WORKSHEET for PROPOSED Evidence-Based GUIDELINE RECOMMENDATIONS

Worksheet Author:	**Home Subcommittee:** **Taskforce/Subcommittee:** _x**_BLS __ACLS __PEDS __ID __PROAD Other:
Author's Home Resuscitation Council: _X_**AHA __ANZCOR __CLAR _X_*ERC __HSFC __HSFC __RCSA ___IAHF ___Other: _X_*IRC	**Date Submitted to Subcommittee:** July 28, 2004; revised August 23, 2004; revised September 5, 2004

STEP 1: STATE THE PROPOSAL. State if this is a proposed new guideline; revision to current guideline; or deletion of current guideline. Existing guideline, practice or training activity:

Revision of existing Guidelines: adult chest compressions and ventilation ratio, AHA Guidelines 2000 statement:

- The compression-ventilation ratio for 1- and 2-rescuer CPR is 15 compression to 2 ventilations when the victim's airway is unprotected (airway protection = successful placement of endotracheal tube)

- Once the airway is secure (protected by insertion of ETT), compressions and ventilations can be asynchronous, with ventilation rate of about 12 to 15 breaths/minute.

- The respiratory rate during cardiac or respiratory arrest when the patient has been intubated should be 12 to 15 breaths per minute (1 breath every 4 or 5 seconds). Once a tracheal tube is in place, ventilation need not be synchronized with chest compressions. Once spontaneous circulation is restored after cardiac arrest, continue to provide 12 to 15 breaths per minute.

- A deep inspiration is recommended before each breath

Step 1A: Refine the question; state the question as a positive (or negative) hypothesis. State proposed guideline recommendation as a specific, positive hypothesis. Use single sentence if possible. Include type of patients; setting (in- /out-of-hospital); specific interventions (dose, route); specific outcomes (ROSC vs. hospital discharge).

A single compression:ventilation ratio should be adopted to optimize coronary and cerebral oxygen delivery and blood flow during adult CPR.

Step 1B: Gather the Evidence; define your search strategy. Describe search results; describe best sources for evidence.

Searches were limited to: articles in peer reviewed journals between the years 1966 and 2004, English language, and no abstracts.

Database search strategy:

- ECC Master library Jul 6, 2004
Query: "compression AND ventilation AND ratio AND resuscitation" in any field – ***173 hits***

- PubMed (NLM) (1966 – Aug 1, 2004)
Query: "compression* AND ventilation* AND ratio* AND resuscitation*" in any field – ***63 hits***
Query: "Cardiopulmonary Resuscitation/methods[MeSH Terms] AND Heart Massage[MeSH Terms] – ***60 hits***
Query: "Cardiopulmonary Resuscitation/methods[MeSH Terms] AND compression* (All Fields) AND ventilation* (All Fields) – ***125 hits***

Matching, excluding duplicates, overall PubMed's and ECC Master Library: ***312 hits***
cardiopulmonary resuscitation/methods[MeSH Terms] AND compression* AND ventilation*

- Cochrane Library (issue 4 – 2003) in all Cochrane Databases
Query: "compression AND ventilation AND ratio" – ***23 hits***

Query: “cardiopulmonary resuscitation” – ***259 hits***
No value added.

- Embase (1988-2004)
Query: “compression AND ventilation AND ratio AND cardiopulmonary AND arrest AND [english]/lim AND [humans]/lim AND [animals]/lim AND [abstracts]/lim” - ***4 hits***
No value added (all already reviewed by medline search)

Query: “compression AND ventilation AND ratio AND resuscitation AND [english]/lim AND [humans]/lim AND [animals]/lim AND [abstracts]/lim” - ***26 hits***
No value added.

List electronic databases searched (at least MEDLINE (http://igm.nlm.nih.gov/), Embase, Cochrane database for systematic reviews and Central Register of Controlled Trials, and hand searches of journals, review articles, and books.

ECC Master library (01 Aug 2004), PubMed’s (NLM), reference in published papers (Use of “related articles” function in PubMed’s database). Follow-up of additional reference in published papers (best additional sources). Cochrane and Embase database (01 Aug 2004)

- State major criteria you used to limit your search; state inclusion or exclusion criteria (e.g., only human studies with control group? no animal studies? N subjects > minimal number? type of methodology? peer-reviewed manuscripts only? no abstract-only studies?)

Inclusion: human, surrogate (manikin), animal and mathematical models studies.

Exclusion: pediatric and alternative method for CPR (abdominal compression, active compression-decompression (ACD), ITV, ecc.), not English language, reviews articles.

297 articles excluded: not matching the specific query (compression-ventilation ratio in resuscitation).

- Number of articles/sources meeting criteria for further review: Create a citation marker for each study (use the author initials and date or Arabic numeral, e.g., “Cummins-1”). . If possible, please supply file of best references; End Note 4+ preferred as reference manager, though other reference databases acceptable.

Searches narrowed after title / abstract review to **25 articles.**

STEP 2: ASSESS THE QUALITY OF EACH STUDY

Step 2A: Determine the Level of Evidence. For each article/source from step 1, assign a level of evidence—based on study design and methodology.

Level of Evidence	Definitions (See manuscript for full details)
Level 1	Randomized clinical trials or meta-analyses of multiple clinical trials with substantial treatment effects
Level 2	Randomized clinical trials with smaller or less significant treatment effects
Level 3	Prospective, controlled, non-randomized, cohort studies
Level 4	Historic, non-randomized, cohort or case-control studies
Level 5	Case series: patients compiled in serial fashion, lacking a control group
Level 6	Animal studies or mechanical model studies
Level 7	Extrapolations from existing data collected for other purposes, theoretical analyses
Level 8	Rational conjecture (common sense); common practices accepted before evidence-based guidelines

Step 2B: Critically assess each article/source in terms of research design and methods.
Was the study well executed? Suggested criteria appear in the table below. Assess design and methods and provide an overall rating. Ratings apply within each Level; a Level 1 study can be excellent or poor as a clinical trial, just as a Level 6 study could be excellent or poor as an animal study. Where applicable, please use a superscripted code (shown below) to categorize the primary endpoint of each study. For more detailed explanations please see attached assessment form.

Component of Study and Rating	Excellent	Good	Fair	*Poor*	*Unsatisfactory*
Design & **Methods**	Highly appropriate sample or model, randomized, proper controls **AND** Outstanding accuracy, precision, and data collection in its class	Highly appropriate sample or model, randomized, proper controls **OR** Outstanding accuracy, precision, and data collection in its class	Adequate, design, but possibly biased **OR** Adequate under the circumstances	*Small or clearly biased population or model* ***OR*** *Weakly defensible in its class, limited data or measures*	*Anecdotal, no controls, off target end-points* ***OR*** *Not defensible in its class, insufficient data or measures*

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

Step 2C: Determine the <u>direction</u> of the results and the statistics: supportive? neutral? opposed?

DIRECTION of study by results & statistics:	SUPPORT the proposal	NEUTRAL	OPPOSE the proposal
Results	Outcome of proposed guideline superior, to a clinically important degree, to current approaches	Outcome of proposed guideline no different from current approach	Outcome of proposed guideline inferior to current approach

Step 2D: Cross-tabulate assessed studies by a) *level*, b) *quality* and c) *direction* (ie, supporting or neutral/ opposing)**; combine and summarize.** Exclude the *Poor* and *Unsatisfactory* studies. Sort the *Excellent, Good,* and *Fair* quality studies by both *Level and Quality of evidence,* and *Direction of support* in the summary grids below. Use citation marker (e.g. author/ date/source). In the *Neutral* or *Opposing* grid use bold font for *Opposing* studies to distinguish them from merely neutral studies. Where applicable, please use a superscripted code (shown below) to categorize the primary endpoint of each study.

Supporting Evidence

A single compression:ventilation ratio should be adopted to optimize coronary and cerebral oxygen delivery and blood flow during adult CPR

Quality of Evidence	1	2	3	4	5	6	7	8
Excellent						Aufderheide, 2004[A,B] [Asynchronous 100C:12 V] Dorph, 2003[E,B] [15:2]		
Good					Aufderheide, 2004[A,B] [Asynchronous 100C:12 V]	Sanders, 2002[B,D,E] [100:2]	Berg, 2001[B,D] [100:0] Kern, 2002[E,D,B] [100:0] Babbs, 2002[E] [30:2 for 2 sec breath 60:2 for 8 sec breath]	
Fair						Kill, 2004[E] [50:5]	Berg, 2000[E] [15:2 vs CConly, Vonly, noCPR] Berg, 1997a[E] [CConly vs 15:2, noCPR] Berg, 1997b[E] [CConly vs 15:2, noCPR] Turner, 2002[E] [100:0 for 3-4 min, then 50:5] Turner, 2004[E] [20:1] Dorph, 2004[E] [30:2] Assar, 2000[E] [50:5] Chamberlain, 2001[E] [50:5] Hallstrom, 2000[C,D] [100:0] Herlitz, 2000[C,E] [15:2 as LOE7] Holmberg, 2001[C,E] [15:2 as LOE7] Waalewijn, 1998[C,E] [15:2 as LOE7] Waalewijn, 2001a[C,E] [15:2 as LOE7] Waalewijn, 2001b[C,E] [15:2 as LOE7] Waalewijn, 2002[C,E] [15:2 as LOE7] Walker, 2001[E] [15:2] Thierbach, 2003[E] [no deep breath before V]	

Level of Evidence

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

Individual Compression:Ventilation ratio supported is appended in brackets to Citation.

Neutral or Opposing Evidence

A single compression:ventilation ratio should be adopted to optimize coronary and cerebral oxygen delivery and blood flow during adult CPR

Quality of Evidence									
	Excellent								
	Good							Greingor, 2002[E] [5:1]	
	Fair								
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
		Level of Evidence							

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

Individual Compression:Ventilation ratio supported is appended in brackets to Citation.

STEP 3. DETERMINE THE CLASS OF RECOMMENDATION. Select from these summary definitions.

CLASS	CLINICAL DEFINITION	REQUIRED LEVEL OF EVIDENCE
Class I *Definitely recommended.* Definitive, **Excellent** evidence provides support.	• Always acceptable, safe • Definitely useful • Proven in both efficacy & effectiveness • Must be used in the intended manner for proper clinical indications.	• One or more Level 1 studies are present (with rare exceptions) • Study results consistently positive and compelling
Class II: *Acceptable and useful*	• Safe, acceptable • Clinically useful • Not yet confirmed definitively	• Most evidence is positive • Level 1 studies are absent, or inconsistent, or lack power • No evidence of harm
• *Class IIa:* *Acceptable and useful* **Good** evidence provides support	• Safe, acceptable • Clinically useful • Considered treatments of choice	• Generally higher levels of evidence • Results are consistently positive
• ***Class IIb:*** *Acceptable and useful* **Fair** evidence provides support	• Safe, acceptable • Clinically useful • Considered optional or alternative treatments	• Generally lower or intermediate levels of evidence • Generally, but not consistently, positive results
Class III: *Not acceptable, not useful, may be harmful*	• Unacceptable • Not useful clinically • May be harmful.	• No positive high level data • Some studies suggest or confirm harm.
Indeterminate	• Research just getting started. • Continuing area of research • No recommendations until further research	• Minimal evidence is available • Higher studies in progress • Results inconsistent, contradictory • Results not compelling

STEP 3: DETERMINE THE CLASS OF RECOMMENDATION. State a Class of Recommendation for the Guideline Proposal. State either a) the intervention, and then the conditions under which the intervention is either Class I, Class IIA, IIB, etc.; or b) the condition, and then whether the intervention is Class I, Class IIA, IIB, etc.

Indicate if this is a __Condition or _X_Intervention
A single compression:ventilation ratio should be adopted to optimize coronary and cerebral oxygen delivery and blood flow during adult CPR

Final Class of recommendation: As Follow:

- For unintubated children or adults in cardiac arrest, whether one or two rescuers, chest compression rate of 100 per minute and a single compression: ventilation ratio of 15:2 ratio is recommend to improve cardiopulmonary circulation, to simplify the training message, and to improve skill retention. ***[Class IIb]*** (LOE 5)

-For adults in cardiac arrest who are intubated, rescuers should provide 100 chest compressions per minute without interruption for ventilation, and 12 breaths per minute with an inspiratory time lasting 1 sec. per breath ***[Class IIb]*** .(LOE 5)

REVIEWER'S PERSPECTIVE AND POTENTIAL CONFLICTS OF INTEREST: Briefly summarize your professional background, clinical specialty, research training, AHA experience, or other relevant personal background that define your perspective on the guideline proposal. List any potential conflicts of interest involving consulting, compensation, or equity positions related to drugs, devices, or entities impacted by the guideline proposal. Disclose any research funding from involved companies or interest groups. State any relevant philosophical, religious, or cultural beliefs or longstanding disagreements with an individual.

