SHORT TERM MECHANICAL CIRCULATORY SUPPORT:

EXTRACORPOREAL LIFE SUPPORT

Prof. Alexandre OUATTARA

Département of Anaesthesia and Critical Care, Medical and Surgical Magellan Centre

INSERM, UMR 1034 Biology of cardiovascular diseases

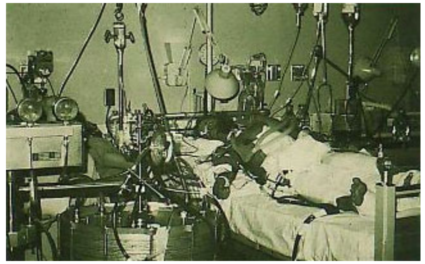
Haut-Lévêque university hospital, 33600 Pessac, FRANCE

CONFLICTS OF INTEREST

ExtraCorporeal Membrane Oxygenation (ECMO)

Hill JD et al. N Engl J Med 1972; 286:629-34
Zapol WM et al. JAMA 1979;242:2193-6

Respiratory supply
Mostly veno-arterial
Experience limited and delayed use
Bleeding
NO concomitant protective ventilatory strategies

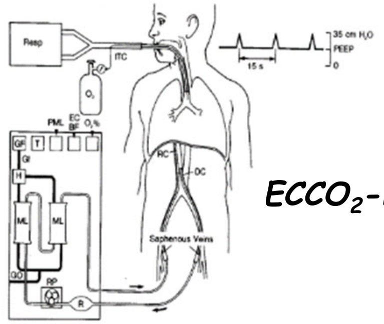


The first successful extracorporeal life support patient treated by J. Donald Hill using Bramson oxygenator (Santa barbara 1971)

ExtraCorporeal CO_2 Removal ($ECCO_2R$)

Gattinoni L et al. JAMA 1986; 256:881-6

Respiratory supply
Veno-venous circuit with oxygenation by diffusion
CO2 extraction by membrane
Epuration CO2 par membrane

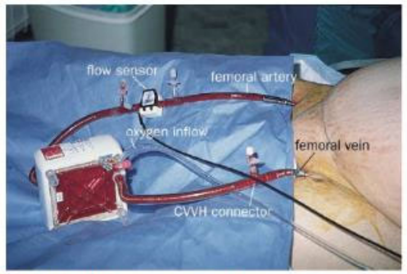


$ECCO_2$-R

Extracorporeal Lung Assist (ECLA)

Reng M et al. Lancet 2000; 356:219-220

Respiratory supply
Pump is not required
Arterio-venous shunt between femoral artery and vein



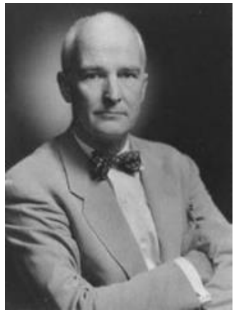
ECLA

ExtraCorporeal Life Support (ECLS)

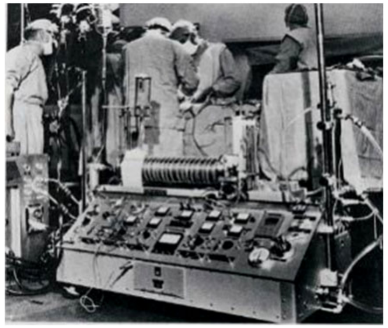
Global term to define a respiratory and circulatory supply device
Improve tissular perfusion (circulatory and/or respiratory supply)

Extracorporeal Cardiopulmonary Resuscitation (ECCPR)

Respiratory and circulatory supply for CPR



John and Marry Gibbon (1953)



- Therapeutics with high technology
- Circulatory and/or respiratory supply
- Derivated from Cardiopulmonary bypass of cardiac surgery
- Technology progress
  - Hemo-compatibility (coating),
  - Miniaturization,
  - Membrane of diffusion…

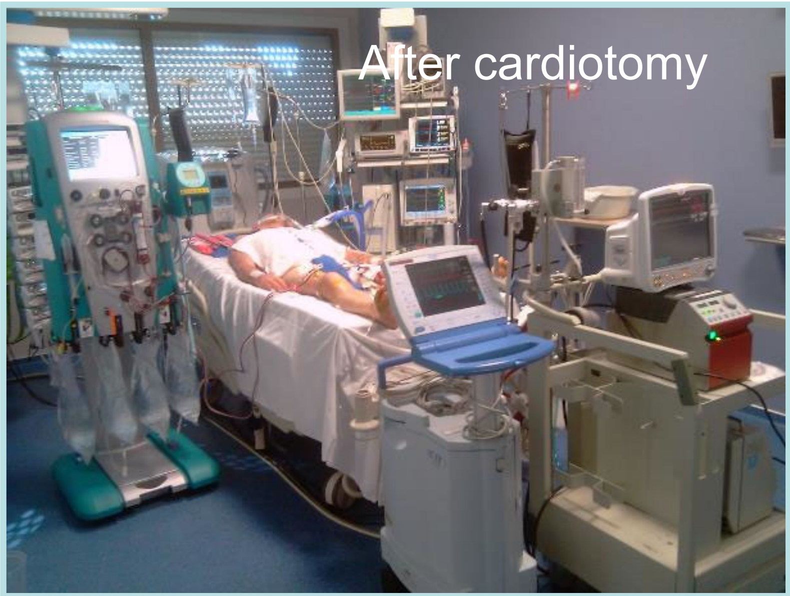
- Intensive care unit, emergency department and now for pre-hospital care…

Edmunds LH Jr N Engl J Med 2004; 351:1603-6

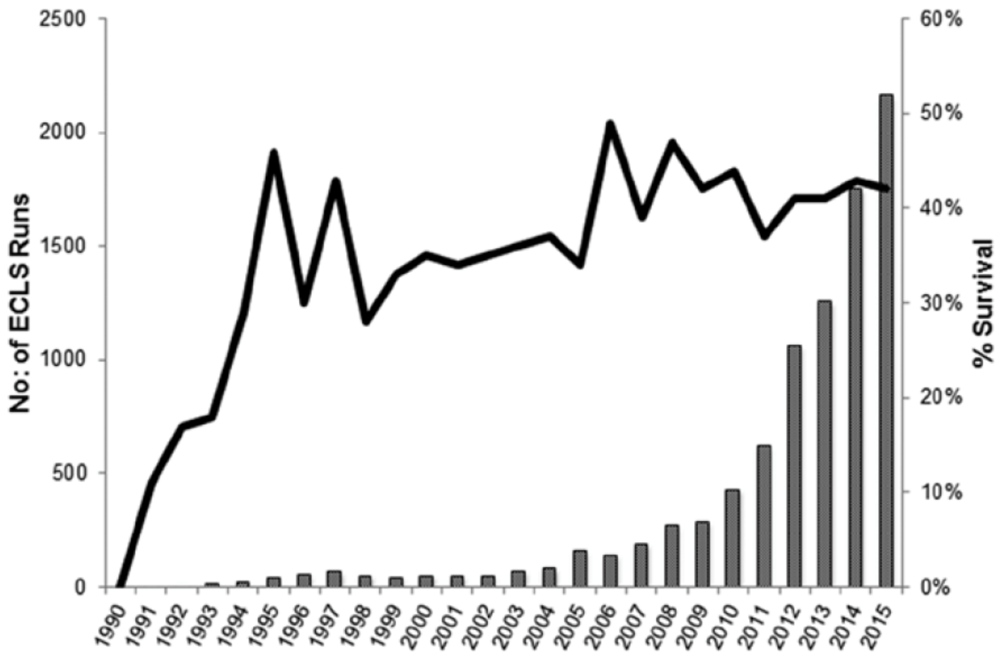
Stoney WS Circulation 2009; 119:2844-53


Pediatric ECLS

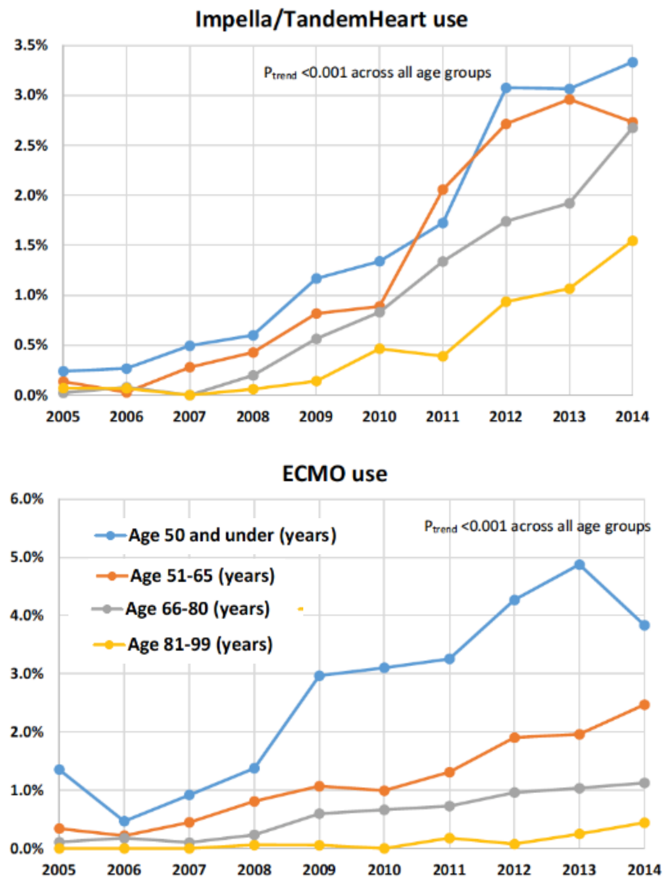

Mobile unit


After cardiotomy


Out-hospital cardiac arrest
« Louvre Museum »

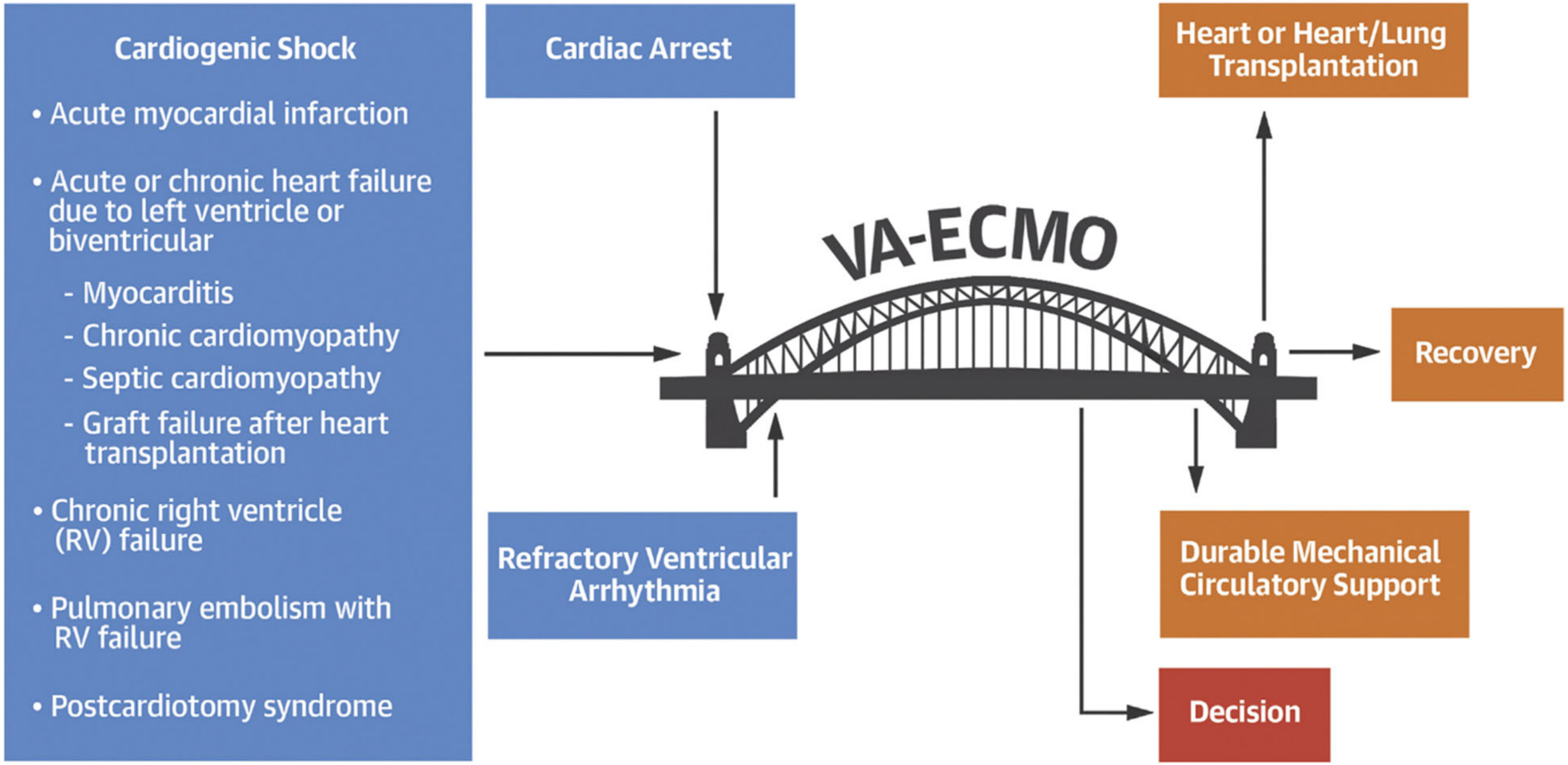


Thiagarajan RR et al. ASAIO Journal 2017;63:60-7



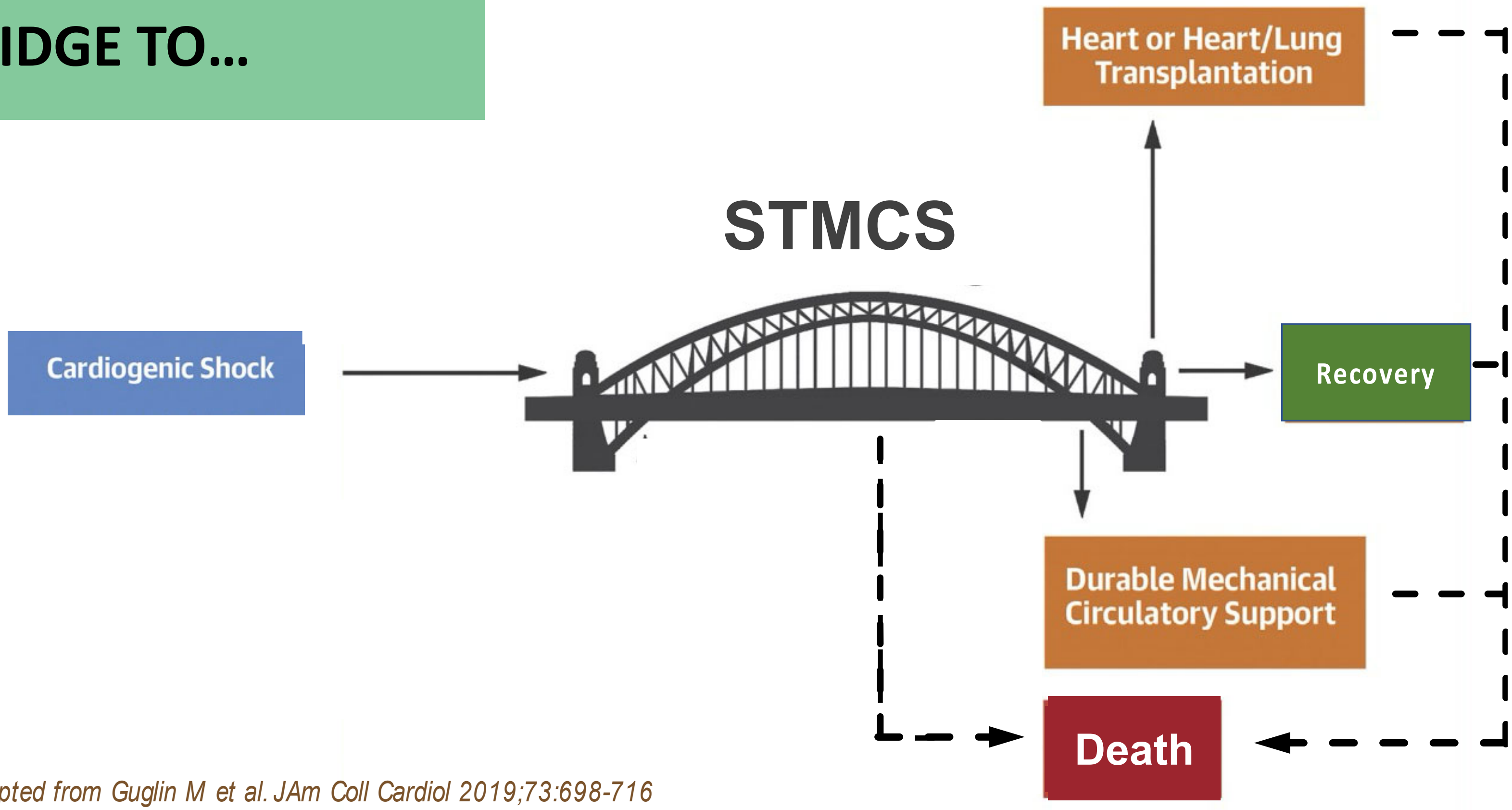
Shah M et al. Clin Res Cardiol 2018;107:287-303

