“The Artificial Lung”: new techniques of extracorporeal respiratory support in Acute Respiratory Failure

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Introduction:

- The treatment of acute lung failure includes artificial ventilation with a lung protective concept.
- Life-threatening respiratory failure with persistent hypoxia/hypercapnia → extracorporeal lung assist.

OPTIONS:

- Veno-venous pump-driven extracorporeal membrane oxygenation (ECMO).
- Arterio-venous pump-less interventional lung assist (iLA-NovaLung, “Artificial Lung”).
TABLE III. Comparative technical difficulty of haemodialysis, extracorporeal removal of carbon dioxide and extracorporeal oxygenation

<table>
<thead>
<tr>
<th></th>
<th>Renal haemodialysis</th>
<th>Extracorporeal removal of carbon dioxide</th>
<th>Extracorporeal oxygenation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extracorporeal blood flow (ml min⁻¹)</td>
<td>200–300</td>
<td>500–1000</td>
<td>2000–4000</td>
</tr>
<tr>
<td>Blood pumping</td>
<td>optional</td>
<td>optional</td>
<td>required</td>
</tr>
<tr>
<td>Haemodynamic changes</td>
<td>small</td>
<td>small</td>
<td>major</td>
</tr>
<tr>
<td></td>
<td>A–V shunt or A–V fistula</td>
<td>A–V shunt or A–V fistula</td>
<td>V–A or V–V</td>
</tr>
<tr>
<td>Vascular access</td>
<td>simple</td>
<td>simple</td>
<td>complex</td>
</tr>
<tr>
<td>Surgical complexity</td>
<td>moderate</td>
<td>simple</td>
<td>advanced</td>
</tr>
<tr>
<td>Complexity of equipment</td>
<td>small</td>
<td>small</td>
<td>large</td>
</tr>
<tr>
<td>Requirement for heparin</td>
<td></td>
<td>small</td>
<td></td>
</tr>
</tbody>
</table>
iLA Membrane Ventilator:

Membrane ventilator

NovaPort® vascular access

NovaFlow® blood flow monitor
iLA Membrane Ventilator:

- Diffusion across plasma-tight membrane¹
- Gas exchange surface: 1,3m²¹
- Consists of heparin-coated polymethyl pentene (PMP) hollow-fiber mats¹
- High CO2 diffusion gradient from blood to gas¹
- PTT ≥ 55s²
- Low-dose acetylsalicylic acid (ASA 1.5 mg/kg body weight/d)²

Protective and ultra-protective ventilation: using pumpless interventional lung assist (iLA)¹ O. MOERER, M. QUINTE-MINERVA ANESTESIOLOGICA May 2011, Vol. 77 - No. 5
Addition of Acetylsalicylic Acid to Heparin for Anticoagulation Management During Pumpless Extracorporeal Lung Assist²; THOMAS BEIN, MARKUS ZIMMERMANN-ASAIO Journal 2011
iLA Membrane Ventilator:

- Efficient CO2 elimination + modest improvement in arterial oxygenation¹
- Typical blood flow 1,0 – 1,5 l/min ¹
- Max. gas flow 10-12 l/min ¹
- Priming volume 240 ml isotonic saline solution (total system)²

Novalung Presentation² 2011
Effects on CO2 elimination and pH:

- Removed ~ 50% of the calculated total CO2 production

- The capacity of iLA to remove CO2 ↑:
  → ↑ PaCO2
  → ↑ sweep gas flow
  → ↑ blood flow

- Hb → no correlation

- Extracorporeal removal of CO2 → improvement of respiratory acidosis
Effect on oxygen transport:

- Oxygen transfer capacity ~ 42 ml/min

- O2 transfer capacity of iLA $\rightarrow$ SaO2,
  $\rightarrow$ blood flow
  $\rightarrow$ haemoglobin
  $\rightarrow$ membrane surface (MaxiLung)

- Sweep gas flow $\rightarrow$ slight correlation

Clinical studies:

- Over 500 scientific relevant articles on Novalung therapy

- Pumpless extracorporeal removal of carbon dioxide combined with ventilation using low tidal volume and high positive end-expiratory pressure in a patient with severe acute respiratory distress syndrome
  
  Bein T, Zimmermann M, Hergeth K, Ramming M, Rupprecht L, Schlitt HJ, Slutsky AS.
  Department of Anaesthesia & Intensive Care, University Hospital of Regensburg, Regensburg, Germany.
  Anesthesia, 2009, 64: 195-8

- Extracorporeal pumpless interventional lung assist in clinical practice: determinants of efficacy
  
  Müller T, Lubnow M, Philipp A, Bein T, Jeron A, Luchner A, Rupprecht L, Reng M,
  Langgartner J, Wrede CE, Zimmermann M, Birnbaum D, Schmid C, Riegger GA, Pfeifer M.
  Department of Internal Medicine II, University Hospital of Regensburg, Franz-Josef-Strauss, Regensburg, Germany
  The European Respiratory Journal, 2009, 33: 558