Reviewer 1: Emergency Physician; Internal Medicine Specialist; Completing PhD in Cardiology. Department of Emergency Medicine of the Catholic University of Rome; Biomag – Clinical Physiology Research Unit of the Catholic University of Rome; Member of the BLSD Commission of the Italian Resuscitation Council; ERC BLS AED Working Group; ERC Member and Course Director for ALS and BLSD. No conflicts of interest.

Reviewer 2: Intensive Care Specialist / Anesthesiologist. University Hospital. Current AHA BLS subcommittee member (year 5). No conflict of interest.

REVIEWER'S FINAL COMMENTS AND ASSESSMENT OF BENEFIT / RISK: Summarize your final evidence integration and the rationale for the class of recommendation. Describe any mismatches between the evidence and your final Class of Recommendation. "Mismatches" refer to selection of a class of recommendation that is heavily influenced by other factors than just the evidence. For example, the evidence is strong, but implementation is difficult or expensive; evidence weak, but future definitive evidence is unlikely to be obtained. Comment on contribution of animal or mechanical model studies to your final recommendation. Are results within animal studies homogeneous? Are animal results consistent with results from human studies? What is the frequency of adverse events? What is the possibility of harm? Describe any value or utility judgments you may have made, separate from the evidence. For example, you believe evidence-supported interventions should be limited to in-hospital use because you think proper use is too difficult for pre-hospital providers. Please include relevant key figures or tables to support your assessment

Summary

- No data from level of evidence 1 to 4 to support variation in current guideline on compression to ventilation ratio of 15:2.
- Data from animal and mathematical model studies, although not uniform in their conclusions, suggest moving to a higher compression to ventilation ratio, but without a clear definition of the best ratio (30:2, 50:2, 100:2?) ***[Babbs 2002 ,Turner 2002, Dorph 2003, Sanders 2002, Dorph 2004]***
- Lack of human case series and human studies defining the best compression-to-ventilation ratio in term of survival and neurological outcome.
- Level 7 evidence suggest better outcome for patients managed with dispatcher-instructed bystander chest compression CPR (CCCPR) without ventilations compared with dispatcher-instructed bystander chest compression with ventilation CPR ***[Hallstrom 2000]***
- Level 7 evidence from several recent large prospective human studies suggest/confirm better outcome for patients managed with bystander standard 15:2 CPR compared with no CPR ***[Herlitz 2000, Holmberg 2001, Waalewijn 1998, Waalewijn 2001a, Waalewijn 2001b, Waalewijn 2002]***
- Level 6 evidence suggests better outcome for animals managed with bystander CCCPR without ventilations ***[Kern 2002, Berg 2001]***

- Further investigations specifically are needed to define the best method for coordinating ventilation and chest compressions during real CPR for BLS and ALS with and without unprotected airway (endotracheal tube in place).

Animal models:
- 15:2 ventilation to compression ratio provides better pulmonary gas exchange and cerebral oxygen delivery than both 50:2 and 50:5 ***[Dorph 2003]***
- 50:2 ratio tends to give a better carotid blood flow, but less oxygen delivery ***[Dorph 2003]***
- 50:2 ratio provide the same gas exchange but less chest compression and blood flow than 50:5 ***[Dorph 2003]***
- lay persons may require 16 sec break in the compression for two mouth-to-mouth ventilations, that means no circulation during resuscitation for 60% of total time with 15:2 and 35% if 50:2 ratios ***[Assar 2000]***
- 30:2 ratio may be an even more optimal C:V ratio in a more realistic model of partial airway obstrution, as indicated by cerebral cortical blood flow continuous monitoring ***[Dorph 2004]***
- 15:2, 50:2, 100:2, CCCPR: no statistically significant difference in 24 hours survival ***[Sanders, 2002]***
- 15:2, 50:5, 100:2, CCCPR: no difference in perfusion pressures ***[Sanders, 2002]***
- 100:2 shows best neurologic outcome at 24 hours ***[Sanders, 2002]***
- Continuous chest compression CPR (CCCPR) shows better neurologic outcome at 24 hours, vs 15:2 ***[Kern 2002]***
- CCCPR shows better coronary perfusion, vs 15:2 ***[Kern 2002]***
- Interrupting chest compressions for rescue breathing can adversely affect haemodynamics ***[Berg 2001]***

Manikin models:
- 15:2 provides more numerous but less effective compressions than with 5:1 ***[Greingor 2002]***
- The 58% more compressions given with 50:5 ratio may have important clinical implications during the first 8 min of resuscitation ***[Chamberlain 2001]***
- Symptoms of hypocarbia may occur in the rescuer providing prolonged mouth-to-mouth ventilation ***[Walker 2001]***
- 50:2 can be well sustained during adult CPR ***[Assar 2000]***

Computer - mathematical models:
- optimal number of chest compressions is between 30 to 70:2, based on optimal (2sec/breath) vs “real world (8 sec/ breath) performance of the rescuer ***[Babbs 2002]***
- 50:2 ratio is adequate for single and two rescuer basic CPR ***[Babbs 2002]***
- CCCPR helps simplify CPR delivery and may increase overall benefit (20-80%) ***[Babbs 2002]***
- CCCPR is associated with greater “cardiac output”; 5:1 is the worst ***[Babbs 2002]***
- CCCPR provides a significantly greater amount of oxygen delivery during the first 2 min of CPR ***[Babbs 2002]***
- CCCPR resulted in grossly hypoxic arterial blood after 6 min of CPR ***[Babbs 2002]***
- 5:1 ratio, despite producing high arterial blood oxygen levels, resulted in lowest oxygen delivery ***[Turner 2002]***
- 15:2 and 50:5 should be approximately equivalent in term of gas exchange. This conclusion does not agree with data from animal model (probably because do not consider pulmonary shunting) ***[Turner 2002]***
- 20:1 optimum ratio in term of CO2 clearance and oxygen delivery (DO2: 0.19 L/min vs 0.13 L/min for standard 15:2 CPR) for M-to-M ventilation or BVM FiO2 > 0.5. Continous chest compression and simultaneous asynchronous ventilation 20:1 gives best DO2. Hypoxic cardiac arrest with 3 minutes of respiratory arrest before cardiac arrest were considered theoretical model only. Assumptions somewhat unrealistic for lay rescuer (2 sec ventilation). 6 minutes calculated PaO2, PaCO2, PvO2 and PvCO2 are not representing the means values observed in animal models (mathematical model all values in and beyond the upper range). 3 minute respiratory arrest assumes baseline PaCO2 of 12.62 Kpa (assumption error in the method and result since CO2 is knows to increase only 3 mmHg/min in total respiratory arrest). Author conclusions: 20:1 ratio theoretical best compromise of DO2, PaO2, PaCO2, PvO2 and PvCO2 ***[Turner 2004]***
-using a high ventilation rate when the airway is protected is an independent variable that can decrease survival from cardiac arrest. The probable mechanism for this adverse effect is secondary to reduced venous return from increased intrathoracic pressure, which then reduces coronary and cerebral perfusion ***[Aufderheide 2004]***. The effect of Vt on mean intrathoracic pressure during CPR has not been studied.

Human studies:
- survival rates to hospital discharge (29%) and rate of hospital admission (15%) are higher with dispatcher-instructed chest compression alone (29%) versus dispatcher-instructed standard CPR ***[Hallstrom 2000]***
- CCCPR indicated in telephone CPR ***[Hallstrom 2000]***
- CCCPR may be applicable to the more general setting of bystander CPR ***[Hallstrom 2000]***
- 15:2 CPR may be supported by human data from same out-of-hospital cardiac arrest (OHCA) registry in term of better outcome if compared with no CPR. No comparison was made between different C:V ratios ***[Herlitz 2000, Holmberg 2001, Waalewijn 1998, Waalewijn 2001a, Waalewijn 2001b, Waalewijn 2002]***

–eccessive ventilation during CPR is common and it is believed deleterious to organ perfusion through an increased intrathoracic pressure ***[Aufderheide 2004]***.
It has become clear that in intubated patients, the lower the ventilation frequency, the greater the vital organ perfusion ***[Aufderheide 2004]***.
-with each positive pressure ventilation, even with continuous compressions, the cerebral and coronary perfusion pressures are reduced ***[Berg 2001, Dorph 2004]***

-with ventilation rates of ≥20/minute, ventilation is deadly in animal models of cardiac arrest and is also likely deadly in patients ***[Aufderheide 2004]***. Furthermore, when excessive, the quality of ventilation can be adversely affected by fatigue or hyperventilation-related symptoms of the rescuer ***[Walker 2001]***.

A message must be given that while some ventilation is important, especially by BLS and ALS providers of victims with airway obstruction, ventilation rates of >20 breaths/minutes have been shown to be harmful ***[Aufderheide 2004, Dorph 2004]***.

Discussion:

The Guidelines should reflect the importance of limiting ventilation rate in order to maximize vital organ blood flow by chest compression. The optimal compression:ventilation ratio is unknown. However, it is now accepted that during cardiac arrest mixed venous blood gases will reflect tissue oxygenation and acid-base state more accurately than arterial blood gases. Thus, providing a minute ventilation that is considerably less than that required in the presence of a normal cardiac output may produce normal arterial blood gases and provide adequate exchange of alveolar gas during CPR.

Mathematical models of the ideal C:V ratio are purely speculative and have not been validated by animal studies where arterial and venous desaturation during BLS is usually more profound than estimated values ***[Babbs 2002, Turner 2002]***.

Furthermore, animal models are affected by the presence of an endotracheal tube that allows substantial gas exchange during chest compression or spontaneous gasping. In this regard, the use of a more realistic animal model of human airway obstruction during chest compression should probably be recommended ***[Dorph 2003]***.

In general, data from animal ***[Dorph 2004, Sanders 2002]*** and mathematical model studies ***[Babbs 2002, Turner 2002]*** although not uniform, suggest a move to a higher compression-to-ventilation ratio, but without a clear definition of the best ratio (30:2, 50:2, 100:2 etc.). A more recent mathematical model of Turner suggests a single ratio of 20:1 for M-to-M, BVM O2 and hypoxic cardiac arrest. Furthermore, a C:V ratio of 30:2 seems to achieve the advantage of increasing coronary perfusion in both a mathematical model and animal model when realistic airway obstruction is simulated during CPR, but ventilation time was maintained at a clinically unlikely long period (2 seconds/breath) ***[Babbs 2002, Turner 2002, Dorph 2004]***.

In general, in all the animal models, the presence of profound arterial and venous desaturation during resuscitation does not support an extension of the C:V ratio higher than 30:2 ***[Dorph 2004]***.

Another theoretical reason to increase C:V ratio above 15:2 is the proven inefficiency of the lay rescuer in ventilating the victim with an unprotected airway. In fact, ventilation time intervals that are longer than what is recommended by the AHA are generally observed in lay rescuer CPR (8 sec/breath) ***[Assar 2000]*** and suggests that the C:V ratio should be increased to minimize the effect of "no compression time" on the coronary and cerebral circulation.

Other potential advantages of increasing the C: V ratio includes decreasing the risk of the rescuer hyperventilation syndrome causing fatigue and dizziness during M-to-M ventilation. ***[Walker 2001, Thierbach 2003]***
With respect to rescuer hyperventilation, eliminating a "deep breath" by the rescuer before exhalation in the victim's airway during M-to-M ventilation could be beneficial and ***[Thierbach 2003]*** should be further investigated to decrease the rescuer's symptoms of hyperventilation, ***[Walker 2001]*** which can potentially affect the safety, feasibility and efficacy of CPR.
The optimal number of ventilations to provide in series is not known. In a manikin study when BVM was compared between a 15:2 and 50:5 ratio, the predicted 25% reduction of ventilation in the 50:5 group could not be demonstrated ***[Kill 2004]***. This study suggests a theoretical advantage of using 5 ventilations in sequence instead of 2 to maximize the effect of chest compression ***[Kill 2004]***.

