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

Worksheet author(s)

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Clinical question.

In adult and pediatric patients with cardiac arrest (prehospital [OHCA], in-hospital [IHCA]) (P), does the use of another specific C:V ratio (I) compared with standard care (30:2) (C), improve outcome (eg. ROSC, survival) (O)?

Is this question addressing an intervention/therapy, prognosis or diagnosis? Intervention/therapy
State if this is a proposed new topic or revision of existing worksheet: Revision (W154 in 2005)

Conflict of interest specific to this question

Do any of the authors listed above have conflict of interest disclosures relevant to this worksheet? None

Search strategy (including electronic databases searched)

PubMed search strategy is as follows:

1 cardiopulmonary resuscitation [mh] OR heart arrest [mh]
2 compression* AND ventilation* AND ratio*
3 1 AND 2

AHA EndNote library, Cochrane library, OVID and cited references of each study were also searched.

- State inclusion and exclusion criteria

Inclusion criteria: 1) study associated with cardiac arrest
Exclusion criteria: 1) compression to ventilation ratio is not studied
2) compared with hands-only CPR
3) abstract only or not peer reviewed study
4) not written in English

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

PubMed search yielded 122 responses, Cochrane library yielded 17 responses (No additional study), OVID (1950 or Nov week 1, 2009) search yielded 177 responses (No additional study). Further forward hand searches found 15 another articles.
Among the 137 articles, 103 were excluded as following reasons:
1) not address compression to ventilation ratio (53)
2) compared with no other CV ratio but hands-only CPR (18)
3) abstract only or not peer reviewed study (17)
4) not written in English (15)
Finally, 34 articles were enrolled to evidence evaluation process.

Summary of evidence

Evidence Supporting Clinical Question (supporting another ratio)

Good					**Babbs 2004 E [function of BW]** **Babbs 2002 E [60:2 in lay rescuer]** **Chamberlain 2001 E [50:5]** **Deschilder 2007 E [15:2]** **Dorph 2002 E [15:2]** **Hill 2009 E [15:2]** **Kill 2005 E [50:5]** ***Sanders 2002 BDE [100:2]***
Fair					**Eisenburger 2007 E [30:5, 50:5]** **Greingor 2002 E [5:1]** **Hostler 2002 E [30,40,50,60:2]** **Kinney 2000 E [5:1]** **Srikantan 2005 E [10:2]** **Turner 2002 E [15:2, 50:5]** **Turner 2004 E [20:1]** **Walker 2001 E [15:2]** **Wik 1996 E [15:2]** ***Yannopoulos 2005 AE [15:1]***
Poor					***Dorph 2003 E [15:2]*** ***Garza 2009 AC [50:2>5:1]**
	1	**2**	**3**	**4**	**5**
			Level of evidence		

A = Return of spontaneous circulation C = Survival to hospital discharge E = Other endpoint
B = Survival of event D = Intact neurological survival *Italics = Animal studies*
* The implemented protocol included other interventions as well as CV ratio change

Evidence Neutral to Clinical question

Good					**Betz 2008 E [=15:2]** **Bjørshol 2008 E [=15:2,50:2]** **Haque 2008 E [=15:2]** **Odegaard 2006 E [=15:2]**
Fair					***Cavus 2008 AE [=15:2]*** ***Hwang 2008 AE [=15:1, 15:2]*** ***Kill 2009 AE [=100:5]*** ***Yannopoulos 2004 A [10:1]*** **Yannopoulos 2006 AE [=15:2]**
Poor			***Hostler 2007 AE [=15:2]** ***Baker 2008 AC [=15:2]** ***Olasveengen 2009 ACD [=15:2]**		
	1	**2**	**3**	**4**	**5**
			Level of evidence		

A = Return of spontaneous circulation C = Survival to hospital discharge E = Other endpoint
B = Survival of event D = Intact neurological survival *Italics = Animal studies*
* The implemented protocol included other interventions as well as CV ratio change

Evidence Opposing Clinical Question (supporting 30:2)

Good					**Babbs 2002 E [30:2 in HCP]**
Fair					***Kill 2009 AE [30:2>100:2]*** ***Yannopoulos 2006 AE [30:2>15:2]***
Poor			***Sayre 2009 BC [30:2>15:2]** ***Steinmetz 2008 ABC [30:2>15:2]**		
	1	**2**	**3**	**4**	**5**
			Level of evidence		

A = Return of spontaneous circulation
B = Survival of event
C = Survival to hospital discharge
D = Intact neurological survival
E = Other endpoint
Italics = Animal studies
* The implemented protocol included other interventions as well as CV ratio change

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

I excluded the studies comparing compression-only CPR with standard CPR because it was reviewed in another worksheet.

Clinical study
There were 5 LOE 3 and a LOE 5 studies compared between before and after period of implementing new guideline or protocol including CV ratio change. However, the quality of these studies should be downgraded to poor because various interventions from guideline changes other than the CV ratio change were also included in the protocol.

