac arrest. METHODS AND RESULTS: Thirty seconds after ventricular fibrillation, swine were randomly assigned to 12 minutes of chest compressions plus mechanical ventilation (group A), chest compressions only (group B), or no CPR (group C). Standard advanced cardiac life support was then provided. Animals successfully resuscitated were supported for 2 hours in an intensive care setting, and then observed for 24 hours. All 16 swine in groups A and B were successfully resuscitated and neurologically normal at 24 hours, whereas only 2 of 8 group C animals survived for 24 hours ($P < .001$, Fisher's exact test). One of the 2 group C survivors was comatose and unresponsive. CONCLUSIONS: In this swine model of witnessed prehospital cardiac arrest, the survival and neurological outcome data establish that prompt initiation of chest compressions alone appears to be as effective as chest compressions plus ventilation and that both techniques of bystander CPR markedly improve outcome compared with no bystander CPR.

8) Berg, R. A., A. B. Sanders, et al. (2001). "Adverse hemodynamic effects of interrupting chest compressions for rescue breathing during cardiopulmonary resuscitation for ventricular fibrillation cardiac arrest." Circulation **104**(20): 2465-2470.

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.

9) Bobrow, B. J., L. L. Clark, et al. (2008). "Minimally interrupted cardiac resuscitation by emergency medical services for out-of-hospital cardiac arrest." JAMA **299**(10): 1158-1165.

CONTEXT: Out-of-hospital cardiac arrest is a major public health problem. OBJECTIVE: To investigate whether the survival of patients with out-of-hospital cardiac arrest would improve with minimally interrupted cardiac resuscitation (MICR), an alternate emergency medical services (EMS) protocol. DESIGN, SETTING, AND PATIENTS: A prospective study of survival-to-hospital discharge between January 1, 2005, and November 22, 2007. Patients with out-of-hospital cardiac arrests in 2 metropolitan cities in Arizona before and after MICR training of fire department emergency medical personnel were assessed. In a second analysis of protocol compliance, patients from the 2 metropolitan cities and 60 additional fire departments in Arizona who actually received MICR were compared with patients who did not receive MICR but received standard advanced life support. INTERVENTION: Instruction for EMS personnel in MICR, an approach that includes an initial series of 200 uninterrupted chest compressions, rhythm analysis with a single shock, 200 immediate postshock chest compressions before pulse check or rhythm reanalysis, early administration of epinephrine, and delayed endotracheal intubation. MAIN OUTCOME MEASURE: Survival-to-hospital discharge. RESULTS: Among the 886 patients in the 2 metropolitan cities, survival-to-hospital discharge increased from 1.8% (4/218) before MICR training to 5.4% (36/668) after MICR training (odds ratio [OR], 3.0; 95% confidence interval [CI], 1.1-8.9). In the subgroup of 174 patients with witnessed cardiac arrest and ventricular fibrillation, survival increased from 4.7% (2/43) before MICR training to 17.6% (23/131) after MICR training (OR, 8.6; 95% CI, 1.8-42.0). In the analysis of MICR protocol compliance involving 2460 patients with cardiac arrest, survival was significantly better among patients who received MICR than those who did not (9.1% [60/661] vs 3.8% [69/1799]; OR, 2.7; 95% CI, 1.9-4.1), as well as patients with witnessed ventricular fibrillation (28.4% [40/141] vs 11.9% [46/387]; OR, 3.4; 95% CI, 2.0-5.8). CONCLUSIONS: Survival-to-hospital discharge of patients with out-of-hospital cardiac arrest increased after implementation of MICR as an alternate EMS protocol. These results need to be confirmed in a randomized trial.

10) Bobrow, B. J., D. W. Spaite, et al. (2010). "Chest compression-only CPR by lay rescuers and survival from out-of-hospital cardiac arrest." JAMA **304**(13): 1447-1454.

CONTEXT: Chest compression-only bystander cardiopulmonary resuscitation (CPR) may be as effective as conventional CPR with rescue breathing for out-of-hospital cardiac arrest. OBJECTIVE: To investigate the survival of patients with out-of-hospital cardiac arrest using compression-only CPR (COCPR) compared with conventional CPR. DESIGN, SETTING, AND PATIENTS: A 5-year prospective observational cohort study of survival in patients at least 18 years old with out-of-hospital cardiac arrest between January 1, 2005, and December 31, 2009, in Arizona. The relationship between layperson bystander CPR and survival to hospital discharge was evaluated using multivariable logistic regression. MAIN OUTCOME MEASURE: Survival to hospital discharge. RESULTS: Among 5272 adults with out-of-hospital cardiac arrest of cardiac etiology not observed by responding emergency medical personnel, 779 were excluded because bystander CPR was provided by a health care professional or the arrest occurred in a medical facility. A total of 4415 met all inclusion criteria for analysis, including 2900 who received no bystander CPR, 666 who received conventional CPR, and 849 who received COCPR. Rates of survival to hospital discharge were 5.2% (95% confidence interval [CI], 4.4%-6.0%) for the no bystander CPR group, 7.8% (95% CI, 5.8%-9.8%) for conventional CPR, and 13.3% (95% CI, 11.0%-15.6%) for COCPR. The adjusted odds ratio (AOR) for survival for conventional CPR vs no CPR was 0.99 (95% CI, 0.69-1.43), for COCPR vs no CPR, 1.59 (95% CI, 1.18-2.13), and for COCPR vs conventional CPR, 1.60 (95% CI, 1.08-2.35). From 2005 to 2009, lay rescuer CPR increased

from 28.2% (95% CI, 24.6%-31.8%) to 39.9% (95% CI, 36.8%-42.9%; P < .001); the proportion of CPR that was COCPR increased from 19.6% (95% CI, 13.6%-25.7%) to 75.9% (95% CI, 71.7%-80.1%; P < .001). Overall survival increased from 3.7% (95% CI, 2.2%-5.2%) to 9.8% (95% CI, 8.0%-11.6%; P < .001). CONCLUSION: Among patients with out-of-hospital cardiac arrest, layperson compression-only CPR was associated with increased survival compared with conventional CPR and no bystander CPR in this setting with public endorsement of chest compression-only CPR.

11) Bohm, K., M. Rosenqvist, et al. (2007). "Survival is similar after standard treatment and chest compression only in out-of-hospital bystander cardiopulmonary resuscitation." Circulation **116**(25): 2908-2912.

BACKGROUND: We sought to compare the 1-month survival rates among patients after out-of-hospital cardiac arrest who had been given bystander cardiopulmonary resuscitation (CPR) in relation to whether they had received standard CPR with chest compression plus mouth-to-mouth ventilation or chest compression only. METHODS AND RESULTS: All patients with out-of-hospital cardiac arrest who received bystander CPR and who were reported to the Swedish Cardiac Arrest Register between 1990 and 2005 were included. Crew-witnessed cases were excluded. Among 11,275 patients, 73% (n=8209) received standard CPR, and 10% (n=1145) received chest compression only. There was no significant difference in 1-month survival between patients who received standard CPR (1-month survival=7.2%) and those who received chest compression only (1-month survival=6.7%). CONCLUSIONS: Among patients with out-of-hospital cardiac arrest who received bystander CPR, there was no significant difference in 1-month survival between a standard CPR program with chest compression plus mouth-to-mouth ventilation and a simplified version of CPR with chest compression only.