The fatiguing effect of increased ventilation should be balanced with the fatiguing effect of increasing compression.
A manikin model showed that a C:V of 15:2 provides only 14.5% more compressions than a C:V ratio of 5:1 and that nearly 81% of the rescuers perceived that a C:V ratio of 15:2 was more tiring than a 5:1. The quality of compressions decreased significantly after one minute and then again between 4 and 5 minutes of CPR, suggesting the need for frequent rescuer rotations, between 1 and 5 minutes, to optimize effectiveness of chest compression. ***[Greingor 2002]***

The potentially deleterious effect of ventilation was investigated recently. With each positive pressure ventilation, the cerebral and coronary perfusion pressures are reduced ***[Berg 2001, Dorph 2004]*** .

Furthermore, it has become clear by anecdotal observations in intubated patients that very high ventilation frequencies can significantly increase intrathoracic pressure and decrease organ perfusion during CPR ***[Aufderheide 2004]***.

When ventilation rates of ≥20/minute are provided through an endotracheal tube, it is deadly in an animal model of cardiac arrest ***[Aufderheide 2004]***.
Therefore, a consistent message is needed for BLS and ALS providers emphasizing that while ventilation is important, especially in victims of hypoxic cardiac arrest, ventilation rates of >20 breaths/minutes can be harmful when an endotracheal tube is in place ***[Aufderheide 2004, Dorph 2004]***. No studies are available on a ventilatory rate between 12 and 20/min. Therefore the effect of this range of ventilation rate on the hemodynamics of CPR is unknown.

The existing 2000 AHA guidelines recommend a respiratory rate of 12 to 15 breaths per minute (1 breath every 4 or 5 seconds) during cardiac or respiratory arrest when the patient has been intubated**.** No references were cited. Despite the lack of evidence above level 5, it is now reasonable to limit the recommendation to a ventilatory rate of 12 breaths per minute.

The effect of high ventilatory rate when the airway in not protected by an endotracheal tube is unclear. The likely presence of an unquantified airway leak is probably a protective mechanism that decreases the deleterious effect of high ventilatory rate on the cardiovascular system of the victim.

In conclusion, the scientific evidence on C:V > 15:2 in patients with an unprotected airway is limited to low level evidence, and there are no human studies available at this time to recommend a change of existing guidelines.
On the contrary, new anecdotal evidence in human and animal studies of cardiac arrest when the airway is protected by an endotracheal tube suggests a likely deleterious effect of high ventilatory rate on the cardiovascular system; therefore the ventilatory rate should be reduced to 12 breaths per minute.

Further studies are specifically needed to define the best method for coordinating ventilation and chest compressions during CPR and define the best compression to ventilation ratio in terms of survival and neurological outcome in both patients with protected and unprotected airways.

Preliminary draft/outline/bullet points of Guidelines revision: Include points you think are important for inclusion by the person assigned to write this section. Use extra pages if necessary.

Publication: ____ Chapter: ___ Pages:
Topic and subheading:

For BLS-CPR with the patient non intubated (unprotected airway):

- Evidence from 3 mathematical models suggests the benefits of increasing C:V > 15:2
- Evidence from animal studies of ventricular fibrillation arrest suggests a better neurological recovery at higher C:V rate than 15:2 with best outcome at 100:2 and a similar cerebral blood flow between 15:2 to 50:2
- A mathematical model of hypoxic cardiac arrest suggest best C:V of 20 to 30:1 when providing M-to-M ventilation and between 30:1 to 40:1 for FIO2 > 0.5
- Unfortunately, parameters studied in both mathematical and animal models are not uniform and the models differ for FiO2 and CO2 level, C:V ratios studied and characteristics of ventilation.
- One study that reproduces a likely situation of airway obstruction in humans during CA shows best cerebral oxygen delivery at a 30:2 ratio.
- Hyperventilation syndrome of *the rescuer* during CPR is real and proven harmful in one study with M-to-M ventilation provided at a ventilatory rate of 12 per minute and Vt of 800mL; each breath was preceded by a deep inspiration (but without chest compression).
- However the fatiguing effect of a higher ventilation rate is counterbalanced by the fatiguing effect of increasing the number of chest compressions; this adverse effect appeared after one minute of compression at a rate of 100 per minute and a C:V ratio of 15:2.
- Real world BLS time interval during which rescue ventilation is provided is much slower than recommended by the 2000 AHA guidelines (2 seconds recommended and 8 seconds observed).
- A C:V ratio higher than the existing guidelines (C:V ratio more than 15:2) while theoretically more suitable to the “real world” of ventilation during CPR (delivery time per breath 8 sec by lay rescuer) has not been studied in humans

- Based on the lack of human studies with higher C:V ratio, a single compression:ventilation ratio of 15:2 continues to be recommended for all adults in cardiac arrest receiving BLS - CPR to simplify the training message, maximize skill retention, and allowing the second rescuer, if present to focus on applying an AED when applicable. As a result of the same rationale, a similar C:V rate is recommended for non-neonatal pediatric patients

When the patient is intubated and the airway protected:

- The risk of harming *the victim* by using a high ventilatory rate during CPR is real and was harmful in one animal study by a mechanism of increased intrathoracic pressure. A ventilatory rate of 12 per minute is recommended. Higher respiratory rates should be avoided since they can decrease organ perfusion and potentially affect the outcome of resuscitation

See detailed comments, including Classes for recommendations in previous section.

Attachments:

- Bibliography in electronic form using Endnote. It is recommended that the bibliography be provided in annotated format. This will include the article abstract (if available) and any notes you would like to make providing specific comments on the quality, methodology and/or conclusions of the study.

Citation List (included studies)

Citation Marker	Full Citation*
Assar, 2000	**Assar, D., D. Chamberlain, et al. (2000). "Randomised controlled trials of staged teaching for basic life support, 1: skill acquisition at bronze stage."** ***Resuscitation 45(1): 7-15.*** We have investigated a method of teaching community CPR in three stages instead of in a single session. These have been designated bronze, silver, and gold stages. The first involves only opening of the airway and chest compression with back blows for choking, the second adds ventilation in a ratio of compressions to breaths of 50:5, and the third is a conversion to conventional CPR. In a controlled randomised trial of 495 trainees we compared the performance in tests immediately after instruction of those who had received a conventional course and those who had had the simpler bronze level tuition. The tests were based on video recordings of simulated resuscitation scenarios and the readouts from recording manikins. Differences occurred as a direct consequence of ventilation being required in one group and not the other, some variation probably followed from unforeseen minor changes in the way that instruction was given, whilst others may have followed from the greater simplicity in the new method of training. A careful approach was followed by slightly more trainees in the conventional group whilst appreciably more in the bronze group remembered to shout for help (44% vs. 71%). A clear advantage was also seen for bronze level training in terms of those who opened the airway as taught (35% vs. 56%), for checking breathing (66% vs. 88%), and for mentioning the need to phone for an ambulance (21% vs. 32%). Little difference was observed in correct or acceptable hand position between the conventional group who were given detailed guidance and the bronze group who were instructed only to push on the centre of the chest. The biggest differences related to the number of compressions given. The mean delay to first compression was 63 s and 34 s, and the mean duration of pauses between compressions was 16 s and 9 s, respectively. Average performed rates were similar in the two groups, but more in the conventional group compressed too slowly whereas more in the bronze group compressed too rapidly. Observations were made for only three cycles of compression, but extrapolating these to the 8 min often considered a watershed for chances of survival for victims of cardiac arrest, an average of 308 compressions would be expected from those using conventional CPR compared with 675 for those using bronze level CPR. The implications of this difference are discussed. *Evidence:* **Supporting** *Quality of evidence:* **Fair** *Level of evidence:* **7** Teaching method. Supporting more chest compressions delivered in CV 50:5 vs CV 15:2. Three stages teaching strategy for CPR (50 compression only; CV 50:5; CV 15:2) Primary end point: - Evaluation of skill retention and performance difference in CPR Results: - Extrapolated observation that using a CV of 50:5 delivered 58% more compressions in the first 8 minutes Authors conclusions: An increase in chest compressions may result in a significant increase in blood flow, perfusion and outcome

Aufderheide, 2004	**Aufderheide, T. P., G. Sigurdsson, et al. (2004). "Hyperventilation-induced hypotension during cardiopulmonary resuscitation." *Circulation* 109(16): 1960-5.** BACKGROUND: A clinical observational study revealed that rescuers consistently hyperventilated patients during out-of-hospital cardiopulmonary resuscitation (CPR). The objective of this study was to quantify the degree of excessive ventilation in humans and determine if comparable excessive ventilation rates during CPR in animals significantly decrease coronary perfusion pressure and survival. METHODS AND RESULTS: In humans, ventilation rate and duration during CPR was electronically recorded by professional rescuers. In 13 consecutive adults (average age, 63+/-5.8 years) receiving CPR (7 men), average ventilation rate was 30+/-3.2 per minute (range, 15 to 49). Average duration per breath was 1.0+/-0.07 per second. No patient survived. Hemodynamics were studied in 9 pigs in cardiac arrest ventilated in random order with 12, 20, or 30 breaths per minute. Survival rates were then studied in 3 groups of 7 pigs in cardiac arrest that were ventilated at 12 breaths per minute (100% O2), 30 breaths per minute (100% O2), or 30 breaths per minute (5% CO2/95% O2). In animals treated with 12, 20, and 30 breaths per minute, the mean intrathoracic pressure (mm Hg/min) and coronary perfusion pressure (mm Hg) were 7.1+/-0.7, 11.6+/-0.7, 17.5+/-1.0 (P<0.0001), and 23.4+/-1.0, 19.5+/-1.8, and 16.9+/-1.8 (P=0.03), respectively. Survival rates were 6/7, 1/7, and 1/7 with 12, 30, and 30+ CO2 breaths per minute, respectively (P=0.006). CONCLUSIONS: Professional rescuers were observed to excessively ventilate patients during out-of-hospital CPR. Subsequent animal studies demonstrated that similar excessive ventilation rates resulted in significantly increased intrathoracic pressure and markedly decreased coronary perfusion pressures and survival rates. *Evidence:* **Supporting** *Quality of evidence:* **Good or Excellent** *Level of evidence:* **5 Good or 6 Excellent (a two part study)** A two-step study. A preliminary prehospital prospective observational study in humans. Primary end-point: to determine the pattern of ventilation by EMS before and after a retraining session emphasizing to limit ventilation to 12 breaths/minute. Intrathoracic pressure was inferred by recording airway pressure. Result: This phase showed a remarkable involuntary hyperventilation. (approximately double the AHA recommendation) Re-training decreased significantly the ventilatory rate provided but increased the inspiratory time. The final effect is equal amount of increased intrathoracic pressure in both groups. *Good* part of the study but small patient population. Intrathoracic pressure is only infered by the measurement of airway pressure, introducing a potential error. The second step is a prospective randomized study in animals in cardiac arrest where rate was set at 12 and 30 breaths/ minute. Primary end-point: hemodynamics including coronary perfusion pressure (CPP), intrathoracic pressure (ITP) arterial blood gas recording. Survival by ROSC was the outcome variable followed. Results: CPP and ITP were higher in the 30 breaths/ minute group. Increased ITP, but not change of ABG (pCO2) was responsible for adverse outcome. Survival rate was 6/7 pigs (86%) at 12 breaths/min compared with 1/7 (17%) at 30 breaths/ min. Excellent study but limited by number of subjects. Intrathoracic pressure is only inferred by the measurement of airway pressure, introducing a potential error. No breath/minute rate < 12 was studied.