BRIDGE TO…


Cardiogenic Shock
• Acute myocardial infarction
• Acute or chronic heart failure due to left ventricle or biventricular
- Myocarditis
- Chronic cardiomyopathy
- Septic cardiomyopathy
- Graft failure after heart transplantation
• Chronic right ventricle (RV) failure
• Pulmonary embolism with RV failure
• Postcardiotomy syndrome
Cardiac Arrest
Refractory Ventricular Arrhythmia
VA-ECMO
Heart or Heart/Lung Transplantation
Recovery
Durable Mechanical Circulatory Support
Decision

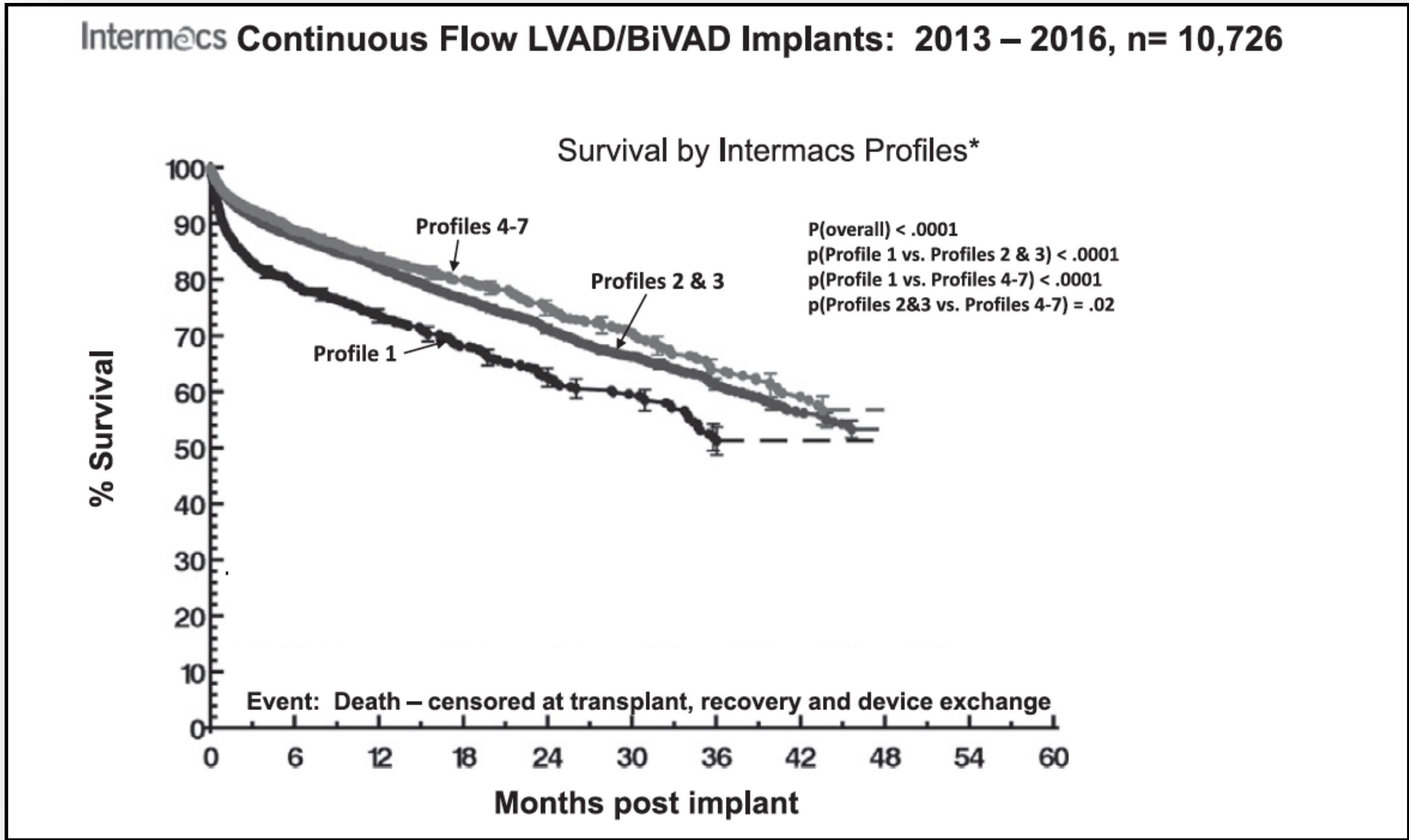
Outcomes of Short Term Mechanical Circulatory Support (STMCS)

BRIDGE TO…

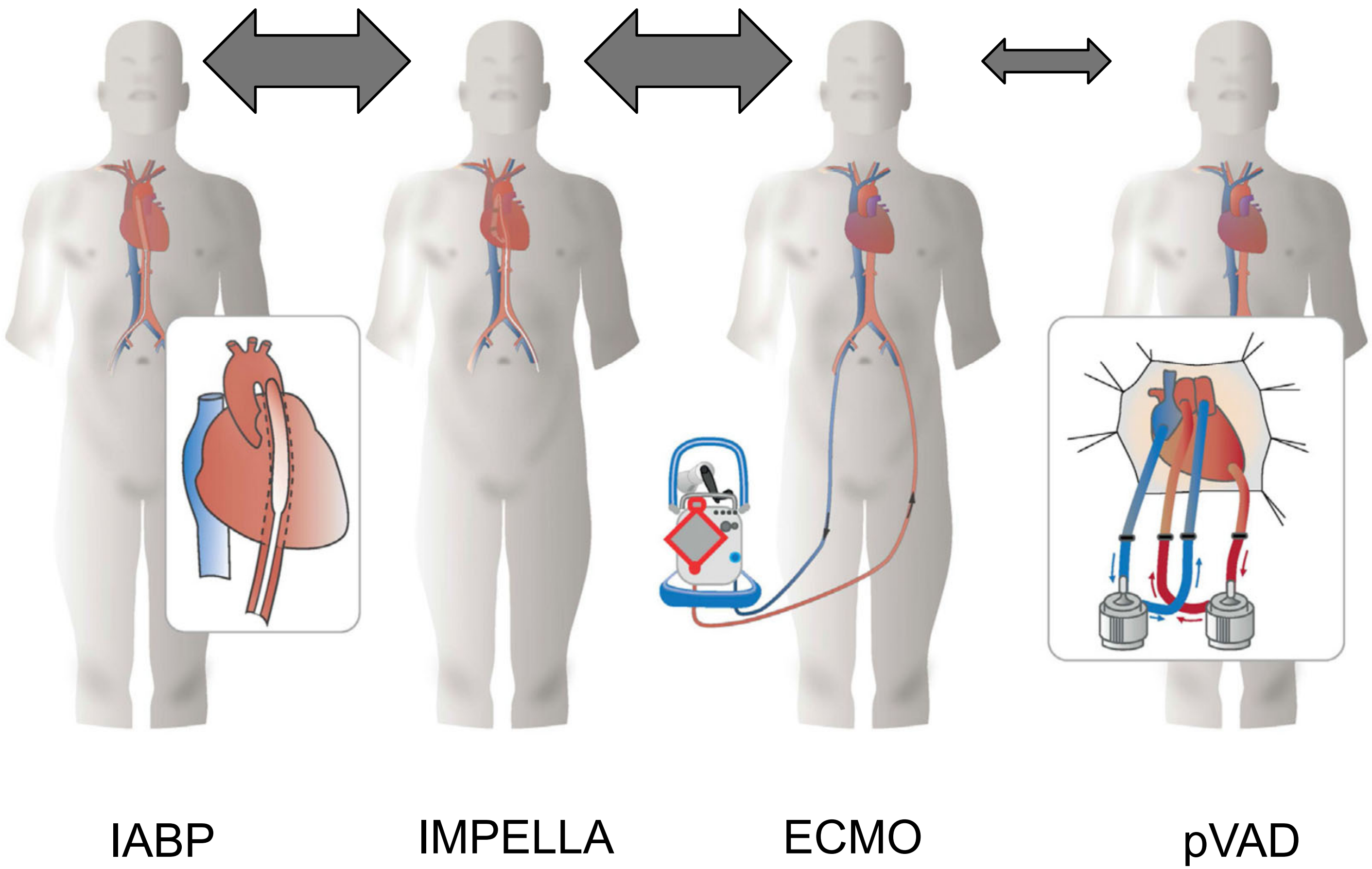


Adapted from Guglin M et al. JAm Coll Cardiol 2019;73:698-716

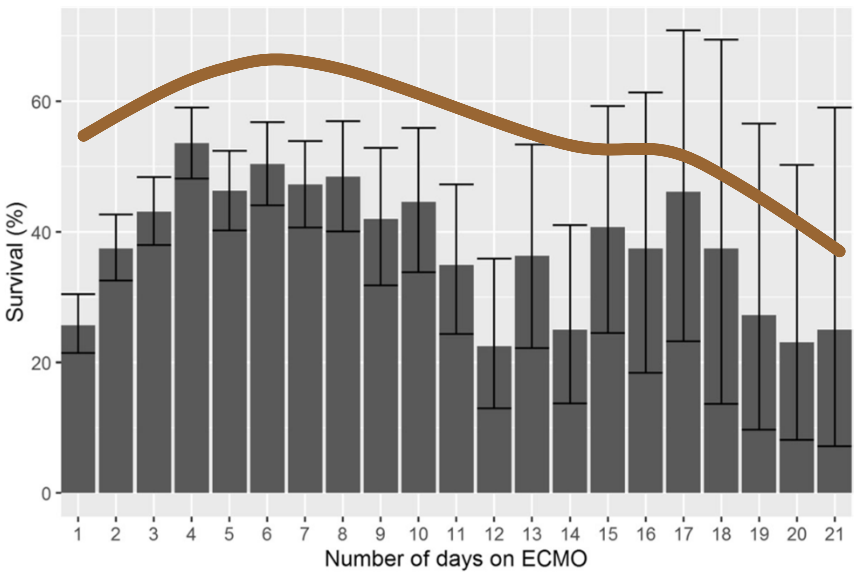
Short-term Mechanical Circulatory Support (STMCS) prior to Left Ventricular Assist Device (LVAD)



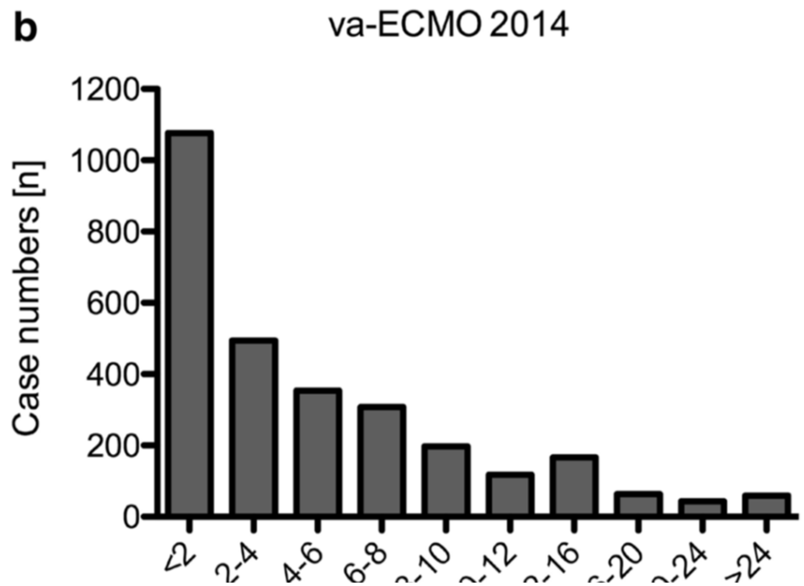
SHORT TERM MECHANICAL CIRCULATORY SUPPPORT (STMCS)



ECLS DURATION AND OUTCOMES



Smith M et al. Crit Care 2017; 21:45



Karagiannidis C et al. Intensive Care Med 2016;42:889-96


SOLUTION
PROBLEM

	IABP (7.5-9 Fr)	IMPELLA 2.5 and CP	IMPELLA 5.0	ECLS
Size of MCS	7.5 to 8 Fr	Motor 12/14 Fr/Catheter 9 Fr	Motor 21 Fr/Catheter 9 Fr	A: 15-19 Fr/V: 23-29 Fr
Very frequent (> 10%)	• Thrombocytopenia	• Severe *access vascular bleeding***	• Severe *access vascular bleeding* **	• Severe *access vascular bleeding*** • Site infection
Frequent (5-10%)		• Intravascular hemolysis • Site infection	• Limb ischemia* • Site infection	• Limb ischemia*
Non exceptional (1-5%)	• Device malfunction • Severe Limb ischemia* • Severe *access vascular bleeding* **	• Limb ischemia* • Device malfunction • Pump displacement	• Intravascular hemolysis • Device malfunction • Pump displacement	• Intravascular hemolysis • Pulmonary hemorrhage
Exceptional (<1%)	• Retroperitoneal bleeding • Intravascular hemolysis • Aortic complication • Cerebral embolism • Paraplegia • Site infection • Mesenteric ischemia • Balloon leak	• Retroperitoneal bleeding • Functional mitral stenosis • Mitral regurgitation (chordal rupture) • Left ventricular wall perforation • Intra ventricular thrombosis	• Functional mitral stenosis • Mitral regurgitation (chordal rupture) • Aortic regurgitation • Left ventricular wall perforation • Intra ventricular thrombosis	• Aortic complication • Device malfunction

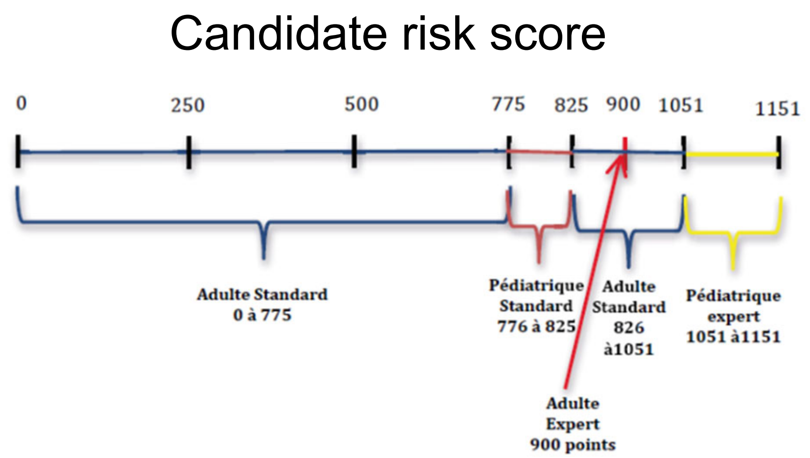
Bonello L et al. Arch Cardiovasc Dis 2020 ;113:448-60

ECLS for cardiac indications

Diagnosis	No. Runs, N	Average ECLS Duration (hour)	Survival, N (%)
Adult (>16 years)			
Shock*	2,083	144	882 (42)
Cardiomyopathy	704	162	358 (51)
Myocarditis	227	188	143 (65)
Congenital defect	420	129	156 (37)
		~ 6 to 8 days	**~ 50%**

Thiagarajan RR et al. ASAIO Journal 2017;63:60-7

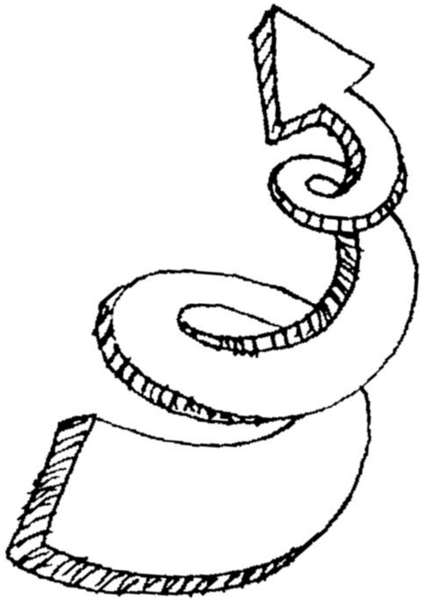
New graft allocation rules for heart transplantation *in France* (from January 2108)