12) Chandra, N. C., K. G. Gruben, et al. (1994). "Observations of ventilation during resuscitation in a canine model." Circulation **90**(6): 3070-3075.

BACKGROUND: Fear of infection limits the willingness of laymen to do cardiopulmonary resuscitation (CPR). This study assessed the time course of change in arterial blood gases during resuscitation with only chest compression (no ventilation) in an effort to identify the time for which ventilation could be deferred. METHODS AND RESULTS: Aortic pressures and arterial blood gases were monitored in seven 20- to 30-kg dogs in ventricular fibrillation (VF) at 2-minute intervals during chest compression alone (no ventilation) at 80 to 100 compressions per minute. Before the induction of ventricular fibrillation, all animals were intubated and ventilated with room air, 10 mL/kg. The endotracheal tube was removed when VF was induced. Pre-VF arterial pH, PCO2, and O2 saturation were (mean +/- SEM) 7.39 +/- 0.02, 27.0 +/- 1.5 mm Hg, and 97.5 +/- 0.5%, respectively, with aortic pressures being 143.2 +/- 5.7/116.2 +/- 4.6 mm Hg. At 4 minutes of chest compression alone, the corresponding values were 7.39 +/- 0.03, 24.3 +/- 3.1 mm Hg, and 93.9 +/- 3.0%, with an arterial pressure of 48.1 +/- 7.7/22.6 +/- 3.9 mm Hg. Mean minute ventilation during the fourth minute of CPR, measured with a face mask-pneumotachometer, was 5.2 +/- 1.1 L/min. CONCLUSIONS: These data suggest that in the dog model of witnessed arrest, chest compression alone during CPR can maintain adequate gas exchange to sustain O2 saturation > 90% for > 4 minutes. The need for immediate ventilation during witnessed arrest should be reexamined.

13) Dorph, E., L. Wik, 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**(3): 309-318.

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.

14) Engoren, M., M. C. Plewa, et al. (1997). "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 **29**(5): 607-615.

STUDY OBJECTIVE: To assess the effects of simulated mouth-to-mouth (MTM) ventilation on blood gases, gas exchange, and minute ventilation during external cardiac compression (ECC) or active compression-decompression (ACD) in a swine model of witnessed cardiac arrest and bystander CPR. METHODS: Twenty swine were anesthetized, intubated, ventilated with room air, and monitored for aortic and right atrial pressure and blood gas sampling. After 1 minute of ventricular fibrillation cardiac arrest, ECC or ACD was manually performed at a rate of 100 per minute for 12 minutes. Animals in the room air group had their endotracheal tubes open to air, whereas those in the MTM group were mechanically ventilated with a gas mixture of 16% oxygen and 4% carbon dioxide. Arterial and venous PO2, PCO2, and pH values; oxygen consumption (VO2); carbon dioxide production (VCO2); and minute ventilation (VE) were measured at baseline and 1, 5, 9, and 13 minutes after induction of cardiac arrest. RESULTS: MTM ventilation did not alter arterial or venous PO2 values in comparison with room air but did result in higher arterial PCO2 values at 5 and 9 minutes (although the mean PCO2 was 40 mm Hg or less [5.3 kPa] in all groups) and significant central venous hypercarbic acidosis at 9 and 13 minutes. Arterial PO2 values were greater in the ACD than the ECC groups at 5, 9, and 13 minutes, although all groups maintained acceptable PO2 (mean values > or = 60 mm Hg [8.0 kPa]) through 9 minutes of CPR and through 13 minutes in all but the ECC-room air group. PCO2 values were lower in the ACD groups beyond 1 minute, with the ACD-room air group showing extreme hyperventilation (mean PCO2 < or = 20 mm Hg [2.7 kPa]). MTM ventilation resulted in negative VO2 and VCO2 for the first few minutes, reflecting changes in pulmonary gas stores. As equilibrium was approached, VO2 and VCO2 approached zero in all groups, reflecting low cardiac output. MTM ventilation did not improve VE over room air at any time during ACD. It did improve VE during ECC, but only at the 12th interval. CONCLUSION: In this swine model of witnessed CPR, simulated MTM ventilation was not beneficial for blood gases, gas exchange, or ventilation during ECC or ACD CPR.

15) Ewy, G. A., R. W. Hilwig, et al. (2010). "Continuous chest compression resuscitation in arrested swine with upper airway inspiratory obstruction." Resuscitation **81**(5): 585-590.

BACKGROUND: This study was designed to compare 24-h survival rates and neurological function of swine in cardiac arrest treated with one of three forms of simulated basic life support CPR. METHODS: Thirty swine were randomized equally among three experimental groups to receive either 30:2 CPR with an unobstructed endotracheal tube (ET) or continuous chest compression (CCC) CPR with an unobstructed ET or CCC CPR with a collapsable rubber sleeve on the ET allowing air outflow but completely restricting air inflow. The swine were anesthetized but not paralyzed. Two min of untreated VF was followed by 9 min of simulated single rescuer bystander CPR. In the 30:2 CPR group, each set of 30 chest compressions was followed by a 15-s pause to simulate the realistic duration of interrupted chest compressions required for a single rescuer to deliver 2 mouth-to-mouth ventilations. The other two groups were provided continuous chest compressions (CCC) without assisted ventilations. At 11 min post-arrest a biphasic defibrillation shock (150 J) was administered followed by a period of advanced cardiac life support. RESULTS: In the 30:2 group, 8 of 10 animals had good neurological function at 24-h post-resuscitation. In the CCC open airway group, 10 of 10, and in the CCC inspiratory obstructed group, 9 of 10. The number of shocks ($P<0.05$) and epinephrine doses ($P<0.05$) required for ROSC was

greater in the 30:2 CPR group than in the other two groups. CONCLUSIONS: There were no differences in 24-h survival with good neurological function among these three different CPR protocols.

16) Ewy, G. A., M. Zuercher, et al. (2007). "Improved neurological outcome with continuous chest compressions compared with 30:2 compressions-to-ventilations cardiopulmonary resuscitation in a realistic swine model of out-of-hospital cardiac arrest." Circulation **116**(22): 2525-2530.

