BLS 2102: Clinician Recognition data tables

Table 1: Studies of pulse assessment (n=10)

<table>
<tr><th>Author, Year, Country</th><th>Type of study</th><th>Aim
Study Design</th><th>Clinician Population</th><th>'Patient' population</th><th>Outcomes measured</th><th>Main findings</th></tr>
<tr><td colspan="7">1.1 HUMAN STUDIES OF ECMO / CARDIAC BYPASS - ADULT</td></tr>
<tr><td>Dick et al. 2000
Germany</td><td>ECMO / cardiac bypass
Pulse check
ADULT</td><td>Evaluate accuracy and time requirements of left carotid pulse check</td><td>First responders (n=99)
• 16 EMTs in training
• 74 paramedics in training
• 9 certified paramedics
Blinded to spontaneous circulation vs non-pulsatile cardiopulmonary bypass</td><td>Adults undergoing coronary artery bypass grafting (n=16)</td><td>Carotid pulse check: accuracy and time to decision</td><td>
<table>
<tr><th>Training level</th><th>n</th><th>Sensitivity (%)</th><th>Specificity (%)</th></tr>
<tr><td>EMT-training</td><td>16</td><td>100</td><td>30</td></tr>
<tr><td>Paramedic – training</td><td>74</td><td>100</td><td>76</td></tr>
<tr><td>Paramedic - certified</td><td>9</td><td>N/A</td><td>89</td></tr>
</table>
</td></tr>
<tr><td>Eberle et al. 1996
Germany</td><td>ECMO / cardiac bypass
Pulse check
ADULT</td><td>Evaluate diagnostic accuracy and time required to assess carotid pulse</td><td>First responders (n=99)
• 16 EMTs in training
• 74 paramedics in training
• 9 certified paramedics
Blinded to spontaneous circulation vs non-pulsatile cardiopulmonary bypass</td><td>Adults undergoing coronary artery bypass grafting (n=16)</td><td>Carotid pulse check: accuracy and time to decision</td><td>
<table>
<tr><th>Training level</th><th>n</th><th>Sensitivity (%)</th><th>Specificity (%)</th><th>Diagnostic Accuracy (%)</th><th>Delay to decision re pulse status* (median, IQR minutes)</th></tr>
<tr><td>EMT-training</td><td>16</td><td>100</td><td>30</td><td>56</td><td>3.0, 2.0-5.0</td></tr>
<tr><td>Paramedic – training</td><td>74</td><td>100</td><td>76</td><td>81</td><td>2.0, 1.0 – 3.0</td></tr>
<tr><td>Paramedic - certified</td><td>9</td><td>N/A</td><td>89</td><td>89</td><td>2.0, 1.5 – 3.5</td></tr>
</table>
* post training
</td></tr>
<tr><td>Smith et al. 2021
Canada</td><td>ECMO / cardiac bypass

POCUS pulse detection

ADULT</td><td>Determine whether physicians agree regarding presence or absence of carotid pulse in pre-recorded POCUS clips from patients who are in cardiac arrest.</td><td>ED residents and staff physicians (n=68)
• junior resident (n=15)
• senor resident (n=24)
• staff physician (n=29)</td><td>Scenario: 55 year-old man in cardiac arrest. 15 ultrasound video clips: 5s ultrasound looped for a total of 20s</td><td>Absence or presence of carotid pulse
Time to decision</td><td>Correct identification of pulse
• presence ranged from 91.2% to 100%
• absence ranged from 39.7% to 100%
Median pulse assessment duration was 6 s (IQR 5) with 76% of assessments completed within 10s
<table>
<tr><th rowspan="2">Video clip number</th><th rowspan="2">Sonographic features</th><th colspan="2">Participant decision</th></tr>
<tr><th>Pulse present (%)</th><th>Pulse absent (%)</th></tr>
<tr><td>1</td><td>Weak pulsations, bradycardia</td><td>95.6*</td><td>4.4</td></tr>
<tr><td>2</td><td>Full collapse, no pulsations</td><td>1.5</td><td>98.5*</td></tr>
<tr><td>3</td><td>No collapse, strong pulsations</td><td>100.0*</td><td>0</td></tr>
<tr><td>4</td><td>Collapse, no clear pulsations</td><td>60.3</td><td>39.7*</td></tr>
<tr><td>5</td><td>No collapse, weak pulsations</td><td>98.5*</td><td>1.5</td></tr>
<tr><td>6</td><td>No collapse, no pulsations</td><td>0</td><td>100.0*</td></tr>
<tr><td>7</td><td>Collapse, weak pulsations, bradycardia</td><td>98.5*</td><td>1.5</td></tr>
<tr><td>8</td><td>Strong pulsations</td><td>100.0*</td><td>0</td></tr>
<tr><td>9</td><td>Collapse, very weak pulsations</td><td>91.2*</td><td>8.8</td></tr>
<tr><td>10</td><td>Collapse, no pulsations</td><td>1.5</td><td>98.5*</td></tr>
<tr><td>11</td><td>No collapse, strong pulsations</td><td>100.0*</td><td>0</td></tr>
<tr><td>12</td><td>Minimal collapse, strong pulsations</td><td>100.0*</td><td>0</td></tr>
<tr><td>13</td><td>Collapse, no pulsations</td><td>0</td><td>100.0*</td></tr>
<tr><td>14</td><td>Collapse, pulsations</td><td>98.5*</td><td>1.5</td></tr>
<tr><td>15</td><td>Collapse, no pulsations</td><td>0</td><td>100.0*</td></tr>
</table>
* correct answer
</td></tr>
<tr><td>Sanchez et al. 2020
Australia</td><td>ECMO / cardiac bypass