The study of Holster et al (2007) showed neutral result between before (15:2) and after (30:2) the implementation of new guideline. Although ROSC rate was similar for total OHCA patients (so, it is neutral study), subgroup analysis for the patients treated by fire department first responders, a statistically significant difference in rate of ROSC was found between two periods (32.2% vs 42.2%, p=0.02). However, it was not derived from C:V ratio change because other interventions were also implemented such as single shock strategy and reducing the frequency of AED rhythm analysis during the post-protocol period. Moreover, bystander CPR rate was significantly higher in post-protocol period (31.6% vs 46.7%).

The study of Steinmetz et al (2008) showed improved survival in the post 2005 guideline period.

		2000 guideline (2004.6~2005.8)	2005 guideline (2006.1~2007.3)	P
N		372	419	
CV ratio		15:2	30:2	
Outcome	ROSC	23.4%	39.1%	<0.0001
	Discharge alive	7.9%	16.3%	0.0004
	30-day survival	8.3%	16.0%	0.001

The study of Sayre et al (2009) also showed improved survival in the post 2005 guideline period.

	2000 guideline (2004.4~2005.12)	2005 guideline (2006.1~2007.12)	95% CI
N	660	1021	

CV ratio	15:2	30:2	
Outcome Discharge alive	6.1%	9.4%	1.1~2.4
Survival to admission	23%	31%	1.2~2.0

Multiple logistic regression analysis showed that experiencing OHCA in the post-guideline period was associated with 1.8 greater odds of survival than in the pre-guideline period (95% CI = 1.2~2.7).

On the contrary, the study of Baker et al (2008) did not show improvement of survival after guideline change.

	Pre 2006 guideline (2005.7~2006.6)	Post 2006 guideline (2006.7~2007.7)	P
N	91	111	
CV ratio	15:2	30:2	
Outcome ROSC	50.5% (46/91)	53.2% (59/111)	0.71
Discharge alive	8.8% (8/91)	18.0% (20/111)	0.059

The study of Olasveengen et al (2009) showed improvement of CPR quality after implementation of 2005 guideline but there are also no significant differences in survival such as ROSC, discharge alive, and CPC grade. According to the authors, it might be derived from the unchanged EMS response time of 8 minutes.

	2000 guideline (2003.5~2005.4)	2005 guideline (2006.1~2007.12)	p
N	435	481	
CV ratio	15:2	30:2	
Overall outcome ROSC	35%	38%	NS
Discharge alive	11%	13%	NS
CPC 1 or 2	10%	12%	NS
Witnesses VF Outcome ROSC	60%	59%	NS
Discharge alive	27%	31%	NS
CPC 1 or 2	26%	29%	NS

The study of Garza et al (2009) supported the CV ratio of 50:2. Their revised protocol included mandatory pre-shock chest compression, delayed intubation, and strict use of manual defibrillators as well as CV ratio change from 5:1 to 50:2. The rates of both ROSC (37.8% vs 59.6%) and discharge alive(22.4% vs 43.9%) were significantly increased in the post-protocol group. However, this study did not compared with current standard ratio of 30:2, so this study classified into LOE 5.

	Pre-protocol (2003.1~2006.3)	Post-protocol (2006.4~2007.3)	95% CI
N (witnessed VF)	143	57	
CV ratio	5:1	50:2	
Outcome ROSC	37.8%	59.6%	1.24~4.80
Discharge alive	22.4%	43.9%	1.34~5.49

The above 6 clinical studies are summarized in the table:

Study	Compared ratio	Supported CV ratio
Hostler, 2007	15:2/30:2	A=
Steinmetz, 2008	15:2/30:2	ABC30:2
Baker, 2008	15:2/30:2	AC=
Olasveengen, 2009	15:2/30:2	ACD=
Garza, 2009	5:1/50:2 (LOE 5)	AC50:2>5:1
Sayre, 2009	15:2/30:2	BC30:2

A: ROSC, B: survival of event, D: intact neurological survival, = no significant difference

Animal studies

There were 8 animal studies addressed this question. All of them were using swine model except one canine model.

Sanders et al (2002) evaluated 24-hr neurologic function among 15:2, CC-CPR, 50:5 and 100:2 CV ratios using a swine model (3-min VF + 12-min CPR). The 100:2 CV ratio group had significantly better neurologic outcome.

	15:2	CC	50:5	100:2
N	10	10	10	10
24-h survival	7	7	8	9
24-h neurologic deficit	2.5	2.3	1.9	1.5
Normal neurology at 24-h	5	6	7	8

Dorph et al (2003) compared arterial and mixed venous blood gas exchange and cerebral circulation and oxygen delivery among 15:2, 50:2, and 50:5 CV ratios using a swine model (3-min VF). The 15:2 CV group showed better cerebral oxygen delivery and pulmonary gas exchange.

Yannopoulos et al (2004) evaluated hemodynamics and gas exchange between 5:1 and 10:1 CV ratios using a swine model (6-min VF + 6-min CPR). It was classified into neutral study because the ROSC rate was same (2/8 animals). The number of animals that received adrenaline was lower in the 10:1 group (3/8 vs 6/8). At 2 min after CPR, MAP and CPP was better in 10:1 than 5:1.