BACKGROUND: The 2005 Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care changed the previous ventilations-to-chest-compression algorithm for bystander cardiopulmonary resuscitation (CPR) from 2 ventilations before each 15 chest compressions (2:15 CPR) to 30 chest compressions before 2 ventilations (30:2 CPR). It was acknowledged in the guidelines that the change was based on a consensus rather than clear evidence. This study was designed to compare 24-hour neurologically normal survival between the initial applications of continuous chest compressions without assisted ventilations with 30:2 CPR in a swine model of witnessed out-of-hospital ventricular fibrillation cardiac arrest. METHODS AND RESULTS: Sixty-four animals underwent 12 minutes of ventricular fibrillation before defibrillation attempts. They were divided into 4 groups, each with increasing durations (3, 4, 5, and 6 minutes, respectively) of untreated ventricular fibrillation before the initiation of bystander resuscitation consisting of either continuous chest compression or 30:2 CPR. After the various untreated ventricular durations plus bystander resuscitation durations, all animals were given the first defibrillation attempt 12 minutes after the induction of ventricular fibrillation, followed by the 2005 guideline-recommended advanced cardiac life support. Neurologically normal survival at 24 hours after resuscitation was observed in 23 of 33 (70%) of the animals in the continuous chest compression groups but in only 13 of 31 (42%) of the 30:2 CPR groups (P=0.025). CONCLUSIONS: In a realistic model of out-of-hospital ventricular fibrillation cardiac arrest, initial bystander administration of continuous chest compressions without assisted ventilations resulted in significantly better 24-hour postresuscitation neurologically normal survival than did the initial bystander administration of 2005 guideline-recommended 30:2 CPR.

17) Gundersen, K., J. T. Kvaloy, et al. (2009). "Development of the probability of return of spontaneous circulation in intervals without chest compressions during out-of-hospital cardiac arrest: an observational study." BMC Med **7**: 6.

BACKGROUND: One of the factors that limits survival from out-of-hospital cardiac arrest is the interruption of chest compressions. During ventricular fibrillation and tachycardia the electrocardiogram reflects the probability of return of spontaneous circulation associated with defibrillation. We have used this in the current study to quantify in detail the effects of interrupting chest compressions. METHODS: From an electrocardiogram database we identified all intervals without chest compressions that followed an interval with compressions, and where the patients had ventricular fibrillation or tachycardia. By calculating the mean-slope (a predictor of the return of spontaneous circulation) of the electrocardiogram for each 2-second window, and using a linear mixed-effects statistical model, we quantified the decline of mean-slope with time. Further, a mapping from mean-slope to probability of return of spontaneous circulation was obtained from a second dataset and using this we were able to estimate the expected development of the probability of return of spontaneous circulation for cases at different levels. RESULTS: From 911 intervals without chest compressions, 5138 analysis windows were identified. The results show that cases with the probability of return of spontaneous circulation values 0.35, 0.1 and 0.05, 3 seconds into an interval in the mean will have probability of return of spontaneous circulation values 0.26 (0.24-0.29), 0.077 (0.070-0.085) and 0.040(0.036-0.045), respectively, 27 seconds into the interval (95% confidence intervals in parenthesis). CONCLUSION: During pre-shock pauses in chest compressions mean probability of return of spontaneous circulation decreases in a steady manner for cases at all initial levels. Regardless of initial level there is a relative decrease in the probability of return of spontaneous circulation of about 23% from 3 to 27 seconds into such a pause.

18) Hallstrom, A., L. Cobb, et al. (2000). "Cardiopulmonary resuscitation by chest compression alone or with mouth-to-mouth ventilation." N Engl J Med **342**(21): 1546-1553.

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.

19) Hallstrom, A. P. (2000). "Dispatcher-assisted "phone" cardiopulmonary resuscitation by chest compression alone or with mouth-to-mouth ventilation." Crit Care Med **28**(11 Suppl): N190-192.

Based on both animal studies and field studies of the process and intermediate outcomes related to cardiopulmonary resuscitation (CPR), we initiated a randomized trial of dispatcher-assisted CPR, with the intervention arm receiving instructions for chest compression only and the control arm receiving standard instructions for airway maintenance ventilation, and chest compression. Of 241 patents randomized to chest compression instructions only, 35 survived (14.6%) compared with 29 of 279 (10.4%) patients in the control arm (p = .09). These results may have implications for future guidelines and teaching CPR.

20) Hupfl, M., H. F. Selig, et al. (2010). "Chest-compression-only versus standard cardiopulmonary resuscitation: a meta-analysis." Lancet **376**(9752): 1552-1557.

BACKGROUND: In out-of-hospital cardiac arrest, dispatcher-assisted chest-compression-only bystander CPR might be superior to standard bystander CPR (chest compression plus rescue ventilation), but trial findings have not shown significantly improved outcomes. We aimed to establish the association of chest-compression-only CPR with survival in patients with out-of-hospital cardiac arrest. METHODS: Medline and Embase were systematically reviewed for studies published between January, 1985, and August, 2010, in which chest-compression-only bystander CPR was compared with standard bystander CPR for adult patients with out-of-hospital cardiac arrest. In the primary meta-analysis, we included trials in which patients were randomly allocated to receive one of the two CPR techniques, according to dispatcher instructions; and in the secondary meta-analysis, we included observational cohort studies of chest-compression-only CPR. All studies had to supply survival data. The primary outcome was survival to hospital discharge. A fixed-effects model was used for both meta-analyses because of an absence of heterogeneity among the studies (I(2)=0%). FINDINGS: In the primary meta-analysis, pooled data from three randomised trials showed that chest-compression-only CPR was associated with improved chance of survival compared with standard CPR (14% [211/1500] vs 12% [178/1531]; risk ratio 1.22, 95% CI 1.01-1.46). The absolute increase in survival was 2.4% (95% CI 0.1-4.9), and the number needed to treat was 41 (95% CI 20-1250). In the secondary meta-analysis of seven observational cohort studies, no difference was recorded between the two CPR techniques (8% [223/2731] vs 8% [863/11 152]; risk ratio 0.96, 95% CI 0.83-1.11). INTERPRETATION: For adults with out-of-hospital cardiac arrest, instructions

to bystanders from emergency medical services dispatch should focus on chest-compression-only CPR. FUNDING: US National Institutes of Health and American Heart Association.

21) Idris, A. H., L. B. Becker, et al. (1994). "Effect of ventilation on resuscitation in an animal model of cardiac arrest." Circulation **90**(6): 3063-3069.