Babbs, 2002	**Babbs, C. F. and K. B. Kern (2002). "Optimum compression to ventilation ratios in CPR under realistic, practical conditions: a physiological and mathematical analysis." *Resuscitation* 54(2): 147-57.** OBJECTIVE: To develop and evaluate a practical formula for the optimum ratio of compressions to ventilations in cardiopulmonary resuscitation (CPR). The optimum value of a variable is that for which a desired result is maximized. Here the desired result is assumed to be either oxygen delivery to peripheral tissues or a combination of oxygen delivery and waste product removal. METHOD: Equations describing oxygen delivery and blood flow during CPR as functions of the number of compressions and the number of ventilations delivered over time were developed from principles of classical physiology. These equations were solved explicitly in terms of the compression/ventilation ratio and evaluated for a wide range of conditions using Monte Carlo simulations. RESULTS: As the compression to ventilation ratio was increased from 0 to 50 or more, both oxygen delivery and the combination of oxygen delivery with blood flow increased to maximum values and then gradually declined. For variables typical of standard CPR as taught and specified in international guidelines, maximum values occurred at compression/ventilation ratios near 30:2. For variables typical of actual lay rescuer performance in the field, maximal values occurred at compression/ventilation ratios near 60:2. CONCLUSION: Current guidelines overestimate the need for ventilation during standard CPR by two to four-fold. Blood flow and oxygen delivery to the periphery can be improved by eliminating interruptions of chest compression for these unnecessary ventilations. *Evidence:* **Supporting** *Quality of evidence:* **Good** *Level of evidence:* **7** Mathematical model. Supporting no chest compression interruption for ventilation. In real conditions, better compression ventilation ratios are 50:2 or 60:2. The best may be CVR 30:2. Computer based simulation of hemodynamic condition during cardiac arrest using Monte Carlo simulation. Have evaluated oxygen delivery and blood flow variability during progressively increasing compression-to-ventilation ratios. For simplicity, explored only compression-to-ventilation ratios of the form n:2 (such as 15:2, 30:2 or 50:2). Other schemes may have merit. Primary end point: - To develop and evaluate a pratical formula for the optimum ratio of compressions-to-ventilation in CPR Measured and calculated: Oxygen delivery, blood flow Results: - Increasing the compression-to-ventilation ratio from 0 to 50 or more, both oxygen delivery and the combination of oxygen delivery and blood flow increased to maximum values and then gradually declined - For variables typical of standard COR as specified in international guideline, maximum values occurred at CVR 30:2 - For variables typical of actual lay rescuer performance in the field, maximum values occurred at CVR 60:2 Authors conclusions: current guidelines overestimate the need for ventilation during standard CPR. Blood flow and oxygen delivery can be improved by eliminating interruptions of chest compression for ventilation. Converting from CV 15:2 to CV 50:2, a 7-33% improvement in oxygen delivery is achived and perhaps an 18-80% increase in overall benefit.
Berg, 2001	**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): 2465-70.** 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. *Evidence:* **Supporting**

	Quality of evidence: **Good** *Level of evidence:* **7** *Animal model. Supporting no chest compression interruption for ventilation (ventilation lasting for 4 seconds to deliver)* *14 pigs. Ventricular fibrillation model. Untreated CA for 3 minutes, then BLS (for 12 minutes) and ACLS resuscitation care (in accordance with AHA algorithms for VF, defibrillation energy level at 120, 120, 200 J (4-6 J/Kg), ICU stay (60 minutes) and 24 hours observation for late survival and 24h neurological outcome evaluated by a swine Cerebral Performance Category (CPC) score. Autopsy performed. Left ventricle tissue samples to determine regional blood flow by using fluorescent, nonradioactive, color-microsphere techniques. Randomisation in two groups: chest compression only (CConly) vs chest compression plus ventilation at ratio 15:2 (CV 15:2). Not blinded.* *Well designed study to evaluate 24h survival and neurological outcome after CPR by CConly vs CV 15:2.* *Ventilation administered by a manual bag mask at 17% oxygen and 4% carbon dioxide via endotracheal tube. Chest compression pause of 16 seconds, to deliver 2 breaths in the CV 15:2, and for two breaths for the rescuer (no ventilation to the pig) every minute (100 compressions) in the CConly setting. Gasping during CPR. No impedance threshold valve (ITV) device: to prevent the possible passive inhalation/exalation air flow during CPR (open airway model). Ventilatory air flows were measured by a pneumotachometer (Fleich size 0, Intrumentation Associates). Hand made chest compression at 100 compressions per minute, synchronized by a metronome. No compression device: possible variability in depth and compression/release during chest compressions, even if measured pressure are not statistically different.* *Primary end point:* *- 24 hours survival and neurological outcome* *Measured and calculated: Right atrial pressure, aortic pressure, pulmonary artery pressure, ECG, PETCO2, minute ventilation, coronary perfusion pressure (CPP), integrated CPP (iCPP), left ventricle myocardial blood flow and cardiac output (fluorescent color-microsphere technique).* *Results:* *- Aortic relaxation ("diastolic") pressure decreased during the interval of 2 rescue breaths when no compressions were provided in the CV 15:2* *- The mean CPP of the first two compressions in each compression cycle was lower than that of the final two compressions in the CV 15:2* *- During each minute of CPR the number of chest compressions delivered was lower in the CV 15:2 group* *- The iCPP was lower with CV 15:2* *- Minute ventilation in CConly group after 7 minutes of CPR was 2650 +/- 670mL/min, and gasping accounted for 41 +/- 9% of the minute ventilation* *- Better myocardial perfusion in the CConly* *- Number of chest compressions nearly 50% greater in the CConly* *- No statistically significant difference in 24 hours neurologic outcome (CPC score) and 24 hours survival between the CV 15:2 and the CConly groups* *Authors conclusions:* *Interruption of chest compressions for rescue breathing can adversely affect hemodynamics during CPR. No difference in 24h survival and neurological outcome between CConly and CV 15:2 CPR if interruption of chest compression lasting for no more than 4 seconds to deliver ventilation (not consistent with data from real layperson rescuer scenario).*
Berg, 2000	**Berg, R. A., R. W. Hilwig, et al. (2000). ""Bystander" chest compressions and assisted ventilation independently improve outcome from piglet asphyxial pulseless "cardiac arrest". *<u>Circulation</u> 101(14): 1743-8.*** 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. *Evidence:* **Supporting** *Quality of evidence:* **Fair** *Level of evidence:* **7** *Animal model. Supporting that CC and V independently improve outcome in early stages of asphyxial cardiac arrest.* *40 pigs. Pulselessness (PEA) asphyxial induced model. BLS (for 8 minutes) and AHA guideline based ACLS resuscitation care (when indicated (17/40 pigs), defibrillation energy level was 50 - 100 J), ICU stay (60 minutes) and 24 hours*

	observation for late survival and 24h neurological outcome evaluated by a swine Cerebral Performance Category (CPC) score. No autopsy. Randomisation in three groups: chest compression only (CConly); ventilation only (V); chest compression plus ventilation at ratio 15:2 (CV 15:2) and no CPR during the 8 minute BLS period. Not blinded. *Well designed study.* *Ventilation administered by an Ambu manual bag mask at 17% oxygen and 4% carbon dioxide via endotracheal tube. CConly endotracheal tube clamped during BLS period. No ITV device. Manual chest compression at 100 compressions per minute (metronome guided). No compression device.* *Primary end point:* *- Evaluation whether CC alone and V alone can independently improve outcome at an early stage of asphyxial cardiac arrest* *Results:* *- outcome improves both with CC only or V only CPR compared with no-CPR* *- CV 15:2 is superior in terms of time to ROSC* *Authors conclusions:* *in bystander CPR, CC and V independently improve outcome in early stages of asphyxial cardiac arrest. CV 15:2 led to superior initial succesful resuscitation rates (ROSC during bystander CPR) vs CC only or V only in the early stages of apparent asphyxial cardiac arrest.*
Berg, 1997a	**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."** ***<u>Circulation</u>* 95(6): 1635-41.** 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. *Evidence:* **Supporting** *Quality of evidence:* **Fair** *Level of evidence:* **7** *Animal model. Supporting change to chest compression only.* *26 pigs. Ventricular fibrillation model. Untreated CA for 5 minutes, then BLS (for 8 minutes) and AHA guideline based ACLS resuscitation care (monophasic defibrillation energy level 100 - 200 J), ICU stay (60 minutes) and 24 hours observation for late survival and 24 h neurological outcome evaluated by a swine Cerebral Performance Category (CPC) score and Swine Neurological Deficit Score. No autopsy. Randomisation in three groups: chest compression only (CConly); chest compression plus ventilation at ratio 15:2 (CV 15:2) and no CPR during the 8 minute BLS period. Not blinded.* *Well designed study to evaluate 24 h survival and neurological outcome after CPR by CConly vs CV 15:2 vs no-CPR.* *Ventilation administered by an Ambu manual bag mask at 17% oxygen and 4% carbon dioxide via endotracheal tube. CConly endotracheal tube remouved during BLS period. No ITV device. Manual chest compression at 100 compressions per minute (metronome guided). No compression device.* *Primary end point:* *- Evaluation of the need for assisted ventilation in a single rescuer bystander CPR scenario in term of 24h neurological outcome and survival* *Secondary end point:* *- CPR (CC or CC + V) is better than no-CPR in terms of 24 hour survival and neurological outcome* *Results:* *- 24 hours survival and neurologic outcome were similar after CConly or CPR 15:2* *- CConly and CPR 15:2 improve outcome compared with no bystander CPR* *Authors conclusions:* *CConly CPR produces similar neurologically normal 24-hour survival compared with CV 15:2 in a realistic single layperson rescuer simulated scenario of VF arrest due to acute miocardial infarction.* *CConly and CV 15:2 CPR shows better 24h survival and neurological outcome compared with no-CPR.*
Berg, 1997b	**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."** ***<u>Circulation</u>* 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. *Evidence:* **Supporting** *Quality of evidence:* **Fair** *Level of evidence:* **7** *Animal model. Supporting change to chest compression only.* *43 pigs. Ventricular fibrillation model, induced myocardial infarction. Untreated CA for 2 minutes, then BLS (for 10 minutes) and AHA GL based ACLS resuscitation care (monophasic defibrillation energy level 120 - 200 J), ICU stay (60 minutes) and 24 hours observation for late survival and 24h neurological outcome evaluated by a swine Cerebral Performance Category (CPC) score and Swine Neurological Deficit Score. Autopsy for infarct documentation. Randomisation in three groups: chest compression only (CConly); chest compression plus ventilation at ratio 15:2 (CV 15:2) and no CPR during the 8 minute BLS period. Not blinded.* *Well designed study to evaluate 24h survival and neurological outcome after CPR by CConly vs CV 15:2 vs no-CPR. Ventilation administered by an Ambu manual bag mask at 17% oxygen and 4% carbon dioxide via endotracheal tube. CConly endotracheal tube removed during BLS period. No ITV device. Manual chest compression at 100 compressions per minute (metronome guided). No compression device.* *Primary end point:* *- Evaluation of the need for assisted ventilation in a single rescuer bystander CPR scenario (myocardial infarction model) in terms of 24h neurological outcome and survival* *Results:* *- 24 hour survival was better in the CConly vs no-CPR* *Authors conclusions:* *assisted ventilation did not improve outcome in a realistic single layperson rescuer CPR simulated scenario (myocardial infarction induced).*
Chamberlain, 2001	**Chamberlain, D., A. Smith, et al. (2001). "Randomised controlled trials of staged teaching for basic life support: 2. Comparison of CPR performance and skill retention using either staged instruction or conventional training."** ***Resuscitation*** ***50(1): 27-37.*** Teaching CPR in stages is a strategy designed to improve skill acquisition and retention. This method has been compared with conventional teaching in a randomised trial involving 495 volunteers. The first ('bronze') stage was simplified by omitting ventilation and giving compressions in sets of 50 with pauses to open the victim's airway; in the second ('silver') stage ventilation was introduced in a ratio of 50 compressions to five breaths, and in the third ('gold') stage, the volunteers were converted to conventional CPR. 51% of those taught by this method reattended for the second ('silver') stage compared with 25% who were taught conventional CPR and advised to return for a revision session. 38% of the staged group reattended for the third ('gold') compared with 8% for the conventional group. Modest improvement in skill acquisition has earlier been reported for the 'bronze' stage teaching, and this has been followed by better performance in some of the components tested after the subsequent stages. Comparisons after the 'gold' stage were limited by the small numbers who reattended for a third session of conventional training, but no special difficulties were noted in changing the ratio of compressions to ventilation that was necessary to convert the staged training volunteers to conventional CPR. The increased number of compressions that can be achieved by teaching 'bronze' stage CPR with no ventilation was retained, to a lesser degree, when the 'silver' ratio of 50 compressions to five breaths was compared with the conventional 15:2 ratio. Our observations suggest that during the first critical 8 min of a resuscitation attempt, 58% more compressions might be delivered by using the 50:5 ratio – an increase that is likely to result in a significant augmentation of blood flow with important clinical implications. More comparative information will become available when the results of unannounced home testing are analysed. *Evidence:* **Supporting** *Quality of evidence:* **Fair** *Level of evidence:* **7**

