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

<table>
<thead>
<tr>
<th>Worksheet author(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lindsay Mildenhall MBChB FRACP</td>
</tr>
<tr>
<td>Date Submitted for review:</td>
</tr>
<tr>
<td>24 September 2009</td>
</tr>
</tbody>
</table>

**Clinical question.**

| In babies receiving chest compressions (P) do other ratios (5:1, 15:2) (I) versus a 3:1 (C) improve outcomes (O)? |
| Is this question addressing an intervention/therapy, prognosis or diagnosis? | Intervention |
| State if this is a proposed new topic or revision of existing worksheet: | Revision |

**Conflict of interest specific to this question**

Do any of the authors listed above have conflict of interest disclosures relevant to this worksheet? No

**Search strategy (including electronic databases searched).**

- Cochrane Library: resuscitation as “search all text” and ratio* as “search all text” and neonate* or infant* (27 hits)
- Cochrane Library: resuscitation or heart massage as “search all text” or “record title” and compression* ventilation* as “search all text” and neonate* or infant* as “search all text” (17 hits)
- Ovid (Medline) cardiopulmonary resuscitation or heart massage (MESH Headings) and ratio$ as “key word”. Limits to English language, 1950-2009 and birth-23 months: (55 hits)
- Ovid (Medline) cardiopulmonary resuscitation or heart massage (MESH Headings) and 5:1, 15:2, 3:1, 30:2 as “key words”. Limits to English language, 1950-2009 and birth-23 months: (37 hits)
- Ovid (Medline) cardiopulmonary resuscitation or heart massage (MESH Headings) and ratio$ and compression-ventilation or ventilation-compression as “key word”. Limits to English language, 1950-2009 and birth-23 months: (27 hits)
- PubMed: Cardiopulmonary resuscitation or heart massage MESH Headings. Chest compression(s) ventilation(s) as key words Limits: 1950-2009, English language, Newborn to 1 month, Animals/Humans (13 hits)
- AHA Endnote Master Library 24 March 08 “ventilation compression ratio” (35 hits)
- Google Scholar “ventilation compression ratio”

Pertinent articles were cross referenced with “find related article” or “find citing article” searches

All searches completed 22nd September 2009

**State inclusion and exclusion criteria**

**Inclusions:**
- Human, animal or mechanical (manikin) subjects.
**Exclusions:**
- Abstract-only articles
- Subjects older than 1 year of age (select adult manikin studies included)
- Articles in languages other than English

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

11 studies met criteria for further review. All studies were LOE 5.
## Summary of evidence

### Evidence Supporting Clinical Question

<table>
<thead>
<tr>
<th>Good</th>
<th>Fair</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Srikantan 2005E</td>
<td>Whyte 1999E</td>
</tr>
<tr>
<td></td>
<td>Berg 1999E</td>
<td>Berg 2000E</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

**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*
### Evidence Neutral to Clinical question

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<thead>
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<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

**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*

### Evidence Opposing Clinical Question

<table>
<thead>
<tr>
<th>Good</th>
<th>Fair</th>
<th>Poor</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
</table>

**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 use of a 3 chest compressions to 1 ventilation ratio in Neonatology stems from the theoretical premise that newborn resuscitation, when compared with adults and to a lesser extent children and infants is primarily a respiratory focused resuscitation. The newborn lung, unlike other resuscitation scenarios, has no or minimally established functional residual capacity and current guidelines emphasize good airway management to address this. The focus is therefore on proportionally more ventilations over a set time period in relation to chest compressions. In ventricular fibrillation or asystolic cardiac arrest typical of adult collapse effective forward pumping of blood ceases and oxygen levels in the blood remain relatively high for many minutes. This is the reason why some adult researchers focus on chest compression only forms of resuscitation or ratios delivering infrequent ventilations. In contrast during the perinatal asphyxia typically preceding the need for neonatal resuscitation the heart is often still beating, pumping blood around the body and thus levels of oxygen fall and carbon dioxide and lactate rise. The focus therefore is to replenish oxygen with effective ventilation and swing the emphasis away from supporting the relatively resilient heart.