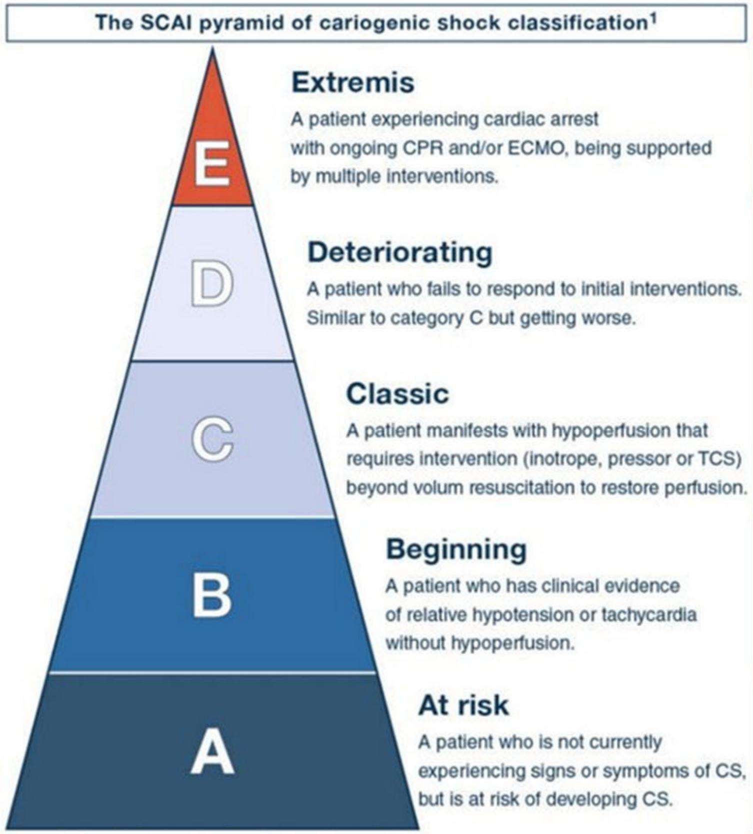


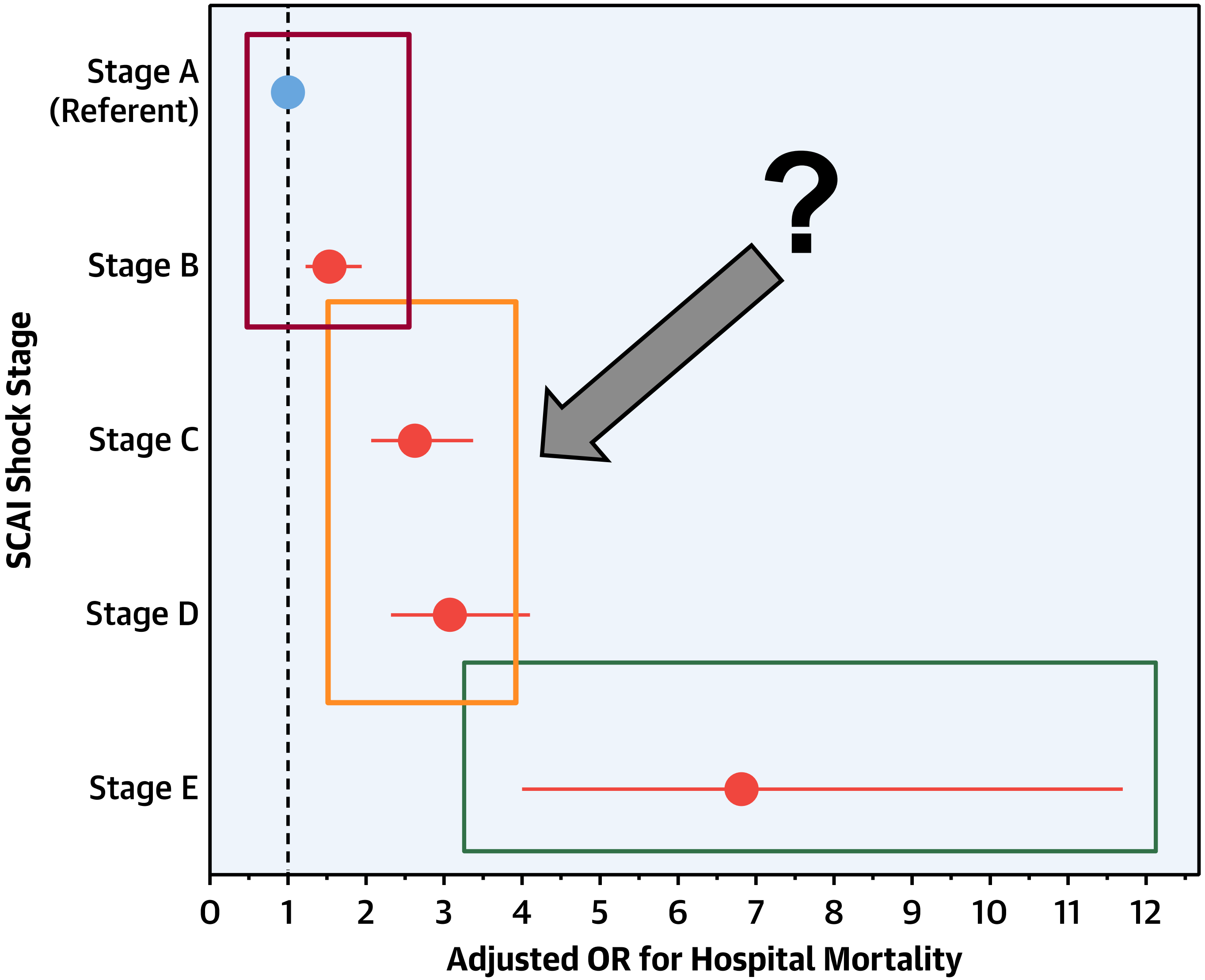
Since April 2019, the score decreases from 100% to 0% in candidates on VA-ECMO from 12 to 16 days of support duration.

WHEN ? "NEITHER TOO EARLY NOR TO LATE"

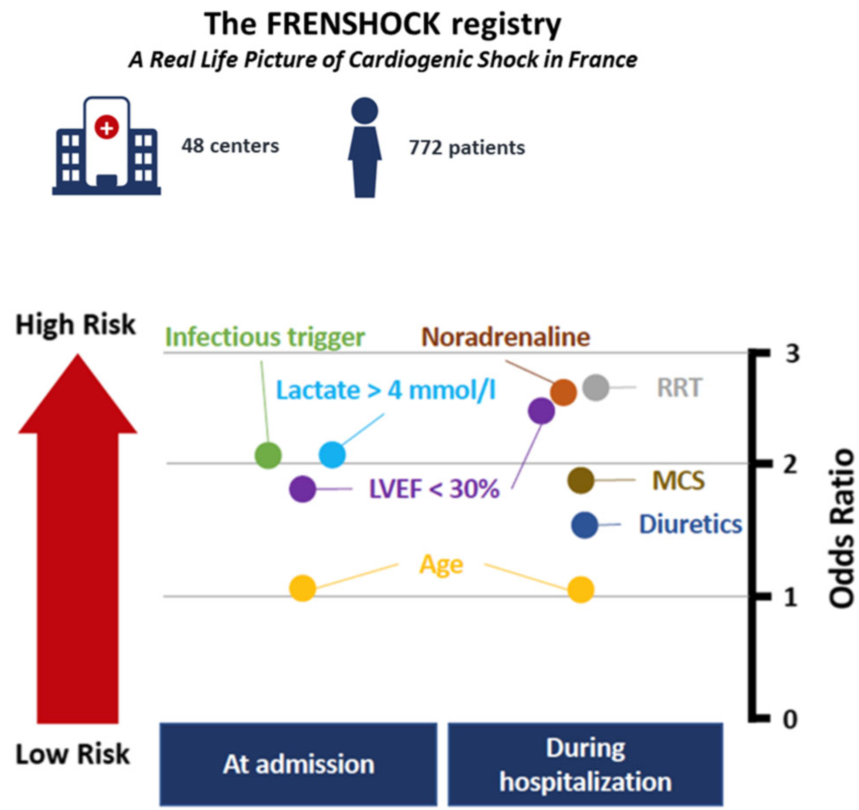
SCAI: Society for Cardiovascular Angiography and Interventions (SCAI)



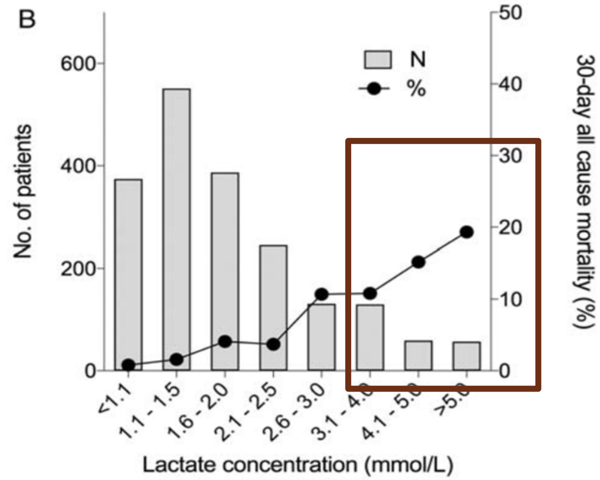




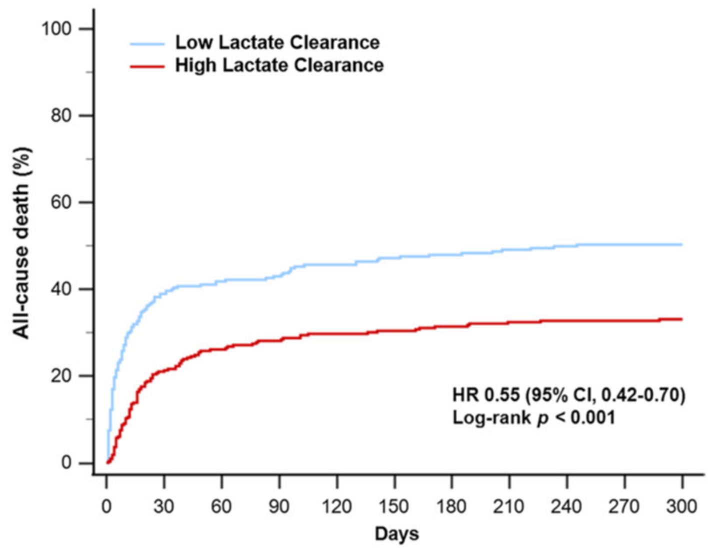
Jentzer JC et al. A Am Coll Cardiol 2019; 74:2117-28



Delmas C et al. ECS Heart Failure 2022; 9:408-19

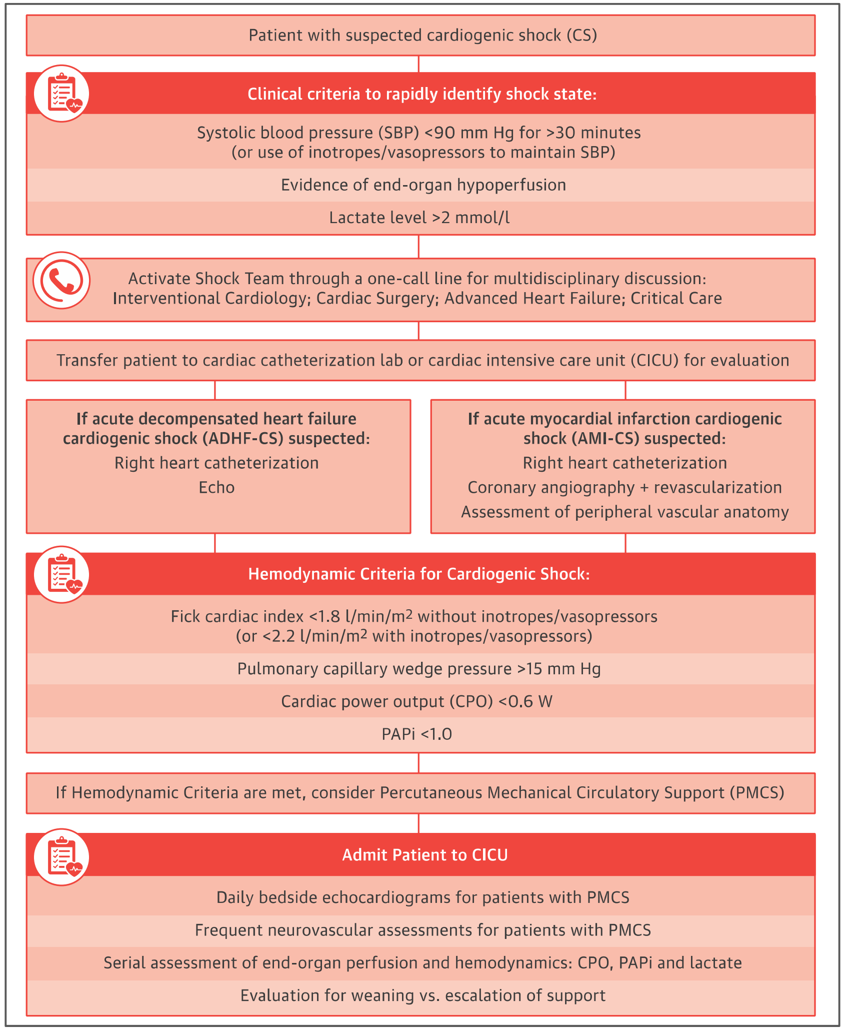


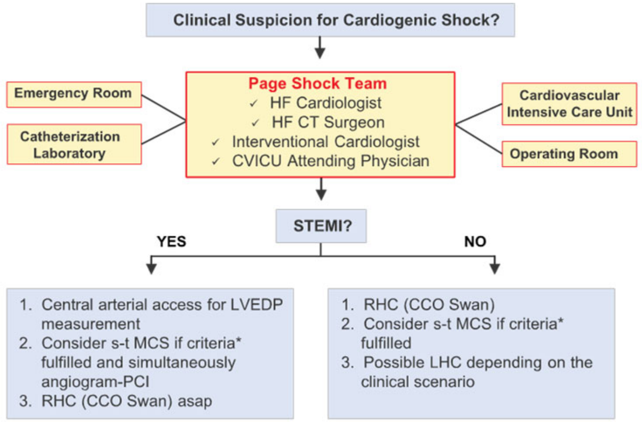
Frydland M et al. Shock 2019;51:321-7

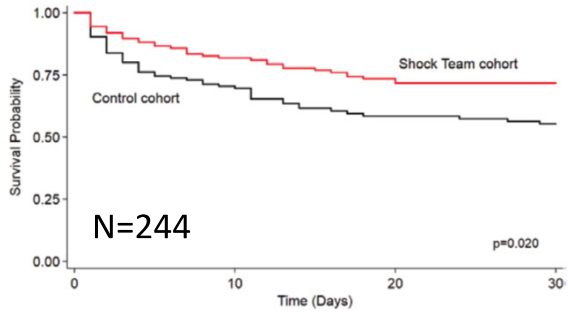


Park IH et al. J Intensive Care 2021;9:63

BY WHO? CARDIOGENIC SHOCK TEAM





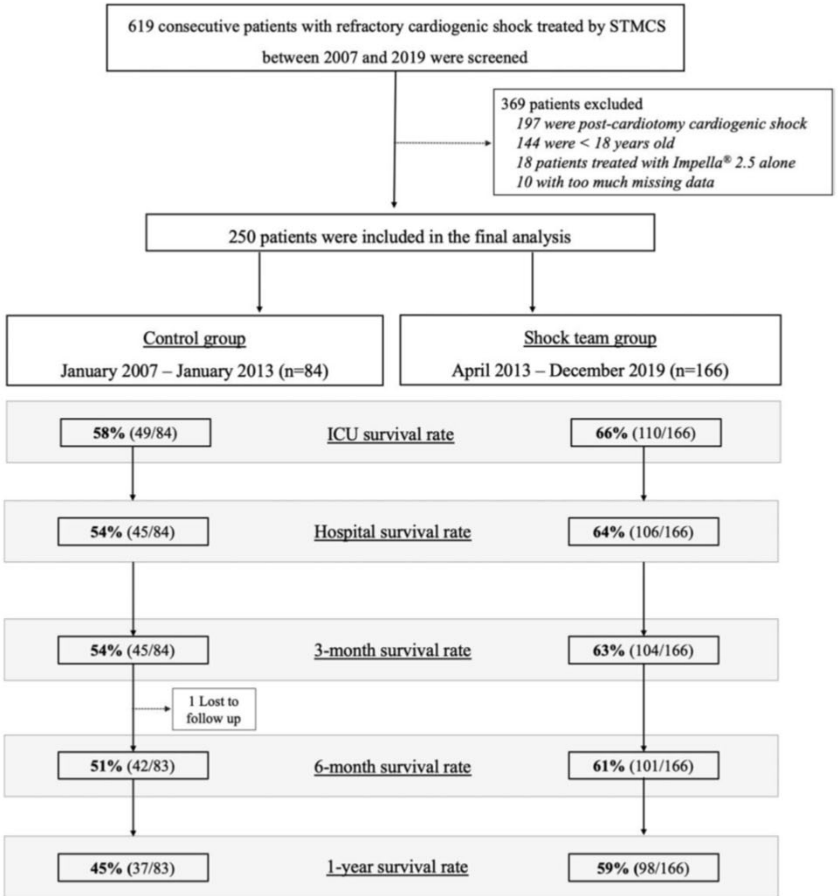


Tehrani BN et al. J Am Coll Cardiol 2019; 73:1659-69
Taleb I et al. Circulation 2019;140:98-100