	Teaching method. Supporting more chest compressions delivered in CV 50:5 vs CV 15:2. *Three stage teaching strategy for CPR (50 compression only; CV 50:5; CV 15:2)* *Primary end point:* *- Evaluation of skill retention and performance difference in CPR* *Results:* *- Extrapolated observation that in the CV 50:5 58% more compressions were delivered in the first 8 minutes* *Authors conclusions:* *An increase in chest compressions may result in a significant increase in blood flow, perfusion and improved outcome.*
Dorph, 2003	**Dorph, E., L. Wik, et al. (2003). "Quality of CPR with three different ventilation:compression ratios." *<u>Resuscitation</u>* *58(2): 193-201.*** Current adult basic cardiopulmonary resuscitation (CPR) guidelines recommend a 2:15 ventilation:compression ratio, while the optimal ratio is unknown. This study was designed to compare arterial and mixed venous blood gas changes and cerebral circulation and oxygen delivery with ventilation:compression ratios of 2:15, 2:50 and 5:50 in a model of basic CPR. Ventricular fibrillation (VF) was induced in 12 anaesthetised pigs, and satisfactory recordings were obtained from 9 of them. A non-intervention interval of 3 min was followed by CPR with pauses in compressions for ventilation with 17% oxygen and 4% carbon dioxide in a randomised, cross-over design with each method being used for 5 min. Pulmonary gas exchange was clearly superior with a ventilation:compression ratio of 2:15. While the arterial oxygen saturation stayed above 80% throughout CPR for 2:15, it dropped below 40% during part of the ventilation:compression cycle for both the other two ratios. On the other hand, the ratio 2:50 produced 30% more chest compressions per minute than either of the two other methods. This resulted in a mean carotid flow that was significantly higher with the ratio of 2:50 than with 5:50 while 2:15 was not significantly different from either. The mean cerebrocortical microcirculation was approximately 37% of pre-VF levels during compression cycles alone with no significant differences between the methods. The oxygen delivery to the brain was higher for the ratio of 2:15 than for either 5:50 or 2:50. In parallel the central venous oxygenation, which gives some indication of tissue oxygenation, was higher for the ratio of 2:15 than for both 5:50 and 2:50. As the compressions were done with a mechanical device with only 2-3 s pauses per ventilation, the data cannot be extrapolated to laypersons who have great variations in quality of CPR. However, it might seem reasonable to suggest that basic CPR by professionals should continue with ratio of 2:15 at present if it can be shown that similar brief pauses for ventilation can be achieved in clinical practice. *Evidence:* **Supporting** *Quality of evidence:* **Excellent** *Level of evidence:* **6** *Animal model. Supporting no change from CVR 15:2 for health care professionals and higher CV ratios for lay people.* *9 pigs. Ventricular fibrillation model. Untreated CA for 3 minutes, then BLS at CVR 15:2, 50:2, 50:5 was performed subsequently in each pig (each ratio being used for 5 minutes). No ALS resuscitation care nor post-resuscitation care to evaluate late survival and 24h neurological outcome. Autopsy performed. Randomization: the priority list was written so that the performance of the different methods as evenly spread as the first, second and third method. Three groups: chest compression plus ventilation at ratio 15:2 (CV 15:2), 50:2 (CV 50:2) and 50:5 (CV 50:5). Not blinded. ETCO2 and minute ventilation not recorded for CVR 15:2 and 50:2 in one pig (malfunction of the analyser), arterial oxygen saturation not obtained in two pigs.* *Well designed study to directly compare O2 delivery during CPR by different CV ratios (15:2, 50:2, 50:5). Good literature review in the specific field for the definition of the best CVR in basic CPR.* *Obstructed airway by a valve hindering passive inhalation, without impeding expiratory air flow (ITV Resusci-valve, CPRxLLC, Minneapolis, USA). Chest compression device (Heartsaver 2000, Medreco, Bodø, Norway), settings: 100/min, depth 4 cm, compression-relaxation 50:50. Ventilation administered by adult size manual bag mask (Laerdal, Stavanger, Norway) at 17% oxygen and 4% carbon dioxide; inhalation over 1.0-1.5 seconds each.* *Primary outcomes:* *- To compare arterial and mixed venous blood gas changes and cerebral circulation and oxygen delivery with CVR 15:2, 50:2, 50:5 in a model of basic CPR.* *Calculated: coronary perfusion pressure (CPP); brain (carotid) oxygen delivery (O2D in ml/min).* *Results:* *- Mean carotid flow was significantly lower with the ratio 50:5 than 50:2 while 15:2 was not significantly different from either.* *- Mean carotid flow and focal cerebrocortical microcirculation during chest compression cycles alone (excluding ventilation period) was approximately 34% and 37% respectively of the pre-arrest control with no significant difference between methods.* *- Carotid oxygen delivery was significantly higher for the CV 15:2 vs 50:5 and there was a strong trend towards the same vs 50:2.* *- No significant differences between methods on the aortic pressure, right atrial pressure, left ventricular pressure, and coronary perfusion pressure.* *- Arterial pO2 and oxygen saturation were significantly lower and end-tidal pCO2 and arterial pCO2 significantly higher for ratios 50:2 and 50:5 vs 15:2. Mixed venous pO2 was significantly lower for CVR 50:5 vs 15:2 with a trend toward the same for 50:2 vs 15:2.*

	- Pauses for ventilation were 4.9 +/- 0.3 seconds (2 breaths) and 13.5 +/- 0.8 seconds (5 breaths). *- The number of breaths per minute and the minute ventilation were significantly greater with CVR 15:2 vs 50:2 and 50:5.* *- The number of chest compressions per minute was significantly higher with CVR 50:2 vs 15:2 and 50:5.* *- CVR 15:2 was clearly superior vs CVR 50:2 and 50:5 regarding pulmonary gas exchange, while CVR 50:2 tended to give the best circulation, producing 30% more chest compressions per minute.* *Authors conclusions:* *CVR 15:2 in ideal basic CPR model gave better pulmonary gas exchange and cerebral oxygen delivery than both 50:2 and 50:5. Continuous arterial oxygen saturation tracings indicated that ratio 30:2 might be an even more optimal CVR.* *Not suitable for direct comparison of different compression ventilation ratio efficacy in terms of ROSC, 24h survival and neurological outcome.*
Dorph, 2004	**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): 309-18.*** 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. *Evidence:* **Supporting** *Quality of evidence:* **Fair** *Level of evidence:* **7** *Animal model. Supporting change to CVR 30:2.* *12 pigs. Ventricular fibrillation model. Untreated CA for 3 minutes, then BLS (for 10 minutes) and ALS resuscitation care (performed as continuous chest compressions with manual ventilation at 12,5 ventilations per minute). No post-resuscitation care to evaluate late survival and 24h neurological outcome. Autopsy performed. Randomisation in two groups: chest compression only (CConly) vs chest compression plus ventilation at ratio 30:2 (CV 30:2). Not blinded.* *Well designed study to compare cerebral O2 delivery during CPR by CConly vs CV 30:2. Obstructed airway by a valve hindering passive inhalation, without impeding expiratory air flow (ITV Resusci-valve, CPRxLLC, Minneapolis, USA). Chest compression device (Heartsaver 2000, Medreco, Bodø, Norway), settings: 100/min, depth 4 cm, compression-relaxation 50:50. Ventilation administered by adult size manual bag mask (Laerdal, Stavanger, Norway) at 17% oxygen and 4% carbon dioxide; inhalation over 1.0-1.5 seconds each.* *Primary outcomes:* *- calculated carotid and cerebrocortical O2 delivery* *- time to return of spontaneous circulation (ROSC) in ALS period* *Calculated: coronary perfusion pressure (CPP); cerebral cortical blood flow (CCBF), carotid oxygen delivery (O2D in ml/min).* *Results:* *- No significant difference in baseline data before CA* *- After 3 minutes of untreated VF oxygen saturation not significantly lower than baseline* *- Mean CPP and CCBF remained above 25% and 20% respectively of baseline, no significant difference between methods* *- After 1 minute CPR the arterial pO2, Oxygen saturation and pH were significantly higher and arterial pCO2 lower in the CV 30:2 group* *- Arterial oxygen content and cerebral oxygen delivery were significantly higher in the CV 30:2 group* *- More animals had early ROSC (within 2 minutes) during ALS in the CV 30:2 group.* *Authors conclusions:* *need of ventilation during cardiac arrest with obstructed airway. Not suitable for direct comparison of different compression ventilation ratio efficacy in terms of O2 delivery, ROSC, 24h survival and neurological outcome*
Greingor, 2002	**Greingor, J. L. (2002). "Quality of cardiac massage with ratio compression-ventilation 5/1 and 15/2." *Resuscitation* *55(3): 263-7.*** OBJECTIVE: The aim of this study is to study the quality of chest compressions over a period of 5

	min with a compression-ventilation ratio of 5/1 and 15/2. MATERIAL AND METHODS: This prospective study was carried out with an electronic CPR manikin (ResusciAnne with Skillmeter; Laerdal). The participants were 'ambulancier SMUR' (Emergency and Resuscitation Mobil Unit) belonging to a French prehospital emergency team. They all have been trained in cardiopulmonary resuscitation (CPR) and are certified to perform CPR. The quality of chest compression has been evaluated according to the international recommendations. Each participant provided CPR with ratio 5/1 and 15/2. RESULTS: Twenty-one subjects participated in this experiment. The mean number of attempted compressions per min was 69.24 (S.D.=8.7) for a ratio of 5/1 and 79.26 (S.D.=6.7) for a ratio of 15/2. The rates achieved were similar between the two ratios with, respectively, a mean of 103.5 and 112 per min. The mean correct compression was 56.5 (S.D.=15.7) per min for group 5/1 and 44.16 (S.D.=24.8) for group 15/2. Quality of closed chest compression was very significantly better with a ratio of 5/1 than 15/2 (P=0.0002). A significant decrease in compression quality has been found over the time for a ratio of 15/2 (P=0.011). No correlation between correct compression and duration appeared for group 5/1. Incorrect location on sternum was 24 times most frequent with a ratio of 15/2 than ratio 5/1. Compression of insufficient depth remained the most frequent error both with ratio 5/1 and 15/2 and was 2.2 times more frequent with a ratio of 15/2 than a ratio of 5/1. CONCLUSION: Effective closed chest compression was significantly better with a ratio of 5/1 than 15/2. Better management of cardiac arrest suggested by an increase in a number of compressions with a ratio of 15/2 could be attenuated by cardiac compressions of lesser quality. *Evidence:* **Opposing** *Quality of evidence:* **Good** *Level of evidence:* **7** *Manikin model. Supporting CV 5:1 compared with CV 15:2 in terms of quality of chest compression.* *21 French prehospital emergency team members involved in a simulated basic CPR scenario based on a Resusci Anne manikin (Laerdal Medical Ltd.) during the different settings of a single-man (CV 15:2) and a two-man (CV 5:1) resuscitation.* *Primary end point:* *- To determine the quality of chest compressions over a period of 5 minutes during the different settings of a one- and two-person BLS (CV 15:2 vs 5:1)* *Results:* *- CV 15:2 provided 14.5% more compressions than CV 5:1* *- The quality of chest compression was significantly better in the CV 5:1 than in the CV 15:2* *- Nearly 81% of rescuers perceived CV 15:2 more tiring.* *Authors conclusions:* *The CV ratio affects the quality of chest compressions. The CV 15:2 produced more chest compressions, but less effective. Fatigue can explain this result. Better management of cardiac arrest suggested by an increase in CVR could be attenuated by less effective cardiac compressions.*
Hallstrom, 2000	**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): 1546-53.*** 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.