The evidence based literature addressing this topic in Neonatology is threadbare. Most of the research is from adult medicine involving manikin or animal based work primarily in pig or dog models. Investigations have focused on a number of scenarios of limited value to Neonatology, often using single versus dual rescuers designs mimicking out-of-hospital ventricular fibrillation or asystolic cardiac arrests. The end points of these studies are usually defibrillation coupled with return to sinus rhythm scenarios. No studies investigating various ratios have anything other than short term outcome goals or quality measures during resuscitation as their endpoints. While these have little relevance to newborns some information can be teased out of these studies to assist with recommendations here. The focus here is that ventilations have a higher priority in any neonatal resuscitation guideline than in other age groups.

Eleven studies were identified as relevant to this topic seven from manikin work, three animal studies and one theoretical paper.

**Manikin Studies:**

Only one paper has a purely neonatal focus (Whyte 1999). This manikin study asked the question whether a rate of 120 events per minute (3 compressions / 1 breath) could be practically performed by experienced personnel in a dual (bag and mask) or single (mouth to mouth) rescuer scenario. This paper was based on European guidelines current at the time (1999) which advocated breaths paired with compressions, thus 40 breaths and 120 compressions per minute. Median breaths per minute actually delivered over 5 minutes numbered 20 for the single rescuer and 35 for the paired arm. This paper concluded that it was inappropriate for guidelines to suggest largely unachievable rates and to concentrate on quality of breaths and compressions rather than quantity. A second manikin study (Srikantan et al 2005) compared four ratios including 3:1 in a single rescuer design aiming to quantify actual delivery rates of ventilations and compressions plus indices of rescuer fatigue over 5 minutes. Departure from a purely neonatal regime included a compression rate of 100 per minute, 1 second inspiratory time for the breath, and two finger technique only for the compressions. Results confirmed the 3:1 ratio could be achieved and significantly more breaths than compressions were delivered than other ratios although in no ratios was the rate of 100 per minute achieved. All rescuers rated the 3:1 ratio as more difficult to perform than other ratios and this paper advocated a single ratio (10:2) for all age groups as being easy to remember and expected to support a wide age group of victims. Comparing other ratios Wik and Steen (1996) contrasted 5:1 verses 15:2 with two rescuers where in the latter group one rescuer performed tasks (IV lines, drug administration) other than ventilation and compressions. Interestingly more sequences were performed without ventilations in the 5:1 ratio (2 persons performing the ventilation/compressions) than the 15:2. To contrast this (Kinney 2000) in an infant manikin study showed with 2 rescuers more ventilations and compressions in the 5:1 ratio group when compared with 10:2 and 15:2 with no difference in quality of compressions between ratios. Greiinger (2002) compared quality of compressions with 5:1 verses 15:2 and 2 rescuers finding that while the 15:2 ratio delivered a higher number of compressions, the number of compressions of suitable quality was significantly higher in the 5:1 ratio group. While of limited relevance to Neonatology single rescuer studies in pediatric manikins mimicking out of hospital arrests show somewhat different results. Dorph et al (2002) compared ratios of 5:1 with 15:2 with ventilations delivered by mouth to mouth. They theorized that the advantage of more frequent breaths in the 5:1 ratio would be negated by the more frequent airway repositioning. They confirmed a higher compression rate of equal quality between the two ratios but also no difference in minute ventilation Haque et al (2008) compared 15:2 with 30:2 ratios in adult, child and infant manikins focusing on chest compression quality and rescuer fatigue variables. Ventilation was by mouth to mouth and simulated thus no ventilation quality measures were tabulated. They found the expected increased number of
compression cycles with the 30:2 ratio but no difference in quality measures between the two ratios. Rescuer fatigue measures were essentially the same between ratios.