POCUS pulse detection

ADULT</td><td>Test diagnostic accuracy of two-dimensional carotid ultrasound to detect presence or absence of a pulse</td><td>Physicians (n=46)
• anaesthesia (n=23)
• emergency medicine (n=22)
• intensive care (n=1)
Viewed four 10 second videos of carotid artery ultrasound under following conditions:
• low SBP <70 mmHg
• medium SBP 70-90 mmHg
• high SBP >90 mmHg
• following aorta cross-clamp</td><td>Adults undergoing cardiopulmonary bypass (n=23)</td><td>Diagnostic accuracy: pulse vs no pulse</td><td>Diagnostic accuracy
• sensitivity for pulse detection = 0.91 (95% CI 0.89-0.93)
• specificity for no-pulse detection = 0.90 (95% CI 0.86-0.93)
Sensitivity for pulse detection
• highest in the high SBP group (0.96, 95% CI 0.93-0.98)
• lowest in the low SBP group (0.83, 95% CI 0.78-0.87).</td></tr>
</table>

Table 1: Studies of pulse assessment (n=10)

<table>
<tr><th>Author, Year, Country</th><th>Type of study</th><th>Aim
Study Design</th><th>Clinician Population</th><th>'Patient' population</th><th>Outcomes measured</th><th>Main findings</th></tr>
<tr><td colspan="7">1.2 HUMAN STUDIES OF ECMO / CARDIAC BYPASS – PAEDIATRIC</td></tr>
<tr><td>Tibballs & Weeranatna
2010
Australia</td><td>ECMO / cardiac bypass

Pulse check

PAEDIATRIC</td><td>Determine time and accuracy diagnosing paediatric cardiac arrest by pulse palpation.</td><td>Hospital based doctors (n=71) and nurses (n=82) entering ICU asked to palpate brachial pulse
Of the 153 rescuers, 38 doctors (25%) and 21 nurses (14%) were "inexperienced".
Thirty-three doctors (21%) and 61 nurses (40%) were "experienced".</td><td>17 children in ICU with non-pulsatile extracorporeal circulation for cardiac arrest or cardiac failure
• 9 infants (median age 2 weeks, range 1 day–11 months)
• 8 children aged 3–11 years</td><td>Time to rescuer decision (pulse present/absent)</td><td>Cardiac arrest (n=55) was correctly diagnosed by 76% rescuers in mean (±SD) time 30±19. Cardiac arrest absence (n=98) was correctly confirmed by 79% rescuers in 13±13s. Overall
• accuracy = 78% (95%CI 71–84%)
• sensitivity = 0.76 (95%CI 0.64–0.86)
• specificity = 0.79 (95%CI 0.69–0.86)
Relationship between accuracy and time to diagnosis (p=0.015)
• 90% accuracy <10s
• 77% accuracy 11–20s
• 62.5% accuracy 21–30

<table>
<tr><th></th><th colspan="4">Cardiac arrest</th></tr>
<tr><td>Rescuer decision</td><td colspan="2">Present (%) = pulse absent</td><td colspan="2">Absent (%) = pulse present</td></tr>
<tr><td>Pulse absent</td><td>true +ve (sensitivity)</td><td>27.5</td><td>false +ve</td><td>13.7</td></tr>
<tr><td>Pulse present</td><td>false -ve</td><td>8.5</td><td>true -ve (specificity)</td><td>50.3</td></tr>
</table>

Time to decisions (seconds)
<table>
<tr><th></th><th colspan="2">Any decision</th><th colspan="2">Correct decision (TP +TN)</th><th colspan="2">Incorrect decisions (FP+FN)</th><th colspan="2">Cardiac arrest present (TP)</th><th colspan="2">Cardiac arrest absent (TN)</th></tr>
<tr><td></td><td>n</td><td>Mean (SD)</td><td>n</td><td>Mean (SD)</td><td>n</td><td>Mean (SD)</td><td>n</td><td>Mean (SD)</td><td>n</td><td>Mean (SD)</td></tr>
<tr><td>All rescuers</td><td>153</td><td>20 ± 17</td><td>119</td><td>19 ± 17</td><td>34</td><td>24 ± 16</td><td>42</td><td>30 ± 19</td><td>77</td><td>13 ± 13</td></tr>
<tr><td>• Experienced</td><td>94</td><td>16 ± 13</td><td>77</td><td>14 ± 12</td><td>17</td><td>25 ± 17</td><td>26</td><td>25 ± 14</td><td>51</td><td>9 ± 5</td></tr>
<tr><td>• Inexperienced</td><td>59</td><td>26 ± 20</td><td>42</td><td>27 ± 22</td><td>17</td><td>24 ± 15</td><td>16</td><td>37 ± 24</td><td>26</td><td>21 ± 19</td></tr>
<tr><td>All doctors</td><td>71</td><td>24 ± 17</td><td>59</td><td>22 ± 21</td><td>12</td><td>33 ± 20</td><td>17</td><td>39 ± 22</td><td>42</td><td>15 ± 15</td></tr>
<tr><td>• Experienced</td><td>33</td><td>17 ± 16</td><td>28</td><td>13 ± 11</td><td>5</td><td>39 ± 21</td><td>5</td><td>29 ± 14</td><td>23</td><td>9 ± 6</td></tr>
<tr><td>• Inexperienced</td><td>38</td><td>30 ± 23</td><td>31</td><td>30 ± 24</td><td>7</td><td>28 ± 19</td><td>12</td><td>43 ± 24</td><td>19</td><td>22 ± 20</td></tr>
<tr><td>All nurses</td><td>82</td><td>17 ± 12</td><td>60</td><td>16 ± 13</td><td>22</td><td>20 ± 11</td><td>25</td><td>23 ± 13</td><td>35</td><td>10 ± 9</td></tr>
<tr><td>• Experienced</td><td>61</td><td>16 ± 12</td><td>49</td><td>15 ± 12</td><td>12</td><td>19 ± 11</td><td>21</td><td>24 ± 14</td><td>28</td><td>9 ± 5</td></tr>
<tr><td>• Inexperienced</td><td>21</td><td>20 ± 13</td><td>11</td><td>18 ± 15</td><td>10</td><td>22 ± 11</td><td>4</td><td>19 ± 9</td><td>7</td><td>18 ± 18</td></tr>
<tr><td colspan="11">Experienced = anaesthesia, intensive care, cardiology, ED; Inexperienced = general medical/ surgical wards</td></tr>
</table>

