$ECCO_2$ Removal
The Perfusionists' Perspective

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Definition

$ECCO_2$ Removal:

- Process by which an extracorporeal circuit is used for removing CO_2 from the body

Arterial blood content

- 500mL/L of CO_2 :
  - 5% dissolved
  - 20% bound
  - 75% as bicarbonates

- CO_2 Production at rest:
  - 200mL/min

Removal factor

- During CPB
  - Gas diffusion gradient
  - Sweep gas
  - Membrane area
  - NOT blood flow
  - NOT thickness of membrane

- During ECCO$_2$R
  - Minimal blood flow
  - CO_2 level before membrane

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Gas exchange efficiency

- Veno-venous device: from 300 to 1500ml/min
  - $PaCO_2$ 40mmHg
    - 500ml/min remove all CO_2
  - $PaCO_2$ 90mmHg
    - 1000ml/min remove all CO_2
  - 500 to 1000ml/min
    - 5min needed to decrease from 75/100mmHg to 45mmHg, gas flow 8 to 16L/min
    - Ok for ARDS
    - Caution for COPD

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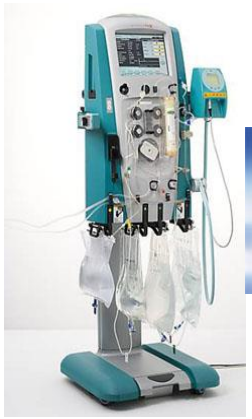
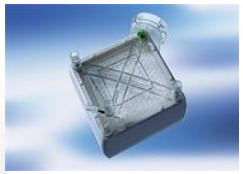
Devices

- 4 modern devices

  Not all CE marked and none FDA approved

  - PALP (Maquet)
  - iLA Active (Novalung)
  - Hemolung (ALung)
  - Decap system





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Cannula

- Double lumen catheters
- Seldinger technique
- Jugular vein
- From 13 to 19 Fr

Pump

- Centrifugal or diagonal
- Electromagnetic field

Membrane

- Polymethylpentene (non-microporous)
- Not polypropylene (use for CPB)
- Heparine coated
- From 0,67 to 3m²

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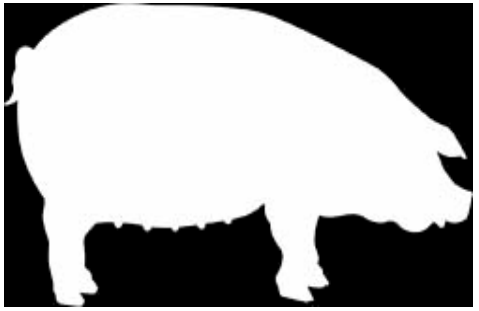
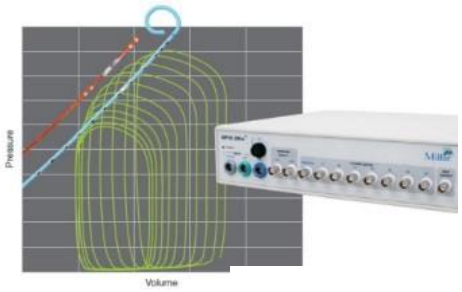
Anticoagulation

- 250ml/min or less
  - Regional anticoagulation Citrate/Calcium
  - Flow control?
- More than 250ml/min
  - Systemic heparinisation
  - Same as for VV ECMO

