E-CPR in Germany

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conflict of interest: none
1. ECLS in Germany

- continuing rapid expansion in all fields of intensive care medicine and emergency medicine
- number of hospitals using extracorporeal support >> 100

- **VV-ECMO**: widespread use, lack of knowledge about
  - best indication
  - complications

- **ECCO$_2$R**: growing interest for use in primary and secondary hypercapnia, pilot trial in NIV failure closed (30 patients)

- **VA-ECMO**: fastest expansion, use in post-cardiotomy failure, cardiogenic shock, back-up in cath-lab for difficult procedures (TAVI, main stem), **E-CPR**
ECMO Centers in Germany

2010:
- Essen
- Göttingen
- Leipzig
- Mainz
- Frankfurt
- Aachen
- Halle
- Düsseldorf
- Münster
- Dortmund
- Bochum
- Hamburg
- Kiel
- Rostock
- Dresden
- Berlin
- Hannover
- Osnabrück
- Gießen
- Marburg
- Mannheim
- Würzburg
- Erlangen
- Ludwigsburg
- Regensburg
- Freiburg
- München

2015:
- Kiel
- Lübeck
- Rostock
- Greifswald
- Hamburg
- Hannover
- Magdeburg
- Oldenburg
- Halle
- Leipzig
- Dresden
- Berlin
- Münster
- Jena
- Marburg
- Gießen
- Marburg
- Heidelberg
- Tübingen
- Regensburg
- Freiburg
- Ulm
- München
2. In-Hospital Resuscitation

- n = 64,339, 2000 – 2008,
- „Get with the Guidelines-Resuscitation Registry“

- < 25% of patients who died, were resuscitated for > 30 min
- 31,198 (48.5%) ROSC, 9,912 (15.4%) discharged, of those 80.6% with good neurological outcome

Goldberger et al, Lancet 2012;380:1473-81
E-CPR for IHCA - Overview

**Table 1. Studies including inhospital cardiac arrest patients**

<table>
<thead>
<tr>
<th>First author</th>
<th>Year</th>
<th>n</th>
<th>Time to ECMO</th>
<th>Survival</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mair [26]</td>
<td>1996</td>
<td>5</td>
<td>NA</td>
<td>2 (40%)</td>
</tr>
<tr>
<td>Willms [27]</td>
<td>1997</td>
<td>68</td>
<td>29 ± 17</td>
<td>17 (25%)</td>
</tr>
<tr>
<td>Chen [20]</td>
<td>2003</td>
<td>57</td>
<td>47.6 ± 13.4</td>
<td>18 (31.6%)</td>
</tr>
<tr>
<td>Sung [28]</td>
<td>2006</td>
<td>22</td>
<td>48.5 ± 29</td>
<td>9 (41%)</td>
</tr>
<tr>
<td>Lin [29]</td>
<td>2010</td>
<td>55</td>
<td>48.7 ± 26.9</td>
<td>13 (23%)</td>
</tr>
<tr>
<td>Shin [30]</td>
<td>2011</td>
<td>85</td>
<td>42 ± 25.7</td>
<td>26 (31%)</td>
</tr>
<tr>
<td>Liu [31]</td>
<td>2011</td>
<td>11</td>
<td>NA</td>
<td>4 (37%)</td>
</tr>
<tr>
<td>Haneya [23]</td>
<td>2012</td>
<td>59</td>
<td>25 (20–50)</td>
<td>25 (42.3%)</td>
</tr>
<tr>
<td>Kagawa [32]</td>
<td>2012</td>
<td>44</td>
<td>NA</td>
<td>25 (57%)</td>
</tr>
<tr>
<td>Loforte [33]</td>
<td>2012</td>
<td>16</td>
<td>31 ± 14</td>
<td>2 (12.5%)</td>
</tr>
<tr>
<td>Sakamoto [34]</td>
<td>2012</td>
<td>64</td>
<td>25 ± 22</td>
<td>18 (28%)</td>
</tr>
<tr>
<td>Fagnoul [35]</td>
<td>2013</td>
<td>10</td>
<td>55 (42–60)</td>
<td>3 (30%)</td>
</tr>
<tr>
<td>Cheng [12]</td>
<td>2013</td>
<td>68</td>
<td>NA</td>
<td>16 (24%)</td>
</tr>
<tr>
<td>Attanò [24]</td>
<td>2013</td>
<td>22</td>
<td>50 (40–60)</td>
<td>5 (23%)</td>
</tr>
<tr>
<td>Guenther [25]</td>
<td>2013</td>
<td>14</td>
<td>NA</td>
<td>4 (29%)</td>
</tr>
</tbody>
</table>

25 – 55 min  20 – 40 %

Problems of peripheral VA-ECMO

1. Cannula associated
   - damage to vessel
   - peripheral ischemia
   - thrombosis, pulmonary embolism
   - poor access for intervention

2. „Harlekin Syndrome“

3. loading of left ventricle

4. bleeding

5. technical failure
   - oxygenator thrombosis
   - pump failure
Peripheral VA-ECMO: Less is more?