Pulse palpation performance (95% CI)
<table>
<tr><th></th><th>n</th><th>Accuracy (%)</th><th>Sensitivity</th><th>Specificity</th></tr>
<tr><td>All rescuers</td><td>153</td><td>78 (71–84)</td><td>0.76 (0.64–0.86)</td><td>0.79 (0.69–0.86)</td></tr>
<tr><td>All doctors</td><td>71</td><td>83 (73–90)</td><td>0.74 (0.53–0.87)</td><td>0.88 (0.75–0.94)</td></tr>
<tr><td>All nurses</td><td>82</td><td>73 (63–82)</td><td>0.78 (0.61–0.89)</td><td>0.70 (0.56–0.81)</td></tr>
<tr><td>Experienced doctors</td><td>33</td><td>85 (69–93)</td><td>1.00 (0.54–1.00)</td><td>0.82 (0.64–0.92)</td></tr>
<tr><td>Experienced nurses</td><td>61</td><td>80 (69–88)</td><td>0.78 (0.59–0.89)</td><td>0.82 (0.66–0.92)</td></tr>
<tr><td>Inexperienced doctors</td><td>38</td><td>82 (66–91)</td><td>0.67 (0.43–0.84)</td><td>0.95 (0.76–0.99)</td></tr>
<tr><td>Inexperienced nurses</td><td>21</td><td>52 (32–72)</td><td>0.80 (0.36–0.96)</td><td>0.44 (0.23–0.67)</td></tr>
</table>
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Table 1: Studies of pulse assessment (n=10)

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<tr><th>Author, Year, Country</th><th>Type of study</th><th>Aim
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<tr><td>Tibballs & Russell
2009
Australia</td><td>ECMO / cardiac bypass

Pulse check

PAEDIATRIC</td><td>Determine reliability of pulse palpation to diagnose paediatric cardiac arrest</td><td>Hospital based doctors (n=110) and nurses (n=101) recruited from ED or entering ICU for other reasons
• 52 doctors (25%) and 40 nurses (19%) from medical and surgical wards
• 56 doctors (27%) and 61 nurses (29%) from acute care (intensive care, anaesthesia, cardiology, emergency)
Were instructed to palpate any pulse of their choice excluding the cardiac apex, and decide if pulse was present or absent within 10 s.</td><td>Infants or children in ICU (n=16) with extracorporeal circulatory life support by ECMO or LVAD
• 8 newborns < 4 weeks
• 4 infants aged 5 weeks to 1 year
• 4 children aged 4, 5, 5 and 13 years
All cardiovascular information obscured from participants.</td><td>Accurately determine if pulse present or absent within 10s</td><td>78% of doctors and nurses correctly ascertained pulse presence or absence

<table><tr><th></th><th>n</th><th>Correct response (%)</th><th>Sensitivity</th><th>Specificity</th></tr><tr><td>All rescuers (all patients)</td><td>209</td><td>78 (71–84)</td><td>0.86 (0.79–0.91)</td><td>0.64 (0.53-0.74)</td></tr><tr><td>• Infants</td><td>191</td><td>78 (71–84)</td><td>0.85 (0.77–0.91)</td><td>0.67 (0.55–0.77)</td></tr><tr><td>• Children</td><td>18</td><td>72 (47–90)</td><td>1.00 (0.66–1.00)</td><td>0.44 (0.14–0.79)</td></tr><tr><td>All doctors</td><td>108</td><td>80 (71–86)</td><td>0.88 (0.78-0.94)</td><td>0.67 (0.51–0.79)</td></tr><tr><td>All nurses</td><td>101</td><td>75 (66–83)</td><td>0.84 (0.73–0.91)</td><td>0.62 (0.46–0.75)</td></tr><tr><td>Acute care doctors</td><td>56</td><td>84 (72–91)</td><td>0.94 (0.81–0.98)</td><td>0.67 (0.45–0.83)</td></tr><tr><td>Acute care nurses</td><td>61</td><td>77 (65–86)</td><td>0.85 (0.71–0.93)</td><td>0.62 (0.41–0.79)</td></tr><tr><td>Non-acute care doctors</td><td>52</td><td>75 (62–85)</td><td>0.81 (0.64–0.91)</td><td>0.67 (0.45–0.83)</td></tr><tr><td>Non-acute care nurses</td><td>40</td><td>73 (57–84)</td><td>0.82 (0.61–0.93)</td><td>0.61 (0.39–0.80)</td></tr><tr><td>Brachial palpation</td><td>125</td><td>78 (70–84)</td><td>0.86 (0.76–0.92)</td><td>0.67 (0.53–0.78)</td></tr><tr><td>Femoral palpation</td><td>70</td><td>77 (66–85)</td><td>0.85 (0.72–0.92)</td><td>0.56 (0.33–0.76)</td></tr></table>
86% of participants able to decide if pulse was present or absent within 10s. Although rescuers were instructed to decide within 10 s, those who took longer were not excluded.</td></tr>
<tr><td colspan="7">Paediatric anesthetised infants</td></tr>
<tr><td>Inagawa et al.
2003
Japan</td><td>Simulation: OR