	Evidence: **Supporting** *Quality of evidence:* **Fair** *Level of evidence:* **7** *Human. Randomized study. Blinded. Study period 1992-1998. EMS telepnone dispatch based setting (Seattle) to compare CPR by chest compressions only with CV 15:2 in terms of survival. Used Utstein reporting. Supporting the applicability of CConly CPR in the setting of bystander-iniziated CPR.* *Primary end point:* *- survival to hospital discharge.* *Results:* *- A strategy of dispathcer-instructed chest compression plus mouth-to-mouth ventilation was not superior to chest compression only* *- The rate of survival to hospital discharge (29% higher) and rate of admission to the hospital (15% higher) were higher with chest compression alone than with CV 15:2 (Not statistically significant).* *Authors conclusions:* *CC only CPR may be applicable to the more general setting of bystander-iniziated CPR.*
Herlitz, 2000	**Herlitz, J., E. Andersson, et al. (2000). "Experiences from treatment of out-of-hospital cardiac arrest during 17 years in Goteborg." *Eur Heart J 21(15): 1251-1258.*** AIMS: To describe changes in different factors at resuscitation and survival in a 17-year survey of patients suffering from out-of-hospital cardiac arrest. METHOD: The investigation was carried out in the community of Goteborg with 450 000 inhabitants during 1981-1997 on all patients suffering out-of-hospital cardiac arrest in whom resuscitation was attempted. RESULTS: The number of cases per year, the proportion of witnessed arrests and the proportion of arrests of cardiac aetiology remained similar over time. There was an increase in median age from 68 to 73 years (P<0.0001), in the proportion of females from 27% to 33% (P=0.035) and in the proportion of patients receiving bystander cardiopulmonary resuscitation from 14% to 28% (P<0.0001) with time. There was a shortening of the median interval from collapse until defibrillation from 9 min to 6 min (P<0.0001) over time but a decrease in the occurrence of ventricular fibrillation as the initially recorded arrhythmia from 39% to 32% (P=0.022). There was an increase in the proportion of patients having a bystander witnessed cardiac arrest of cardiac aetiology being hospitalized alive from 32% to 45% (P<0. 0001 for change over time). The proportion of patients discharged alive from hospital increased from 16% to 29% until 1993, but thereafter decreased to 13% in 1997 (P=0.002 for change over time). CONCLUSION: In a survey covering 17 years of resuscitation of out-of-hospital cardiac arrest patients we found that the occurrence of ventricular fibrillation as the initially recorded arrhythmia decreased. There was an increase in age, in the proportion of females and in the use of bystander cardiopulmonary resuscitation. The interval between collapse and defibrillation was shortened. Survival changed over time with an increase until 1993 but with a decrease thereafter. Copyright 2000 The European Society of Cardiology. *Evidence:* **Supporting** *Quality of evidence:* **Fair** *Level of evidence:* **7** *Human. Observational prospective study. Study period 1981-1997. 4662 patients. Out of hospital cardiac arrest. EMS dispatch based setting (Göteborg). No Utstein. No details on style of CPR (CV ratio). Supporting bystander CPR in out-of-hospital setting to increase survival.* *Primary end point:* *- describe the chain of survival* *- survival to admission and to hospital discharge* *- survival at 1 month* *Results:* *- the median age of the population increased from 68 years to 73 years during the study period from 1981 to 1997* *- the proportion of patients found in VF was below 50%* *- the median collapse to defibrillation time interval ranged between 6 and 10 minutes* *- bystanders performed CPR before arrival of EMS increased from 14% to 31%* *- the proportion of patients found in VF and discharged alive from hospital increased* *- in the last 4 years the proportion of discharged alive decreased (co-morbidity and age)* *- survival 18%.* *Authors conclusions:* *Resuscitation characteristics associated with good survival to cardiac arrest were witnessing the arrest, bystander CPR, time intervals.*
Holmberg, 2001	**Holmberg, M., S. Holmberg, et al. (2001). "Factors modifying the effect of bystander cardiopulmonary resuscitation on survival in out-of-hospital cardiac arrest patients in Sweden." *Eur Heart J 22(6): 511-519.*** AIM: To describe possible factors modifying the effect of bystander cardiopulmonary resuscitation

	on survival among patients suffering an out-of-hospital cardiac arrest. PATIENTS: A national survey in Sweden among patients suffering out-of-hospital cardiac arrest and in whom resuscitative efforts were attempted. Sixty per cent of ambulance organizations were included. DESIGN: Prospective evaluation. Survival was defined as survival 1 month after cardiac arrest. RESULTS: In all, 14065 reports were included in the evaluation. Of these, resuscitation efforts were attempted in 10966 cases, of which 1089 were witnessed by ambulance crews. The report deals with the remaining 9877 patients, of whom bystander cardiopulmonary resuscitation was attempted in 36%. Survival to 1 month was 8.2% among patients who received bystander cardiopulmonary resuscitation vs 2.5% among patients who did not receive it (odds ratio 3.5, 95% confidence interval 2.9-4.3). The effect of bystander cardiopulmonary resuscitation on survival was related to: (1) the interval between collapse and the start of bystander cardiopulmonary resuscitation (effect more marked in patients who experienced a short delay); (2) the quality of bystander cardiopulmonary resuscitation (effect more marked if both chest compressions and ventilation were performed than if either of them was performed alone); (3) the category of bystander (effect more marked if bystander cardiopulmonary resuscitation was performed by a non-layperson); (4) interval between collapse and arrival of the ambulance (effect more marked if this interval was prolonged); (5) age (effect more marked in bystander cardiopulmonary resuscitation among the elderly); and (6) the location of the arrest (effect more marked if the arrest took place outside the home). CONCLUSION: The effect of bystander cardiopulmonary resuscitation on survival after an out-of-hospital cardiac arrest can be modified by various factors. Factors that were associated with the effect of bystander cardiopulmonary resuscitation were the interval between the collapse and the start of bystander cardiopulmonary resuscitation, the quality of bystander cardiopulmonary resuscitation, whether or not the bystander was a layperson, the interval between collapse and the arrival of the ambulance, age and the place of arrest. *Evidence:* **Supporting** *Quality of evidence:* **Fair** *Level of evidence:* **7** *Human. Observational prospective study. Study period 1990-2000. Guidelines revision in 1987 (AHA), 1993 (ERC). 9877/14065 patients. Out of hospital Cardiac arrest. EMS dispatch based setting (Sweden). Utstein. No details on style of CPR (CV ratio). Supporting bystander CPR in OH setting to increase survival.* *Primary end point:* *- describe possible factors modifing the effect of bystander CPR on survival in OH cardiac arrest setting* *- survival at 1 month* *Results:* *- survival at 1 month was 8.2% (bystander basic CPR) vs 2.5% (no bystander CPR)* *- higher survival rate in patients resuscitated by medical personel than by lay persons* *Authors conclusions:* *basic CPR performed before arrival of EMS substantially improved survival*
Kern, 2002	**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): 645-9.** 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. *Evidence:* **Supporting** *Quality of evidence:* **Good** *Level of evidence:* **7** *Animal model. Supporting change to chest compression only (if ventilation lasting for 16 seconds to deliver).* *30 pigs. Ventricular fibrillation model. Untreated CA for 3 minutes, then BLS (for 12 minutes) and ACLS resuscitation care (monophasic defibrillation energy level at 4, 5, 6 J/Kg), ICU stay (60 minutes) and 24 hours observation for late survival and 24h neurological outcome evaluated by a swine Cerebral Performance Category (CPC) score. No autopsy. Randomisation in two groups: chest compression only (CConly) vs chest compression plus ventilation at ratio 15:2 (CV 15:2). Not blinded. Well designed study to evaluate 24 h survival and neurological outcome after CPR by CConly vs CV 15:2.* *Ventilation administered by an Ambu manual bag mask at 17% oxygen and 4% carbon dioxide via endotracheal tube. Chest compression pause of 16 seconds, to deliver 2 breaths in the CV 15:2, and for two breaths for the rescuer (no ventilation to the pig) every minute (100 compressions) in the CConly setting. No ITV device: to prevent the possible passive inhalation/exalation air flow during CPR (open airway model). Ventilatory air flows were measured by a pneumotachometer (MP45-871; Validyne Engineering Corp, Northridge, CA). Manual chest compression at 100 compressions per minute, synchronized by a metronome. No compression device: possible variability in depth and compression/release during chest compressions, even if measured pressure was not statistically different.* *Primary end point:* *- 24 hours survival and neurological outcome* *Secondary end point:* *- ROSC at 30 minutes* *- CPR-generated hemodynamics* *- Arterial, mixed venous blood gases and minute ventilation* *Measured and calculated: Right atrial pressure, Aortic pressure, pulmonary artery pressure, ECG, PETCO2, minute ventilation, coronary perfusion pressure (CPP).* *Results:* *- 24 hour neurologic outcome (CPC score) better in the CConly group* *- 24 hour survival better in the CConly group* *- Coronary perfusion pressure (CPP) was significantly higher with CV 15:2 in the mid portion of the resuscitation period* *- Integrated CPP was significantly greater with CConly during the entire CPR period* *Authors conclusions:* *CConly CPR produces superior neurologically normal 24 hours survival compared with CV 15:2 in a realistic single layperson rescuer simulated scenario of VF arrest.* *Mouth-to-mouth ventilation performed by single layperson rescuer produced substantial interruption in chest compression supported circulation*
Kill, 2004 (#27)	**Kill, C., C. Friedrich, et al. (2004). "Advantages of longer compression intervals during Basic Life Support." *Resuscitation* 60(2): 231-2.** *Evidence:* **Supporting** *Quality of evidence:* **Fair** *Level of evidence:* **6** Letter to the Editor: In 2002, Turner et al. reported in this journal on their computer simulation of different ventilation/compression ratios with a focus on tissue perfusion and oxygen delivery. They concluded that longer compression periods may improve oxygen delivery, although they cause decreased ventilation minute volumes. We would like to report the results of our own study in a BLS manikin model. In our simulation 23 paramedics performed bag/valve/mask ventilation in a manikin (Resusci Anne Skillmeter, Laerdal®, Norway) using both the 2:15 (method A) and the 5:50 (method B) ventilation/ compression ratio. Ventilation was performed with a self-inflating bag (AMBU® Mark 3) and face mask; compressions were simulated with a duration of 0.6 s/compression (simulated heart rate of 100 min-1) occupying 9 s of the minute in method A and 30 s in method B. Expiratory volume and number of ventilations were measured over a 6-min period. Total expiratory volumes were compared using Student's *t*-test. Over this 6 min period, average total expiratory volumes were 32.72l (±9.48l) (method A) and 30.83l (±8.48l) (method B), $P>0.1$(CI 95%). The mean number of applied ventilations was 47.8/6 min (method A) and 44.6/6 min (method B), mean expiratory tidal volumes were 684 ml (method A) and 691 ml (method B). Turner et al. Predicted that optimised tissue perfusion and oxygen delivery can be reached only with at least 50 non-interrupted compressions, although in this model calculated ventilation volumes were 25% lower using a ventilation/ compression ratio of 5:50 compared with 2:15. Several other investigations in animals have shown that interruptions of external cardiac compressions worsen the outcome. There is also some evidence, that at least in the early stages of CPR by laypersons, ventilation may not be necessary at all. Sanders et al. investigated different ventilation/compression ratios in a porcine model and found improved outcome with ventilation/compression ratios of up to 2:100. Babbs and Kern published data from a physiological and mathematical analysis of optimum compression to ventilation ratios in CPR under realistic, practical conditions and found maximum values for oxygen delivery at ventilation/ compression ratios around 2:30 and conclude that interruptions of cardiac compressions should be minimized. All these investigators demonstrated, that the importance of prolonged periods of chest compressions seems to be underestimated, whereas the minimum ventilation volume could not yet be defined. In our study, the applied ventilation volumes are not statistically different between ventilation/compression ratios of 2:15 and 5:50. Although theoretically 5:50 should lead to a 25% reduction in total ventilation volume, the larger number of ventilations run in sequence seems to be more effective and "time-saving" in practice. Data about the "optimum ventilation/compression ratio" in patients with cardiac arrest are still limited, and we believe that the results of our small study using manikin simulation may provide additional information for the ongoing discussion on: "how many ventilations are really necessary during basic life support?"