Yannopoulos et al (2005) also evaluated hemodynamics and gas exchange between 15:1 and 15:2 CV ratios using a swine model (4-min VF + 4-min CPR + 6-min cross over). This study showed that the increase of CV ratio from 15:2 to 15:1 resulted in improvement of vital-organ perfusion pressures, higher EtCO2 levels, but no change in arterial O2 content or acid-base balance.

Yannopoulos et al (2006) supported 30:2 compared to 15:2 in a swine model started ALS after 6 min of untreated VF and 6 min of BLS. The ROSC rate was 1/9 with the 15:2 ratio and 6/9 with the 30:2 ratio group (p<0.03). The coronary perfusion pressure and the carotid blood flow were significantly higher in the 30:2 ratio group.

	15:2	30:2	p
N	9	9	
ROSC	1	6	<0.03
Coronary perfusion pressure (mmHg)	18±1	25±2	<0.05
Carotid blood flow (ml/min)	48±5	82±5	<0.05
Cardiac output (L/min)	0.7±0.1	0.95±0.1	NS

Cavus et al (2008) evaluated arterial and mixed venous gas exchange among 30:2, 15:2, and CC-CPR using a swine model (4-min VF + 6-min CPR). There were no differences in ROSC rate (2/8, 4/8, 0/8 animals). The study showed no difference between 30:2 and 15:2 except arterial oxygenation which was better in the 15:2.

The LOE 5 study using canine model (Hwang, 2008) did not show any differences in the hemodynamics, oxygen profiles, and resuscitation outcome (ROSC) among 15:1 vs 15:2 vs 30:2 groups.

	15:1	15:2	30:2	p
N	10	10	10	
2-h survival	6	6	7	NS
ROSC	8	8	8	NS

Time to ROSC (min)	6.8	7.7	7.2

Kill et al (2009) compared 4 different CV ratios and evaluated their effect on the ROSC, gas exchange, cerebral tissue oxygenation and hemodynamics in a pig model. The ROSC was better achieved in 100:5 or 30:2 than 100:2 CV ratio. $PaCO_2$ significantly increased in all groups compared to the CV ratio of 30:2, whereas PaO_2 was equivalent in the 100:5 group and reduced in the 100:2 and compression only group.

	CC	100:2	100:5	30:2	p
N	8	8	8	8	
ROSC	0	2	5	4	0.043 (χ^2 test)

The 8 animal studies are summarized in the table:

Study	Model	Compared ratio	Supported CV ratio
Sanders, 2002	Pig	15:2/CC/50:5/100:2	D100:2, B=, E=
Dorph, 2003	Pig	15:2/50:2/50:5	E15:2
Yannopoulos, 2004	Pig	5:1/10:1	A=, E10:1
Yannopoulos, 2005	Pig	15:1/15:2	E15:1
Yannopoulos, 2006	Pig	15:2/30:2	A30:2, E30:2
Cavus, 2008	Pig	15:2/30:2/CC	A=, E=
Hwang, 2008	Dog	15:1/15:2/30:2	A=, E=
Kill, 2009	Pig	30:2/100:5/100:2/CC	A30:2=100:5, E30:2

A: ROSC, B: survival of event, D: intact neurologic survival, E: other endpoint
= means no significant difference

Theoretical studies
There were four studies taking mathematical approach to find the optimal compression to ventilation ratio during CPR.

Babbs and Kern (2002) calculated flow and oxygen delivery in the various CV ratio from 0 to 50 using Monte Carlo simulation. As the CV ratio was increased from 0 to 50, both oxygen delivery and the combination of oxygen delivery with blood flow increased to maximum values and then gradually declined. The optimal CV ratio was different to the experience of the rescuers which was located within 24:2~48:2 for ideal CPR (5 sec per 2 breaths) and 50:2~80:2 for lay rescuer (16 sec per 2 breaths).

Babbs and Nadkarni (2004) suggested that the optimal CV ratio for children should be different from that for adults. It was a function of body weight (BW) that was approximately 1.6 square root BW(kg) for professional rescuers and 2.8 square root BW for lay rescuers. It could be approximated for children and teens by the following rules of thumb, based upon the age of the victim: "5 + one half the age in years" for professional rescuers and "5 + age in years" for lay rescuers. Recommended CV ratios were as follows:

Age	Professional rescuer	Lay rescuer
14	12 (24:2)	19 (38:2)
12	11 (22:2)	17 (34:2)
10	10 (20:2)	15 (30:2)
8	9 (18:2)	13 (26:2)

Turner et al (2002) calculated the blood flow, the amount of oxygen uptake and CO2 excretion produced by CPR among normal, 5:1, 15:2, 50:5, and compression only 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.

Turner and Turner (2004) performed similar simulation study to apply to a wide range of situation, from witnessed to hypoxic arrests and over a range of inspired oxygen concentrations. They suggested that the best CV ratio was around 20:1 in terms of both oxygen delivery and carbon dioxide clearance, even when supplemental oxygen was available.