Pulse check

PAEDIATRIC</td><td>Determine efficacy of methods to determine cardiac activity in infants</td><td>Operating room nurses (n=28)
All nurses used all methods in random order
Nurses blinded to pulse oximetry and ECG</td><td>13 anaesthetised infants aged 1-12 months
Having elective surgery
No Hx cardiac disease or arrhythmia</td><td>Finger palpation of brachial, carotid, femoral, apical pulses
Auscultation of apical impulse with naked ear
Palpation success rates within 10 and 30 seconds</td><td>Time intervals to find pulse:
• Apical auscultation: 2.4 ± 1.2
• Apical palpation: 3.5 ± 2.7
• Brachial: 4.0 ± 2.7
• Carotid: 9.9 ± 7.0
• Femoral: 9.1 ± 5.9
Significant differences in time to pulse confirmation between
• Apical auscultation vs carotid (p<0.0001)
• Apical auscultation vs femoral (p=0.0001)
• Apical palpation vs carotid (p=0.0004)
• Apical palpation vs femoral (p=0.0033)
• Brachial vs carotid (p=0.0018)
• Brachial vs femoral (p=0.0121)
Pulse identified within 10 seconds
• Apical auscultation 100%
• Apical palpation 75%
• Brachial palpation 73.1%
• Carotid palpation 50%
• Femoral palpation 42.9%
Pulse identified within 30 seconds
• Apical auscultation 100%
• Apical palpation 78.6%
• Brachial palpation 76.9%
• Carotid palpation 71.4%
• Femoral palpation 67.9%</td></tr>
</table>

Table 1: Studies of pulse assessment (n=10)

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<tr><th>Author, Year, Country</th><th>Type of study</th><th>Aim
Study Design</th><th>Clinician Population</th><th>'Patient' population</th><th>Outcomes measured</th><th>Main findings</th></tr>
<tr><td colspan="7">1.2 SIMULATION STUDIES - ADULT</td></tr>
<tr><td>Nakagawa et al.
2010
Japan</td><td>Simulation: manikin

Pulse check

ADULT</td><td>Demonstrate accuracy of carotid pulse checks by paramedics</td><td>16 paramedics</td><td>Simulation study: Laerdal Resusci Anne connected to a cuff. Researcher Researcher simulated presence of carotid pulse by squeezing the cuff at a rate of 60 times a minute.</td><td>Pulse check accuracy</td><td>Decision accuracy
sensitivity = 97%
specificity = 92%
accuracy = 94%
Mean time to decision 7.04s± 11.23s
pulse present:3.5s ± 3.13s
pulse absent:10.24s±14.53s
<table><tr><th></th><th colspan="2">Carotid pulse</th></tr><tr><td>Rescuer decision</td><td>Present (%)</td><td>Absent (%)</td></tr><tr><td>Pulse absent</td><td>2</td><td>77</td></tr><tr><td>Pulse present</td><td>74</td><td>7</td></tr></table></td></tr>
<tr><td>Albarran et al.
2006
United Kingdom

Note: study appears here and also in Table 2</td><td>Simulation: manikin

Pulse check

ADULT</td><td>Compare diagnostic accuracy of simultaneous assessment of breathing and pulse for up to 10s with a sequential assessment for up to 20s</td><td>Registered healthcare professionals (midwifery, diagnostic radiography, oncology, critical care, orthopaedics, elderly care, health visitors, theatres, community
nurses and lecturer-practitioners): who had completed a BLS course since qualification
Group 1 (n=89): check breathing and pulse using a simultaneous assessment, for up to 10 s on 10 simulated cases
Group 2 (n=29) 10 sequential assessments followed by 10 simultaneous assessments
the scenarios were presented in reverse order</td><td>Simulation scenarios (Laerdal SIM-Man™ Universal Patient Simulator):
1: breathing and pulse absent; four simulated cases.
2: breathing absent, pulse set at 30 beats/min; two simulated cases
3: breathing set at six breaths/min and pulse absent; two simulated cases
4: breathing set at 14, pulse preset at 80 beats/min; two simulated cases</td><td>Diagnosis of pulse and / or breathing within specified time periods</td><td><table><tr><th></th><th>Sensitivity (%)</th><th>Specificity (%)</th><th>Accuracy (%)</th></tr><tr><td>Carotid pulse check</td><td></td><td></td><td></td></tr><tr><td>Simultaneous assessment (up to 10s) (95% CI)</td><td>98.9 (97.8-99.4)</td><td>48.9 (44.5-53.4)</td><td>78.9</td></tr><tr><td>Sequential assessment (up to 20s) (95% CI)</td><td>98.9 (97.8-99.4)</td><td>61.9% (57.4-66.1)</td><td>84.1</td></tr></table>Correct diagnoses within agreed time
48.2% for sequential assessment
33.5% for simultaneous assessment
The mean time for completing assessment
7.3s (SD=2.5s) for simultaneous assessment
13.4s (SD=4.4s) for sequential assessment</td></tr>
<tr><td>Moule et al.
2000
United Kingdom</td><td>Simulation: manikin