1. 15 Fr arterial cannula:
   - less ischemia, less bleeding

2. Blood flow ≤ 3.5 L/min:
   - reduced afterload
   - allow LV to unload (RR amplitude > 10 mm Hg)
   - avoid need of venting

3. Flow is more important than pressure:
   - what matters, is oxygen transport
   - ⇒ vasopressors↓, inotropes ↑
   - MAP 50 – 60 mm Hg

4. Monitoring:
   - NIRS for brain and leg
   - venous saturation (pre oxy) > 65 %
   - lactate ↓
   - urine output o.k.
Monitoring: Control of leg perfusion

ECLS jugular vein > femoral artery

Sensor NIRS

**Monitoring:**
- doppler US
- oxymetrie on toe
- capillary pulse
- NIRS
- documentation
Difficult Access for Intervention

- with VA ECMO, access for PCI or electrophysiologic treatment can be difficult or prolonged
- Y-connector allows access through arterial cannula

Ücer E et al, Europace 2014;16:299-302
VA ECMO „less is more“: patients

<table>
<thead>
<tr>
<th>n = 107</th>
</tr>
</thead>
<tbody>
<tr>
<td>age 57.5 +/- 14 years</td>
</tr>
<tr>
<td>77% male</td>
</tr>
</tbody>
</table>

**indications:**
- unsuccessful conventional resuscitation (n = 50)
- cardiogenic shock post resuscitation (n = 23)
- cardiogenic shock without previous resuscitation (n = 15)
- cardiogenic shock/resuscitation during intervent. cardiology (n = 19)

- distal perfusion cannula: n = 20
- difficult cannulation: n = 27
- bleeding cannulation site: n = 12

<table>
<thead>
<tr>
<th>time on ECMO 4.0 +/- 4.4 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>RBCs per day on ECMO: 0.6 +/- 1.0</td>
</tr>
</tbody>
</table>
VA ECMO „less is more“: hemodynamics

** p< 0.001
VA ECMO „less is more“: results

* Laktate

** p< 0.001

* ven. Saturation

** p< 0.001
VA–ECMO „less is more“: Outcomes UKR (07/2009 – 11/2014)

107 patients

34 (32 %) † on ECMO

time on ECMO: 2.5± 3.8 days

73 (68 %) successful weaning

49 (46 %) survival

time on ECMO: 4.1± 3.4 days

time on ECMO: 5.8± 6.0 days

† on ECMO

central cannulation n = 4
bridge to LVAD n = 8

15 Fr arterial cannula

24 (22 %) † post weaning
3. E-CPR in OHCA?

- National Taiwan University Hospital Taipei
- 2007 – 2012; n = 230, 199 IHCA, 31 OHCA (selected patients)

**results:**

<table>
<thead>
<tr>
<th></th>
<th>IHCA</th>
<th>OHCA</th>
</tr>
</thead>
<tbody>
<tr>
<td>time to ECLS (min)</td>
<td>$44.4 \pm 24.7$</td>
<td>$67.5 \pm 30.6$</td>
</tr>
<tr>
<td>survival to discharge</td>
<td>31.2 %</td>
<td>38.7 %</td>
</tr>
<tr>
<td>survival with good neurology</td>
<td>25.1 %</td>
<td>25.5 %</td>
</tr>
</tbody>
</table>

“Our results suggest that further investigation of the use of ECMO in OHCA is warranted”

Wang CH, Resuscitation 2014;85:1219-24
Mechanical versus manual chest compression for out-of-hospital cardiac arrest (PARAMEDIC): a pragmatic, cluster randomised controlled trial

Gavin D Perkins, Ranjit Lall, Tom Quinn, Charles D Deakin, Matthew W Cooke, Jessica Horton, Sarah E Lamb, Anne-Marie Slowther, Malcolm Woollard, Andy Carson, Mike Smyth, Richard Whitfield, Amanda Williams, Helen Pocock, John J M Black, John Wright, Kyee Han, Simon Gates, PARAMEDIC trial collaborators*

- 2010 – 6/2013; 91 ambulance stations in UK
- n= 4471 patients randomized 2:1 manual : LUCAS-2

- primary endpoint: 30 day survival
- patient characteristics:
  - age 71 ys
  - 80 % at home
  - 60 % witnessed
  - 43 % bystander resuscitation
  - time call to arrival 6.5 min
  - 50 % asystole