Multidisciplinary cardiogenic shock team approach improves the long-term outcomes of patients suffering from refractory cardiogenic shock treated with short-term mechanical circulatory support

François-Xavier Hérion[1,2†], Antoine Beurton [1,2*†], Claire Oddos[1], Karine Nubret[3], Clément Aguerreche[1], Astrid Quessard[1], Maxime Faure[3], Edouard Gerbaud [4,5], Mathieu Pernot [2,6], Julien Imbault[1,2], and Alexandre Ouattara[1,2]

ESC European Society of Cardiology
European Heart Journal: Acute Cardiovascular Care (2023)
https://doi.org/10.1093/ehjacc/zuad108



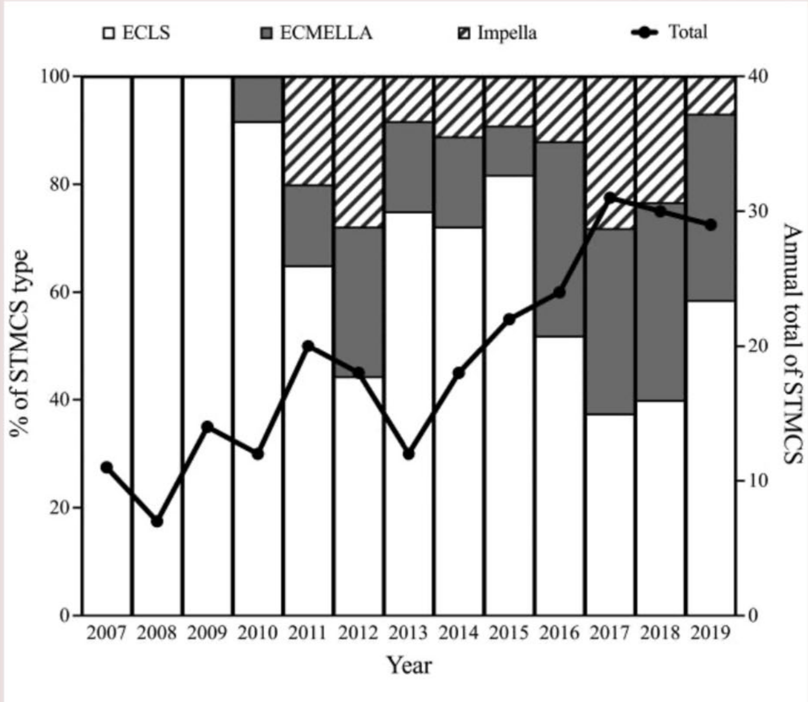
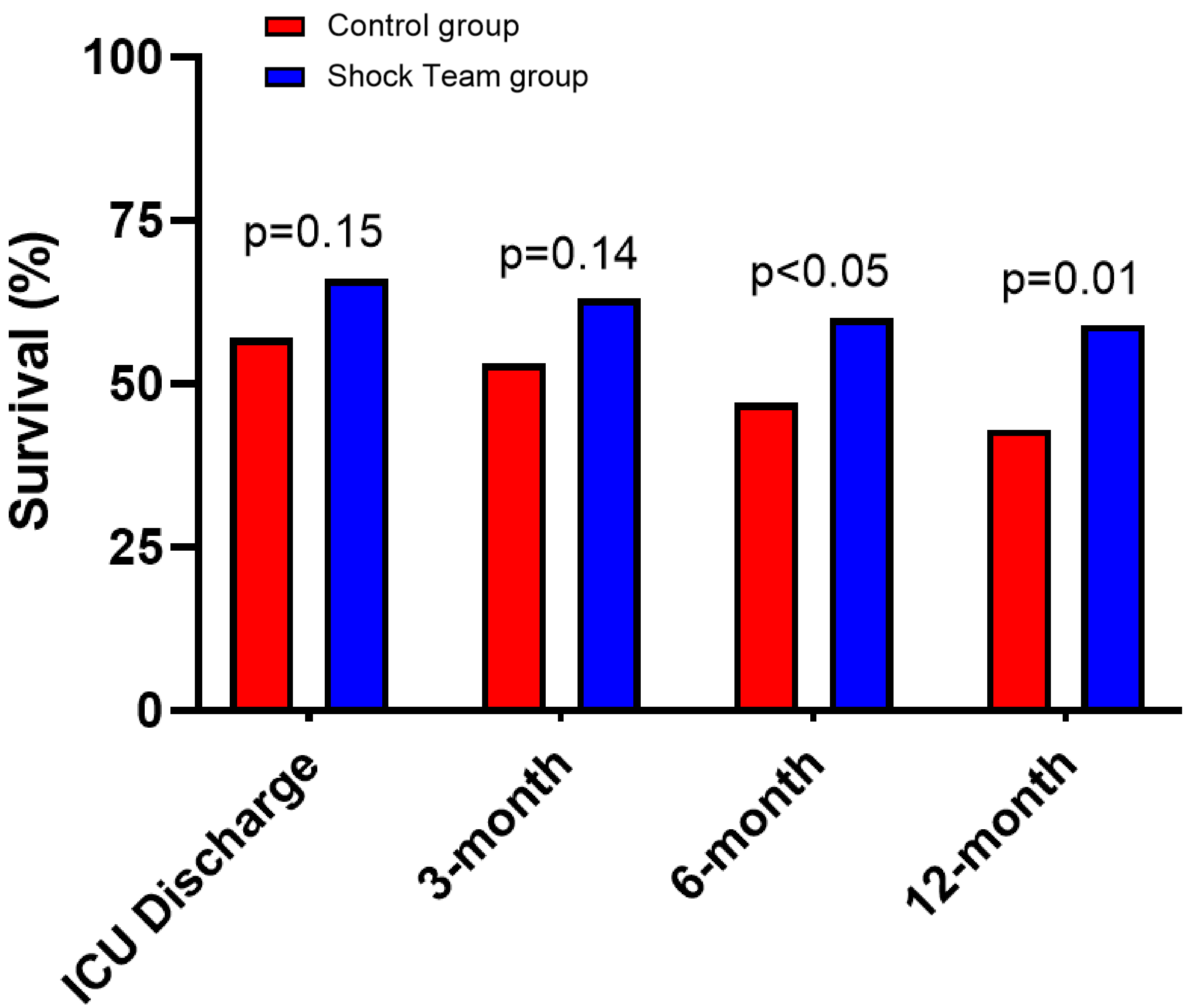


Figure 3 Trends in STMCS over the years. ECLS, extracorporeal life support; ECMELLA, Association of ECLS and Impella® 2.5, CP or 5.0; IABP, intra-aortic balloon pump; STMCS, short-term mechanical circulatory support. The 'Impella®' category includes only CP and 5.0 used alone.

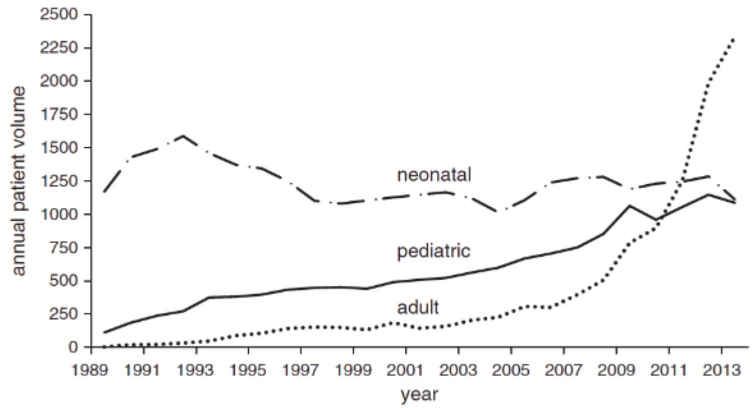
Henrion FX et al. (unpublished data)

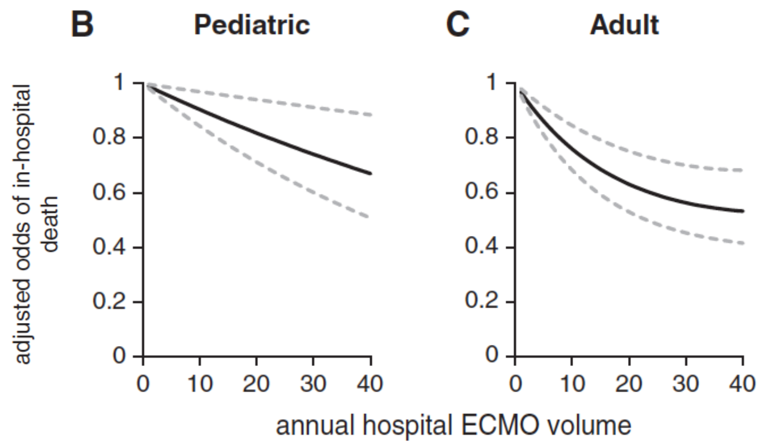


Association of Hospital-Level Volume of Extracorporeal Membrane Oxygenation Cases and Mortality

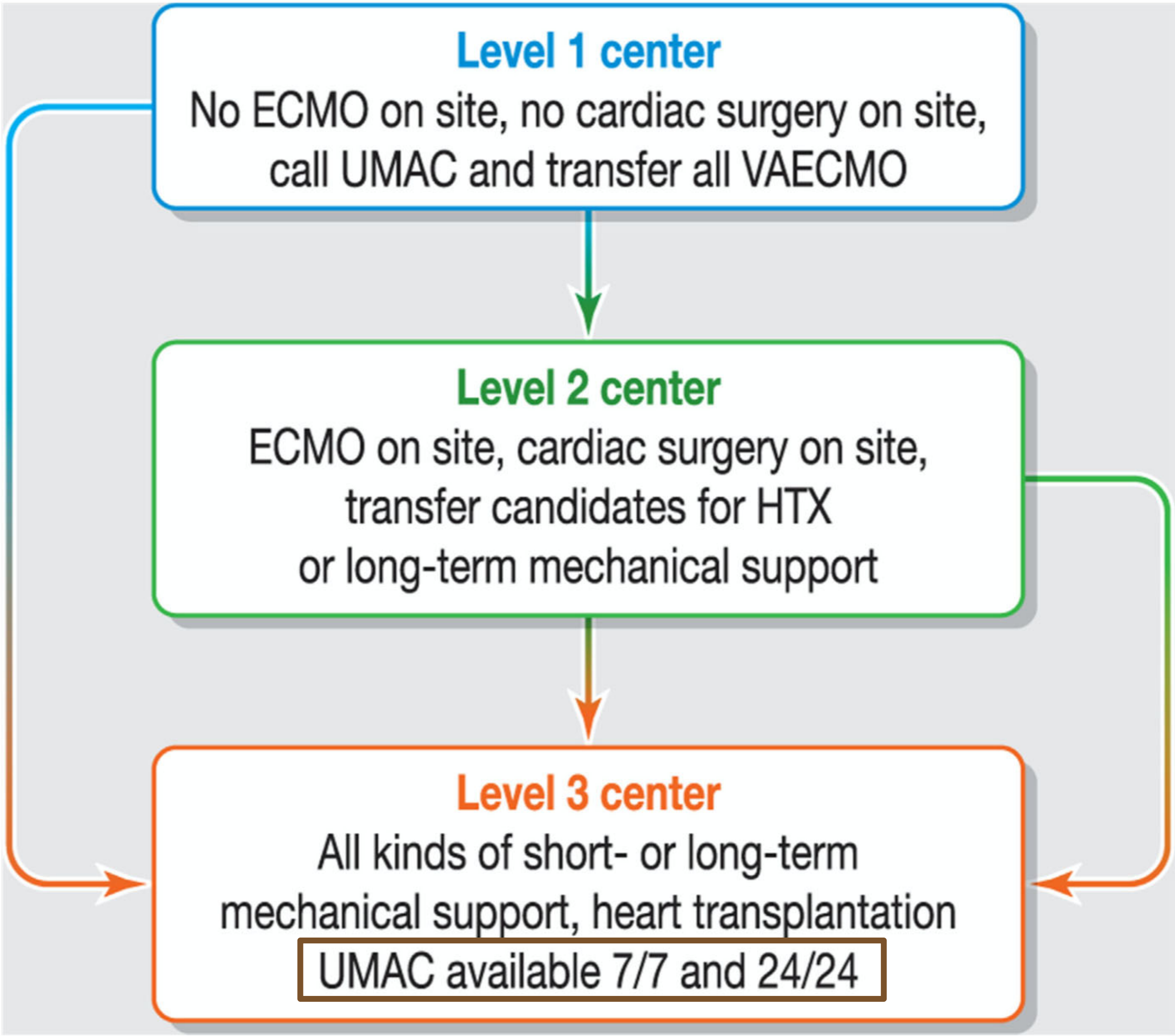
Analysis of the Extracorporeal Life Support Organization Registry

Barbaro RP et al. Am J Crit Care Med 2015;191:894-901





Period	Annual Hospital ECMO Volume	Adjusted Mortality Odds Ratio (95% CI)		
		Neonate	Pediatric	Adult
1989–2013	1–5	Referent	Referent	Referent
	6–14	0.86 (0.75–0.98)	0.99 (0.86–1.13)	0.81 (0.66–0.995)
	15–30	0.74 (0.63–0.88)	0.86 (0.73–1.01)	0.75 (0.59–0.94)
	>30	0.69 (0.56–0.84)	0.89 (0.69–1.14)	0.61 (0.48–0.79)
2008–2013	1–5	Referent	Referent	Referent
	6–14	1.01 (0.79–1.28)	1.03 (0.84–1.25)	0.82 (0.64–1.05)
	15–30	0.94 (0.70–1.25)	0.92 (0.73–1.16)	0.72 (0.55–0.96)
	>30	0.65 (0.42–1.01)	0.85 (0.57–1.28)	0.61 (0.46–0.80)

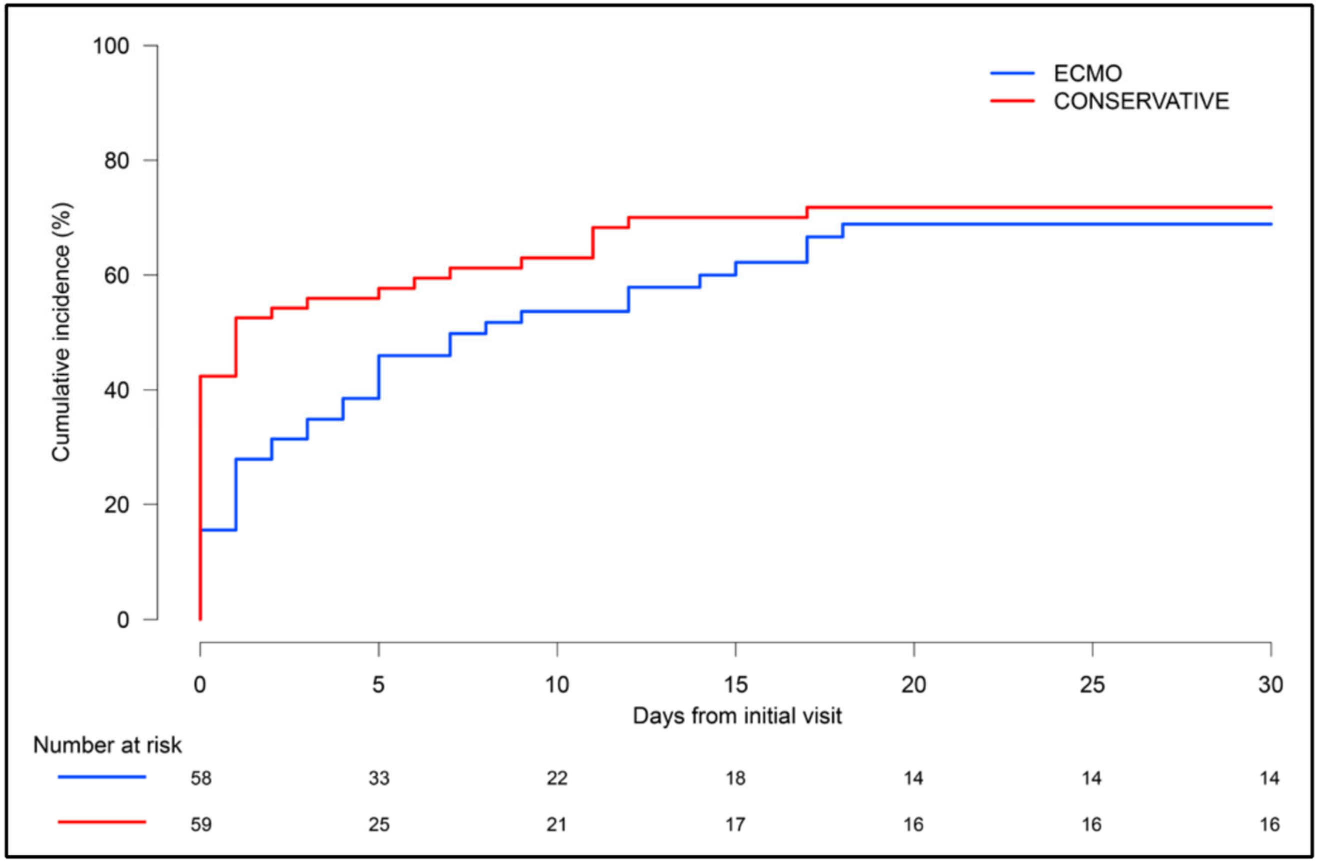


Flecher E et al. Arch Cardiovasc Dis 2019; 12:441-9

ORIGINAL RESEARCH ARTICLE

Extracorporeal Membrane Oxygenation in the Therapy of Cardiogenic Shock: Results of the ECMO-CS Randomized Clinical Trial