**Animal Studies:**

The vast majority of animal studies reflect ventricular fibrillation (VF) models of cardiac arrest performed in adult animals simulating adult collapse and resuscitation. The piglet has demonstrated some validity in pediatric resuscitation studies due to a chest size and stiffness simulating those of an infant but no studies have been discovered in this search utilizing newborn animals. There is little data to assist Neonatology in determining an appropriate ventilation to compression ratio. Some guidance can however be gleaned from these studies. Dean et al (1991) investigated 2 duty cycle variations (duration of compression/total cycle time 30% vs 60%) at two different compression rates (150 vs 100) in a 2 week old piglet VF model ventilated at a ratio of 5:1. Monitoring cerebral and myocardial perfusion parameters they found, especially during prolonged resuscitation (10 minutes) significantly better perfusion markers in the 30% duty cycle at either compression rate than the 60%. This suggested that chest compressions delivered by a sustained compression to have a detrimental effect if the resuscitation is ongoing. The combination of ventilation with compressions is beneficial, at least in the pediatric population. Using an asphyxial model of single rescuer cardiac arrest in 2-3 month old piglets, Berg (1999) compared short and medium term outcomes of a control group verses sub groups receiving initial ventilation plus compressions (ratio 15:1) or compressions or ventilations only. This study was repeated Berg (2000) using the same model except the cardiac arrest was implemented at an earlier stage. The ventilation plus compression group had significantly better outcomes in both studies.

**Theoretical papers:**

Mathematical and physiological analyses have attempted to estimate the optimal ventilation and compression ratios for single rescuers in adult resuscitation. Babbs and Nadkani (2004) repeated this exercise in Pediatrics for single lay rescuers and professionals. Their modeling altered as a function of body size and as such the universal ratio of 50:2 that could function for adult resuscitation would likely underventilate the pediatric population the more so the smaller in size they were. This was deemed especially deleterious based on the importance of ventilation in pediatric asphyxial arrest. While their modeling was based on children of average body weights aged 1 year to 18 years, if one extrapolates their graphical estimates to the body weights of neonates, the ideal compression to ventilation ratios are between 3-5:1 for both single lay rescuers and professionals.

**Summary:**

If the newborn resuscitation is deemed a respiratory focused resuscitation no evidence from this literature review warrants departure from the currently taught 3 compressions : 1 ventilation ratio. A paucity of research to guide this recommendation is noted and properly designed studies involving immediate newborn models could provide guidance here. Outside the newborn period a move toward more uniform ratios across many age groups is occurring. At this stage, in newborn resuscitation, this move cannot be recommended.

**Acknowledgements:**

Ms Joanne Martin, Librarian, Counties Manukau DHB

**Citation List**


**Worksheet author comments:**

1. LOE 5(Theoretical analysis of C/V ratios) / QOE Fair / Neutral

2. Approximations of C/V ratios for single rescuer based on lean body weight and subcategorised for lay verses professional rescuer (latter taking less time to deliver
ventilatory breath). Recognises that adult ratios would under ventilate children.
Extrapolating sensitivity analysis for professional and lay rescuers would suggest a ratio of
3-4:1 appropriate for 0-5 kg lean body weight

3. No industry funding

compressions (bystander cardiopulmonary resuscitation) improves outcome in a swine model
of prehospital pediatric asphyxial cardiac arrest.[see comment]." Critical Care Medicine 27(9):
1893-9.

Worksheet author comments:

1. LOE 5(Animal study) / QOE Fair / Supports
Unlike ventricular fibrillation arrests, when chest compressions alone can produce just as
successful initial single rescuer outcomes, asphyxial arrests have better outcomes in this
piglet model when chest compressions are combined with ventilation. Resuscitation started
when cardiac arrest occurred defined as an aortic pulse pressure less than 2 mmHg.

2. Magnitude of effect

<table>
<thead>
<tr>
<th></th>
<th>Chest compress. + Vent (CC+V)</th>
<th>Chest compress. Only (CC)</th>
<th>Ventilation only</th>
</tr>
</thead>
<tbody>
<tr>
<td>Return of circulation</td>
<td>9/10</td>
<td>10/14</td>
<td>3/7</td>
</tr>
<tr>
<td>24 hour survival</td>
<td>8/10</td>
<td>3/14&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1/7&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>24hr neuro. normal</td>
<td>7/10</td>
<td>1/14&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1/7&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

a = p ≤ 0.01 vs CC+V; b = p ≤ 0.05 vs CC+V

3. No industry funding


Worksheet author comments:

1. LOE 5(Animal study) / QOE Fair / Supports
Piglet model of asphyxia comparing chest compressions + ventilation (15:2) verses ventilation
or chest compressions alone. Experimental model attempting to mimic out of hospital lone
rescuer arrest. Differs from Berg (1999) in that cardiac arrest in an early stage (defined as
aortic systolic pressure < 50mm Hg). All groups compared with controls. Physiological data
recorded during resuscitation plus survival and neurological status after 24 hours. Outcomes
for chest compressions combined with ventilation better than either alone. Trend toward more
piglets being neurologically normal in the combined group than other groups.