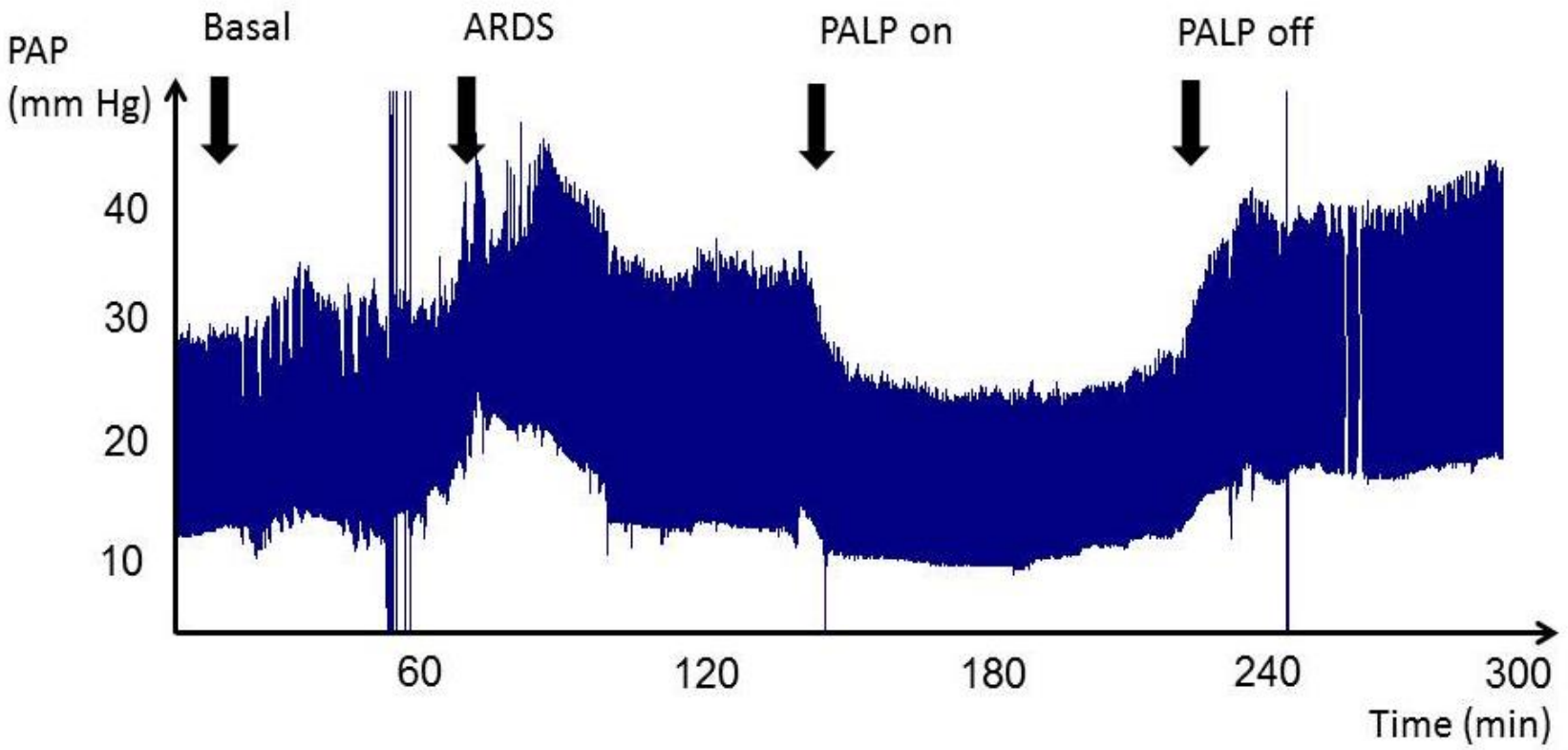
Experimental study – CHU Liège

- 10 pigs
- PALP
  - No heat exchanger
  - Polymethylpentene (PMP)
  - Bioline or Softline
  - Blood flow: 0,2 – 2,8 L/min
  - Gas flow: 0 – 10 L/min
  - Ratio 10/1





Morimont P. et al. Acta Anaesthesiol Scand 2015



- Hemodynamics probes:
  - Baseline
  - ARDS created
  - ARDSnet ventilation
  - PALP On
  - PALP Off