Ostadal P et al. Circulation 2023; 147:454–64



ORIGINAL ARTICLE

Extracorporeal Life Support in Infarct-Related Cardiogenic Shock

H. Thiele, U. Zeymer, I. Akin, M. Behnes, T. Rassaf, A.A. Mahabadi, R. Lehmann, I. Eitel, T. Graf, T. Seidler, A. Schuster, C. Skurk, D. Duerschmied, P. Clemmensen, M. Hennersdorf, S. Fichtlscherer, I. Voigt, M. Seyfarth, S. John, S. Ewen, A. Linke, E. Tigges, P. Nordbeck, L. Bruch, C. Jung, J. Franz, P. Lauten, T. Goslar, H.-J. Feistritzer, J. Pöss, E. Kirchhof, T. Ouarrak, S. Schneider, S. Desch, and A. Freund, for the ECLS-SHOCK Investigators*

Design

- Prospective, randomized multicentre study (Slovenia and Germany)
- AMI complicated by CS (SAP<90 mmHg and lactate>3) early revascularized (PCI or CABG)
- SCAI C to E requiring early use of ECLS after coronarography
- Crossover to ECLS was possible
- Primary outcome: all cause death at D30

Results

- Inclusion period 2019 to 2022 (44 centers) n=417
- Cross over from control to ECLS group for n=26

Characteristic	ECLS (N = 209)	Control (N = 208)
SCAI shock stage — no. (%)‡		
C	104 (49.8)	111 (53.4)
D	38 (18.2)	18 (8.7)
E	67 (32.1)	79 (38.0)
Catheterization access — no./total no. (%)		
Femoral	156/208 (75.0)	148/207 (71.5)
Radial	52/208 (25.0)	59/207 (28.5)
Type of revascularization — no./total no. (%)		
PCI	199/208 (95.7)	199/204 (97.5)
CABG	1/208 (0.5)	0/204
PCI with transfer to CABG	2/208 (1.0)	0/204
No revascularization	6/208 (2.9)	5/204 (2.5)
ECLS therapy — no. (%)	192 (91.9)	26 (12.5)
Initiation in catheterization laboratory		
Before revascularization	42/192 (21.9)	4/26 (15.4)
During revascularization	50/192 (26.0)	8/26 (30.8)
After revascularization	100/192 (52.1)	7/26 (26.9)
Median duration of ECLS therapy (IQR) — days	2.7 (1.5–4.8)	2.7 (2.2–3.8)
Resuscitation before randomization — no. (%)	162 (77.5)	162 (77.9)

Thiele H et al. New Engl J Med 2023; 389:1286-97

Characteristic	ECLS (N = 209)	Control (N = 208)
Target temperature management — no./total no. (%)	82/209 (39.2)	109/208 (52.4)
Invasive mechanical ventilation		
Patients — no./total no. (%)	183/203 (90.1)	177/202 (87.6)
Median duration (IQR) — days	7.0 (4.0–12.0)	5.0 (3.0–9.0)
Catecholamine requirement — no./total no. (%)	203/209 (97.1)	195/208 (93.8)
Norepinephrine	181/203 (89.2)	181/195 (92.8)
Epinephrine	63/203 (31.0)	69/195 (35.4)
Dobutamine	88/203 (43.3)	59/195 (30.3)
Dopamine	1/203 (0.5)	0/195
Sepsis within 30 days after randomization — no. (%)	21 (10.0)	21 (10.1)
Intraaortic balloon pump	—	1/28 (3.6)
Impella 2.5	—	1/28 (3.6)
Impella CP	—	24/28 (85.7)
Impella 5.0	—	1/28 (3.6)
Impella 5.5	—	1/28 (3.6)
Permanent left ventricular assist device — no./total no. (%)	1 (0.5)	1 (0.5)

Thiele H et al. New Engl J Med 2023; 389:1286-97

	ECLS (n=209)	Control (n=208)
All-cause mortality at 30 days; n/total (%)	100/209 (47.8)	102/208 (49.0)
Causes of death at 30 days		
Refractory cardiogenic shock¸ n/total (%)	51/100 (51.0)	56/102 (54.9)
Sudden cardiac death; n/total (%)	7/100 (7.0)	5/102 (4.9)
Recurrent myocardial infarction; n/total (%)	2/100 (2.0)	2/102 (2.0)
Mechanical complication of infarction; n/total (%)	1/100 (1.0)	1/102 (1.0)
Bleeding; n/total (%)	4/100 (4.0)	0/102
Brain injury; n/total (%)	26/100 (26.0)	27/102 (26.5)
Sepsis; n/total (%)	4/100 (4.0)	10/102 (9.8)
Unknown cause; n/total (%)	0/100	1/102 (1.0)
Other cause; n/total (%)	5/100 (5.0)	0/102

Thiele H et al. New Engl J Med 2023; 389:1286-97

	ECLS (n=209)	Control (n=208)
Active left ventricular unloading during ECLS therapy;	11/190 (5.8)	6/19 (31.6)
Type of unloading; n/total (%)		
Additional insertion of IABP	2/11 (18.2)	2/6 (33.3)
Additional insertion of percutaneous left ventricular assist device (Impella®)	9/11 (81.8)	4/6 (66.7)
Atrial septostomy with drainage of the left atrium by a pigtail catheter connected to the venous cannula of the ECLS	0/11	0/6
Pulmonary artery drainage with connection to the venous cannula of the ECLS	0/11	0/6
Transaortic venting by pigtail catheter insertion into the left ventricle and connection to the venous cannula of the ECLS	0/11	0/6

Thiele H et al. New Engl J Med 2023; 389:1286-97

2021 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure

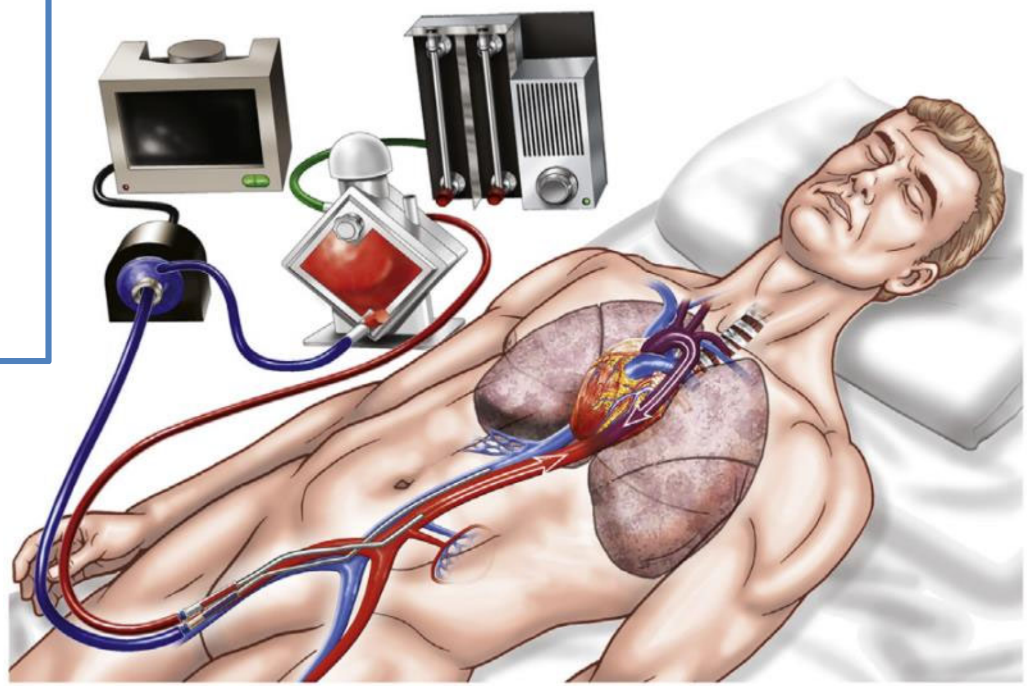
Recommendations	Class[a]	Level[b]
Short-term MCS should be considered in patients with cardiogenic shock as a BTR, BTD, BTB. Further indications include treatment of the cause of cardiogenic shock or long-term MCS or transplantation.	IIa	C
IABP may be considered in patients with cardiogenic shock as a BTR, BTD, BTB, including treatment of the cause of cardiogenic shock (i.e. mechanical complication of acute MI) or long-term MCS or transplantation.[450]	IIb	C
IABP is not routinely recommended in post-MI cardiogenic shock.[500–502]	III	B

McDonagh TA et al. Eur Heart J 2021; 42:3599-3726

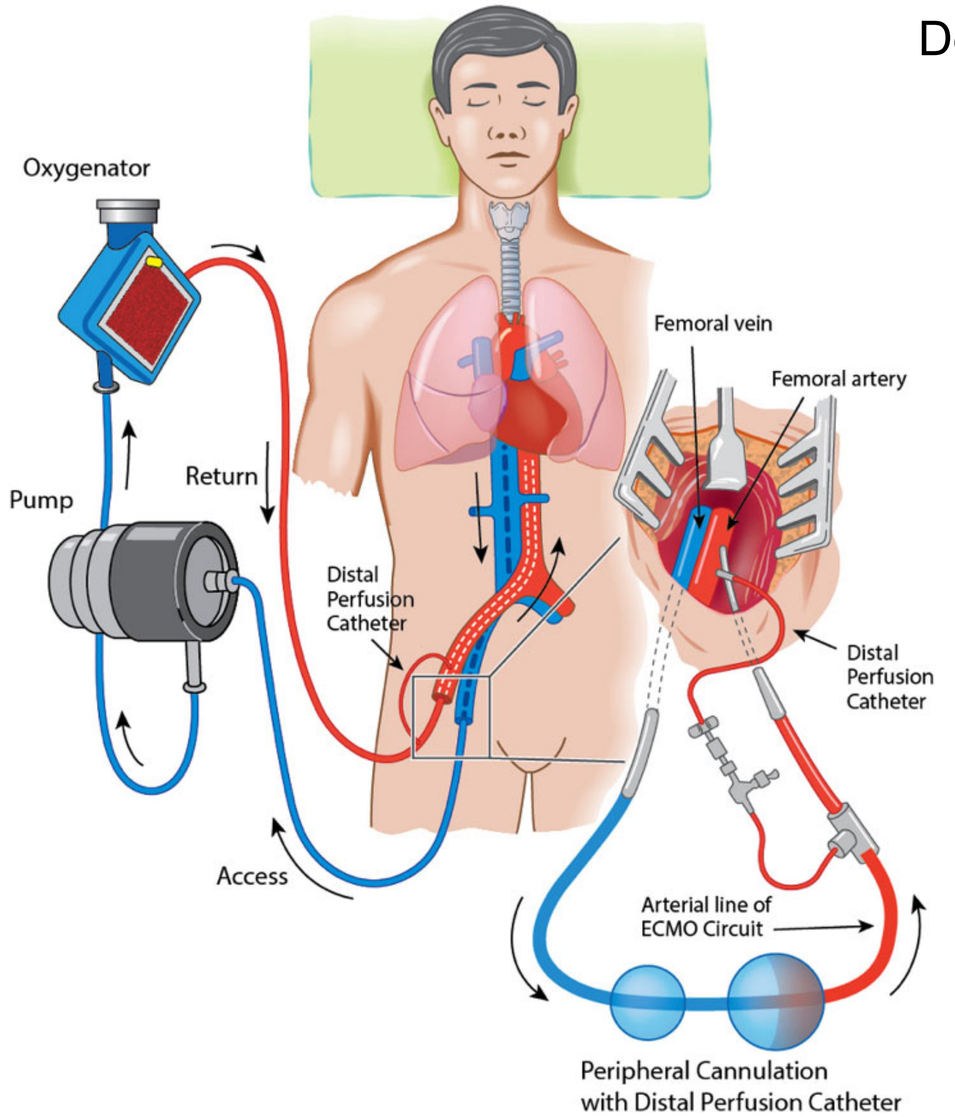
Extracorporeal Membrane Oxygenation in Cardiopulmonary Disease in Adults

Abrams D et al. J Am Coll Cardiol 2014; 63:2769-78

- Rescue therapy (no first line)
- Refractory cardiogenic shock
- Respiratory and/or cardiac supply
- Ensure "optimal" peripheral organs perfusion
- Cardiac function recovery (+++)
- Left ventricular loading conditions
- Coronary perfusion and myocardial working
- No influence on myocardial recovery (+++)



Dennis M JAHA 2020



Several advantages…

- Respiratory and/or cardiac supply
- Biventricular supply (including right ventricular dysfunction)
- Restore peripheral end-organ perfusion by providing high flow (up to 7 $L.min^{-1}$)
- Rapid insertion (cardiac arrest…)
- Peripheral canulation (femoral access)
- Cheap and easily reliable
- Biventricular supply
- Mobile

INDICATIONS

- Post-cardiotomy (conventional or heart transplantation)
  - Immediately when the CPB weaning appears to be impossible
  - Secondary in presence of refractory Low cardiac output syndromue

Bakhtiari F et al. J Thorac Cardiovasc Surg 2008;135:382-8

Rastan AJ et al. J Thorac Cardiovasc Sug 2010; 139:302-11

- Medical indications
  - Myocardial infarction Infarctus du myocarde
  - Dilated cardiomyopathy
  - Acute Myocarditis fulminante
  - CIntoxication médicamenteuse cardio-toxiques
  - Pulmonary Cœur pulmonaire aigue (embolie pulmonaire, embolie amniotique)
  - Accidental hypothermia (noyade)

Marasco SF et al. Heart, Lung and Circulation 2008; 17:S41-7

Baud F et al. Crit Care 2007;11:207

Outcomes and long-term quality-of-life of patients supported by extracorporeal membrane oxygenation for refractory cardiogenic shock*

Crit Care Med 2008; 36:1404–1411

Alain Combes, MD, PhD; Pascal Leprince, MD, PhD; Charles-Edouard Luyt, MD, PhD; Nicolas Bonnet, MD; Jean-Louis Trouillet, MD; Philippe Léger, MD; Alain Pavie, MD; Jean Chastre, MD

Table 4. Multivariable logistic-regression analysis: early independent predictors of intensive care unit death

Factor	OR (95% CI)	*p*
Female sex	3.89 (1.06–14.22)	.04
Myocarditis	0.13 (0.02–0.78)	.03
ECMO under CPR	20.68 (1.09–392.03)	.04
Prothrombin activity <50%	3.93 (1.11–13.85)	.03
24-hr urine output <500 mL	6.52 (1.87–22.74)	.003

OR, odds ratio; CI, confidence interval; CPR, cardiopulmonary resuscitation; ECMO, extracorporeal membrane oxygenation.