2. Magnitude of observed effect

<table>
<thead>
<tr>
<th></th>
<th>Chest comp+vent</th>
<th>Chest comp. only</th>
<th>Ventilation only</th>
<th>No CPR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Return of circl (n)</td>
<td>10/10*</td>
<td>4/10</td>
<td>6/10</td>
<td>0/10</td>
</tr>
</tbody>
</table>
*p ≤ 0.01 vs CC and Vent combined

3. No industry funding


**Worksheet author comments:**

1. LOE 5(Animal study) / QOE Poor / Neutral
All animals were ventilated at a ratio of 5:1 (ventilation with pressure of 30cm H₂O and 100% O₂) and no comparison of different ratios was built into the study design. Physiological variables in all body regions monitored began to decline in the 60% duty cycle after 10 minutes of CPR. No real difference if measures prior to that. Relevance for neonatology to emphasize avoiding a sustained chest compression especially if resuscitation is prolonged.

2. No industry funding


**Worksheet author comments:**

1. LOE 5(Manikin study) / QOE Fair / Neutral
Single rescuer using mouth to mouth ventilation. No difference in minute volume between ratios. Hypothesized that single rescuer would make more mistakes moving from chest to airway in the 5:1 group but minute ventilation the same between groups.

2. **Magnitude of observed effect**

<table>
<thead>
<tr>
<th></th>
<th>5:1</th>
<th>15:2</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minute volume (mls)</td>
<td>1479 +/- 616</td>
<td>1417 +/- 497</td>
<td>0.408</td>
</tr>
<tr>
<td>Chest compressions</td>
<td>41 +/- 7</td>
<td>60 +/- 9</td>
<td>0.001</td>
</tr>
</tbody>
</table>

3. No industry funding


**Worksheet author comments:**

1. LOE 5(Adult Manikin study) / QOE Poor / Neutral
Resuscitation technique involved hand placement on the lower sternum. 2 person resuscitation over 5 minutes with quality of ventilations not assessed. In this adult model quality of compressions greater with 5:1 than 15:2.
2. Magnitude of observed effect

3. No industry funding


**Worksheet author comments:**

1. LOE 5(Manikin study) / QOE Fair / Neutral
Comparison of 15:2 with 30:2 compression to ventilation ratios following a randomised crossover design and single rescuers. Manikin subjects included adult and child trainers but with an infant arm mimicking a 3 month child. Instructed to deliver CPR at a rate of 100 per minute, the 30:2 group achieved more compressions cycles than the 15:2 group over the 5 minute blocks and thus less ventilations. Ventilations were simulated so possible compressions would be less if ventilation was focused on more.

2. Magnitude of observed effect (chest compressions over 5 minutes; mean +/- sd)

<table>
<thead>
<tr>
<th></th>
<th>30:2</th>
<th>15:2</th>
<th>Paired diff 30:2-15:2</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infant two finger</td>
<td>495 +/- 114</td>
<td>410 +/- 70</td>
<td>86 +/- 92</td>
<td>0.002</td>
</tr>
<tr>
<td>Infant two thumb</td>
<td>474 +/- 84</td>
<td>361 +/- 80</td>
<td>113 +/- 40</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

3. No industry funding


**Worksheet author comments:**

1. LOE 5(Manikin study) / QOE Poor / Neutral
Dual rescuers mimicking in-hospital resuscitation. Manikin equivalent to 5 year old. Supports use of 5:1 vs 10:2 / 15:2 in smaller children with equally effective compressions plus more ventilations.