Sanders, 2002	**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): 553-62.** 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. *Evidence:* **Supporting** *Quality of evidence:* **Good** *Level of evidence:* **6** *Animal model. Supporting change to higher CVR: chest compression only for 4 minutes, then CVR 100:2 (CVR 100:2).* *40 pigs. Ventricular fibrillation model. Untreated CA for 3 minutes, then BLS (for 12 minutes), ACLS resuscitation care (performed in accordance with AHA ACLS guidelines, but 120, 120, 200 J defibrillation energy (4-6 J/Kg), ICU stay (60 minutes) and 24 hours observation for late survival and 24h neurological outcome. Autopsy performed. No randomization.* *Four groups: chest compression plus ventilation at ratio 15:2 (CV 15:2); chest compression only CPR (CConly), defined as chest compressions at 100 compressions per minute without ventilation with 4 seconds pause between compressions; chest compression plus ventilation at ratio 50:5 (CV 50:5) and chest compression plus ventilation at ratio 100:2 (CV 100:2), defined as chest compression only for 4 minutes with no ventilations and 4 seconds rest between compression, then 100:2 CVR for the remaining 8 minutes. Not blinded.* *Well designed study to directly compare 24 hour survival, neurological outcome and coronary perfusion (CCP) during CPR by different CV ratios (15:2, CConly, 50:5, 100:2).* *Autopsy tissue samples collection from heart and kidneys to determine regional blood flow by using standard microsphere techniques.* *Manual chest compression at 100 compressions per minute, synchronized by a metronome. No compression device: possible variability in depth and compression/release during chest compressions, even if measured pressure are not statistically different.* *Ventilation administered by an Ambu manual bag at 17% oxygen and 4% carbon dioxide via endotracheal tube. No ITV device: to prevent the possible passive inhalation/exalation air flow during CPR (open airway model). Ventilatory air flows were measured by a pneumotachometer (MP45-871; Validyne Engineering Corp, Northridge, CA).* *Primary outcomes:* *- 24 hour survival and neurological outcome* *Measured: right atrial and aortic pressure, ETCO2, arterial blood gas analysis.* *Calculated: coronary perfusion pressure (CPP); fluorescent microsphere techniques for heart and kidneys perfusion.* *Results:* *- No statistically significant difference in 24 hour survival among the 4 groups.* *- CVR 100:2 had the best neurologic outcome, while CVR 15:2 had the worst neurologic score.* *- Perfusion pressures were not different among the four groups.* *- At 6 and 9 minutes CPR the CVR 50:5 had significantly better perfusion than 100:2 and 15:2, but these trends did not continue during the other 10 minutes of CPR.* *- Minute ventilation and pO2 at 9 minutes are significantly less in the CConly group vs 100:2.* *Authors conclusions:* *CVR 100:2 shows better 24 hour neurologic outcome vs the other tree methods. Some ventilation might be important for maintaining oxygenation when prolonged CPR is necessary. Data collected do not indicate an advantage for frequent*

	ventilation, such as the 15:2 vs 50:5 or 100:2.
Thierbach, 2003	**Thierbach, A. R., B. B. Wolcke, et al. (2003). "Artificial ventilation for basic life support leads to hyperventilation in first aid providers." *Resuscitation* 57(3): 269-77.** The 'Guidelines 2000 for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care – International Consensus on Science' recommend an artificial ventilation volume of 10 ml/kg bodyweight (equivalent to a tidal volume of 700-1000 ml) without the use of supplemental oxygen in adults with respiratory arrest. For first aid providers using the mouth-to-mouth or mouth-to-nose-ventilation technique, respectively, a ventilation volume of approximately 9.6 l/min results. Additionally, a deep breath is recommended before each ventilation to increase the end-expiratory oxygen concentration of the air exhaled by the first aid provider. To investigate the effects of these recommendations in healthy volunteers, test persons were asked to ventilate an artificial lung model for a period of up to 10 min. The tidal volume was set at 800 ml at a breathing rate of 12/min. End-tidal carbon dioxide, oxygen saturation (measured by pulse oximetry), and heart rate were measured continuously. Capillary blood gas samples were collected and non-invasive blood pressure readings were recorded prior to the start of ventilation and immediately after the end of the measuring period. The data reveal a statistically significant and clinically relevant decrease in end-tidal carbon dioxide pressure ($P<0.001$, median decrease 14 mmHg), and the occurrence of hyperventilation-associated symptoms such as paraesthesia, dizziness, and carpopedal spasms in more than 75% of the participants. Clinically and statistically significant hyperventilation results in first aid providers performing artificial ventilation according to the guidelines. This artificial ventilation is associated with a significant decrease in capillary and end-tidal carbon dioxide pressure as well as with multiple symptoms of an acute hyperventilation syndrome. Ventilation performed according to these guidelines may cause injury to the health of the first aid provider. Rescuers ventilating the victim should be replaced at regular intervals and the recommendation to take a deep breath before each ventilation should not be upheld in order to minimise the risk of hyperventilation. *Evidence:* **Supporting** *Quality of evidence:* **Fair** *Level of evidence:* **7** *Manikin model. 53 adult participants asked to ventilate an anritficial lung (Vent Aid Training Test Lung, Michigan Instruments Inc., Grand Rapids, Michigan, USA) for max 10 minutes. Tidal volume set to 800 mL, respiratory rate 12/min, stop one over five seconds. Measured in continous end-tidal dioxide pressure, pulse oxymetry, pulse rate, non-invasive blood pressure, capillary blood samples.* *Primary end point:* *- To evaluate the incidence of the hyperventilation sindrome in healty volunteers of the recomended artificila ventilation (10 mL/Kg – tidal volume 700/1000 mL)* *Results:* *- peak of the heart rate after 1-3 minutes, max rate over 140 bpm* *- non-invasive blood pressure values and the median capillary pO2 did not reveal any significant changes* *- the quality of chest compression was significantly better in the CV 5:1 than in the CV 15:2* *- the median EtCO2 decreased significantly from 35 to 20 mmHg* *Authors conclusions:* *M-to-M ventilation performed according to the ILCOR Guidelines 2000 may cause injury to the health of the rescuer. Rescuers doing ventilations should be replaced at regular intervals. The recommendation to take a deep breath before each ventilation should not be upheld in ordeeer to minimise the risk of hyperventilation sindrome in the rescuer.*
Turner, 2002	**Turner, I., S. Turner, et al. (2002). "Does the compression to ventilation ratio affect the quality of CPR: a simulation study." *Resuscitation* 52(1): 55-62.** Experience has shown that better quality CPR leads to a greater chance of a patient surviving a cardiac arrest. Simple CPR techniques, such as using only chest compressions, lead to better skill retention and greater willingness to attempt resuscitation on strangers. However, it is not clear from clinical or experimental studies whether such techniques offer any physiological benefit over more usual 5:1 or 15:2 compression:ventilation ratios. Computer simulations of blood flow and gas exchange during CPR showed that continuous chest compressions produced much greater blood flow (1.39 l/min) than 5:1 (0.73 l/min), 15:2 (0.86 l/min) or 50:5 (0.94 l/min) ratios. However, the ratio of 5:1 produced the highest arterial oxygen levels, with continuous chest compressions the lowest. The most appropriate measure of CPR efficiency appears to be the amount of oxygen delivered to the body during CPR. The ratios of 15:2 and 50:5 produced significantly greater oxygen delivery to the body than 5:1, the greater blood flow with these techniques offsetting the slightly lower arterial oxygen levels. The best oxygen delivery was provided by continuous chest compression in the early stages of CPR. After 3-4 min however, hypoxia meant that continuous

	compressions became worse than the other techniques. Spontaneous gasping by the patient during CPR was able to extend the effectiveness of chest compression only CPR for much longer. *Evidence:* **Supporting** *Quality of evidence:* **Fair** *Level of evidence:* **7** *Mathematical model. Supporting more chest compression compared with CV 5:1 (15:2, 50:2 CConly)* *Computer based simulation of blood flow and gas exchange during cardiac arrest by using different compression-to-ventilation ratios (CV 5:1, CV 15:2, CV 50:5, CConly). Other ratios were also briefly investigated to see if oxygen deliveries were significantly different. None of them (50:2, 50:3, 50:4, 15:1) showed any significant benefit.* *Primary end point:* *- To evaluate theoretical optimum ratio of compressions to ventilation in CPR* *Measured and calculated: cardiac output, blood flow, oxygen delivery* *Results:* *- CConly produce a cardiac output significantly greater than that of CV 5:1, CV 15:2 or CV 50:5* *- CV 5:1 allows for the greatest amount of ventilation, resulting in arterial oxygen and CO2 level that are close to normal* *- The greater the number of compressions in each cycle, the more hypoxic and hypercarbic the arterial blood becomes during CPR* *- In terms of blood gas values CV 5:1 offers an advantage over the other methods, but resulted in the lowest oxygen delivery* *- CConly showed a much higher oxygen delivery during the first 2 minutes than any of the other of the CV ratios, with similar values during the 3-4 minutes interval and, after this, the worst oxygen delivery* *- The inclusion of three gasping ventilation during CConly CPR, resulted in an oxygen delivery significantly higher than that archived by standard CPR (spontaneous gasping can explain the success of CConly in clinical studies)* *- CV 15:2 and CV 50:5 are roughly equivalent to each other in terms of oxygen delivery* *Authors conclusions:* *The results do not clarify the benefits of the different compression to ventilation ratio during CPR. The oxygen delivery appears to offer a simple method of defining the efficiency of any CPR techniques as it includes the effects of both blood flow and oxygen uptake.*
Turner, 2004	**Turner, I. and S. Turner (2004). "Optimum cardiopulmonary resuscitation for basic and advanced life support: a simulation study." Resuscitation 62(2): 209-17.** Optimum cardiopulmonary resuscitation (CPR) for both basic and advanced cardiac life support depends on a compromise between the number of chest compressions delivered and the amount of ventilation provided. This study used theoretical models of blood flow and both arterial and venous blood gas values to investigate the influence of different compression to ventilation ratios on CPR efficiency, as well as the effects of different inspired oxygen concentrations. With mouth-to-mouth ventilation, greater numbers of compressions between each ventilation provided progressively greater blood flow. However, a greater the number of compressions, reduced the arterial oxygen levels and carbon dioxide clearance. There was an optimum ratio, in terms of both oxygen delivery and carbon dioxide clearance, of around 20:1 compressions to ventilation. Optimum oxygen delivery was 0.19L/min at 20:1, which was better than the oxygen delivery for standard CPR based on a ratio of 15:2 (0.13L/min). When patients were ventilated with supplemental oxygen (either 50 or 85%) the lungs rapidly became saturated with oxygen, and oxygen delivery depended more on blood flow. Higher numbers of compressions provided greater oxygen delivery, but at the cost of increasing hypercarbia, which is thought to affect resuscitation success rates adversely. The simulation results suggested ratios around 20:1 would be the best compromise between blood flow, oxygen delivery (0.25L/min) and avoidance of hypercarbia. The best results were provided by continuous chest compressions and simultaneous, asynchronous ventilation in an intubated patient. Arterial and venous oxygen and carbon dioxide levels were well maintained, with very good oxygen delivery (0.32L/min). Intubation with continuous chest compressions and asynchronous ventilation can therefore significantly improve the quality of CPR as a whole, and not just ventilation. *Evidence:* **Supporting** *Quality of evidence:* **Fair** *Level of evidence:* **7** *Mathematical model: "* *Three mathematical models of 'best DO2' are presented, based on the assumption that ventilation is provided according to the ECC standards (2 seconds inflation) and that calculated PaO2, PaCo2, PvO2 and PvCo2 after 6 minutes of CPR are within the range of measured values available in the literature for animal model and case reports in human.* *1) M to M ventilation, 2) BVM with FiO2 > 0.5, 3) hypoxic cardiac arrest with 3 minutes of respiratory arrest before cardiac arrest were considered* *Primary end point:* *Calculation of best DO2 for C:V ratio*