Pulse check

ADULT</td><td>Measure competence of healthcare students in carotid pulse assessment</td><td>healthcare students (n=105)
10 physiotherapy
16 radiotherapy
23 degree and 38 diploma nursing students
12 midwifery students (also RNs)
6 nurses undertaking a postgraduate emergency nursing course</td><td>Pulse-check-mechanism on a computerised adult manikin
Manikin placed in standardised position</td><td>Diagnostic accuracy in a single pulse check attempt, within 10 seconds</td><td>38% (40/105) able to diagnose accurately <10s
83.8% (88/105) had an accurate diagnosis, not necessarily <10s
when the pulse was present, diagnostic accuracy <10 seconds was 55.3% (31/56)
when the pulse was absent, diagnostic accuracy <10 seconds was 18.3% (9/49)
30.5% (32/81) who had received training within the last year were accurate in their diagnosis
<table><tr><th>Student</th><th>n</th><th><10 sec and accurate (%)</th></tr><tr><td>physiotherapy</td><td>10</td><td>30</td></tr><tr><td>radiotherapy</td><td>16</td><td>50</td></tr><tr><td>emergency nursing course</td><td>6</td><td>66.7</td></tr><tr><td>midwifery</td><td>12</td><td>25</td></tr><tr><td>degree nursing</td><td>23</td><td>39.1</td></tr><tr><td>diploma nursing</td><td>38</td><td>34.2</td></tr></table></td></tr>
</table>

Table 2: Studies of breathing assessment (n=3)

<table>
<tr><th>Author, Year, Country</th><th>Type of study</th><th>Aim
Study Design</th><th>Clinician Population</th><th>'Patient' population</th><th>Outcomes measured</th><th>Main findings</th></tr>
<tr><td colspan="7">2.1 BREATHING: SIMULATION STUDIES - ADULT</td></tr>
<tr><td colspan="7">2.1.1 Simulation: Healthy human volunteer</td></tr>
<tr><td>Perkins et al. 2006 United Kingdom</td><td>Randomised controlled simulation trial: healthy human volunteer

Breathing

ADULT</td><td>Test whether specific tuition on recognising agonal breathing improves the diagnosis and treatment of cardiac arrest</td><td>Medical students: 1st year (n=64)
• Control: standard CPR tuition (n=32)
• Intervention: standard CPR tuition PLUS an additional slide and video clip in plenary lecture explaining agonal breathing was a sign of cardiac arrest requiring prompt initiation of CPR (n=32)</td><td>Simulated cardiac arrest victim (healthy human volunteer)
• Normal breathing = normal tidal respiration @ 12/min
• Absent breathing = breath holding
• Agonal breathing = slow rate (6/min) with deep sighing breaths
• simulations limited to 20s duration</td><td>Students' decision (recovery position or CPR)
Time to reach decision</td><td>Intervention group (compared to control)
• had greater diagnostic accuracy for determining correct treatment (90% vs 78%, p=0.03)
• was significantly more likely to recognise correctly that the unconscious victim was in cardiac arrest (agonal or absent breathing) and required CPR (sensitivity 90% vs 78%, p=0.02)
• were more likely to recognise that agonal breathing in an unconscious patient is a sign of cardiac arrest and requires of CPR (75% vs 43%, p=0.01)

<table>
<tr><th rowspan="2">Breathing pattern</th><th colspan="2">Intervention (%)</th><th colspan="2">Control (%)</th></tr>
<tr><th>Recovery position</th><th>CPR</th><th>Recovery position</th><th>CPR</th></tr>
<tr><td>Normal</td><td>97*</td><td>3</td><td>97*</td><td>3</td></tr>
<tr><td>Agonal</td><td>25</td><td>75*</td><td>56</td><td>44*</td></tr>
<tr><td>Absent</td><td>3</td><td>97*</td><td>6</td><td>94*</td></tr>
</table>
* correct response

<table>
<tr><th></th><th>Intervention (%)</th><th>Control (%)</th><th>p</th></tr>
<tr><td>Diagnostic accuracy</td><td>90</td><td>78</td><td>0.031</td></tr>
<tr><td>Sensitivity</td><td>86</td><td>69</td><td>0.02</td></tr>
<tr><td>Specificity</td><td>97</td><td>97</td><td>0.754</td></tr>
<tr><td>False negative</td><td>14</td><td>31</td><td>0.02</td></tr>
<tr><td>False positive</td><td>3</td><td>3</td><td>0.754</td></tr>
</table>
Positive likelihood ratio (CPR when the patient is in cardiac arrest compared to CPR when the patient not in cardiac arrest)
• intervention group = 29
• control group = 7
Negative likelihood ratio (no CPR when patient is in cardiac arrest compared to no CPR when the patient not in cardiac arrest)
• intervention group = 0.14
• control group = 0.22
In both the intervention and control groups, treatment decision was slower for agonal breathing (12.4s) than for normal (10.6s, p=0.01) or absent breathing (10.5s,p=0.04)
No significant difference in time taken to reach a treatment decision between intervention and control groups</td></tr>
</table>