BACKGROUND: The need for ventilation during the initial management of cardiac arrest is an important public health problem that is being debated. The present study was designed to determine whether ventilation affects return of spontaneous circulation from cardiac arrest in a swine model with an interval of untreated ventricular fibrillation of 6 minutes, as reported in witnessed out-of-hospital human cardiac arrest. METHODS AND RESULTS: Twenty-four animals were randomly assigned to two groups: one that received ventilation during the first 10 minutes of chest compression and one that did not. Coronary perfusion pressure and minute ventilation were continuously recorded. Arterial and mixed venous blood gases were measured at intervals. Return of spontaneous circulation was defined prospectively as an aortic systolic blood pressure of > 80 mm Hg for > 5 minutes and was the primary outcome variable. All animals were anesthetized, paralyzed, and intubated. Ventricular fibrillation was induced and persisted for 6 minutes without chest compression, followed by mechanical chest compression for 10 minutes and then attempted defibrillation. Animals without return of spontaneous circulation were given epinephrine, ventilation, and chest compression for an additional 3 minutes. Defibrillation was again attempted, and animals were assessed for return of spontaneous circulation. There were no significant differences between the two groups in baseline prearrest mean cardiac index, coronary perfusion pressure, or arterial and mixed venous blood gases. However, after 9 minutes of chest compression, significant differences were noted between the ventilated and nonventilated groups. The nonventilated group had significantly ($P < .05$) lower mean arterial PO_2 (38 +/- 17 mm Hg compared with 216 +/- 104 mm Hg) and higher PCO_2 (62 +/- 16 mm Hg compared with 35 +/- 8 mm Hg), lower mixed venous PO_2 (15 +/- 7 mm Hg compared with 60 +/- 7 mm Hg). Nine of 12 (75%) of the ventilated animals, and only 1 of 12 (8%) of the nonventilated animals had return of spontaneous circulation after cardiac arrest ($P < .002$). CONCLUSIONS: In this animal model of cardiac arrest, ventilation was important for resuscitation. The importance of ventilation could be related to the prolonged duration of untreated ventricular fibrillation and the significantly greater hypoxia and hypercarbic acidosis found in the nonventilated animals.

22) Idris, A. H., V. Wenzel, et al. (1995). "Does hypoxia or hypercarbia independently affect resuscitation from cardiac arrest?" Chest **108**(2): 522-528.

STUDY OBJECTIVE: In a previous cardiopulmonary resuscitation (CPR) study in swine, ventilation was associated with improved rate of return of spontaneous circulation (ROSC) compared with nonventilated animals, which had greater hypoxia and hypercarbic acidosis. We used the same model to determine the independent effect of hypoxia and hypercarbic acidosis on ROSC after cardiac arrest. DESIGN: Laboratory model of cardiac arrest. SETTING: University teaching hospital laboratory. PARTICIPANTS: Domestic swine (23 to 61 kg). INTERVENTIONS: Twenty-four swine were randomly assigned to three groups receiving ventilation during CPR with 85% O_2/15% N_2 (control), 95% O_2/5% CO_2 (hypercarbia), or 10% O_2/90% N_2 (hypoxia). All animals had ventricular fibrillation for 6 min without CPR, then CPR with one of the ventilation gases for 10 min, then defibrillation. Animals without ROSC received epinephrine, 85% O_2, CPR for another 3 min, and defibrillation. MEASUREMENTS AND RESULTS: During the tenth minute of CPR, the hypercarbic group had more mean (SD) arterial hypercarbia than the control group (PCO_2, 47 +/- 6, compared with 34 +/- 6; $p < 0.01$), and greater mixed venous hypercarbia (PCO_2, 72 +/- 14, compared with 59 +/- 8; $p < 0.05$), while mean arterial and mixed venous PO_2 was not significantly different. The hypoxic group had significantly less mean arterial (43 +/- 9 compared with 228 +/- 103 mm Hg) and mixed venous (22 +/- 5 compared with 35 +/- 7 mm Hg) PO_2 when compared with the control group ($p < 0.01$), while mean arterial and mixed venous PCO_2 were not significantly different. Thus, the model succeeded in producing isolated hypercarbia without hypoxia in the hypercarbic group and isolated hypoxia without hypercarbia in the hypoxic group. The rate of ROSC was 6/8 (75%) for the control group, 1/8 (13%) for the hypercarbic group, and 1/8 (13%) for the hypoxic group ($p < 0.02$). CONCLUSIONS: Both hypoxia and hypercarbia

independently had an adverse effect on resuscitation from cardiac arrest. In this model with a prolonged interval of untreated cardiac arrest, adequate ventilation was important for resuscitation.

23) Iwami, T., T. Kawamura, et al. (2007). "Effectiveness of bystander-initiated cardiac-only resuscitation for patients with out-of-hospital cardiac arrest." Circulation **116**(25): 2900-2907.

BACKGROUND: Previous animal and clinical studies suggest that bystander-initiated cardiac-only resuscitation may be superior to conventional cardiopulmonary resuscitation (CPR) for out-of-hospital cardiac arrests. Our hypothesis was that both cardiac-only bystander resuscitation and conventional bystander CPR would improve outcomes from out-of-hospital cardiac arrests of < or = 15 minutes' duration, whereas the addition of rescue breathing would improve outcomes for cardiac arrests lasting > 15 minutes. METHODS AND RESULTS: We carried out a prospective, population-based, observational study involving consecutive patients with emergency responder resuscitation attempts from May 1, 1998, through April 30, 2003. The primary outcome measure was 1-year survival with favorable neurological outcome. Multivariable logistic regression analysis was performed to evaluate the relationship between type of CPR and outcomes. Among the 4902 witnessed cardiac arrests, 783 received conventional CPR, and 544 received cardiac-only resuscitation. Excluding very-long-duration cardiac arrests (> 15 minutes), the cardiac-only resuscitation yielded a higher rate of 1-year survival with favorable neurological outcome than no bystander CPR (4.3% versus 2.5%; odds ratio, 1.72; 95% CI, 1.01 to 2.95), and conventional CPR showed similar effectiveness (4.1%; odds ratio, 1.57; 95% CI, 0.95 to 2.60). For the very-long-duration arrests, neurologically favorable 1-year survival was greater in the conventional CPR group, but there were few survivors regardless of the type of bystander CPR (0.3% [2 of 624], 0% [0 of 92], and 2.2% [3 of 139] in the no bystander CPR, cardiac-only CPR, and conventional CPR groups, respectively; P<0.05). CONCLUSIONS: Bystander-initiated cardiac-only resuscitation and conventional CPR are similarly effective for most adult out-of-hospital cardiac arrests. For very prolonged cardiac arrests, the addition of rescue breathing may be of some help.

24) Kellum, M. J., K. W. Kennedy, et al. (2008). "Cardiocerebral resuscitation improves neurologically intact survival of patients with out-of-hospital cardiac arrest." Ann Emerg Med **52**(3): 244-252.

STUDY OBJECTIVE: In an effort to improve neurologically normal survival of victims of cardiac arrest, a new out-of-hospital protocol was implemented by the emergency medical system medical directors in 2 south-central rural Wisconsin counties. The project was undertaken because the existing guidelines for care of such patients, despite their international scope and periodic updates, had not substantially improved survival rates for such patients during nearly 4 decades. METHODS: The neurologic status at or shortly after discharge was documented for adult patients with a witnessed collapse and an initially shockable rhythm. Patients during two 3-year periods were compared. During the 2001 through 2003 period, in which the 2000 American Heart Association guidelines were used, data were collected retrospectively. During the mid-2004 through mid-2007 period, patients were treated according to the principles of cardiocerebral resuscitation. Data for these patients were collected prospectively. Cerebral performance category scores were used to define the neurologic status of survivors, and a score of 1 was considered as "intact" survival. RESULTS: In the 3 years preceding the change in protocol, there were 92 witnessed arrests with an initially shockable rhythm. Eighteen patients survived (20%) and 14 (15%) were neurologically intact. During the 3 years after implementation of the new protocol, there were 89 such patients. Forty-two (47%) survived and 35 (39%) were neurologically intact. CONCLUSION: In adult patients with a witnessed cardiac arrest and an initially shockable rhythm, implementation of an out-of-hospital treatment protocol based on the principles of cardiocerebral resuscitation was associated with a dramatic improvement in neurologically intact survival.