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	SaO2 (%)	PaO2 (mm Hg)	PaCO2 (mm Hg)	pH
Baseline	99 ,8 ± 0,3#	178,8 ± 15,1#	41,7 ± 1,3#	7,44 ± 0,02#
ARDS	68,1 ± 5,9*	54,7 ± 4,4*	78,6 ± 2,9*	7,13 ± 0,02*
ECCO2RT	85,5 ± 3,9	72,2 ± 7,5*	39,8 ± 2,0#	7,36 ± 0,02#
OFF	72,5 ± 6,2*	61,1 ± 5,4*	70,5 ± 4,0*	7,15 ± 0,03*

* Significant difference vs. baseline at p <0.05; # Significant difference vs. ARDS at p <0.05. All data are means ± SEM.

Morimont P. et al. Acta Anaesthesiol Scand 2015

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Results

- Normocapnia while low tidal volumes
- PAP normalization
- Right ventricular function improvement
- Complementary therapy

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Experimental study – Upssala University, Sweden

- Animal study – 6 pigs
- Feasible
  - If blood flow from 750 to 1000ml/min, 19fr cannula
    - CO_2R: 146.1 ± 22.6 mL/minute max
    - pH: increase from 7,13 to 7,41
    - Sweep: 16L/min
  - Sweep decreasing at 8L/min
    - CO_2R: 138,0 ± 16,9ml/min max
  - 14,5Fr cannula:
    - CO_2R: 77,9 ml/min
    - pH not normalized

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Karagiannidis et al. Critical Care 2014, 18:R124 http://ccforum.com/content/18/3/R124

2 Clinical Cases

AF Rousseau – T Amand, JN Koch

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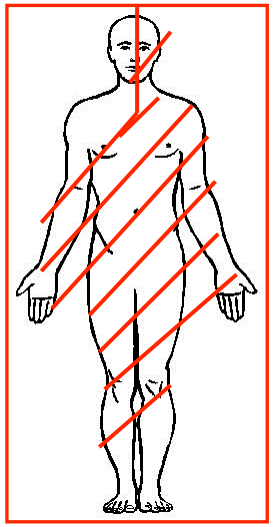
Pediatric oxygenator integrated into CRRT circuit for CO_2 Removal

- Patient 1:
  - 48 year-old man
  - Deep flame burns (+/- 65% total body area)
  - Septic shock
  - Mechanical Ventilation (>24d)
  - Continuous Renal Replacement therapy (dialysis catheter subclavian vein 13Fr, 15 cm)
  - Neuromuscular block, NO, prone position
  - Day 29: hypercapnia