Extracorporeal Life Support Organization Registry Report 2012

Matthew L. Paden,* Steven A. Conrad,† Peter T. Rycus,‡ and Ravi R. Thiagarajan§, on Behalf of the ELSO Registry

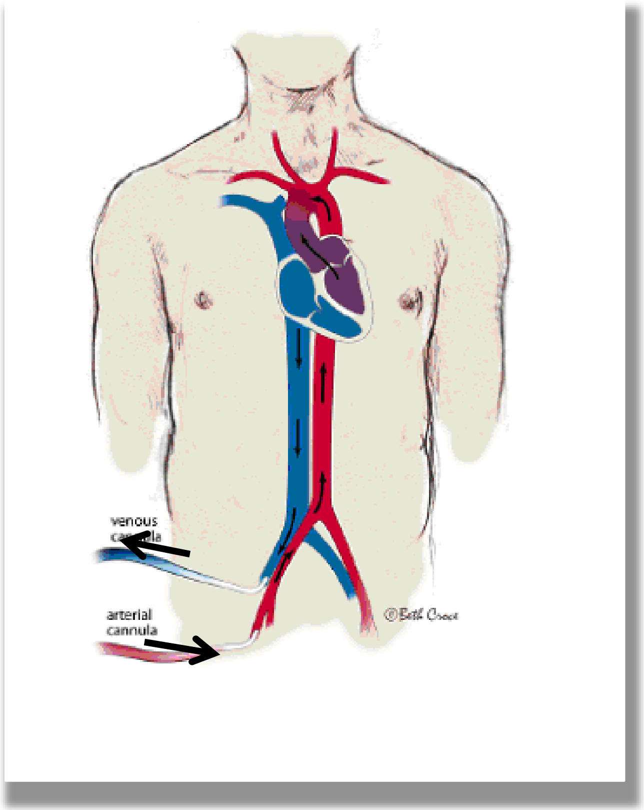
ASAIO Journal 2013;59:202–210.

Table 7. Mechanical and Patient-related Complications for Cardiac ECLS

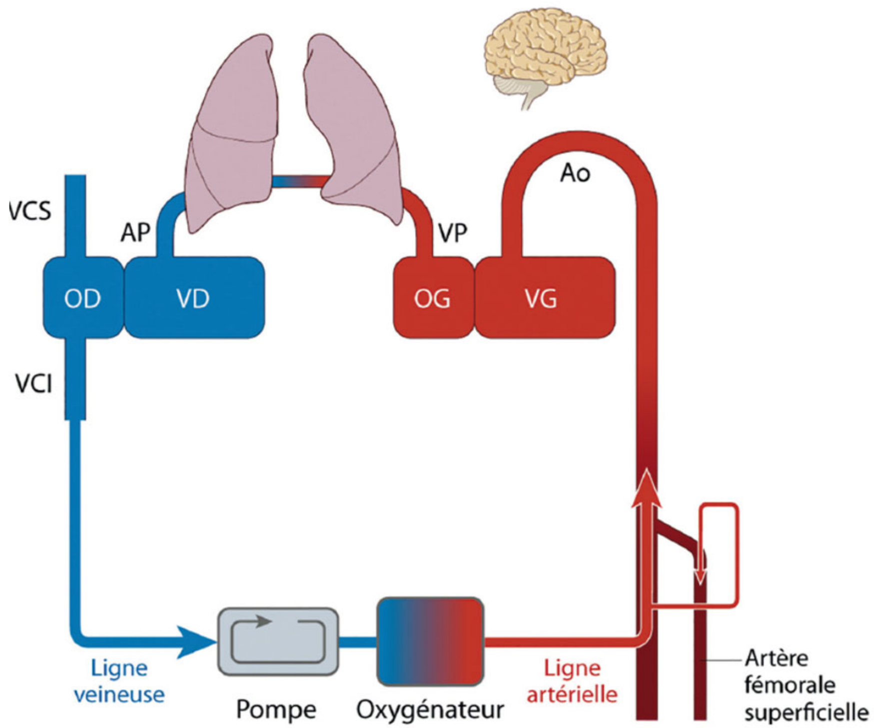
	0–30 Days	31 Days and <1 Year	1 Year and <16 Years	>16 Years
Mechanical				
Oxygenator failure	7.4 (24)	8.1 (29)	9 (43)	15.1 (36)
Tubing rupture	0.3 (25)	0.6 (50)	0.7 (47)	0.2 (0)
Pump malfunction	1.6 (29)	2.1 (35)	2.1 (50)	0.7 (28)
Cannula problems	6.1 (33)	5.6 (38)	6.3 (42)	4.4 (27)
Patient-related				
ICH	11.3 (23)	5.7 (29)	3.8 (21)	1.7 (7)
Cannula site bleeding	10.4 (30)	11.9 (40)	17.6 (52)	20.9 (39)
Surgical site bleeding	31.7 (30)	33 (39)	28.8 (48)	25.5 (34)
Cardiac tamponade	6.1 (27)	5.1 (38)	5.1 (50)	5.7 (27)
Clinical seizures	7.3 (29)	9 (26)	4.5 (21)	2.1 (15)

Table entries are reported in percentage (% survival).
ECLS, extracorporeal life support; ICH, intracranial hemorrhage.

Peripheral veno-arterial ECLS

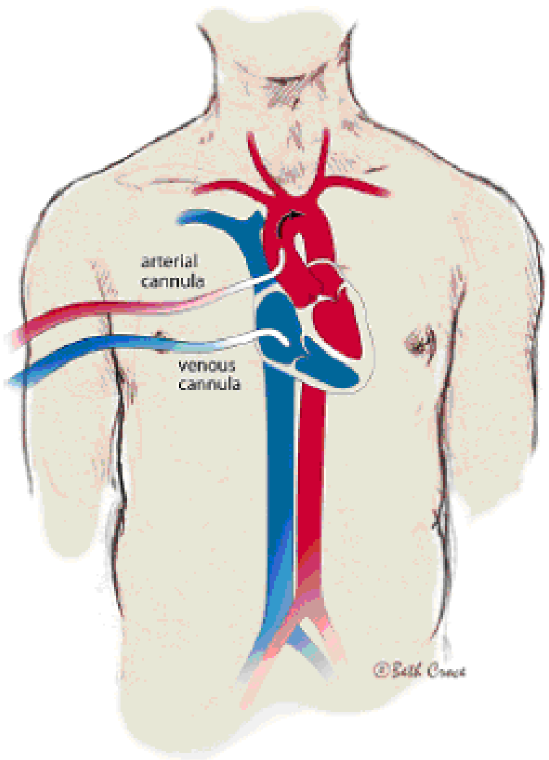


Retrograde aortic flow in total competition with native stream



Calderon J et al. Traité Anesthésie-Réanimation O. Fourcade (4ème Edition)

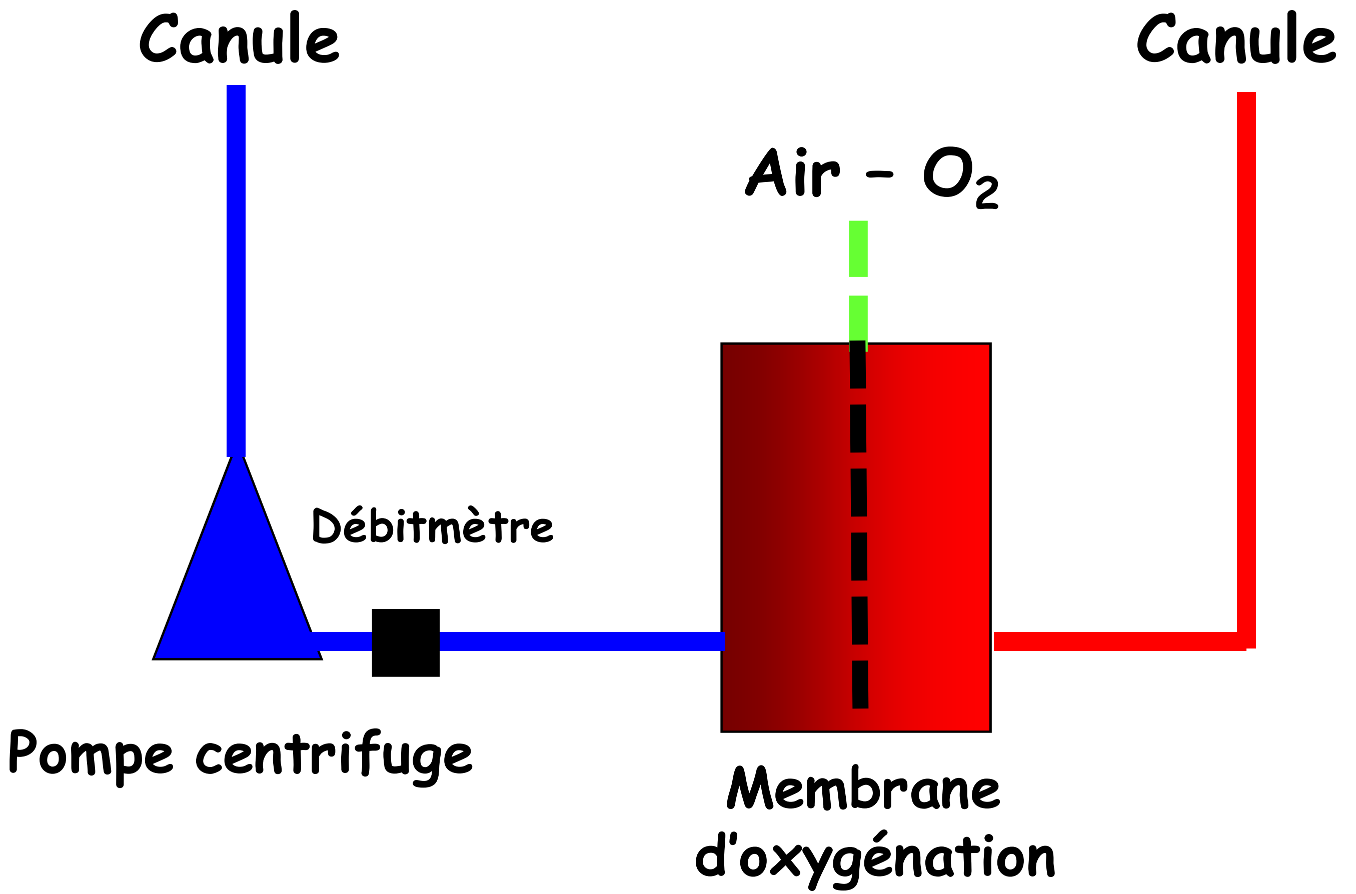
Central veno-arterial ECLS

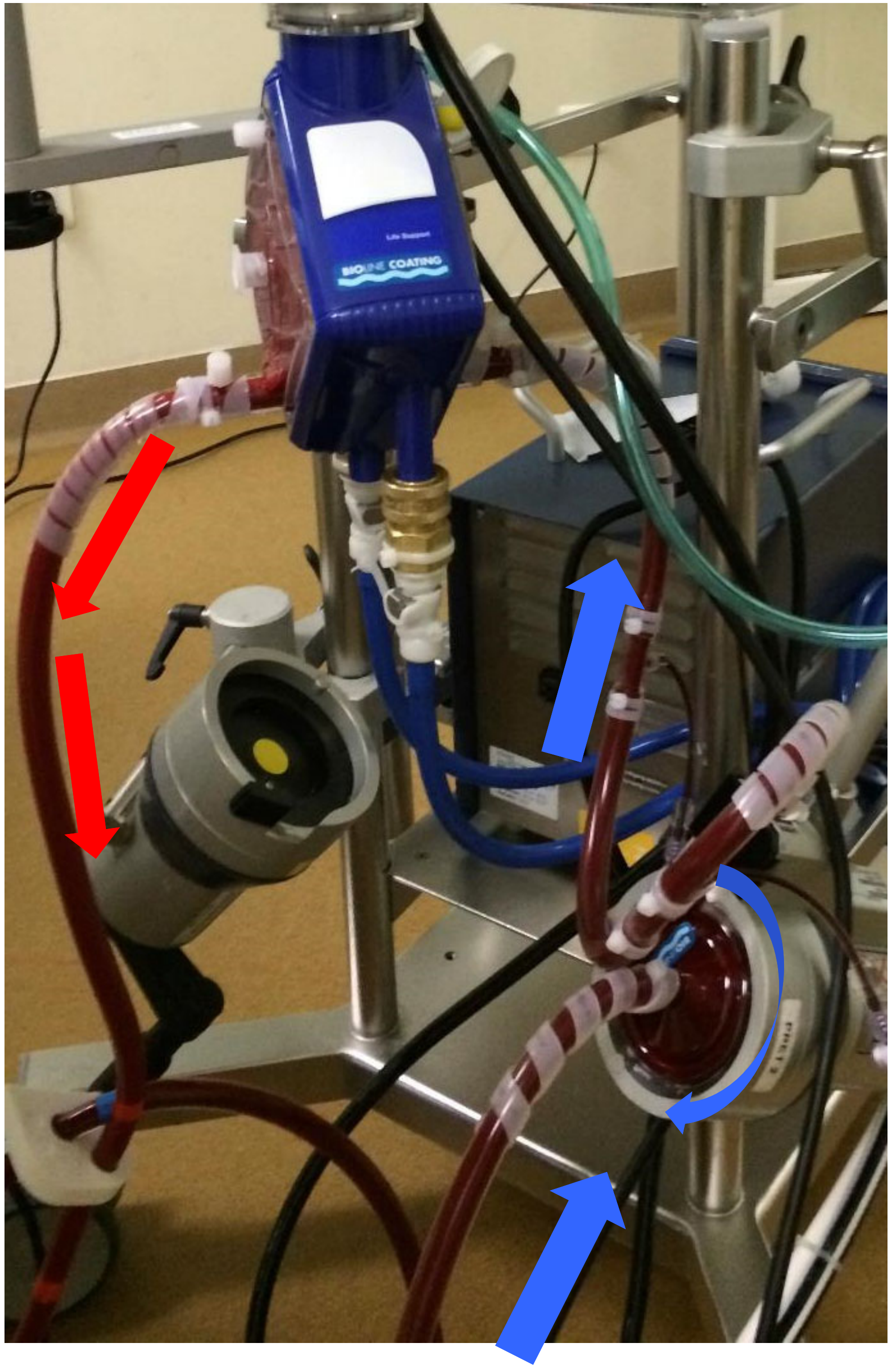


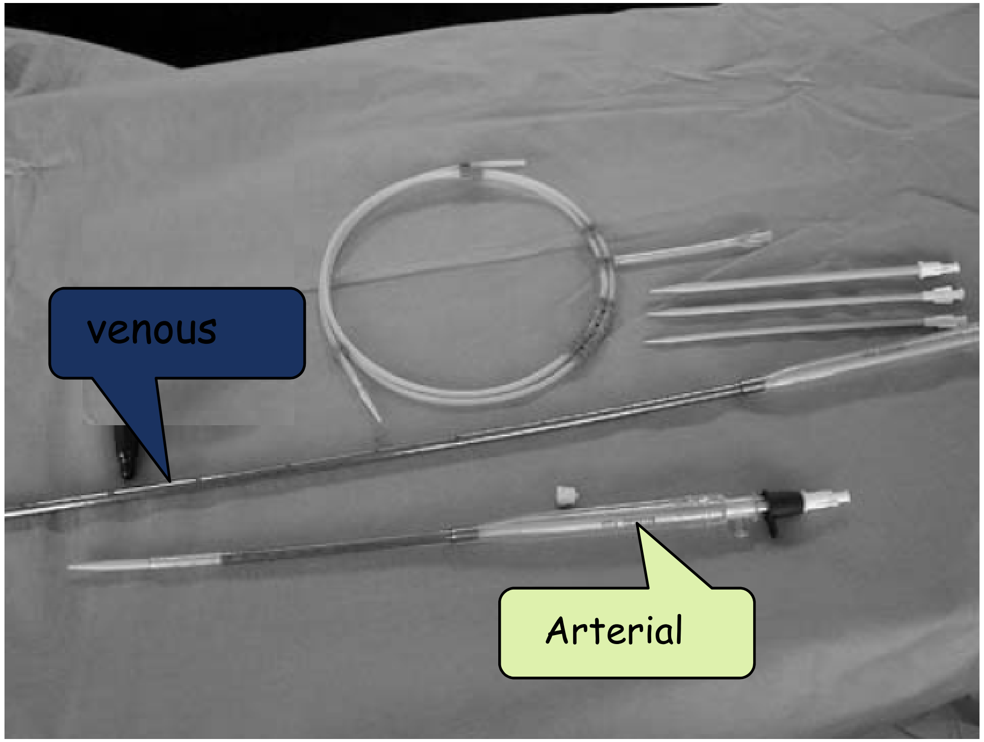
Central ECLS
(anterograde flow)