Lancet 2014; online Nov.16
### PARAMEDIC-Trial: Results

<table>
<thead>
<tr>
<th></th>
<th>LUCAS-2 (n=1652)</th>
<th>Control (n=2819)</th>
<th>Unadjusted OR (95% CI)</th>
<th>Adjusted OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Survival to 30 days</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Survived to 30 days</td>
<td>104 (6%)</td>
<td>193 (7%)</td>
<td>0.91 (0.71-1.17)</td>
<td>0.86 (0.64-1.15)</td>
</tr>
<tr>
<td>Not known</td>
<td>0</td>
<td>1 (&lt;1%)</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td><strong>ROSC</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ROSC</td>
<td>522 (32%)</td>
<td>885 (31%)</td>
<td>1.02 (0.89-1.16)</td>
<td>0.99 (0.86-1.14)</td>
</tr>
<tr>
<td>Not known</td>
<td>58 (4%)</td>
<td>82 (3%)</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td><strong>Survived event</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Survived event</td>
<td>377 (23%)</td>
<td>658 (23%)</td>
<td>0.97 (0.83-1.14)</td>
<td>0.97 (0.82-1.14)</td>
</tr>
<tr>
<td>Not known</td>
<td>82 (5%)</td>
<td>129 (5%)</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td><strong>Survival to 3 months</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Survived to 3 months</td>
<td>96 (6%)</td>
<td>182 (6%)</td>
<td>0.89 (0.69-1.15)</td>
<td>0.83 (0.61-1.12)</td>
</tr>
<tr>
<td>Not known</td>
<td>0</td>
<td>1 (&lt;1%)</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td><strong>Survival to 12 months</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Survived to 12 months</td>
<td>89 (5%)</td>
<td>175 (6%)</td>
<td>0.86 (0.60-1.12)</td>
<td>0.83 (0.62-1.11)</td>
</tr>
<tr>
<td>Survival with favourable neurological outcome (CPC 1–2)</td>
<td>77 (5%)</td>
<td>168 (6%)</td>
<td>0.77 (0.59-1.02)</td>
<td>0.72 (0.52-0.99)</td>
</tr>
</tbody>
</table>

*Lancet 2014; online Nov.16*
E-CPR for OHCA - Overview

Table 2. Studies including out-of-hospital cardiac arrest patients

<table>
<thead>
<tr>
<th>First author</th>
<th>Year</th>
<th>n</th>
<th>Time to ECMO (min)</th>
<th>Survival</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nagao [38]</td>
<td>2000</td>
<td>36</td>
<td>67 ± 43</td>
<td>9 (25%)</td>
</tr>
<tr>
<td>Haneya [23]</td>
<td>2012</td>
<td>26</td>
<td>70 (55-110)</td>
<td>4 (15%)</td>
</tr>
<tr>
<td>Kagawa [32**]</td>
<td>2012</td>
<td>42</td>
<td>59 (45-65)*</td>
<td>7 (24%)</td>
</tr>
<tr>
<td>Nagao [39]</td>
<td>2010</td>
<td>171</td>
<td>66 ± 3</td>
<td>21 (12%)</td>
</tr>
<tr>
<td>Le Guen [40]</td>
<td>2011</td>
<td>51</td>
<td>120 (102-149)</td>
<td>2 (4%)</td>
</tr>
<tr>
<td>Avalli [41]</td>
<td>2012</td>
<td>18</td>
<td>77 (69-101)</td>
<td>1 (5.5%)</td>
</tr>
<tr>
<td>Fagnoul [35*]</td>
<td>2013</td>
<td>14</td>
<td>66 (56-80)</td>
<td>3 (21%)</td>
</tr>
<tr>
<td>Maekawa [22*]</td>
<td>2013</td>
<td>53</td>
<td>49 (41-59)</td>
<td>17 (32.1%)</td>
</tr>
<tr>
<td>Leick [42*]</td>
<td>2013</td>
<td>28</td>
<td>53 (40-61) non-survivors, 44 (31-45) survivors</td>
<td>11 (39%)</td>
</tr>
</tbody>
</table>

44 – 120 min  
4 – 39 %

A 5-year experience with cardiopulmonary resuscitation using extracorporeal life support in non-postcardiotomy patients with cardiac arrest

Assad Haneya\textsuperscript{a,*}, Alois Philipp\textsuperscript{a}, Claudius Diez\textsuperscript{a}, Simon Schopka\textsuperscript{a}, Thomas Bein\textsuperscript{b}, Markus Zimmermann\textsuperscript{b}, Matthias Lubnow\textsuperscript{c}, Andreas Luchner\textsuperscript{c}, Ayman Agha\textsuperscript{d}, Michael Hilker\textsuperscript{a}, Stephan Hirt\textsuperscript{a}, Christof Schmid\textsuperscript{a}, Thomas Müller\textsuperscript{c}