Manikin simulation studies

There were many studies using manikin to compare quality of CPR performance, training effectiveness and fatigue of rescuer among various CV ratios. Manikin studies were summarized in the table:

Study	Primary outcome	Supported ratio	Remarks
Betz, 2008	CPR performance Perceived exertion	30:2=15:2 30:2=15:2	
Bjorshol, 2008	Compression quality	30:2=15:2=50:2	
Chamberlain, 2001	CPR performance & skill retention	50:5>15:2	
Deschilder, 2007	Compression quality Exhaustion	30:2=15:2 30:2<15:2	Exhaustion score (VAS): 5.9 vs 4.5
Dorph, 2002	Ventilation efficacy Chest compression efficacy	15:1=5:2 15:1>5:2	Compressions per minute: 41 vs 60
Eisenburger, 2007	Quality of rescuer's expired air	50:5,30:5>30:2	End tidal O2
Greingor, 2002	Quality of chest compression	15:2<5:1	Correct comp: 0~86 vs 7~97
*Haque, 2008	Compression quality Rescuer fatigue	30:2=15:2 30:2=15:2	
Hill, 2009	CPR performance	30:2<15:2	Depth, optimal %
Hostler, 2005	CPR performance	30,40,50,60:2>15:2	#comp, hands-off time
Kill, 2005	Time to treatment	50:5>15::2	
*Kinney, 2000	Quality of compression & ventilation	5:1>10,15:2	
Odegaard, 2006	CPR performance	30:2=15:2	
*Srikantan, 2005	Effective compression per min Effective ventilation per min Rescuer fatigue	3:1<5:1<10:2<15:2 3:1>5:1,10:2,15:2 3:1,5:1<10:2,15:2	Propose universal 10:2 ratio
Walker, 2001	Quality of rescuer's expired air	15:2>5:1	Hypocarbia in 5:1
Wik, 1996	CPR quality Time to treatment	15:2=5:1 15:2>5:1	
Yannopoulos, 2006	CPR performance fatigue	30:2=15:2 30:2=15:2	

* using pediatric manikin

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None

Citation List

Babbs CF, Nadkarni V. Optimizing chest compression to rescue ventilation ratios during one-rescuer CPR by professionals and lay persons: children are not just little adults. Resuscitation. 2004 May;61(2):173-81.

LOE 5 (mathematical analysis). Good, Support the question. CV ratio is a function of body weight.

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

LOE 5 (mathematical analysis). Good, Oppose the question in experience provider / Support in lay rescuer.
Support 24:2~48:2 for ideal CPR (5 sec per 2 breaths), 50:2~80:2 for lay rescuer (16 sec per 2 breaths). Optimal CV ratio is different to the experience of the rescuers.

Baker PW, Conway J, Cotton C, Ashby DT, Smyth J, Woodman RJ, Grantham H; Clinical Investigators. Defibrillation or cardiopulmonary resuscitation first for patients with out-of-hospital cardiac arrests found by paramedics to be in ventricular fibrillation? A randomised control trial. Resuscitation. 2008;79:424-31.

LOE 3 (before after study, Neutral study, Poor (implemented other interventions from 2006 ARC guideline as well as C:V ratio change from 15:2 to 30:2), Outcomes: ROSC (A; neutral, 50.5% vs 53.2%), discharge alive (C; neutral, 8.8% vs 18.0%, p=0.059)

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

LOE 5(manikin study), Good, Neutral study, endpoint: performance and work of CPR (perceived exertion),
After 5min of compression, heart rate, lactate, and perceived exertion were increased but did not differ between groups. Total number of compression was higher and total no flow time was lower in the 30:2.

Bjørshol CA, Søreide E, Torsteinbø TH, Lexow K, Nilsen OB, Sunde K. Quality of chest compressions during 10min of single-rescuer basic life support with different compression: ventilation ratios in a manikin model. Resuscitation. 2008;77(1):95-100.

LOE 5(manikin study, 1-rescuer 10-min), Good, Neutral study, CPR performance (compression quality) during 15:2 vs 30:2 vs 50:2. The number of chest compressions was linearly increased and no flow time decreased with increasing C:V ratio without affecting compression depth or rate.

Cavus E, Meybohm P, Bein B, Steinfath M, Pöppel A, Wenzel V, Scholz J, Dörges V. Impact of different compression-ventilation ratios during basic life support cardiopulmonary resuscitation. Resuscitation. 2008 Oct;79(1):118-24.

LOE 5 (24 pig, 4-min VF + 6-min BLS), Fair, Neutral study among 30:2 vs 15:2 vs CCC,
Endpoint: ROSC (A; neutral), oxygenation and acid-base status (E; neutral)

Chamberlain D, Smith A, Colquhoun M, Handley AJ, Kern KB, Woollard M. 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. 2001 Jul;50(1):27-37.

LOE 5(manikin study), Good, Supporting 50:5, Evaluating performance and skill retention (15:2 <50:5),
During the first 8 min of resuscitation, 58% more compressions might be delivered by using the 50:5 ratio.

Deschilder K, De Vos R, Stockman W. The effect on quality of chest compressions and exhaustion of a compression - ventilation ratio of 30:2 versus 15:2 during cardiopulmonary resuscitation--a randomised trial. Resuscitation. 2007; 74(1): 113-8.