Marasco SF et al. Heart lung and Circulation 2008

PRINCIPES DE L'ECLS




Life Support
BIOLINE COATING



Percutaneous at the bedside (echography guided +++) or surgical way

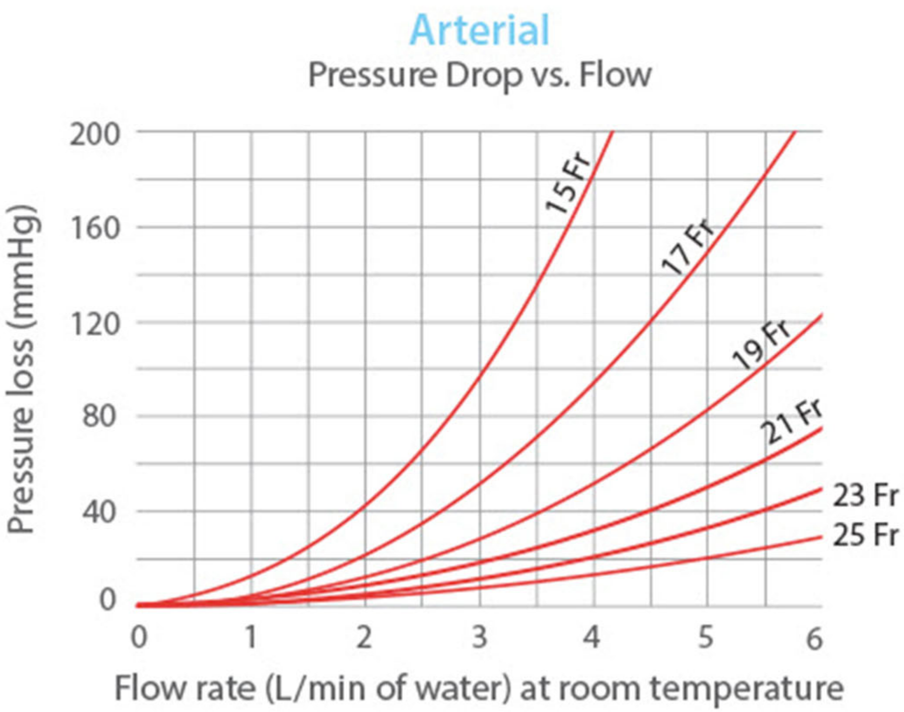
Preferentially removed in operating room ++++

Informations de commande des canules HLS artérielles

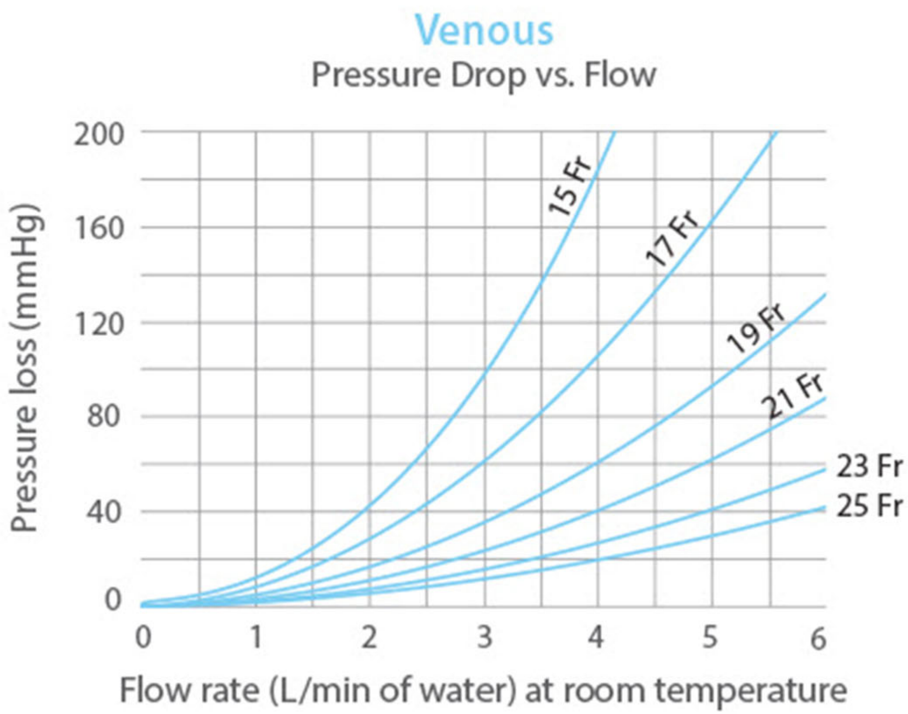
Type	Diamètre extérieur	Longueur d'insertion	Orifices latéraux	Longueur de perforation	Connection	Revêtement Bioline
PAS 1315	13 Fr (4,3 mm)	15 cm	2	1 cm	3/8" LL	BE-PAS 1315
PAS 1515	15 Fr (5,0 mm)	15 cm	2	1 cm	3/8" LL	BE-PAS 1515
PAS 1715	17 Fr (5,7 mm)	15 cm	2	1 cm	3/8" LL	BE-PAS 1715
PAS 1915	19 Fr (6,3 mm)	15 cm	2	1 cm	3/8" LL	BE-PAS 1915
PAS 2115	21 Fr (7,0 mm)	15 cm	2	1 cm	3/8" LL	BE-PAS 2115
PAS 2315	23 Fr (7,7 mm)	15 cm	2	1 cm	3/8" LL	BE-PAS 2315
PAL 1523	15 Fr (5,0 mm)	23 cm	2	1 cm	3/8" LL	BE-PAL 1523
PAL 1723	17 Fr (5,7 mm)	23 cm	2	1 cm	3/8" LL	BE-PAL 1723
PAL 1923	19 Fr (6,3 mm)	23 cm	2	1 cm	3/8" LL	BE-PAL 1923
PAL 2123	21 Fr (7,0 mm)	23 cm	2	1 cm	3/8" LL	BE-PAL 2123
PAL 2323	23 Fr (7,7 mm)	23 cm	2	1 cm	3/8" LL	BE-PAL 2323

Informations de commande des canules HLS veineuses

Type	Diamètre extérieur	Longueur d'insertion	Orifices latéraux	Longueur de perforation	Connection	Revêtement Bioline
PVS 1938	19 Fr (6,3 mm)	38 cm	12	10 cm	3/8"	BE-PVS 1938
PVS 2138	21 Fr (7,0 mm)	38 cm	12	10 cm	3/8"	BE-PVS 2138
PVS 2338	23 Fr (7,7 mm)	38 cm	16	10 cm	3/8"	BE-PVS 2338
PVS 2538	25 Fr (8,3 mm)	38 cm	20	10 cm	3/8"	BE-PVS 2538
PVL 2155	21 Fr (7,0 mm)	55 cm	20	20 cm	3/8"	BE-PVL 2155
PVL 2355	23 Fr (7,7 mm)	55 cm	20	20 cm	3/8"	BE-PVL 2355
PVL 2555	25 Fr (8,3 mm)	55 cm	24	20 cm	3/8"	BE-PVL 2555
PVL 2955	29 Fr (9,7 mm)	55 cm	32	20 cm	3/8"	BE-PVL 2955



Arterial
Pressure Drop vs. Flow
Pressure loss (mmHg)
200
160
120
80
40
0
0
1
2
3
4
5
6
Flow rate (L/min of water) at room temperature
15 Fr
17 Fr
19 Fr
21 Fr
23 Fr
25 Fr



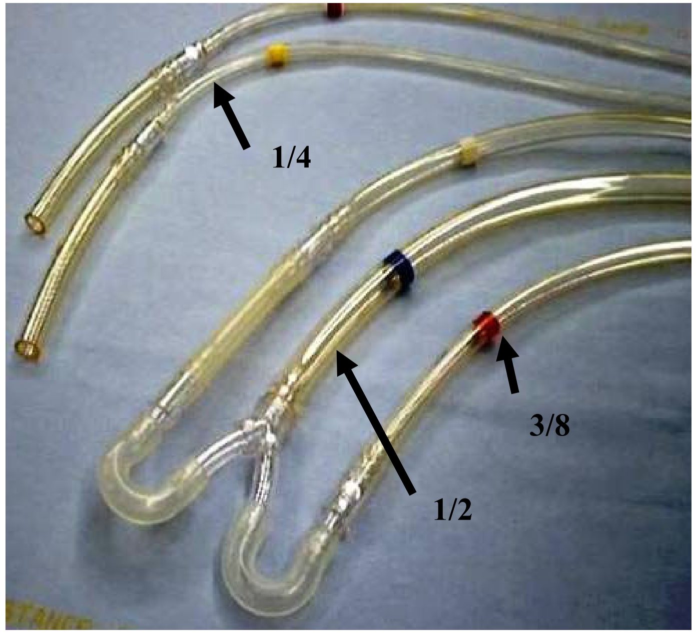
Venous
Pressure Drop vs. Flow
Pressure loss (mmHg)
200
160
120
80
40
0
0
1
2
3
4
5
6
Flow rate (L/min of water) at room temperature
15 Fr
17 Fr
19 Fr
21 Fr
23 Fr
25 Fr

Lignes de connexion

Connexion des divers éléments de l'ECMO

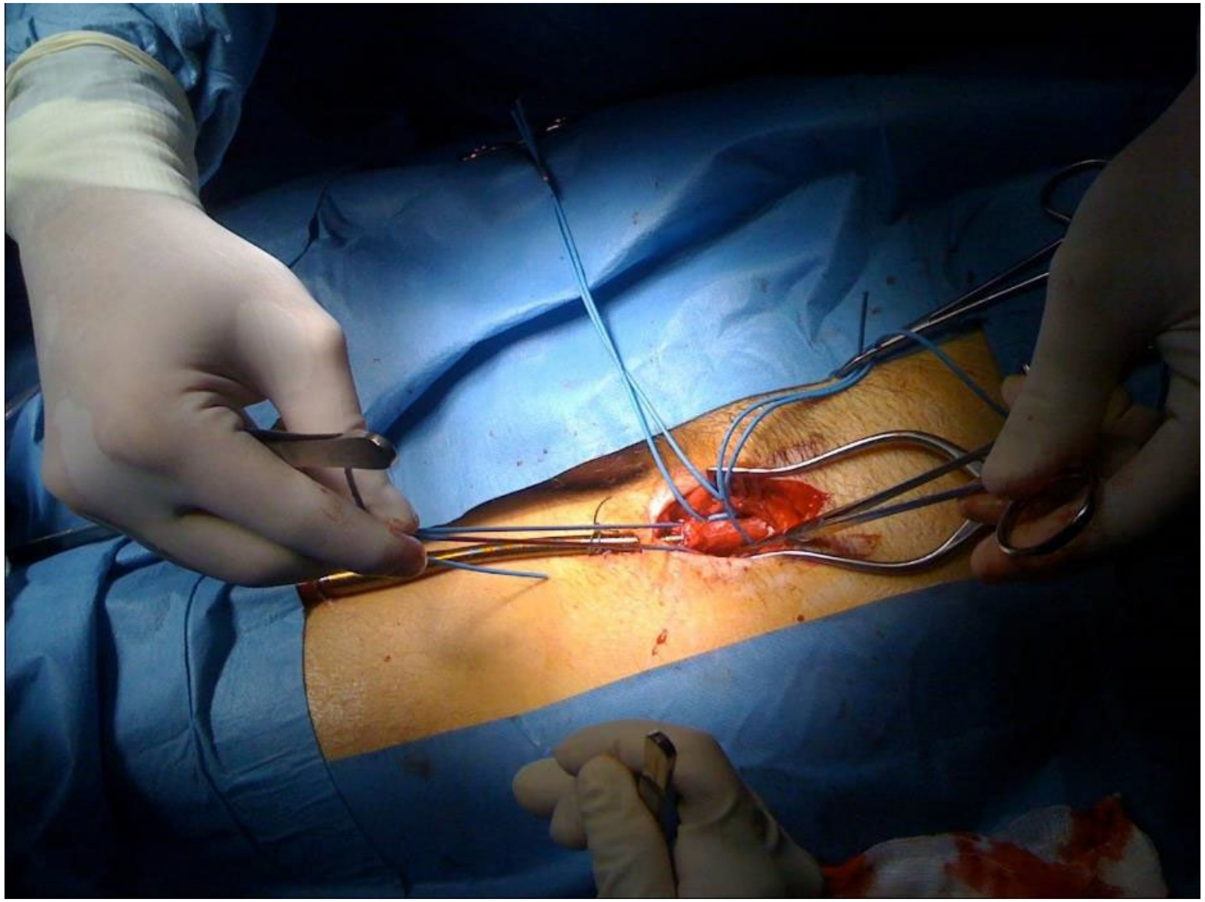
Unité de mesure : inch ou pouce (25, 4 mm)

- 1/2 (≃ 12 mm) (CEC)
- **3/8 (≃ 10 mm) (ECMO +++)**
- 1/4 (≃ 6,4 mm) Bonne hémocompatibilité



Bonne souplesse

Surgical access



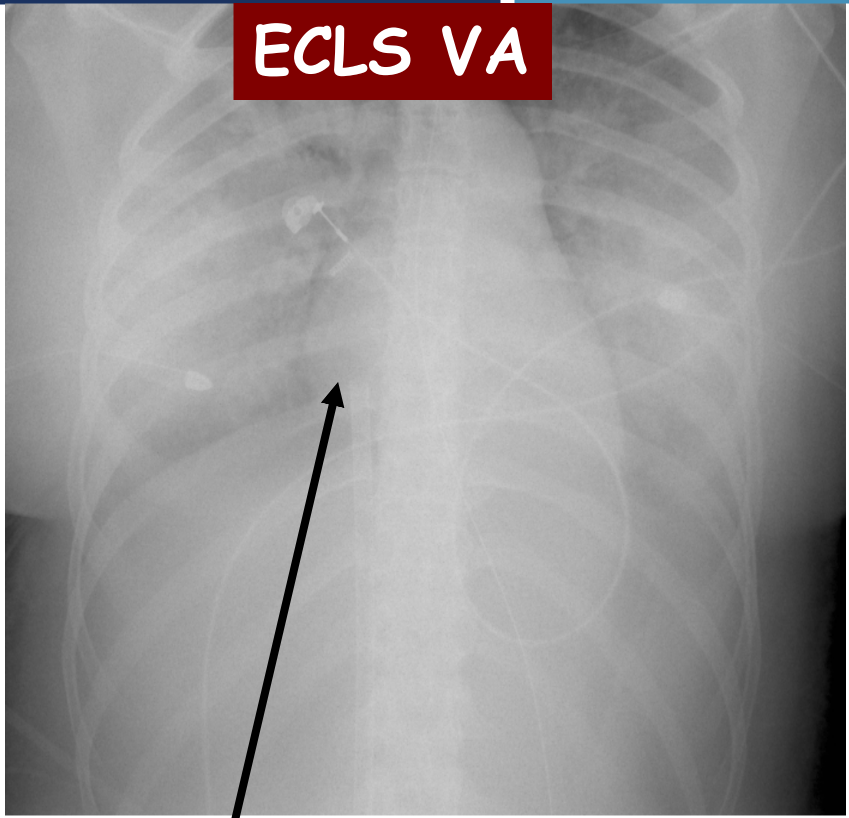
Percutaneous versus surgical femoro-femoral veno-arterial ECMO: a propensity score matched study

Table 2 VA-ECMO-related outcomes in the propensity matched population

	Surgical group *n* = 266 (%)	Percutaneous group *n* = 266 (%)	*p* value
30-Day overall survival	150 (56.3)	170 (63.8)	0.034
Cannulation site infection	74 (27.8)	44 (16.5)	0.001
Infection requiring surgical revision[a]	40 (15.0)	14 (5.3)	< 0.001
Vascular complications at cannulation[b]	7 (2.6)	10 (3.8)	0.663
Limb ischemia	33 (12.4)	23 (8.6)	0.347
Cannula relocation or removal	25 (9.4)	15 (5.6)	0.258
Limb fasciotomy	10 (3.8)	6 (2.3)	0.310
Amputation	2 (0.8)	2 (0.8)	1.000
Vascular complications after cannula removal	9 (3.4)	39 (14.7)	< 0.001
Surgical revision for persistent bleeding early after decannulation	4 (1.5)	25 (9.4)	< 0.001
Surgical revision in the days after decannulation[c]	5 (1.9)	14 (5.3)	0.035
Lower limb sensory-motor deficit	6 (2.3)	7 (2.6)	0.779

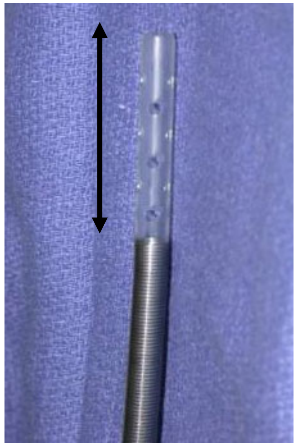
Danial P et al. Intensive Care Med 2018; 44:2153-61