- Pumpless extracorporeal interventional lung assist in patients with acute respiratory distress syndrome: a prospective pilot study
  
  Zimmermann M, Bein T, Arlt M, Philipp A, Rupprecht L, Mueller T, Lubnow M, Graf BM, Schlitt HJ.
  Department of Anesthesiology, University of Regensburg Medical Center, Regensburg, Germany.
  Critical Care, 2009, 13: R10
The concept of evaluation, insertion and clinical monitoring of the pumpless interventional lung assist (iLA) in patients with acute respiratory distress syndrome (ARDS):

<table>
<thead>
<tr>
<th>Evaluation and preparation</th>
<th>Insertion</th>
<th>Monitoring</th>
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</table>
| **Echocardiography:** exclusion of significant cardiac dysfunction | **Preparation**  
of iLA system and introducer kit | **System:**  
- continuous calculation of blood flow through the device by transit time Doppler technology |
| **Ultrasound:** assessment of femoral artery and vein diameter | **Vascular cannula:**  
**Artery:** allowing a residual lumen ≥ 30% of the vessel diameter maximum 17 Fr (adults) | **Patient:**  
- continuous limb pulse oxymetry distal the arterial cannulation site (toe) |
| **Coagulation:** platelets > 60000/μl aPTT< 60 seconds haemoglobin ≥ 9mg/dl access to blood bank | **Vein:** + 2 Fr. compared with arterial cannula | - clinical inspection for any signs of restricted perfusion |
| **Contraindication:**  
- coagulation disorder e.g. HIT  
- severe peripheral vascular disease  
-- continuously highly dosed vasoactive or inotropic agents (Noradrenaline > 0,4μg/kg/min) | - cannulation by two experienced physicians | - assessment of serum creatine kinase and lactate regularly |
|                          | - bolus application of 5000 IU heparin iv | **Arterial blood gases:** |
|                          | - connection of the system stepwise increase of sweep gas flow to 10 l O2/min |  
- early period (24 hours): frequently = every 4 hours |
|                          | - continuous infusion of heparin (600 to 800 IU/hour via the arterial inflow cannula) |  
- late period (>24hours): every 8 hours |

APTT = activated partial thromboplastin time, HIT = heparin-induced thrombocytopenia, iv = intravenous
Romanian experience

ICU Timisoara 2013

5 cases
Case 1

- M, 22 years
- ICU: 08.02.2013 – 21.02.2013
- **Dg: Severe ARDS post -AH1N1**
- Vascular:A-V, femural billateral, echoguided, Seldinger
- Heparine infusion - APTT 64±17s +Aspirine 1,5mg/kgc/zi (day 2)
- NOVALUNG: 09.02.2013 – 18.02.2013 **(10 days)**
Case 2

- F, 31 years
- Transfer from Infectious Disease Dept
- Dg: Severe ARDS post AH1N1; Pregnancy 26 weeks
- NOVALUNG: 9 days
- Cesarean
Case 3

- F, 33 ani
- ICU: 28.02.2013 - 29.03.2013
- Dg: ARDS sever post AH1N1; Post partum day 8
- NOVALUNG 18 days
Case 4

- F, 26 years
- Dg: Severe AIDS+Severe ARDS-AH1N1
- NOVALUNG-4 days
Case 5

- F, 23 ani
- ICU: 23 DAYS
- Dg: Acute severe, tuberculosis, bilateral Pneumonia, Severe ARDS
- Novalung: 21 days
Results
Results
Results
Results

Duration Novalung(days)

- 18 zile (Caz 3)
- 10 zile (Caz 1)
- 9 zile (Caz 2)
- 14 zile (Caz 5)
- 4 zile (Caz 4)
Complications

Case 1

Membrane thrombosis day 2

Change of membrane + Aspirine 1,5mg/kgc/zi
Complicatii si tratament

Caz 1
Tromboza membrana
Schimbare membrana + Aspirina 1,5mg/kgc/zi

Caz 2
Hematoma
Hemostasis + arterial bypass
Complicatii si tratament

Caz 1
Tromboza membrana
Schimbare membrana + Aspirina 1,5h/kgc/zi

Caz 2
Suprimare accidental + hematom
Hemostaza + bypass arterial

Caz 3
Hematoma
Surgical Hemostasis


Discussions

- 1 case:
  - Novalung + HDF on the venous arm of Novalung

- 1 case:
  - Novalung installed in other hospital, before the transfer in our ICU
Particularitati
Evolution

- 2 Deaths
- 3 Survived
Conclusions

- iLA *Active*, VV, pump driven
- iLA attached to CRRT machine
- portable iLA for COPD patients
- BIOLUNG: total respiratory support

The future of ventilation