25) Kellum, M. J., K. W. Kennedy, et al. (2006). "Cardiocerebral resuscitation improves survival of patients with out-of-hospital cardiac arrest." Am J Med **119**(4): 335-340.

PURPOSE: The guidelines for cardiopulmonary resuscitation (CPR) have been in place for decades; but despite their international scope and periodic updates, there has been little improvement in survival rates in out-of-hospital cardiac arrest for patients who did not receive early defibrillation. The Emergency Medical Service directors in 2 rural Wisconsin counties initiated a new protocol for the pre-hospital

management of adult cardiac arrest victims in an attempt to improve survival rates. The results observed after implementation of this protocol are presented and compared with those observed during a three-year period that preceded initiation of the project. METHODS: The protocol, based upon the principles of cardiocerebral resuscitation, was significantly different from the standard CPR protocol. A major objective was to minimize interruptions of chest compressions. Each defibrillation, including the first, was preceded by 200 uninterrupted chest compressions. Single shocks, rather than stacked shocks, were utilized. Post shock rhythm and pulse checks were eliminated, and chest compressions were resumed immediately after a shock was delivered. Initial airway management was limited to an oral pharyngeal device and supplemental oxygen. If the arrest was witnessed, assisted ventilations and intubation were delayed until either a return of spontaneous circulation or until three series of "compressions + analysis +/- shock" were completed. RESULTS: In the 3 years preceding the change in protocol, where standard CPR was utilized, there were 92 witnessed out-of-hospital adult cardiac arrests with an initially shockable rhythm. Eighteen patients survived, and 14 of 92 (15%) were neurologically intact. After implementing the new protocol in early 2004, there were 33 witnessed out-of-hospital adult cardiac arrests with an initially shockable rhythm. Nineteen survived, and 16 of 33 (48%) were neurologically normal. Differences in both total and neurologically normal survival are significant (chi-squared = 0.001). CONCLUSION: Instituting the new cardiocerebral resuscitation protocol for managing prehospital cardiac arrest improved survival of adult patients with witnessed cardiac arrest and an initially shockable rhythm.

26) Kern, K. B., R. W. Hilwig, et al. (1998). "Efficacy of chest compression-only BLS CPR in the presence of an occluded airway." Resuscitation **39**(3): 179-188.

Reluctance of the lay public to perform bystander CPR is becoming an increasingly worrisome problem in the USA. Most bystanders who admit such reluctance concede that fear of contagious disease from mouth-to-mouth contact is what keeps them from performing basic life support. Animal models of prehospital cardiac arrest indicates that 24-h survival is essentially as good with chest compression-only CPR as with chest compressions and assisted ventilation. This simpler technique is an attractive alternative strategy for encouraging more bystander participation. Such experimental studies have been criticized as irrelevant however secondary to differences between human and porcine airway mechanics. This study examined the effect of chest compression-only CPR under the worst possible circumstances where the airway was totally occluded. After 6 min of either standard CPR including ventilation with a patent airway or chest compressions-only with a totally occluded airway, no difference in 24 h survival was found (10/10 vs. 9/10). As anticipated arterial blood gases were not as good, but hemodynamics produced were better with chest compression-only CPR ($P < 0.05$). Chest compression-only CPR, even with a totally occluded airway, is as good as standard CPR for successful outcome following 6.5 min of cardiac arrest. Such a strategy for the first minutes of cardiac arrest, particularly before professional help arrives, has several advantages including increased acceptability to the lay public.

27) Kern, K. B., R. W. Hilwig, et al. (2002). "Importance of continuous chest compressions during cardiopulmonary resuscitation: improved outcome during a simulated single lay-rescuer scenario." Circulation **105**(5): 645-649.

BACKGROUND: Interruptions to chest compression-generated blood flow during cardiopulmonary resuscitation (CPR) are detrimental. Data show that such interruptions for mouth-to-mouth ventilation require a period of "rebuilding" of coronary perfusion pressure to obtain the level achieved before the interruption. Whether such hemodynamic compromise from pausing to ventilate is enough to affect outcome is unknown. METHODS AND RESULTS: Thirty swine (weight 35 +/- 2 kg) underwent 3 minutes of untreated ventricular fibrillation before 12 minutes of basic life support CPR. Animals were randomized to receive either standard airway (A), breathing (B), and compression (C) CPR with expired-gas ventilation in a 15:2 compression-to-ventilation ratio or continuous chest compression CPR. Those randomized to the standard 15:2 group had no chest compressions for a period of 16 seconds each time the 2 ventilations were delivered. Defibrillation was attempted at 15 minutes of cardiac arrest. All resuscitated animals were supported in an intensive care environment for 1 hour, then in a maintenance facility for 24 hours. The primary end point of neurologically normal 24-hour survival was significantly better in the experimental group receiving continuous chest compression CPR (12 of 15 versus 2 of 15;

P<0.0001). CONCLUSIONS: Mouth-to-mouth ventilation performed by single layperson rescuers produces substantial interruptions in chest compression-supported circulation. Continuous chest compression CPR produces greater neurologically normal 24-hour survival than standard ABC CPR when performed in a clinically realistic fashion. Any technique that minimizes lengthy interruptions of chest compressions during the first 10 to 15 minutes of basic life support should be given serious consideration in future efforts to improve outcome results from cardiac arrest.

28) Kill, C., A. Torossian, et al. (2009). "Basic life support with four different compression/ventilation ratios in a pig model: the need for ventilation." Resuscitation **80**(9): 1060-1065.

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, 1mg 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 mm Hg (30:2), 68 mm Hg (100:5; p=0.0001), 66 mm Hg (100:2; p=0.002) and 72 mm Hg (compr-only; p<0.0001). PaO(2) decreased to 58 mmg (30:2), 40 mm Hg (100:5; p=0.15), 43 mm Hg (100:2; p=0.04) and 26 mm Hg (compr-only; p<0.0001). PtiO(2) baseline values were 12.7, 12.0, 11.1 and 10.0 mm Hg and decreased to 8.1 mm Hg (30:2), 4.1 mm Hg (100:5; p=0.08), 4.3 mm Hg (100:2; p=0.04), and 4.5 mm Hg (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.

29) Kitamura, T., T. Iwami, et al. (2011). "Time-dependent effectiveness of chest compression-only and conventional cardiopulmonary resuscitation for out-of-hospital cardiac arrest of cardiac origin." Resuscitation **82**(1): 3-9.