LOE 5(manikin study), good, Supporting 15:2, evaluating quality of compression and exhaustion during 30:2 vs 15:2. Exhaustion score and subjective fatigability were higher in the 30:2 (favor 15:2).
Compression rate, total number of compression/ 5min, and correct compression/ 5min were significantly higher in the 30:2 with same compression depth.

Dorph E, Wik L, Steen PA. Effectiveness of ventilation-compression ratios 1:5 and 2:15 in simulated single rescuer paediatric resuscitation. Resuscitation. 2002; 54(3): 259-64.

LOE 5 (pediatric manikin study), Good, (5:1<15:2),
No difference in ventilation variable between 5:1 vs 15:2 but greater number of compressions with 15:2

Dorph E, Wik L, Strømme TA, Eriksen M, Steen PA. Quality of CPR with three different ventilation:compression ratios. Resuscitation. 2003; 58(2): 193-201.

LOE 5 (animal study, 12 pig), Poor (surrogate outcome only), (2:15>2:50, 5:50)
15:2 CV ratio showed better cerebral oxygen delivery and pulmonary gas exchange

Eisenburger P, Funk GC, Burda G, Sterz FR, Laggner AN, Herkner H. Gas concentrations in expired air during basic life support using different ratios of compression to ventilation. Resuscitation. 2007; 73(1): 115-22.

LOE 5(manikin study) Fair (non randomized simulation), Evaluating rescuer's expired air composition, (15:2 vs 5:1, 30:2, 30:5, 50:5, 100:10), (30:5 or 50:5>30:2)
End tidal oxygen(%) was increased in 30:2, 30:5, 50:5, and 100:10 than 15:2, and increased in 30:5 and 50:5 than 30:2.

Garza AG, Gratton MC, Salomone JA, Lindholm D, McElroy J, Archer R. Improved patient survival using a modified resuscitation protocol for out-of-hospital cardiac arrest. Circulation. 2009; 119(19): 2597-605.

LOE 5 (before after study, but not compared to standard 30:2 ratio), Supporting 50:2, Poor (other interventions such as CPR before defibrillation, minimizing pauses for ventilation or other procedure as well as C:V ratio change from 5:1 to 50:2), Outcomes: ROSC (A; favor 50:2; 37.8% vs 59.6%), discharge alive (C; favor 50:2; 22.4% vs 43.9%)

Greingor JL. Quality of cardiac massage with ratio compression-ventilation 5/1 and 15/2. Resuscitation. 2002; 55(3): 263-7.

LOE 5 (manikin study), Fair, (5:1>15:2), better quality compression with 5:1 than with 15:2 maybe due to fatigue

Haque IU, Udassi JP, Udassi S, Theriaque DW, Shuster JJ, Zaritsky AL. Chest compression quality and rescuer fatigue with increased compression to ventilation ratio during single rescuer pediatric CPR. Resuscitation. 2008; 79(1): 82-9.

LOE 5(manikin study, 1-rescuer pediatric), Good, Neutral study, Evaluating compression quality and rescuer fatigue (15:2 vs 30:2), The number of compression (30:2>15:2), peak and mean compression pressure, compression depth (same). HR, RR change, recovery time (same), subjective evaluation (15:2 is easier)

Hill K, Mohan C, Stevenson M, McCluskey D. Objective assessment of cardiopulmonary resuscitation skills of 10-11-year-old schoolchildren using two different external chest compression to ventilation ratios. Resuscitation. 2009; 80(1): 96-9.

LOE 5(manikin study, 10-11 yr), Good, supporting 15:2, Primary focus is educational effectiveness, (15:2>30:2)
The percentage of optimal compressions and average depth of compression was better in the 15:2 group.
The percentage of effective ventilations or average ventilation volume was not significantly different.

Hostler D, Guimond G, Callaway C. A comparison of CPR delivery with various compression-to-ventilation ratios during two-rescuer CPR. Resuscitation. 2005; 65(3): 325-8.

LOE 5(manikin study), Fair, supporting 30,40,50,60:2, Evaluating quality of CPR delivery (number of compression, pause for ventilation and hands-off time between 15:2 vs 30:2, 40:2, 50:2, 60:2.
The number of compression was higher, pause for ventilation, and hands off time per minute were lower significantly.

Hostler D, Rittenberger JC, Roth R, Callaway CW. Increased chest compression to ventilation ratio improves delivery of CPR. Resuscitation. 2007; 74(3): 446-52.

LOE 3 (before after study), OHCA setting, 3.5 yr (1,243 patients), Supporting 30:2
Poor (implemented another interventions such as single shock strategy as well as C:V ratio change)
30:2 CV ratio increase the number of compressions per minute (E)
When considered only subgroup patients treated by fire department first responders, a statistically significant difference in rate of ROSC is found between two periods (32.2% vs 42.2%, p=0.02) → favor 30:2 CV ratio (A)

Hwang SO, Kim SH, Kim H, Jang YS, Zhao PG, Lee KH, Choi HJ, Shin TY. Comparison of 15:1, 15:2, and 30:2 compression-to-ventilation ratios for cardiopulmonary resuscitation in a canine model of a simulated, witnessed cardiac arrest. Acad Emerg Med. 2008; 15(2): 183-9.