Table 2: Studies of breathing assessment (n=3)

<table>
<tr><th>Author, Year, Country</th><th>Type of study</th><th>Aim
Study Design</th><th>Clinician Population</th><th>'Patient' population</th><th>Outcomes measured</th><th>Main findings</th></tr>
<tr><td colspan="7">2.1 BREATHING: SIMULATION STUDIES - ADULT</td></tr>
<tr><td colspan="7">2.1.2 Simulation: Video clips of healthy volunteer</td></tr>
<tr><td>Perkins et al. 2005
United Kingdom</td><td>Simulation: video clips

Breathing

ADULT</td><td>Test medical students' ability to discriminate between different simulated breathing patterns and
choose the correct treatment</td><td>Medical students: 2nd year (n=48)</td><td>Six video clips of simulated breathing shown in random order:
• Normal
• Abnormal: shallow, rapid, agonal (obstructed and unobstructed airways)
• Absent breathing</td><td>Discrimination between
• normal
• abnormal
• absent
breathing</td><td>Diagnosis
• 72% diagnostic accuracy (rescuer makes correct diagnosis):
• 60% sensitivity (rescuers ability to identify normal breathing when normal breathing present)
• 75% specificity (rescuers ability to recognise abnormal/absent breathing when present)
• 32% positive predictive value: (number of times the rescuer correctly reports normal breathing present when compared to the total number of times they report it was present)
• 90%; negative predictive value (number of times the rescuer correctly reports normal breathing absent compared to the total number of times they report it was absent)
Treatment
• 61% diagnostic accuracy (rescuer makes correct treatment decision)
• 42%; sensitivity (rescuers recognise rescue breathing required when it is required)
• 80% specificity (rescuers recognise rescue breathing not required when not required)
• 67% positive predictive value: (number of times the rescuer correctly reports
• rescue breathing required compared to the total number they reported it was required)
• 58% negative predictive value (number of times the rescuer correctly
• reports rescue breathing not required compared to the number of times they reported it was not required)
<table>
<tr><th rowspan="2">Breathing pattern</th><th colspan="2">Breathing present? (%)</th><th colspan="3">Treatment (%)</th></tr>
<tr><th>Yes - normal</th><th>Yes- abnormal</th><th>No</th><th>Rescue breathing</th><th>Recovery position</th></tr>
<tr><td>Normal</td><td>61</td><td>33</td><td>6</td><td>14</td><td>86</td></tr>
<tr><td>Rapid</td><td>42</td><td>58</td><td>0</td><td>2</td><td>98</td></tr>
<tr><td>Shallow</td><td>44</td><td>23</td><td>33</td><td>46</td><td>54</td></tr>
<tr><td>Apenoic</td><td>8</td><td>6</td><td>86</td><td>86</td><td>14</td></tr>
<tr><td>Agonal gasp (obstructed airway)</td><td>0</td><td>94</td><td>6</td><td>45</td><td>55</td></tr>
<tr><td>Agonal gasp (unobstructed airway)</td><td>31</td><td>69</td><td>0</td><td>8</td><td>92</td></tr>
</table></td></tr>
<tr><td colspan="7">2.1.3 Simulation: Manikin</td></tr>
<tr><td>Albarran et al. 2006
United Kingdom

Note: study appears here and also in Table 1</td><td>Simulation: manikin

Breathing

ADULT</td><td>Compare diagnostic accuracy of simultaneous assessment of breathing and pulse for up to 10s with a sequential assessment for up to 20s</td><td>Registered healthcare professionals (midwifery, diagnostic radiography, oncology, critical care, orthopaedics, elderly care, health visitors, theatres, community
nurses and lecturer-practitioners):
• Group 1 (n=89): check breathing and pulse using a simultaneous assessment, for up to 10 s on 10 simulated cases
• Group 2 (n=29) 10 sequential assessments followed by 10 simultaneous assessments
• the scenarios were presented in reverse order</td><td>Simulation scenarios (Laerdal SIM-Man™ Universal Patient Simulator):
• 1: breathing and pulse absent; four simulated cases.
• 2: breathing absent, pulse set at 30 beats/min; two simulated cases
• 3: breathing set at six breaths/min and pulse absent; two simulated cases
• 4: breathing set at 14, pulse preset at 80 beats/min; two simulated cases</td><td>Diagnosis of pulse and / or breathing within specified time periods</td><td>
<table>
<tr><th></th><th>Sensitivity (%)</th><th>Specificity (%)</th><th>Accuracy (%)</th></tr>
<tr><td>Breathing check</td><td></td><td></td><td></td></tr>
<tr><td>Simultaneous assessment (up to 10s) (95% CI)</td><td>99.6 (98.8-99.9)</td><td>50.4 (45.9-54.9)</td><td>79.9</td></tr>
<tr><td>Sequential assessment (up to 20s) (95% CI)</td><td>99.6 (98.8-99.9)</td><td>70.6 (66.3-74.5)</td><td>88.0</td></tr>
</table>
Correct diagnoses within agreed time
• 48.2% for sequential assessment
• 33.5% for simultaneous assessment
The mean time for completing assessment
• 7.3s (SD=2.5s) for simultaneous assessment
• 13.4s (SD=4.4s) for sequential assessment</td></tr>
</table>