BACKGROUND: Little is known about the effect of the type of bystander-initiated cardiopulmonary resuscitation (CPR) for prolonged out-of-hospital cardiac arrest (OHCA). OBJECTIVES: To evaluate the time-dependent effectiveness of chest compression-only and conventional CPR with rescue breathing for witnessed adult OHCA of cardiac origin. METHODS: A nationwide, prospective, population-based, observational study of the whole population of Japan included consecutive OHCA patients with emergency responder resuscitation attempts from 1 January 2005 to 31 December 2007. Multiple logistic regression analysis was performed to assess the contribution of the bystander-initiated CPR technique to favourable neurological outcomes. RESULTS: Among 55014 bystander-witnessed OHCA of cardiac origin, 12165 (22.1%) received chest compression-only CPR and 10851 (19.7%) received conventional CPR. For short-duration OHCA (0-15min after collapse), compression-only CPR had a higher rate of survival with favourable neurological outcome than no CPR (6.4% vs. 3.8%; adjusted odds ratio (OR), 1.55; 95% confidence interval (CI), 1.38-1.74), and conventional CPR showed similar effectiveness (7.1% vs. 3.8%; adjusted OR, 1.78; 95% CI, 1.58-2.01). For the long-duration arrests (>15min), conventional CPR showed a significantly higher rate of survival with favourable neurological outcome than both no CPR (2.0% vs. 0.7%; adjusted OR, 1.93; 95% CI, 1.27-2.93) and compression-only CPR (2.0% vs. 1.3%; adjusted OR, 1.56; 95% CI, 1.02-2.44). CONCLUSIONS: For prolonged OHCA of cardiac origin, conventional CPR with rescue breathing provided incremental benefit compared with either no CPR or compression-only CPR, but the absolute survival was low regardless of type of CPR.

30) Kitamura, T., T. Iwami, et al. (2010). "Bystander-initiated rescue breathing for out-of-hospital cardiac arrests of noncardiac origin." Circulation **122**(3): 293-299.

BACKGROUND: Although chest compression-only cardiopulmonary resuscitation (CPR) is effective for adult out-of-hospital cardiac arrest (OHCA) of cardiac origin, it remains uncertain whether bystander-initiated rescue breathing has an incremental benefit for OHCA of noncardiac origin. METHODS AND RESULTS: A nationwide, prospective, population-based, observational study covering the whole population of Japan and involving consecutive OHCA patients with emergency responder resuscitation attempts was conducted from January 2005 through December 2007. The primary outcome was neurologically intact 1-month survival. Multiple logistic regression analysis was used to assess the contribution of bystander-initiated CPR to better neurological outcomes. Among a total of 43 246 bystander-witnessed OHCAs of noncardiac origin, 8878 (20.5%) received chest compression-only CPR, and 7474 (17.3%) received conventional CPR with rescue breathing. The conventional CPR group (1.8%) had a higher rate of better neurological outcome than both the no CPR group (1.4%; odds ratio, 1.58; 95% confidence interval, 1.28 to 1.96) and the compression-only CPR group (1.5%; odds ratio, 1.32; 95% confidence interval, 1.03 to 1.69). However, the compression-only CPR group did not produce better neurological outcome than the no CPR group (odds ratio, 1.19; 95% confidence interval, 0.96 to 1.47). The number of OHCAs needed to treat with conventional CPR versus compression-only CPR to save a life with favorable neurological outcome after OHCA was 290. CONCLUSIONS: This nationwide observational study indicates that rescue breathing has an incremental benefit for OHCAs of noncardiac origin, but the impact on the overall survival after OHCA was small.

31) Kitamura, T., T. Iwami, et al. (2010). "Conventional and chest-compression-only cardiopulmonary resuscitation by bystanders for children who have out-of-hospital cardiac arrests: a prospective, nationwide, population-based cohort study." Lancet **375**(9723): 1347-1354.

BACKGROUND: The American Heart Association recommends cardiopulmonary resuscitation (CPR) by bystanders with chest compression only for adults who have cardiac arrests, but not for children. We assessed the effect of CPR (conventional with rescue breathing or chest compression only) by bystanders on outcomes after out-of-hospital cardiac arrests in children. METHODS: In a nationwide, prospective, population-based, observational study, we enrolled 5170 children aged 17 years and younger who had an out-of-hospital cardiac arrest from Jan 1, 2005, to Dec 31, 2007. Data collected included age, cause, and presence and type of CPR by bystander. The primary endpoint was favourable neurological outcome 1 month after an out-of-hospital cardiac arrest, defined as Glasgow-Pittsburgh cerebral performance category 1 or 2. FINDINGS: 3675 (71%) children had arrests of non-cardiac causes and 1495 (29%) cardiac causes. 1551 (30%) received conventional CPR and 888 (17%) compression-only CPR. Data for type of CPR by bystander were not available for 12 children. Children who were given CPR by a bystander had a significantly higher rate of favourable neurological outcome than did those not given CPR (4.5% [110/2439] vs 1.9% [53/2719]; adjusted odds ratio [OR] 2.59, 95% CI 1.81-3.71). In children aged 1-17 years who had arrests of non-cardiac causes, favourable neurological outcome was more common after bystander CPR than no CPR (5.1% [51/1004] vs 1.5% [20/1293]; OR 4.17, 2.37-7.32). However, conventional CPR produced more favourable neurological outcome than did compression-only CPR (7.2% [45/624] vs 1.6% [six of 380]; OR 5.54, 2.52-16.99). In children aged 1-17 years who had arrests of cardiac causes, favourable neurological outcome was more common after bystander CPR than no CPR (9.5% [42/440] vs 4.1% [14/339]; OR 2.21, 1.08-4.54), and did not differ between conventional and compression-only CPR (9.9% [28/282] vs 8.9% [14/158]; OR 1.20, 0.55-2.66). In infants (aged <1 year), outcomes were uniformly poor (1.7% [36/2082] with favourable neurological outcome). INTERPRETATION: For children who have out-of-hospital cardiac arrests from non-cardiac causes, conventional CPR (with rescue breathing) by bystander is the preferable approach to resuscitation. For arrests of cardiac causes, either conventional or compression-only CPR is similarly effective. FUNDING: Fire and Disaster Management Agency and the Ministry of Education, Culture, Sports, Science and Technology (Japan).

32) Ogawa, T., M. Akahane, et al. (2011). "Outcomes of chest compression only CPR versus conventional CPR conducted by lay people in patients with out of hospital cardiopulmonary arrest witnessed by bystanders: nationwide population based observational study." BMJ **342**: c7106.

OBJECTIVE: To compare the effectiveness of cardiopulmonary resuscitation (CPR) with chest compression only and conventional CPR on outcomes after cardiopulmonary arrest out of hospital.