LOE 5, Fair (1-min VF arrest canine model), Neutral study,
Endpoints: ROSC (A; neutral), hemodynamics and arterial oxygen profiles (E; neutral).

Kill C, Torossian A, Freisburger C, Dworok S, Massmann M, Nohl T, Henning R, Wallot P, Gockel A, Steinfeldt T, Graf J, Eberhart L, Wulf H. Basic life support with four different compression/ventilation ratios in a pig model: the need for ventilation. Resuscitation. 2009; 80(9): 1060-5.

LOE 5, Fair (3-min VF arrest and 10-min BLS in pig model), Supporting 30:2 and 100:5,
Endpoints: ROSC (A; 30:2=100:5>100:2), arterial blood gas profiles (E; favor 30:2 in $PaCO_2$, 30:2=100:5>100:2 in PaO_2). Venous blood gas and hemodynamics (E; neutral)

Kill C, Giesel M, Eberhart L, Geldner G, Wulf H. Differences in time to defibrillation and intubation between two different ventilation/compression ratios in simulated cardiac arrest. Resuscitation. 2005; 65(1): 45-8.

LOE 5 (manikin study), Good, (50:5>15:2), endpoints: time intervals, ventilation volume, compression per minute
5:50 ratio reduces the time until the first defibrillation and tracheal intubation was performed
Paramedics stated that the 5:50 ratio improved the work-flow and reduced the emotional stress.

Kinney SB, Tibballs J. An analysis of the efficacy of bag-valve-mask ventilation and chest compression during different compression-ventilation ratios in manikin-simulated paediatric resuscitation. Resuscitation. 2000; 43(2): 115-20.

LOE 5 (pediatric manikin study), Fair, (5:1>10:2, 15:2), efficacy of ventilation and compression
Mean tidal volume or % effective chest compressions (no difference),
The number of breaths and effective compressions was greatest with a ratio of 5:1.

Odegaard S, Saether E, Steen PA, Wik L. Quality of lay person CPR performance with compression: ventilation ratios 15:2, 30:2 or continuous chest compressions without ventilations on manikins. Resuscitation. 2006 Dec;71(3):335-40.

LOE 5(manikin study), Good, Neutral study, CPR performance (15:2 vs 30:2 vs CCC), No flow time is reduced in the 30:2 than 15:2, tidal volume, compression depth & rate, compression per minute (30:2=15:2)

Olasveengen TM, Vik E, Kuzovlev A, Sunde K. Effect of implementation of new resuscitation guidelines on quality of cardiopulmonary resuscitation and survival. Resuscitation. 2009 Apr;80(4):407-11.

LOE 3, Impact on CPR quality and survival of before and after implementing new 2005 guidelines,
Neutral for survival, Supporting 30:2 for CPR quality, Poor (implemented simultaneously another interventions as well as C:V ratio change from 5:1 to 30:2)
Outcomes: ROSC (A=), Discharge alive (C=), good CPC (D=); CPR quality such as hands-off intervals and pre-shock pause (E; favor 30:2)

Sanders AB, Kern KB, Berg RA, Hilwig RW, Heidenrich J, Ewy GA. Survival and neurologic outcome after cardiopulmonary resuscitation with four different chest compression-ventilation ratios. Ann Emerg Med. 2002; 40(6): 553-62.

LOE 5 (animal study, pig), Good, Supporting 100:2, 24-hr neurologic function, (15:2 vs CC-CPR vs 50:5 vs 100:2), 24-hr survival (B=), 24-hr neurologic function (D, 100:2 is better than CC or 15:2), CPP(E=)

Sayre MR, Cantrell SA, White LJ, Hiestand BC, Keseg DP, Koser S. Impact of the 2005 American Heart Association cardiopulmonary resuscitation and emergency cardiovascular care guidelines on out-of-hospital cardiac arrest survival. Prehosp Emerg Care. 2009 Oct-Dec;13(4):469-77.

LOE 3 (before after study), Supporting 30:2(new guideline), Poor (not limited to CV ratio), Outcomes: survival to hospital admission (B: 23% vs 31%, 95% CI = 1.2~2.0), Discharge alive (C: favor new guideline, 6.1% vs 9.4%, 95% CI = 1.1~2.4). Multiple logistic regression analysis showed post-guideline period had 1.8 greater odds of survival (95% CI = 1.2~2.7)

Srikantan SK, Berg RA, Cox T, Tice L, Nadkarni VM. Effect of one-rescuer compression/ventilation ratios on cardiopulmonary resuscitation in infant, pediatric, and adult manikins. Pediatr Crit Care Med. 2005; 6(3): 293-7.

LOE 5 (manikin study: infant, ped and adult) Fair, Supporting 10:2 (10:2>3:1, 5:1, 15:2)
Universal 10:2 C:V ratio for one-rescuer layperson CPR is physiologically reasonable

Steinmetz J, Barnung S, Nielsen SL, Risom M, Rasmussen LS. Improved survival after an out-of-hospital cardiac arrest using new guidelines. Acta Anaesthesiol Scand. 2008; 52(7): 908-13.