VV ECMO



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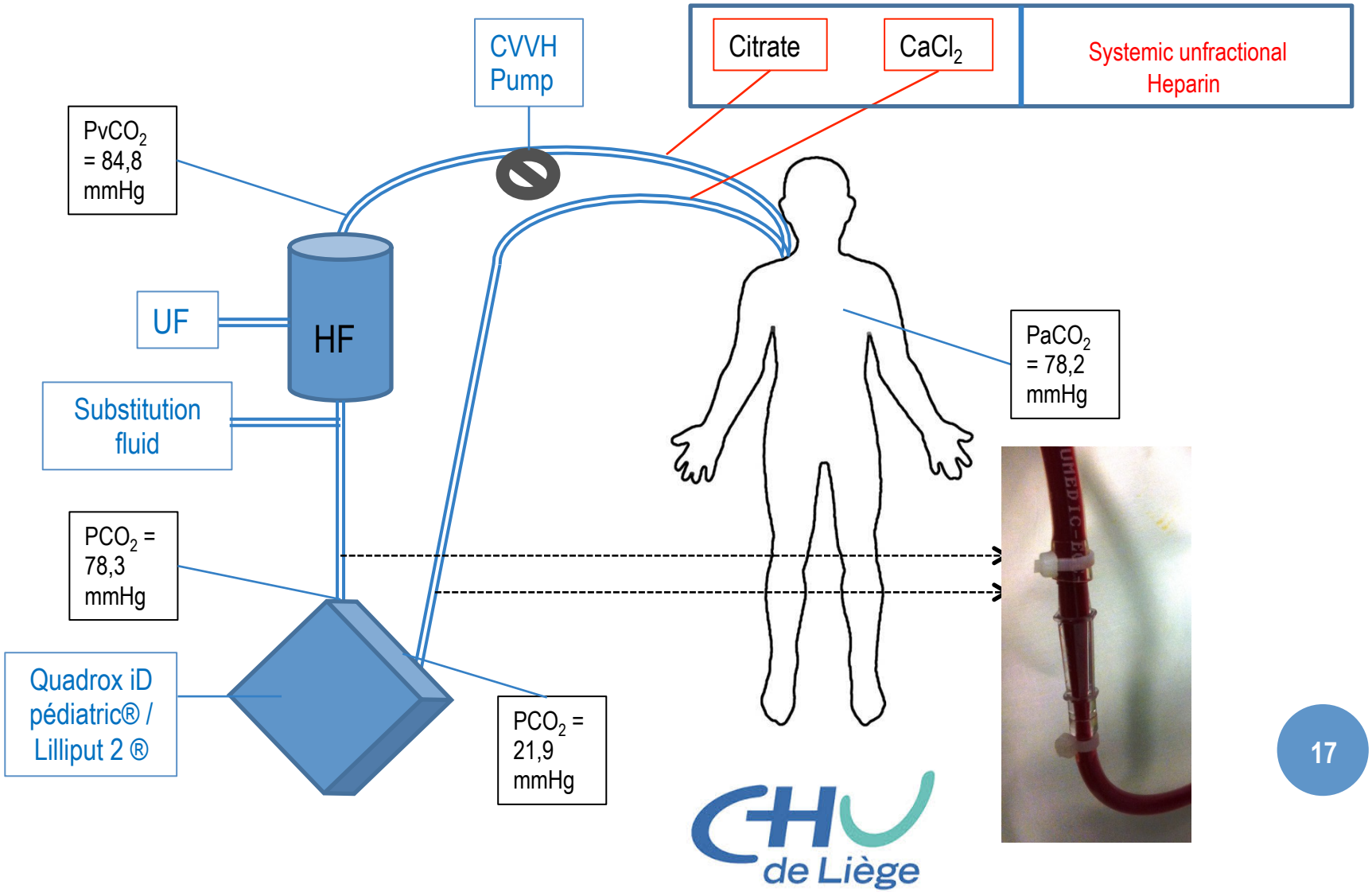