2. Magnitude of effect

<table>
<thead>
<tr>
<th></th>
<th>5:1</th>
<th>10:2</th>
<th>15:2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breaths / minute</td>
<td>18.2 +/- 1.3**</td>
<td>17.3 +/- 1.4**</td>
<td>12.3 +/- 1.1**</td>
</tr>
<tr>
<td>Minute ventilation (l)</td>
<td>2.2**</td>
<td>2.0**</td>
<td>1.4**</td>
</tr>
<tr>
<td>Compressions / minute</td>
<td>87.9 +/- 6.8**</td>
<td>78.9 +/- 4.2**</td>
<td>83.7 +/- 4.6**</td>
</tr>
<tr>
<td>% effective compressions</td>
<td>84.6 +/- 26.6*</td>
<td>84.6 +/- 22.4*</td>
<td>84.6 +/- 27.9*</td>
</tr>
</tbody>
</table>

Mean +/- sd: Results either not significant* or no analysis performed**

3. No industry funding

Worksheet author comments:

1. LOE 5(Manikin study) / QOE Fair / Supports
Single rescuer study (BLS only trained to mimic layperson rescuers) using only the two finger technique for the infant manikin compressions. Also study design had a prolonged inspiratory time (1 second) when compared with neonatal resuscitation (0.5 sec). 3:1 ratio gives more ventilations per minute than 5:1, 10:2, 15:2 but less compressions than the 15:2 rate. Rescuers rated the 3:1 ratio as more exertional than other ratios but the change in rescuer heart rates was inconclusive between ratios due to wide interindividual variability. Rescuers subjectively preferred higher ratios

2. Magnitude of observed effect

<table>
<thead>
<tr>
<th></th>
<th>3:1</th>
<th>5:1</th>
<th>10:2</th>
<th>15:2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressions/min</td>
<td>57 +/- 14&lt;sup&gt;a&lt;/sup&gt;</td>
<td>67 +/- 11</td>
<td>64 +/- 10</td>
<td>70 +/- 7</td>
</tr>
<tr>
<td>Ventilations/min</td>
<td>19 +/- 4&lt;sup&gt;b&lt;/sup&gt;</td>
<td>13 +/- 2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>13 +/- 2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>9 +/- 1</td>
</tr>
<tr>
<td>Rating of CV ratio</td>
<td>3.8 +/- 0.8&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.7 +/- 0.7</td>
<td>1.7 +/- 0.6</td>
<td>1.7 +/- 0.9</td>
</tr>
</tbody>
</table>

Data = mean +/- SEM <sup>a</sup>p < 0.005 vs 15:2, <sup>b</sup>p < 0.05 for 3:1 vs all others

3. No industry funding


Worksheet author comments:

1. LOE 5(Manikin study) / QOE Poor / Supports
Single rescuer ventilated by mouth to mouth, paired rescuers used Laederl bag. Aimed for 120 compressions and 40 breaths per minute i.e. a breath every 1.5 seconds (not 90 compressions / 30 breaths per minute as per other guidelines). Paired rescuers able to maintain 30 breaths per minute. Cardiac compression quality not assessed. Single rescuers who ventilated faster had more inefficient breaths by 5<sup>th</sup> minute.

2. Magnitude of observed effect

<table>
<thead>
<tr>
<th></th>
<th>1&lt;sup&gt;st&lt;/sup&gt; minute</th>
<th>5&lt;sup&gt;th&lt;/sup&gt; minute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median breath rate (single)</td>
<td>20</td>
<td>19</td>
</tr>
<tr>
<td>Median breath rate (paired)</td>
<td>33.5</td>
<td>35</td>
</tr>
</tbody>
</table>

3. No industry funding


Worksheet author comments:
1. **LOE 5(Adult Manikin study) / QOE Fair / Neutral**

Trainee paramedics on adult training course. Very cardiac focused study with endpoint being defibrillation to restore sinus rhythm. Aim to get lines in and defibrillate by one rescuer while the other performs chest compressions and ventilates (15:2 ratio) or one rescuer ventilating and performing all other tasks the other performs chest compressions only (5:1). Of significance more ventilations missed in 5:1 ratio than 15:2. In both groups a trend toward lower (adult) ventilation volumes and higher compression number than in current guidelines. Relevance for neonates only in advanced resuscitation when lines, drugs needed.

2. **Magnitude of observed effect**

<table>
<thead>
<tr>
<th></th>
<th>1:5</th>
<th>15:2</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of chest</td>
<td>7</td>
<td>0</td>
<td>0.00001</td>
</tr>
<tr>
<td>compression series</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>without ventilations</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. No industry funding