DESIGN: Nationwide population based observational study. SETTING: A nationwide emergency medical service system in Japan. Population All consecutive patients with out of hospital cardiopulmonary arrest, January 2005 to December 2007 in Japan, witnessed at the moment of collapse. Lay people attempted chest compression only CPR (n = 20,707) or conventional CPR (mouth to mouth ventilation and chest compression) (n = 19,328), and patients were transferred to hospital by ambulance. MAIN OUTCOME MEASURES: Factors associated with better outcomes (assessed with chi(2), multiple logistic regression analysis, odds ratios and their 95% confidence intervals): one month survival and neurologically favourable one month survival rates defined as category one (good cerebral performance) or two (moderate cerebral disability) of the cerebral performance categories. RESULTS: Conventional CPR was associated with better outcomes than chest compression only CPR, for both one month survival (adjusted odds ratio 1.17, 95% confidence interval 1.06 to 1.29) and neurologically favourable one month survival (1.17, 1.01 to 1.35). Neurologically favourable one month survival decreased with increasing age and with delays of up to 10 minutes in starting CPR for both conventional and chest compression only CPR. The benefit of conventional CPR over chest compression only CPR was significantly greater in younger people in non-cardiac cases (P = 0.025) and with a delay in start of CPR after the event was witnessed in non-cardiac cases (P = 0.015) and all cases combined (P = 0.037). CONCLUSIONS: Conventional CPR is associated with better outcomes than chest compression only CPR for selected patients with out of hospital cardiopulmonary arrest, such as those with arrests of non-cardiac origin and younger people, and people in whom there was delay in the start of CPR.

33) Olasveengen, T. M., L. Wik, et al. (2008). "Standard basic life support vs. continuous chest compressions only in out-of-hospital cardiac arrest." Acta Anaesthesiol Scand **52**(7): 914-919.

BACKGROUND: The importance of ventilations after cardiac arrest has been much debated recently and eliminating mouth-to-mouth ventilations for bystanders has been suggested as a means to increase bystander cardiopulmonary resuscitation (CPR). Standard basic life support (S-BLS) is not documented to be superior to continuous chest compressions (CCC). METHODS: Retrospective, observational study of all non-traumatic cardiac arrest patients older than 18 years between May 2003 and December 2006 treated by the community-run emergency medical service (EMS) in Oslo. Outcome for patients receiving S-BLS was compared with patients receiving CCC. All Utstein characteristics were registered for both patient groups as well as for patients not receiving any bystander CPR by reviewing Ambulance run sheets, Utstein forms and hospital records. Method of bystander CPR as well as dispatcher instruction was registered by first-arriving ambulance personnel. RESULTS: Six-hundred ninety-five out of 809 cardiac arrests in our EMS were included in this study. Two-hundred eighty-one (40%) received S-CPR and 145 (21%) received CCC. There were no differences in outcome between the two patient groups, with 35 (13%) discharged with a favourable outcome for the S-BLS group and 15 (10%) in the CCC group (P=0.859). Similarly, there was no difference in survival subgroup analysis of patients presenting with initial ventricular fibrillation/ventricular tachycardia after witnessed arrest, with 32 (29%) and 10 (28%) patients discharged from hospital in the S-BLS and CCC groups, respectively (P=0.972). CONCLUSIONS: Patients receiving CCC from bystanders did not have a worse outcome than patients receiving standard CPR, even with a tendency towards a higher distribution of known negative predictive features.

34) Ong, M. E., F. S. Ng, et al. (2008). "Comparison of chest compression only and standard cardiopulmonary resuscitation for out-of-hospital cardiac arrest in Singapore." Resuscitation **78**(2): 119-126.

OBJECTIVE: Chest compression only cardiopulmonary resuscitation (CC-CPR) without ventilation has been proposed as an alternative to standard cardiopulmonary resuscitation (CPR) for bystanders. However, there has been controversy regarding the relative effectiveness of both of these techniques. We aim to compare the outcomes of cardiac arrest patients in the cardiac arrest and resuscitation epidemiology study who either received CC-CPR, standard CPR or no bystander CPR. METHODS: This prospective cohort study involved all out-of-hospital cardiac arrest (OHCA) patients attended to by emergency medical service (EMS) providers in a large urban centre. The data analyses were conducted secondarily on these collected data. The technique of bystander CPR was reported by paramedics who arrived at the scene. RESULTS: From 1 October 2001 to 14 October 2004, 2428 patients were enrolled

into the study. Of these, 255 were EMS-witnessed arrests and were excluded. 1695 cases did not receive any bystander CPR, 287 had standard CPR and 154 CC-CPR. Patient characteristics were similar in both the standard and CC-CPR groups except for a higher incidence of residential arrests and previous heart disease sufferers in the CC-CPR group. Patients who received standard CPR (odds ratio (OR) 5.4, 95% confidence interval (CI) 2.1-14.0) or CC-CPR (OR 5.0, 95% CI 1.5-16.4) were more likely to survive to discharge than those who had no bystander CPR. There was no significant difference in survival to discharge between those who received CC-CPR and standard CPR (OR 0.9, 95% CI 0.3-3.1). CONCLUSION: We found that patients were more likely to survive with any form of bystander CPR than without. This emphasises the importance of chest compressions for OHCA patients, whether with or without ventilation.

35) Rea, T. D., C. Fahrenbruch, et al. (2010). "CPR with chest compression alone or with rescue breathing." N Engl J Med **363**(5): 423-433.

BACKGROUND: The role of rescue breathing in cardiopulmonary resuscitation (CPR) performed by a layperson is uncertain. We hypothesized that the dispatcher instructions to bystanders to provide chest compression alone would result in improved survival as compared with instructions to provide chest compression plus rescue breathing. METHODS: We conducted a multicenter, randomized trial of dispatcher instructions to bystanders for performing CPR. The patients were persons 18 years of age or older with out-of-hospital cardiac arrest for whom dispatchers initiated CPR instruction to bystanders. Patients were randomly assigned to receive chest compression alone or chest compression plus rescue breathing. The primary outcome was survival to hospital discharge. Secondary outcomes included a favorable neurologic outcome at discharge. RESULTS: Of the 1941 patients who met the inclusion criteria, 981 were randomly assigned to receive chest compression alone and 960 to receive chest compression plus rescue breathing. We observed no significant difference between the two groups in the proportion of patients who survived to hospital discharge (12.5% with chest compression alone and 11.0% with chest compression plus rescue breathing, P=0.31) or in the proportion who survived with a favorable neurologic outcome in the two sites that assessed this secondary outcome (14.4% and 11.5%, respectively; P=0.13). Prespecified subgroup analyses showed a trend toward a higher proportion of patients surviving to hospital discharge with chest compression alone as compared with chest compression plus rescue breathing for patients with a cardiac cause of arrest (15.5% vs. 12.3%, P=0.09) and for those with shockable rhythms (31.9% vs. 25.7%, P=0.09). CONCLUSIONS: Dispatcher instruction consisting of chest compression alone did not increase the survival rate overall, although there was a trend toward better outcomes in key clinical subgroups. The results support a strategy for CPR performed by laypersons that emphasizes chest compression and minimizes the role of rescue breathing. (Funded in part by the Laerdal Foundation for Acute Medicine and the Medic One Foundation; ClinicalTrials.gov number, NCT00219687.)