LOE 3 (before after study), Supporting 30:2(new guideline), Poor (not limited to CV ratio), Outcomes: ROSC (A; favor new guideline, 23% vs 39%), Discharge alive (C: favor new guideline, 8% vs 16%), 30-day survival (B: 8% vs 16%)

Turner I, Turner S, Armstrong V. Does the compression to ventilation ratio affect the quality of CPR: a simulation study. Resuscitation. 2002; 52(1): 55-62.

LOE 5 (mathematical model), Fair, (5:1 vs 15:2 vs 50:2 vs CC), Calculated cardiac output, blood flow, oxygen delivery
The ratios of 15:2 and 50:5 produced significantly greater oxygen delivery to the body than 5:1.

Turner I, Turner S. Optimum cardiopulmonary resuscitation for basic and advanced life support: a simulation study. Resuscitation. 2004 Aug;62(2):209-17.

LOE 5 (theoretical analysis), Fair, 20:1>10:1, 15:1, 30:1 and 40:1
There was an optimum ratio, in terms of both oxygen delivery and carbon dioxide clearance, of around 20:1.

Walker GM, Liddle R. Prolonged two-man basic life support may result in hypocarbia in the ventilating rescuer. Resuscitation. 2001 Aug;50(2):179-83.

LOE 5 (manikin study), Fair, (5:1<15:2), outcome: expired O2/CO2 of ventilating rescuer.
FeCO2 gradually declined until the 15 min session was completed in 2 rescuer, 5:1 CV ratio scenario.

Wik L, Steen PA. The ventilation/compression ratio influences the effectiveness of two rescuer advanced cardiac life support on a manikin. Resuscitation. 1996; 31(2): 13-9.

LOE 5 (manikin study), Good, (5:1<15:2) endpoints: time intervals and CPR quality
In the 2-rescuer CPR, 2: 15 method appeared to be time saving vs. 1:5 without reducing the quality of CPR.

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

LOE 5, Animal study (Pig), Fair, Endpoints: ROSC (A; no difference, Neutral study), MAP, CPP, EtCO2, required adrenaline, 10:1>5:1 (with ITD), At 2 min after CPR, MAP and CPP was better in 10:1 than 5:1.

Yannopoulos D, Tang W, Roussos C, Aufderheide TP, Idris AH, Lurie KG. Reducing ventilation frequency during cardiopulmonary resuscitation in a porcine model of cardiac arrest. Respir Care. 2005; 50(5): 628-35.

LOE 5(animal study), Fair, Cerebral and coronary perfusion pressure, 15:1>15:2
CV ratio 15:1 resulted in improved vital-organ perfusion pressures, higher EtCO2 levels, and no change in arterial O2 content or acid-base balance.

Yannopoulos D, Aufderheide TP, Gabrielli A, Beiser DG, McKnite SH, Pirrallo RG, Wigginton J, Becker L, Vanden Hoek T, Tang W, Nadkarni VM, Klein JP, Idris AH, Lurie KG. Clinical and hemodynamic comparison of 15:2 and 30:2 compression-to-ventilation ratios for cardiopulmonary resuscitation. Crit Care Med. 2006; 34(5): 1444-9.

LOE 5 (animal model, pig), Fair, supporting 30:2 on 15:2 CV ratio.
Endpoints: ROSC (A; favor 30:2), cerebral perfusion pressure and cardiac output (E; favor 30:2).
LOE 5 (manikin study), Good, Neutral study, evaluate CPR performance and fatigue,
There were no differences in the quality of CPR performance or measurement of fatigue. Significantly more compressions per minute were delivered with 30:2.

Excluded references:

Compared with compression only CPR

o Assar D, Chamberlain D, Colquhoun M, Donnelly P, Handley AJ, Leaves S, Kern KB. Randomised controlled trials of staged teaching for basic life support. 1. Skill acquisition at bronze stage. Resuscitation. 2000 Jun;45(1):7-15. Evaluating performance among 15:2 vs 50 compression only

o Berg RA, Kern KB, Hilwig RW, Berg MD, Sanders AB, Otto CW, Ewy GA. Assisted ventilation does not improve outcome in a porcine model of single-rescuer bystander cardiopulmonary resuscitation. Circulation. 1997 Mar 18;95(6):1635-41. Compared 15:2 with compression only CPR and no CPR in swine model

o Berg RA, Hilwig RW, Kern KB, Ewy GA. "Bystander" chest compressions and assisted ventilation independently improve outcome from piglet asphyxial pulseless "cardiac arrest". Circulation. 2000 Apr 11;101(14):1743-8. Compared among 15:2 vs compression only vs ventilation only CPR

o Berg RA, Sanders AB, Kern KB, Hilwig RW, Heidenreich JW, Porter ME, Ewy GA. Adverse hemodynamic effects of interrupting chest compressions for rescue breathing during cardiopulmonary resuscitation for ventricular fibrillation cardiac arrest. Circulation. 2001 Nov 13;104(20):2465-70. Compared 15:2 with compression only CPR

o Bobrow BJ, Clark LL, Ewy GA, Chikani V, Sanders AB, Berg RA, Richman PB, Kern KB. Minimally interrupted cardiac resuscitation by emergency medical services for out-of-hospital cardiac arrest. JAMA. 2008 Mar 12;299(10):1158-65. OHCA in Arizona. Before(05.1~05.6) vs after minimally interrupted cardiac resuscitation, Favor MICR (Survival discharge, 5.4% vs 1.8%)