Table 3: Studies of cardiac arrest rhythm assessment (n=8)						
Author, Year, Country	**Type of study**	**Aim Study Design**	**Clinician Population**	**'Patient' population**	**Outcomes measured**	**Main findings**
3.1 CARDIAC ARREST RHYTHM: SIMULATION STUDIES - ADULT						
3.1.1 Simulation: Manikin						
Attin et al. 2024 United States of America	Randomised controlled simulation study: manikin Cardiac arrest rhythm recognition ADULT	Investigate effect of animation on nursing students' response time to cardiac arrest	Senior-year, bachelor degree nursing students (n=31) • control (n=14) • experimental (n=17): additional preparation using three animation scenarios demonstrating a nurse finding a patient unresponsive in a hospital bed. Two scenarios showed correct response to an unresponsive patient, one scenario showed the nurse leaving the room to focus on a different task instead of calling for help	Simulation scenario: ED presentation from extended care facility without family, care evolves from ED to ICU with the end result of cardiac arrest. Deterioration to cardiac arrest presented as decreasing BP followed by VF shown by the arterial line reading and ECG tracing on bedside monitor	Time to correct response to cardiac arrest: i) calling a code blue, ii) flattening head of bed, iii) starting chest compressions without pulse check	Median response time (p<0.0001) • control group = 42.75 s (range 16 to 101s) • experimental group = 7.6 s (range 1.7 to 13.8s)
Hansen et al. 2014 Denmark	Simulation: manikin Cardiac arrest rhythm recognition ADULT	Tested whether time for recognition of a cardiac rhythm was a time-limiting factor during ALS	Doctors regional teaching hospital (n=35) • 12 interns, 5 first-year residents, 9 senior residents, 9 attending physicians • 11 internal medicine, 5 surgical disciplines, 3 family medicine, 2 paediatrics, 1 biochemistry, 1 anesthesiology	Laerdal Sim-Man simulations: • ventricular fibrillation • sinus rhythm • atrial fibrillation • ventricular tachycardia • torsade des pointes tachycardia • complete heart block (third-degree heart block) • asystole	Rhythm interpretation Need for defibrillation Time to decision	Mean time from presentation until decision-making was 4.0 s (CI: 3.5–4.5) for all rhythms, and shorter for shockable rhythms (p<0.05) • 3.4 s (CI: 2.8–3.9) for shockable rhythms • 4.4 s (CI: 3.6–5.3) for nonshockable rhythms Decision accuracy • 91.4% of all cardiac rhythms were correctly identified as either shockable or nonshockable • 95.2% of shockable rhythms correctly identified as shockable • 88.6% nonshockable rhythms correctly as nonshockable Participants with CPR experience (compared to no CPR experience) were • significantly quicker in deciding whether to defibrillate or not [mean time 3.5 s (CI: 2.8–4.2) vs. 4.9 s (CI: 4.0–5.7), p<0.0001] • more accurate in determining the exact cardiac rhythm/arrhythmia (81 vs. 64%, p<0.01) No significant correlations between 'years from graduation' and the mean decision time for shockable (R^2=0.01), nonshockable (R^2=0.06) and all rhythms combined (R^2=0.03).
Vincelette et al. 2018 Canada	Simulation: manikin Cardiac arrest rhythm recognition ADULT	Determine if ICU nurses' have skills to initiate the first steps of CPR following onset of VF	ICU nurses (n=22)	Laerdal Sim-Man simulation: patient reports dyspnoea at t=0.5 minutes; nurse expected to evaluate airway and breathing. At t=1.5 minutes, patient gasps and VF displayed on cardiac monitor. Simulation scenario ended when nurses began chest compressions and called for medical assistance	Recognition of VF Time to call for help, commence CPR	91% correctly identified VF and reported that defibrillation had to be performed immediately Average time (95% CI) • call for help = 12s (9.3- 14.8) • initiate chest compressions (28.8 s (23.8-33.7) Code blue call delay • negative correlation with age (r=0.44, p<0.05) and experience (r=0.49, p<0.05) • positive correlation with level of education (r=0.63, p<0.05): nurses with higher education spent more time checking pulse 86% checked for a pulse or verified level of consciousness before initiating CPR The most frequently used methods to assess level of consciousness or the presence of a pulse were • 27% painful stimulation • 27% carotid pulse check • 18% femoral pulse check
3.1.2 Simulation: Electrocardiography						

Table 3: Studies of cardiac arrest rhythm assessment (n=8)						
Author, Year, Country	**Type of study**	**Aim Study Design**	**Clinician Population**	**'Patient' population**	**Outcomes measured**	**Main findings**
Jacek et al. 2013 Poland	Simulation: ECGs Cardiac arrest rhythm recognition PATIENT AGE NOT REPORTED, PRESUMED ADULT as participants were instructed that the duration of the QRS complex in adults is at least 0.06 sec..."	Assess emergency medical care students' accuracy in recognising VF fibrillation when pacing spikes are present	Emergency medical care students (n=39)	Participants asked to interpret ECGs of • VF with pacing artifacts • VF • AF with ventricular pacing	ECG identification of VF	2.5% (n=1) recognised VF with pacing artifacts 95% recognised isolated VF