<table>
<thead>
<tr>
<th></th>
<th>all (n = 79)</th>
<th>In-hospital (n = 55)</th>
<th>Out-of-hospital (n = 24)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>age, years</td>
<td>56 ± 15</td>
<td>64 ± 14</td>
<td>50 ± 15</td>
<td>0.0001</td>
</tr>
<tr>
<td>male, n (%)</td>
<td>57 (72)</td>
<td>40 (73)</td>
<td>17 (71)</td>
<td>0.99</td>
</tr>
<tr>
<td>CPR duration, min</td>
<td>52 ± 36</td>
<td>40 ± 29</td>
<td>82 ± 34</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>pH [venous, pre MO]</td>
<td>7.01 ± 0.22</td>
<td>7.08 ± 0.18</td>
<td>6.86 ± 0.24</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>lactate, mg/dL</td>
<td>99 ± 62</td>
<td>65 ± 51</td>
<td>132 ± 82</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>$PvCO_2$, mmHg</td>
<td>71 ± 21</td>
<td>59 ± 17</td>
<td>86 ± 23</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>intervention possible, n (%)</td>
<td>52 (66)</td>
<td>36 (66)</td>
<td>16 (67)</td>
<td>0.99</td>
</tr>
<tr>
<td>complications, n (%)</td>
<td>23 (29)</td>
<td>15 (27)</td>
<td>8 (33)</td>
<td>0.60</td>
</tr>
<tr>
<td>outcome, n (%) survival to discharge</td>
<td>27 (34)</td>
<td>23 (42)</td>
<td>4 (17)</td>
<td>0.039</td>
</tr>
</tbody>
</table>
cardiac arrest with CPR > 10 min and

- presumably cardiac etiology (VF/VT)
- witnessed cardiac arrest
- bystander-CPR or beginning of ACLS
- age between 18 and 65 yrs
Out of Hospital E-CPR

• 61 yrs, observed collaps, immediate bystander resuscitation

• **time response:**
  - alarm 11:58
  - arrival ambulance + emergency team 12:08 (10 min)
  - VF, continued CPR
  - alarm mobile ECMO-Team 12:20 (12 min)
  - arrival ECMO Team 12:32 (12 min)
  - ECMO-start 12:47 (15 min)

• **diagnosis:** anterior myocardial infarction  
  total: 49 min
Out of Hospital E-CPR

- 25 yrs, thoracic pain on inspiration for 5 days, progressive exertional dyspnoe
- risk factors: oral contraception, Crohn´s Disease + steroids
- 25/09/2014: observed collaps, immediate professional resuscitation
- time to ECMO 59 min

- **Diagnosis**: pulmonary embolism and right heart failure
4. Peri- and Post-Resuscitation Care: Options for Improvement?

- **bystander CPR:**
  - telephone guidance, compressions only
- decrease time to ECMO: move ECMO to patient?
- **therapeutic hypothermia:** early cold infusion
- early diagnostic and therapeutic intervention
- avoid hyperoxemia
- avoid hypocalpnia/alkalosis: „two circulations“
  - → BGA right radial artery and post oxygenator
- aspiration pneumonia: prophylactic antibiotics
- **post-resuscitation SIRS:** hydrocortisone?
- short-acting analgosedation
- adapted, individualized anticoagulation

Müller et al, Resuscitation 2013;84:1463
Summary: one step further

1. E-CPR can save lives
   - if done well
   - in the right patients
2. Important:
   - reduce time to ECMO
   - reduce complications: “less is more”?
   - improve post-resuscitation care
   - find and treat cause of collapse
3. Cardiac Arrest Centres networking with other hospitals may improve results
3. Loading of the Left Ventricle

- high afterload may hinder the LV to empty/ aortic valve to open
  - high wall pressure
  - no recovery
  - pulmonary edema
  - clotting in LV and pulmonary circulation

- management:
  - preserve LV output: inotropes $\uparrow$, vasopressors $\downarrow$
  - reduce ECMO flow, if possible (3.5 L/min)
  - adapt ventilation
  - increase anticoagulation
  - venting (ultima ratio)
Decompression of the Left Ventricle

Table 2. Techniques to Vent the Left Ventricle

<table>
<thead>
<tr>
<th>Surgical</th>
<th>Percutaneous</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sternotomy (pulmonary vein, left atrium, left ventricle, pulmonary artery)</td>
<td>Pulmonary artery vent</td>
</tr>
<tr>
<td>Minimal invasive Subxiphoidal Anterolateral thoracotomy (left ventricle, left atrium)</td>
<td>Transseptal vent</td>
</tr>
<tr>
<td></td>
<td>Transaortic vent</td>
</tr>
<tr>
<td></td>
<td>Impella LP pump</td>
</tr>
<tr>
<td></td>
<td>TandemHeart + oxygenator</td>
</tr>
</tbody>
</table>

Rupprecht L et al, ASAIO Journal 2013;59:547-53