o Bohm K, Rosenqvist M, Herlitz J, Hollenberg J, Svensson L. Survival is similar after standard treatment and chest compression only in out-of-hospital bystander cardiopulmonary resuscitation. Circulation. 2007; 116(25): 2908-12. Compared standard CPR (not 30:2) with compression only CPR

o Dorph E, Wik L, Strømme TA, Eriksen M, Steen PA. Oxygen delivery and return of spontaneous circulation with ventilation:compression ratio 2:30 versus chest compressions only CPR in pigs. Resuscitation. 2004; 60(3): 309-18. LOE 5 (pig model), Fair, Supporting 30:2 compared to CCC, Endpoints: ROSC (A; neutral), time to ROSC and the number of shocks (E; favor 30:2)

o Ewy GA, Zuercher M, Hilwig RW, Sanders AB, Berg RA, Otto CW, Hayes MM, Kern KB. Improved neurological outcome with continuous chest compressions compared with 30:2 compressions-to-ventilations cardiopulmonary resuscitation in a realistic swine model of out-of-hospital cardiac arrest. Circulation. 2007; 116(22): 2525-30. LOE 5 (swine model), good, supporting continuous chest compression (CCC). Endpoints: ROSC (A; neutral), 24-h survival (B; neutral), 24-h neurologically normal survival (D; favor CCC), surrogate endpoints (E; favor CCC)

o Hallstrom A, Cobb L, Johnson E, Copass M. Cardiopulmonary resuscitation by chest compression alone or with mouth-to-mouth ventilation. N Engl J Med. 2000; 342(21): 1546-53. chest compression alone with chest compression plus mouth-to-mouth ventilation

o Iwami T, Kawamura T, Hiraide A, Berg RA, Hayashi Y, Nishiuchi T, Kajino K, Yonemoto N, Yukioka H, Sugimoto H, Kakuchi H, Sase K, Yokoyama H, Nonogi H. Effectiveness of bystander-initiated cardiac-only resuscitation for patients with out-of-hospital cardiac arrest. Circulation. 2007; 116(25): 2900-7. Level 2 (OHCA in Osaka, Japan. 98.5~03.4), Good, Neutral to cardiac only CPR (I) cardiac only CPR vs (C) conventional CPR (Not 30:2), 1-year survival with favorable neurological outcome, (4.3% vs 4.1%)

o Kellum MJ, Kennedy KW, Ewy GA. Cardiocerebral resuscitation improves survival of patients with out-of-hospital cardiac arrest. Am J Med. 2006 Apr;119(4):335-40. 15:2 vs Cardiocerebral resuscitation

o Kern KB, Hilwig RW, Berg RA, Sanders AB, Ewy GA. Importance of continuous chest compressions during cardiopulmonary resuscitation: improved outcome during a simulated single lay-rescuer scenario. Circulation. 2002; 105(5): 645-9. Animal study (Pig), 15:2 vs continuous chest compression CPR

o Nishiyama C, Iwami T, Kawamura T, Ando M, Yonemoto N, Hiraide A, Nonogi H. Effectiveness of simplified chest compression-only CPR training for the general public: a randomized controlled trial. Resuscitation. 2008; 79(1): 90-6. Study about adult training effectiveness between 30:2 and compression only CPR (favor compression only)

o Ong ME, Ng FS, Anushia P, Tham LP, Leong BS, Ong VY, Tiah L, Lim SH, Anantharaman V. Comparison of chest compression only and standard cardiopulmonary resuscitation for out-of-hospital cardiac arrest in Singapore. Resuscitation. 2008; 78(2): 119-26. Compared to 15:2 (standard), no CPR and compression only

o SOS-KANTO study group. Cardiopulmonary resuscitation by bystanders with chest compression only (SOS-KANTO): an observational study. Lancet. 2007 Mar 17;369(9565):920-6. OHCA in Kanto, Japan. 02.9~03.12, Favor cardiac only CPR on conventional CPR (Not 30:2), 30-day neurological outcome, (6.2% vs 3.1%)

o Swor R, Compton S, Vining F, Ososky Farr L, Kokko S, Pascual R, Jackson RE. A randomized controlled trial of chest compression only CPR for older adults-a pilot study. Resuscitation. 2003; 58(2): 177-85. chest-compression only CPR vs traditional CPR

o Williams JG, Brice JH, De Maio VJ, Jalbuena T. A simulation trial of traditional dispatcher-assisted CPR versus compressions--only dispatcher-assisted CPR. Prehosp Emerg Care. 2006 Apr-Jun;10(2):247-53. Compression-only CPR vs 15:2 CPR in dispatcher assisted CPR

o Woollard M, Smith A, Whitfield R, Chamberlain D, West R, Newcombe R, Clawson J. To blow or not to blow: a randomised controlled trial of compression-only and standard telephone CPR instructions in simulated cardiac arrest. Resuscitation. 2003; 59(1): 123-31. compression-only telephone CPR vs standard telephone CPR