36) Sanders, A. B., K. B. Kern, et al. (2002). "Survival and neurologic outcome after cardiopulmonary resuscitation with four different chest compression-ventilation ratios." Ann Emerg Med **40**(6): 553-562.

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.

37) Svensson, L., K. Bohm, et al. (2010). "Compression-only CPR or standard CPR in out-of-hospital cardiac arrest." N Engl J Med **363**(5): 434-442.

BACKGROUND: Emergency medical dispatchers give instructions on how to perform cardiopulmonary resuscitation (CPR) over the telephone to callers requesting help for a patient with suspected cardiac arrest, before the arrival of emergency medical services (EMS) personnel. A previous study indicated that instructions to perform CPR consisting of only chest compression result in a treatment efficacy that is similar or even superior to that associated with instructions given to perform standard CPR, which consists of both compression and ventilation. That study, however, was not powered to assess a possible difference in survival. The aim of this prospective, randomized study was to evaluate the possible superiority of compression-only CPR over standard CPR with respect to survival. METHODS: Patients with suspected, witnessed, out-of-hospital cardiac arrest were randomly assigned to undergo either compression-only CPR or standard CPR. The primary end point was 30-day survival. RESULTS: Data for the primary analysis were collected from February 2005 through January 2009 for a total of 1276 patients. Of these, 620 patients had been assigned to receive compression-only CPR and 656 patients had been assigned to receive standard CPR. The rate of 30-day survival was similar in the two groups: 8.7% (54 of 620 patients) in the group receiving compression-only CPR and 7.0% (46 of 656 patients) in the group receiving standard CPR (absolute difference for compression-only vs. standard CPR, 1.7 percentage points; 95% confidence interval, -1.2 to 4.6; P=0.29). CONCLUSIONS: This prospective, randomized study showed no significant difference with respect to survival at 30 days between instructions given by an emergency medical dispatcher, before the arrival of EMS personnel, for compression-only CPR and instructions for standard CPR in patients with suspected, witnessed, out-of-hospital cardiac arrest. (Funded by the Swedish Heart-Lung Foundation and others; Karolinska Clinical Trial Registration number, CT20080012.)

38) Tang, W., M. H. Weil, et al. (1994). "Cardiopulmonary resuscitation by precordial compression but without mechanical ventilation." Am J Respir Crit Care Med **150**(6 Pt 1): 1709-1713.

It is widely held that mechanical ventilation is essential for cardiopulmonary resuscitation (CPR). However, cardiac output and therefore pulmonary blood flow is reduced to less than one-third of normal during CPR. We therefore reasoned that ventilatory requirements are correspondingly reduced and postulated that gas exchange may be maintained during precordial compression with oxygen passively delivered to the airway in the absence of mechanical ventilation. After tracheal intubation, Sprague-Dawley rats were randomized. Fifteen animals were maintained on positive-pressure ventilation with room air and an additional 15 animals breathed spontaneously. Cardiac arrest was induced by electrical fibrillation. The inspired gas concentration of oxygen was then increased to 100% in both groups. Precordial compression was begun after 4 min of untreated ventricular fibrillation. After an additional 6 min of precordial compression, resuscitation was attempted by DC countershock. During cardiac resuscitation, there were no significant differences in coronary perfusion pressure between mechanically ventilated and spontaneously breathing animals, but arterial PO2 was significantly lower and arterial PCO2 was significantly higher in the absence of positive-pressure ventilation. However, neither resuscitability nor 24-h survival were affected. Postresuscitation myocardial contractility, reflected in the maximally generated dP/dt40, was also not adversely affected. In the unventilated group, only resuscitated animals developed spontaneous gaspings at an average frequency of 17 +/- 2/min-1. The current emphasis on mechanical ventilation as the highest priority for cardiopulmonary resuscitation is therefore not fully supported under the experimental conditions of this study.

39) von Planta, I., M. H. Weil, et al. (1991). "Hypercarbic acidosis reduces cardiac resuscitability." Crit Care Med **19**(9): 1177-1182.

BACKGROUND AND METHODS: Marked increases in myocardial hypercarbia and acidosis accompany cardiac arrest and resuscitation. To investigate whether hypercarbic acidosis independent of oxygenation is of itself detrimental to cardiac resuscitation, three groups of six Sprague-Dawley rats were ventilated with gas mixtures containing concentrations of inspired CO2 (FICO2) of 0.0, 0.3, or 0.5, with oxygen fractions held constant at 0.5. After 4 mins of ventricular fibrillation, mechanical chest compressions were initiated with a pneumatic thumper; 2 mins later, transthoracic defibrillation was attempted. RESULTS: Each animal ventilated with FICO2 of 0.0 or 0.3 was successfully resuscitated. However, none of the animals ventilated with FICO2 of 0.5, in which aortic pH was less than 6.67 and aortic PCO2 was greater than 200 torr (greater than 26.7 kPa), was resuscitated (p less than .001). This finding contrasted with a second control group of seven identically treated animals which, in the absence of cardiac arrest, demonstrated no adverse effects after ventilation with an FICO2 of 0.5. CONCLUSIONS: Increases in FICO2 to levels of 0.5 under conditions of constant arterial oxygenation and controlled coronary perfusion pressure preclude successful resuscitation in this rodent model of CPR.

40) Wang, S., C. Li, 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 **38**(10): 2024-2030.

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. SETTING: A university animal research laboratory. 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.

41) Yakaitis, R. W., J. D. Thomas, et al. (1975). "Influence of pH and hypoxia on the success of defibrillation." Crit Care Med **3**(4): 139-142.

Clinical impressions about the problem of defibrillation during states of acid-base imbalance and hypoxia have been influenced by studies involving the effect of these derangements on the ventricular fibrillation threshold. Based on body weight, energy requirements for defibrillation in normal dogs were compared to requirements in dogs subjected to commonly encountered acid-base disturbances and severe

hypoxemia. No significant differences were found. Seventy-five percent of all animals in the study were electrically converted with low-to-moderate levels of energy. The incidence of spontaneous resumption of circulation following defibrillation was lowest in animals subjected to metabolic acidosis and hypoxia. The results suggest that pH and blood gas alterations, previously shown to influence the normal ventricular fibrillation threshold, do not significantly affect the normal defibrillation threshold.

42) Yannopoulos, D., T. Matsuura, et al. (2010). "No assisted ventilation cardiopulmonary resuscitation and 24-hour neurological outcomes in a porcine model of cardiac arrest." Crit Care Med **38**(1): 254-260.

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. DESIGN: Prospective randomized animal study. SETTING: Animal laboratory. SUBJECTS: Sixteen female intubated pigs (25.2 +/- 2.1 kg) anesthetized with propofol. INTERVENTIONS: : After 8 mins of untreated ventricular fibrillation, the intubated animals 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. MEASUREMENTS, AND MAIN RESULTS: 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). Paco2 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). CONCLUSIONS: 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.