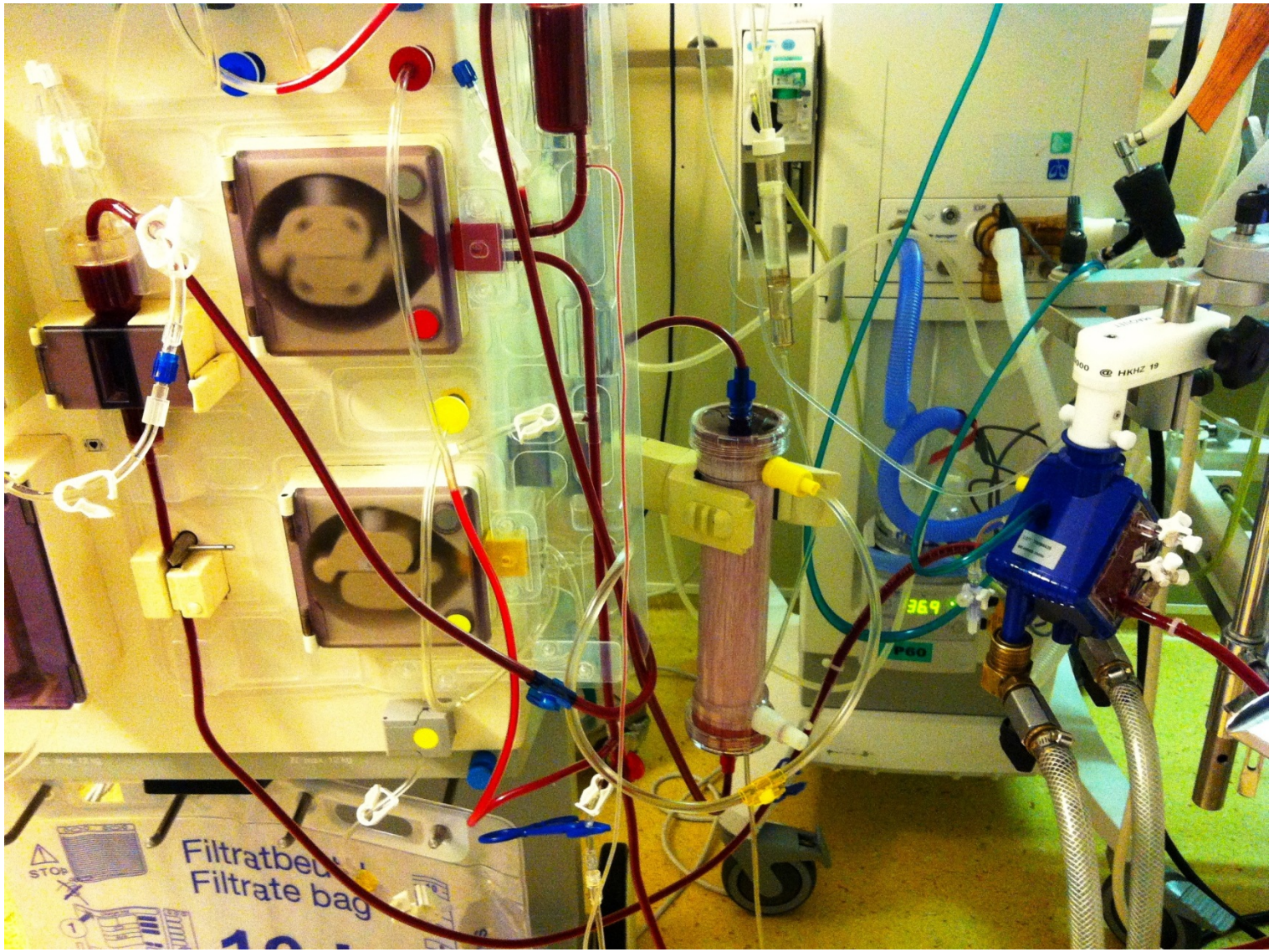
Pediatric oxygenator integarted into CRRT circuit for CO_2 Removal