Table 3: Studies of cardiac arrest rhythm assessment (n=8)						
Author, Year, Country	**Type of study**	**Aim Study Design**	**Clinician Population**	**'Patient' population**	**Outcomes measured**	**Main findings**
Derkenne et al. 2022 France	Simulation: ECGs Cardiac arrest rhythm recognition PATIENT AGE NOT REPORTED	Estimate sensitivity, specificity and speed of shock/no-shock decision-making by prehospital emergency physicians	Prehospital emergency physicians (n=190)	Computer simulation using ECGs from OHCA patients • VT • coarse VF • fine VF • asystole • PEA	Shock / no shock decision Time to shock / no shock decision	Median (IQR) • sensitivity for shock delivery for shockable rhythm = 0.91 (0.81–1.00) • specificity for no-shock delivery for non-shockable rhythms = 0.91 (0.80–0.96) Positive predictive value (probability that a shock delivered to a shockable rhythm) = 0.99 (0.98–1.00) Negative predictive value (probability that a no-shock decision was made on a non-shockable rhythm) = 0.48 (0.33–0.66). Sensitivities for shock delivery • VT= 1.0 (1.0–1.0) • coarse VF = 1.0 (1.0–1.0) • fine VF = 0.6 (0.2–1) Specificity for not shocking • pulseless electrical activity (PEA) = 0.83 (0.72–0.86) • asystole = 0.93 (0.86–1) Median decision speed (seconds) • VT = 2.0 (1.6–2.7) • coarse VF = 2.1 (1.7–2.9) • asystole = 2.4 (1.8–3.5) • PEA = 2.8 (2.0–4.2) • fine VF = 2.8 (2.1–4.3)
3.2 CARDIAC ARREST RHYTHM: SIMULATION STUDIES – PAEDIATRIC						
3.2.1 Simulation: Manikin						
Hunt et al. 2015 United states of America	Simulation: manikin Cardiac arrest rhythm recognition PAEDIATRIC	Measure whether the intuitive use of Action-Linked Phrases was associated with shorter times to initiation of chest compressions in simulated cardiac arrest scenarios	Medical residents (n=68)	Laerdal SimMan simulation: patient transferred from ED to ward, having PVCs, develops pVT 1 minute after the resident entered the simulated hospital room. Retrospective review of video recordings from simulation.	Assessed pulse Started chest compressions Time between pVT onset to starting compressions Words uttered in recognition of pulselessness, and phrases and/or actions that followed	Once the manikin simulator developed pVT • 62% stated aloud "there's no pulse" during initial assessment • 13% assessed the pulse but did not make any verbal comment • 25% did not assess the pulse & focused on cardiac rhythm Of the residents who stated, "there's no pulse" (n=42), the following verbalisations were noted • 38% "start compressions" • 45% "defibrillate" • 5% "intubate" • 5% "check blood pressure" • 2% "place IV" • 2% "call the code team" • 2% "administer epinephrine"

Table 3: Studies of cardiac arrest rhythm assessment (n=8)						
Author, Year, Country	**Type of study**	**Aim Study Design**	**Clinician Population**	**'Patient' population**	**Outcomes measured**	**Main findings**
Tofil et al. 2014 United States of America	Simulation: manikin Cardiac arrest rhythm recognition PAEDIATRIC	Evaluate time to recognise and treat VF in a paediatric prone patient	Anaesthesia residents (n=24)	Laerdal Sim-Man simulation: 14-year-old patient undergoing posterior spinal fusion in prone position: VF occurred three minutes into the case	Time to recognition of VF & request defibrillation	Average time to • recognise VF = 76s • start chest compression = 77s • request defibrillation = 108s
Hunt et al. 2009 United States of America	Simulation: manikin Cardiac arrest rhythm recognition PAEDIATRIC	Determine time between pVT onset and successful delivery of first shock	Paediatric residents (n=70) from a tertiary care, academic hospital	Laerdal SimMan® high fidelity mannequin simulator Simulation: 12-year old child admitted 1h previously from the ED having frequent PVCs	Primary: Time between pVT onset and first shock Secondary: markers of quality and compliance with BLS and ALS guidelines	Apnoea • 93% residents recognized apnoea and assisted or ordered the nurse to assist ventilation: median (IQR) time 24.5s (14.5–114.5) • median (IQR) no blow fraction = 38% (22%–62%) Chest compressions • 66% residents failed to start compressions within 1min of pulselessness • 33% never started compressions • median (IQR) time elapsed from onset of pVT and initiation of compressions: PGY1: 540s (6–900s), PGY2: 210s (32–589s), PGY3: 157s (27–900s) (p = 0.30). • median (IQR) no flow fraction = 74% (49–100%) Defibrillation • 75% of residents noticed change in cardiac rhythm within 9s of conversion from sinus rhythm to pVT: 95% recognised change in less than 40s • median time to asking for the defibrillator = 33s (IQR 15–55s) • 54% residents defibrillated the mannequin in ≤3min pVT onset • median time between pVT onset and defibrillator discharge = 170 s (123–353)

ECG: electrocardiogram
ECMO = veno-arterial extracorporeal membrane oxygenation;
ED = emergency department
LVAD = left ventricular assistance device
OHCA = out-of-hospital cardiac arrest
PEA = pulsness electrical activity
POCUS = point-of-care ultrasound
PVC = premature ventricular contractions
pVT = pulseless ventricular tachycardia
SD = standard deviation
SBP = systolic blood pressure