	Result: *- 20:1 as best C:V in MtoM and BVM O2.* *- Continuous Chest Compression and simultaneous asynchronous ventilation 20:1 best DO2. Theoretical model only.* *- Assumptions somewhat unrealistic for lay rescuer (2 sec ventilation).* *- 6 minutes calculated PaO2, PaCo2, PvO2 and PvCo2 are not representative of the mean values observed in the animal model (mathematical model all value in and beyond the upper range).* *- 3 minute respiratory arrest assume baseline PaCO2 assumed 12.62 KPa (assumption error in the method and results since CO2 is known to increase only 3 mmHg / min in total respiratory arrest)* *Authors conclusions:* *20:1 ratio theoretical best compromise of DO2, PaO2, PaCo2, PvO2 and PvCo2*
Waalewijn, 1998	**Waalewijn, R. A., R. de Vos, et al. (1998). "Out-of-hospital cardiac arrests in Amsterdam and its surrounding areas: results from the Amsterdam resuscitation study (ARREST) in 'Utstein' style." *Resuscitation* *38(3): 157-67.*** The purpose of this study was to describe the chain of survival in Amsterdam and its surroundings and to suggest areas for improvement. To ensure accurate data, collection was made by research personnel during the resuscitation, according to the Utstein recommendations. Between June 1, 1995 and August 1, 1997 all consecutive cardiac arrests were registered. Patient characteristics, resuscitation characteristics and time intervals were analyzed in relation to survival. From the 1046 arrests with a cardiac etiology and where resuscitation was attempted, 918 cases were not witnessed by EMS personnel. The analysis focussed on these 918 patients of whom 686 (75%) died during resuscitation, 148 (16%) died during hospital admission and 84 patients (9%) survived to hospital discharge. Patient and resuscitation characteristics associated with survival were: age, VF as initial rhythm, witnessed arrest and bystander CPR. EMS arrival time was significantly shorter for survivors (median 9 min) compared to non-survivors (median 11 min). In 151 cases the police was also alerted and arrived 5 min (median) earlier than EMS personnel. Using the OPC/CPC good functional health was observed in 50% of the survivors and moderate performance in 29%. All links in the chain of survival must be strengthened, but equipping the police with semi-automatic defibrillators may be the most useful intervention to improve survival. *Evidence:* **Supporting** *Quality of evidence:* **Fair** *Level of evidence:* **7** *Human. Observational prospective study. Study period 1995-1997. 1685 patients. Out of hospital Cardiac arrest. EMS dispatch based setting (Amsterdam). Utstein. No details on style of CPR (CV ratio). Supporting bystander CPR in out-of-hospital setting to increase survival.* *Primary end point:* *- describe the chain of survival* *- survival to admission and to hospital discharge* *Results:* *- bystanders perform CPR before arrival of EMS in 54% of patients.* *- these patients (bystander CPR) had 1.3 times the chance to survive to hospital admission and 2.5 times to survive to hospital discharge compared to patients who had no bystander CPR* *- survival 9%.* *Authors conclusions:* *resuscitation characteristics associated with good survival to cardiac arrest were withnessing the arrest, bystander CPR, time intervals.*
Waalewijn, 2001a	**Waalewijn, R. A., J. G. Tijssen, et al. (2001). "Bystander initiated actions in out-of-hospital cardiopulmonary resuscitation: results from the Amsterdam Resuscitation Study (ARRESUST)." *Resuscitation* *50(3): 273-279.*** The objective of this study was to analyze the functioning of the first two links of the chain of survival: 'access' and 'basic cardiopulmonary resuscitation (CPR)'. In a prospective study, all bystander witnessed circulatory arrests resuscitated by emergency medical service (EMS) personnel, were recorded consecutively. Univariate differences in survival were calculated for various witnesses, the performance of basic CPR, the quality of CPR, the performers of CPR and the delays. A logistic regression model for survival was developed from all potential predictors of these first two links.From the 922 included patients, 93 survived to hospital discharge. In 21% of the cases, the witness did not immediately call 112, but first called others, resulting in a longer delay and a lower survival. Family members were frequent witnesses of the arrest (44%), but seldom started basic CPR (11%). Survival, when basic CPR performers were untrained and had no previous experience, was similar to that when no basic CPR was performed (6%). Not performing basic CPR, delay in basic CPR, the interval between basic CPR and EMS arrival, and being both untrained and inexperienced in basic CPR were independent predictors for survival. Basic CPR performed by persons trained a long time ago did not appear to have a negative

	influence on outcome, nor did basic CPR limited to chest compressions alone. The mere reporting that basic CPR has been performed does not describe adequately the actual value of basic CPR. The interval from collapse to initiation of basic CPR, and the training and experience of the performer must be taken into account. Policy makers for basic CPR training should focus on partners of the patients, who are most likely witness of an arrest. *Evidence:* **Supporting** *Quality of evidence:* **Fair** *Level of evidence:* **7** *Human. Observational prospective study. Study period 1995-1997. 922/1685 patients. Out of hospital Cardiac arrest. EMS dispatch based setting (Amsterdam). Utstein. No details on style of CPR (CV ratio). Supporting bystander CPR in OH setting to increase survival.* *Primary end point:* *- description of three prediction models of survival from OH cardiac arrest* *- survival to admission and to hospital discharge* *Results:* *- in 55% basic CPR was performed by bystander, resulting in survival of 14% compared with 6% when bystander CPR was not performaed. Patients who needed no advanced CPR had the best chance of survival (84%).* *- delay in starting basic CPR has the great impact on survival: a delay of more than 3 minutes decreased surival about 50%* *Authors conclusions: basic CPR performed before arrival of EMS substantially improved survival*
Waalewijn, 2001b	**Waalewijn, R. A., R. de Vos, et al. (2001). "Survival models for out-of-hospital cardiopulmonary resuscitation from the perspectives of the bystander, the first responder, and the paramedic." *<u>Resuscitation</u> 51(2): 113-122.*** Survival from out-of-hospital resuscitation depends on the strength of each component of the chain of survival. We studied, on the scene, witnessed, nontraumatic resuscitations of patients older than 17 years. The influence of the chain of survival and potential predictors on survival was analyzed by logistic regression modeling. From 1030 patients, 139 survived to hospital discharge. Three prediction models of survival were developed from the perspective of the different contributors active in out-of-hospital resuscitation: model I, bystanders; model II, first responders; and model III, paramedics. Predictors for survival (with odds ratio) were: in model I (bystanders): emergency medical service (EMS) witnessed arrest (0.50), delay to basic cardiopulmonary resuscitation (CPR) (0.74/min) and delay to EMS arrival (0.87/min); in model II (first responders): initial recorded heart rhythm (0.02 for nonshockable rhythm), delay to basic CPR (0.71/min and 0.87/min for shockable and nonshockable rhythms) and to defibrillation (0.89/min), and in model III (paramedics): need for advanced CPR (4.74 for advanced CPR not-needed), initial recorded heart rhythm (0.05 for nonshockable rhythm), and delay to basic CPR (0.77/min and 0.72/min for shockable and nonshockable rhythms), to defibrillation and to advanced CPR for shockable rhythms (0.85/min), and to advanced CPR for nonshockable rhythm (0.85/min). The area under the receiver-operator characteristic curve for model I was 0.763, for model II was 0.848, and for model III was 0.896. Of survivors, 50% had restoration of circulation without need for advanced CPR. Three survival models for witnessed nontraumatic out-of-hospital resuscitation based on the information known by bystanders, first responders and paramedics explained survival with increasing precision. Early defibrillation can restore circulation without the need for advanced CPR. When advanced CPR is needed, its delay leads to a markedly reduced survival. *Evidence:* **Supporting** *Quality of evidence:* **Fair** *Level of evidence:* **7** *Human. Observational prospective study. Study period 1995-1997. 1685 patients. Out of hospital Cardiac arrest. EMS dispatch based setting (Amsterdam). Utstein. No details on style of CPR (CV ratio). Supporting bystander CPR in OH setting to increase survival.* *Primary end point:* *- describe the chain of survival* *- survival to admission and to hospital discharge* *Results:* *- bystanders perform CPR before arrival of EMS in 54% of patients.* *- these patients had 1.3 times the chance to survive to hospital discharge and 2.5 times to survive to hospital discharge compared to patients who had no bystander CPR* *- survival 9%.* *Authors conclusions:* *resuscitation characteristics associated with good survival to cardiac arrest were withnessing the arrest, bystander CPR, time intervals.*

Waalewijn, 2002	**Waalewijn, R. A., M. A. Nijpels, et al. (2002). "Prevention of deterioration of ventricular fibrillation by basic life support during out-of-hospital cardiac arrest." *Resuscitation* *54(1): 31-6.*** Survival of cardiac arrest is improved by basic life support (BLS). This study investigated the relationship between ventricular fibrillation (VF) characteristics and survival. In a 2-year prospective study out-of-hospital witnessed non-traumatic cardiac arrests were observed. The probabilities of recording VF, asystole or other rhythms in relation to BLS and the time to the rhythm recording were analyzed with logistic regression. Amplitude and baseline crossings of VF were related to survival, using linear regression analysis.In 873 patients, the probability to record VF decreased per minute (OR 0.92, 95%CI 0.89-0.95) and of asystole increased (OR 1.13, 95%CI 1.09-1.18) as time from collapse elapsed. BLS reduced these trends significantly for VF (OR 0.97, 95%CI 0.94-0.99) and asystole (OR 1.09, 95%CI 1.05-1.13). This effect was not observed for other rhythms. The amplitude of VF decreased in time; significantly less for patients who received BLS than for those who did not (p=0.009). Survival significantly decreased with lower amplitude of VF (OR 0.23 per mV, 95%CI 0.07-0.79) and with less baseline crossings (OR 0.80 per baseline crossings per second, 95%CI 0.71-0.91). Our study demonstrated that BLS and VF as initial rhythm, considered being "baseline" predictors in survival models, were proved not independent of each other. The decrease of VF amplitude and increase in prevalence of asystole is slowed significantly by BLS. Predicting survival from VF amplitude and baseline crossings alone is limited. *Evidence:* **Supporting** *Quality of evidence:* **Fair** *Level of evidence:* **7** *Human. Observational prospective study. Study period 1995-1997. 1046 patients. Out of hospital Cardiac arrest. EMS dispatch based setting (Amsterdam). Utstein. No details on style of CPR (CV ratio). Supporting bystander CPR in OH setting to increase survival.* *Primary end point:* *- investigated the relationship between VF characteristics, relation to basic CPR and survival* *Results:* *- in patients who did not receive basic CPR the probability to record VF as initial rhythm decreased more rapidly per minute delay of EMS arrival then in those who received BLS, and increased the probability to find asystole.* *- delay in start of basic CPR has the great impact on survival: a delay of more than 3 minutes decrease in surival about 50%* *Authors conclusions:* *basic CPR performed before arrival of EMS substantially improved survival and increased the probability to find VF as initial rhythm.*
Walker, 2001	**Walker, G. M. and R. Liddle (2001). "Prolonged two-man basic life support may result in hypocarbia in the ventilating rescuer." *Resuscitation* *50(2): 179-83.*** OBJECTIVES: To determine whether the quality of expired air given during mouth-to-mouth ventilation differs between one- and two-person basic life support. METHODS: 15 young fit volunteers performed 15-min simulated resuscitation on a manikin. The oxygen and carbon dioxide concentration of their expired breath and the total ventilation was continuously monitored. Compression: ventilation ratios of 15:2 for one-person and 5:1 for two-person resuscitation were used. RESULTS: In two-man resuscitation, where the rescuer who is ventilating the patient is not performing chest compressions, the oxygen content of the expired breath rises (P<0.01), and the carbon dioxide content falls (P<0.01). The carbon dioxide concentration declined gradually throughout the 15-min session. Most participants complained of light-headedness on completion of the two-man session. Total ventilation did not differ between the two methods (P=0.757, 95% CI=-0.329, 0.242). CONCLUSION: Trainees in basic life support should be informed that symptoms of hypocarbia may occur in prolonged mouth-to-mouth ventilation, when acting in a two-man team. We would advise rescuers using these protocols to change places every 5 min to avoid these symptoms. These findings add further weight to the recommendations that all resuscitation should be carried out using 15:2 compression: ventilation ratio. *Evidence:* **Supporting** *Quality of evidence:* **Fair** *Level of evidence:* **7** *Manikin model. Supporting CV 15:2 compared with CV 5:1 in terms of rescuer fatigue (feasibility).* *15 young fit volunteers involved in a simulated basic CPR scenario based on a Resusci Anne manikin (Laerdal Medical Ltd.) with the manikin exhaust port, one-way valve for expired air, connected to a PK Morgan exercise system (Rainham, Kent), which sampled gas content of the rescuer's expired breath (percentage of oxygen content, carbon dioxide and delivered ventilation every 30 seconds) during the different settings of a single-man (CV 15:2) and a two-man (CV 5:1)*

	resuscitation. *Primary end point:* *- To determine whether the quality of expired air given during mouth-to-mouth ventilation differ between one- and two-person BLS* *Results:* *- The CO_2 concentration declined gradually throughout the 15 minutes sessions.* *- Most participants complained light-headedness on completion of the two-man session (CV 5:1)* *- Total ventilation did not differ between the two methods* *Authors conclusions:* *to recommend that all the resuscitation should be performed using a CV 15:2 ratio.*

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