- Patient 2:

  - 34 years-old man,
  - Hematologic disease (Lymphoïd leukemia); coagulopathy ++
  - ARDS and hypercapnia
  - Continuous Renal Replacement therapy (dialysis catheter subclavian vein (13Fr, 15 cm)
  - Mechanical Ventilation, NO (20 ppm)

Circuit

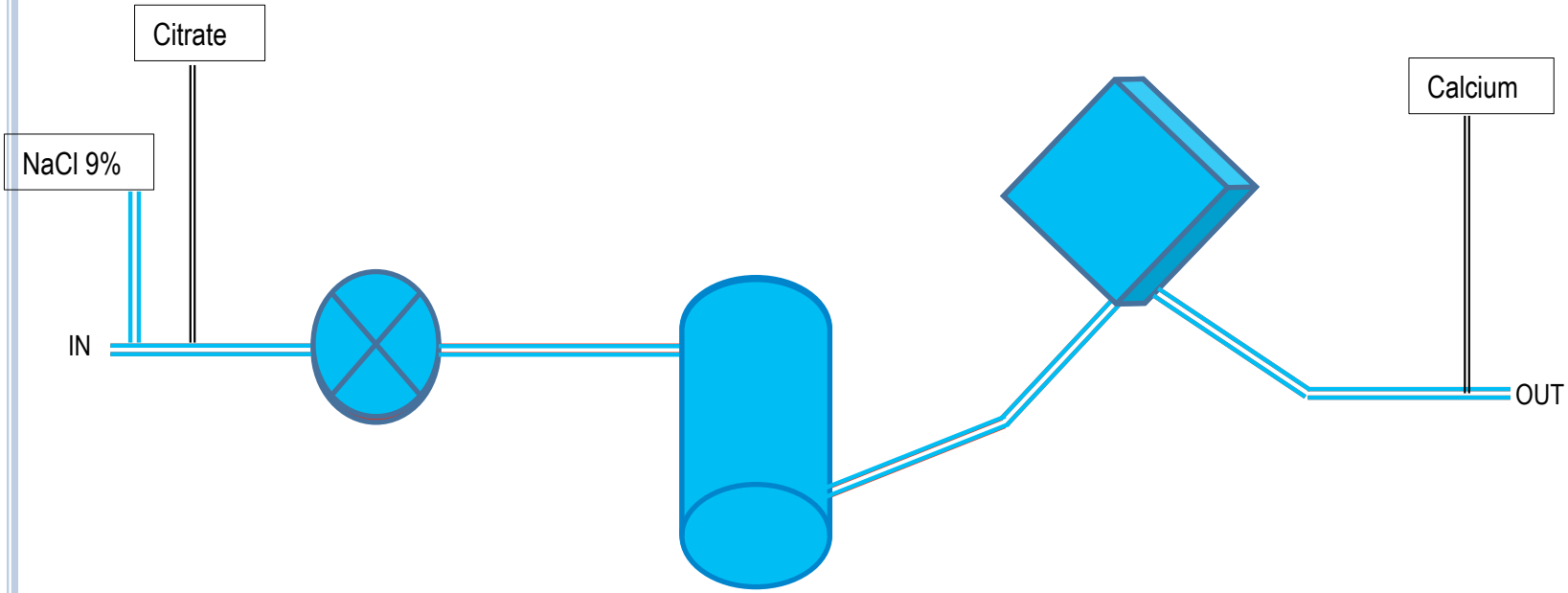

CVVH Pump
Citrate
$CaCl_2$
Systemic unfractional Heparin
$PvCO_2$ = 84,8 mmHg
UF
HF
Substitution fluid
PCO_2 = 78,3 mmHg
Quadrox iD pédiatric® / Lilliput 2 ®
PCO_2 = 21,9 mmHg
$PaCO_2$ = 78,2 mmHg



Blood flow : 170mL/min. to 350 mL/min.

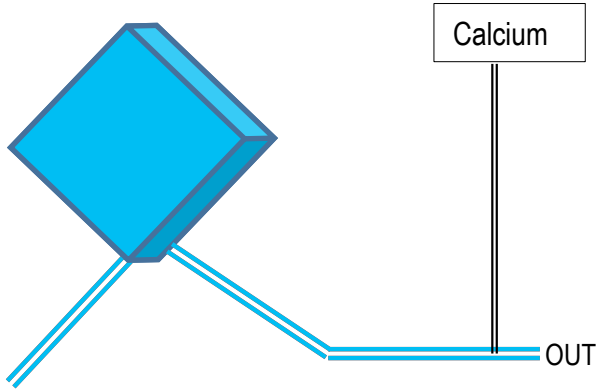
Sweep Gas: 5,5 L/min.

Change of the circuit

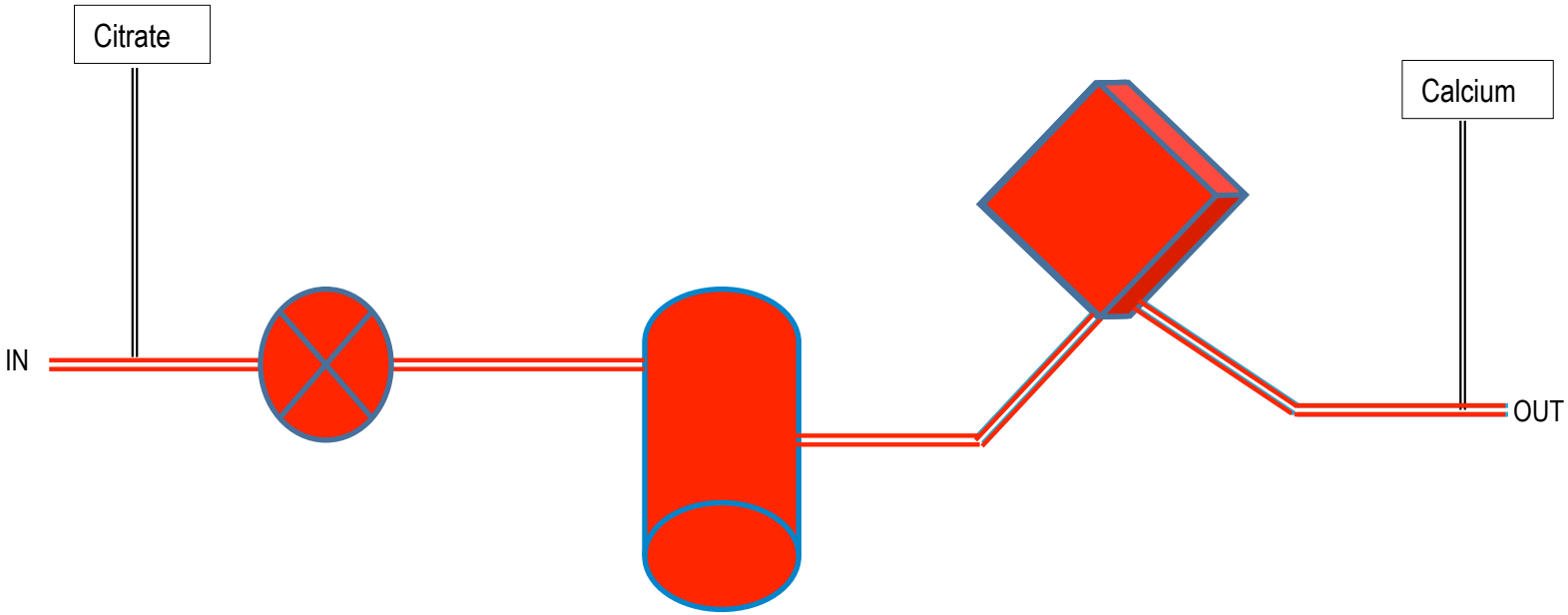


Change of the circuit

IN



Change of the circuit

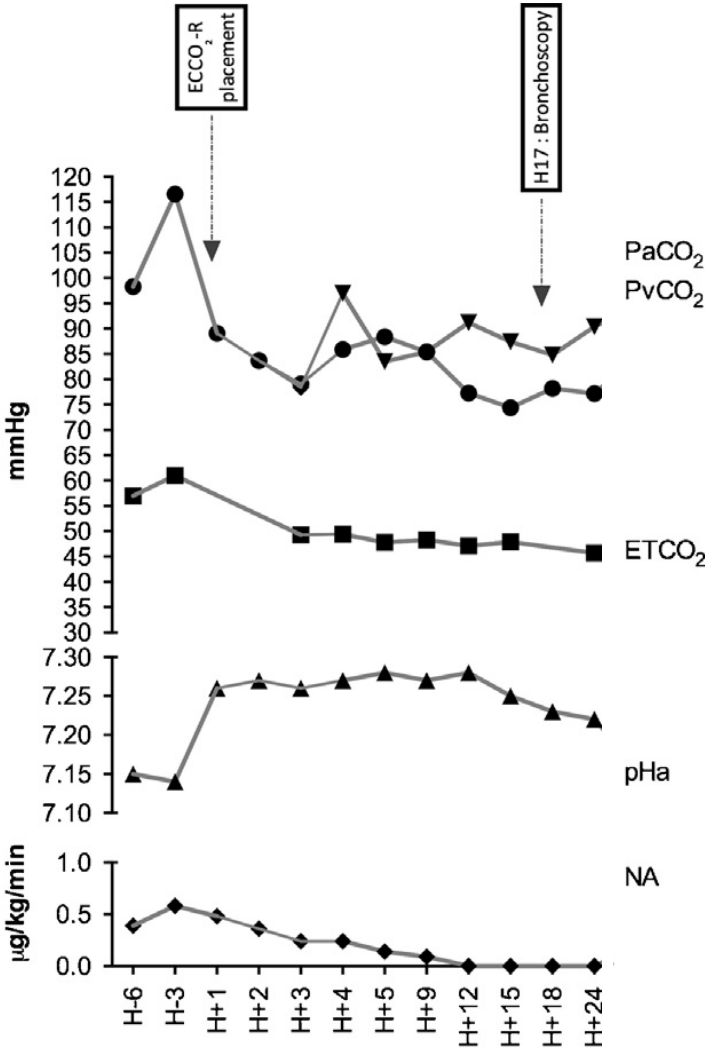


Clinical improvement

- Controlled hypercapnia
- pHa raised to 7,28
- Blood pressure increased

=> Reduce/stop noradrenaline doses

- Ventilation setting unchanged during 24h, than decreased



Blood gas analysis

Pat n°2 one hour after beginning

Pre membrane	Post membrane
7,20	7,72
67,8 mmHg	13,9mmHg
26,0 mmol/L	17,5mmol/L

- Sweep gas : 5L/min
- Blood Flow : 0,3L/min

- RESULTS: 67,9 ml/min CO_2 extracted

- Anticoagulation :
  - Citrate/ Calcium: as a routine C.V.V.H.
    - Ionised calcium patient: 1,12 - 1,20 mmol/l
    - Ionised calcium post-filtre : 0,25 - 0,34 mmol/l
  - Heparin:
    - TCA ratio: 1,5 - 2
- Outcome:
  - Patient 1: Died 33th day (M.O.F.)
  - Patient 2: Died (cerebral ischemia + hemorrhage)

Limit of the technique

CO_2 extraction rate may fluctuate according to:

- Blood flow
- Pre-oxygenator CO_2 content level
- Oxygenator position in the C.V.V.H. circuit
- Ultrafiltration rate
- Bicarbonate content in substitution fluid

Perfusion perspectives?

- CO_2 extraction = “Respiratory dialysis”
- Hope :
  - Simple technique
  - Less invasive
  - More efficient
  - Cheaper
- Ultra protective ventilation
- Avoid mechanical ventilation for COPD

Super Nova Study
European Multicentric Study
Moderate ARDS

Classic ventilation → barotrauma => alveolar injury

Protective ventilation → ↑ CO_2 and respiratory acidosis → ↑ pulmonary resistances ↓cardiac contractility

Solution (?) = Protective ventilation + CO_2 Removal

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Super Nova Study

- Feasibility
- Belgium: 20 Patients (10 CHU Lg, 10 Erasme)
- Moderate ARDS
- HLS® + Novaport® cannula 18Fr.
- Mechanical Ventilation:
  - >24 hours
  - pCO_2 > 60mmHg
- Reduce tidal volume
  - 6ml/kg
  - 5ml/kg
  - 4,5ml/kg
  - 4ml/kg

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Conclusions:

- Clinical cases needed
- Experience needed
- Cannula design?
- Ideal blood flow?
- Ideal sweep gas flow?
- Perfusionist management
  - Continuous training for ICU nurses
  - Circuit manipulation
- $ECCO_2R$ on CVVH with pediatric membrane
  - Partial extraction
  - Easier, less invasive, less expensive

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Conclusions:

We would not recommand this kind of therapy in a center where there is no involvement by the perfusionist.

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