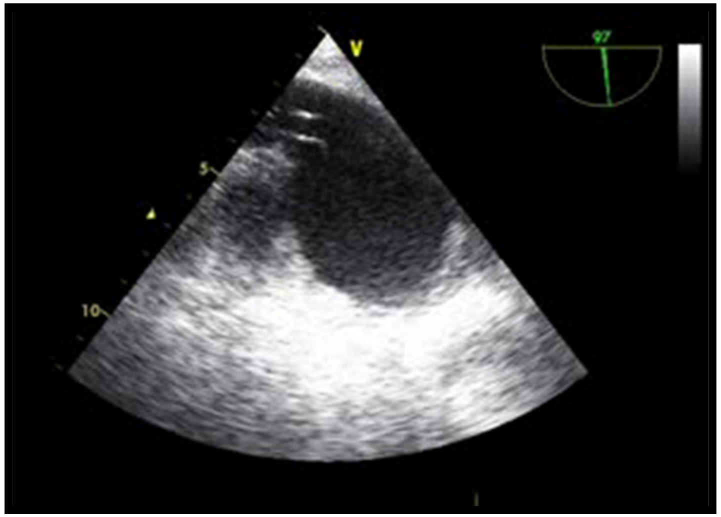
ECLS VA



Veine cave inférieure (drainage)

Extrémité non radio-opaque (2-3 cm)

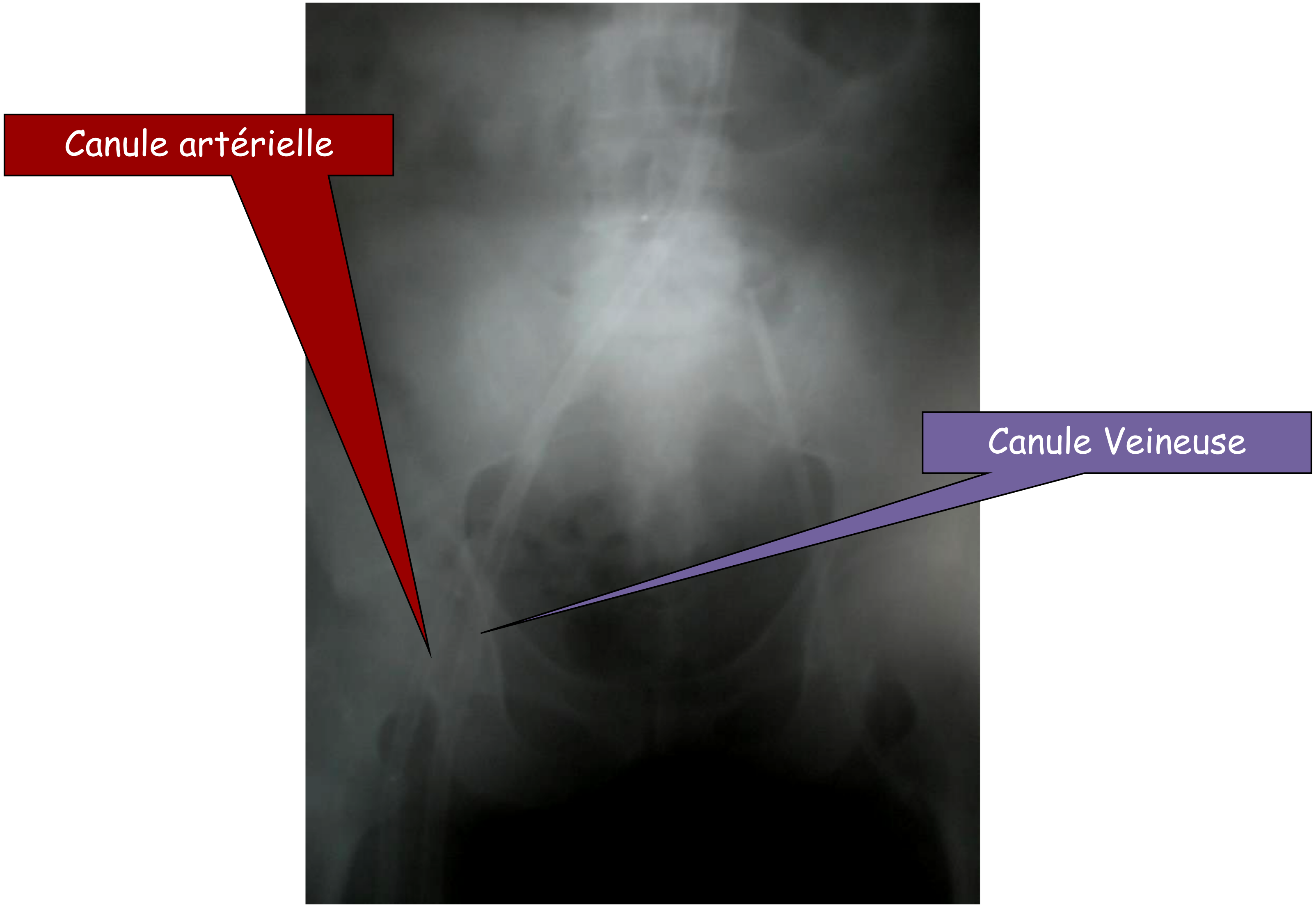




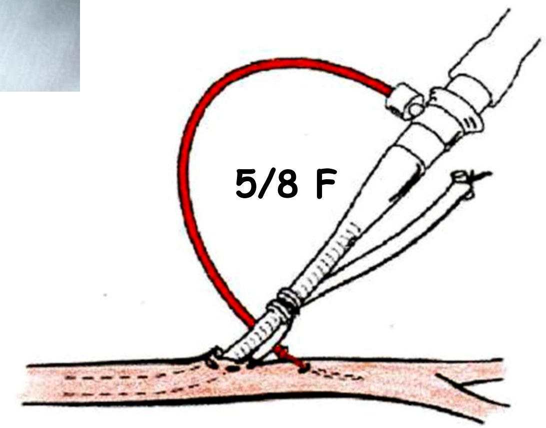
Mise en place sous ETO ou contrôle rapide!

ME bicaval

Peripheral venous-arterial ECLS



Solidement fixée
Contrôlée à l'angio
Fémorale superficielle



Reperfusion line
(systematically inserted)

Peripheral VA ECLS

This reperfusion line is alimented by arterial canula (risk of ischemia when ECLS flow is decrased)

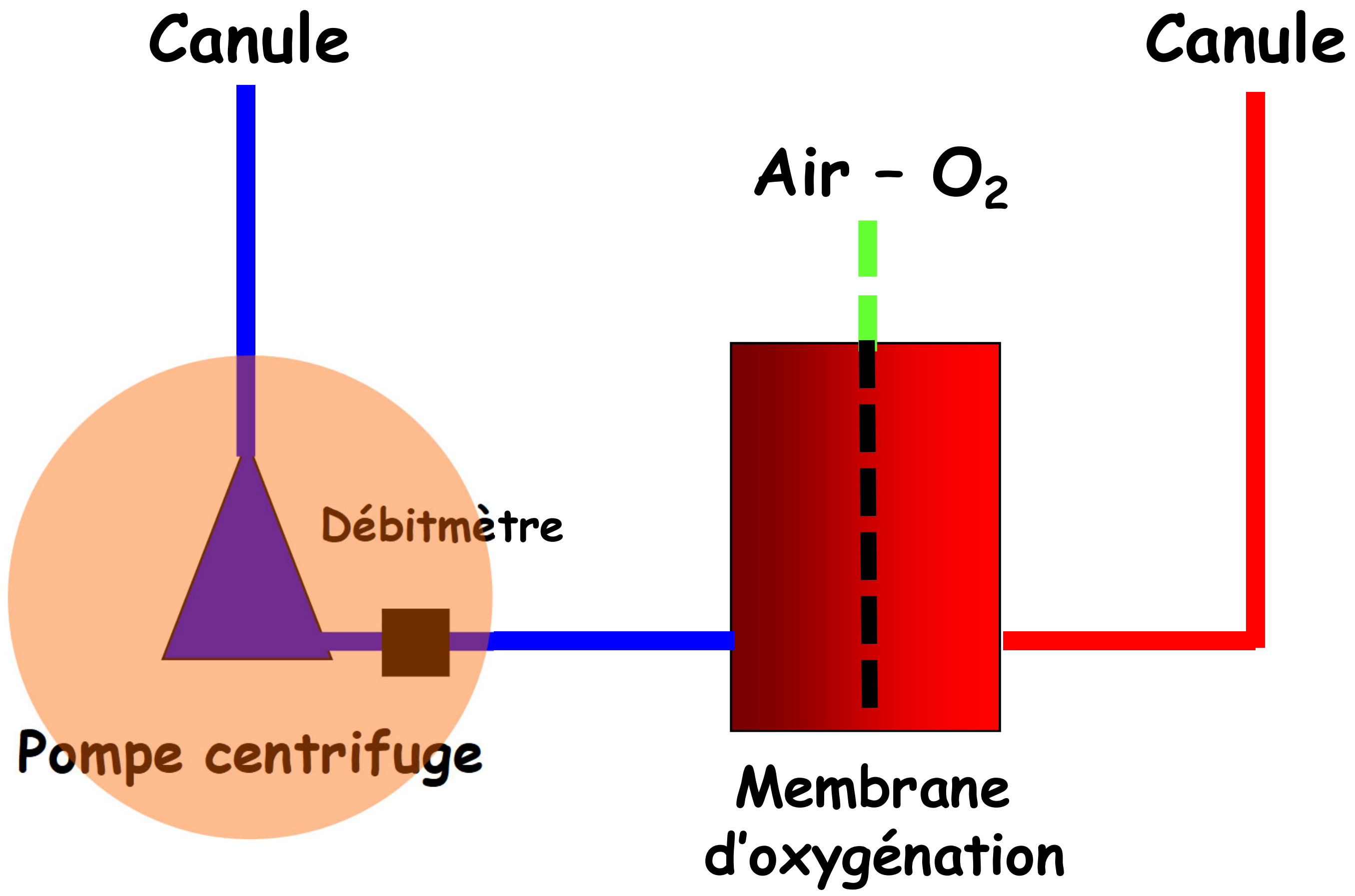
Usefulness of NIRS (STO2) for detecting early lower limb ischemia

Schachner T et al. Eur J Cardiothorac Surg 2008; 34:1253-4

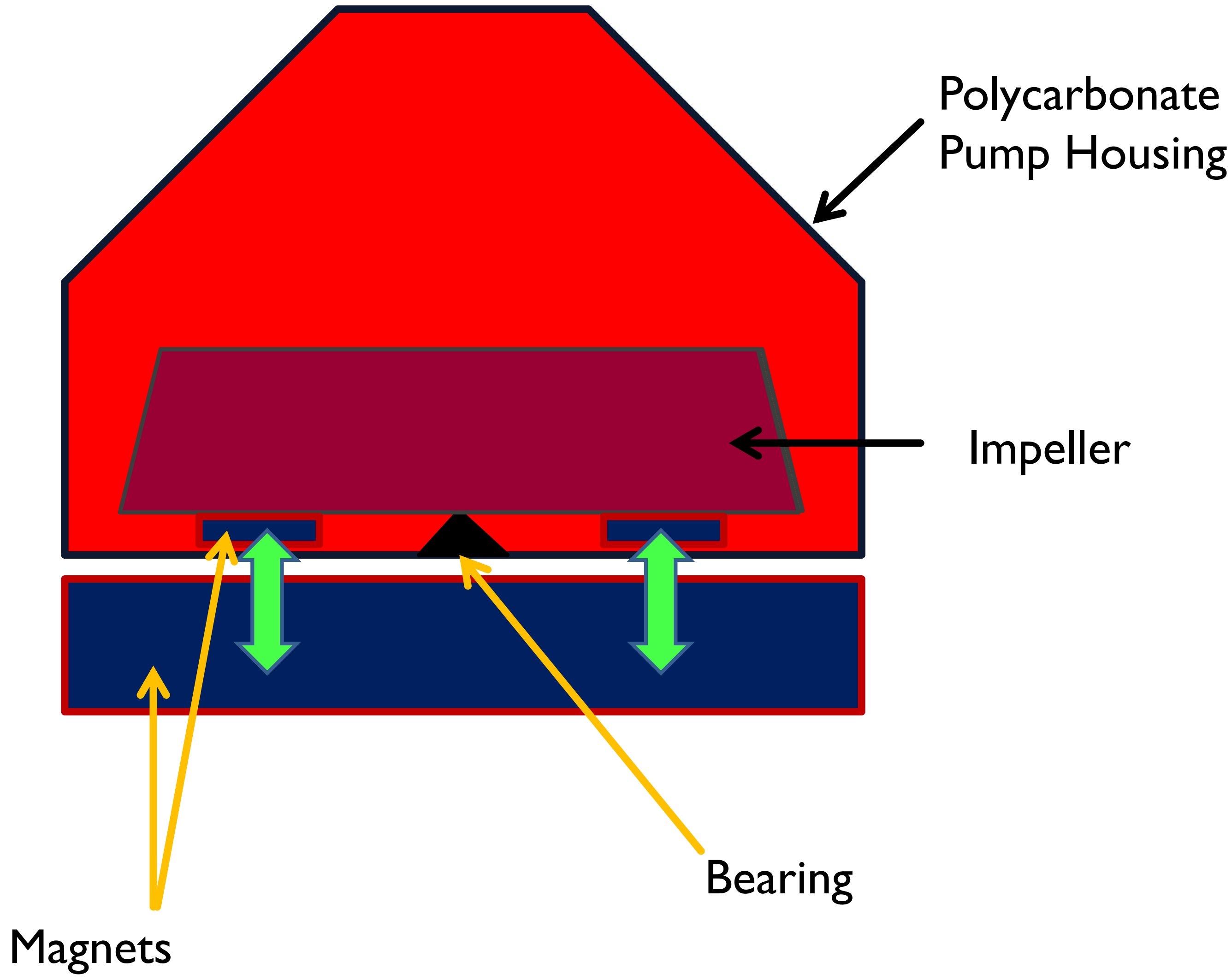
DÉTECTION ISCHÉMIE MI = CLINIQUE ET NIRS +++

Saturométrie Transcutanée

ROTATIVE CENTRIFUGAL PUMP



Magnetically Coupled Pumps



CENTRIFUGAL ROTATIVE PUMP

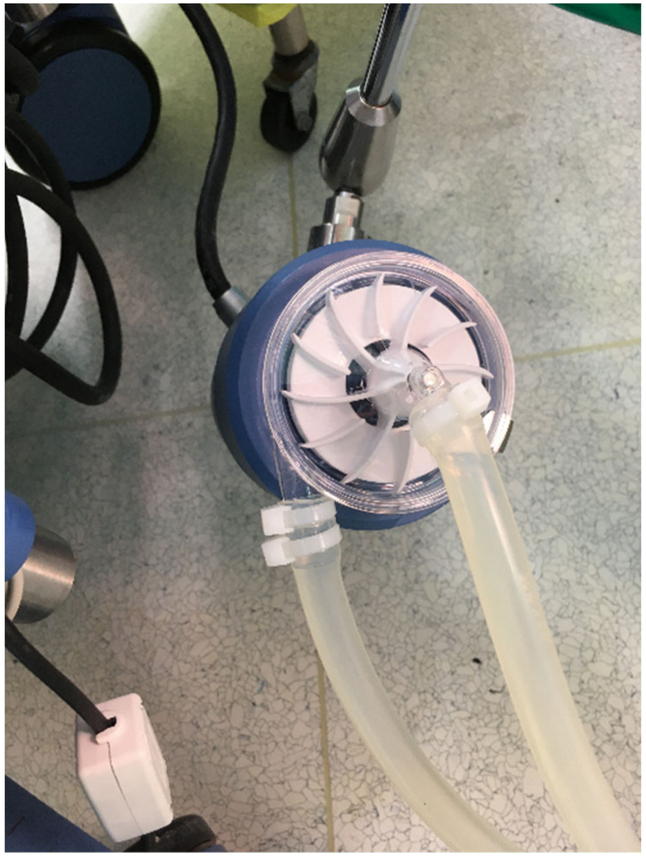
- Non-occlusive
- Flow depends:
  - Gradient pressure generated by impeller (speed of rotation)
  - Size of canula, length and diameter of tubing
  - Volemia of patient (pre-load of the pump)
  - Systemic vascular resistances (after-load of the pump)
- Preload and after-load dependence +++
- Measurement of CO is mandatory (electromagnetic or ultrasonic method)
- Backflow phenomenon possible when speed of pump <1500 TRM **Please clamp the tubing +++**

Rotaflow, MAQUET 32 ml

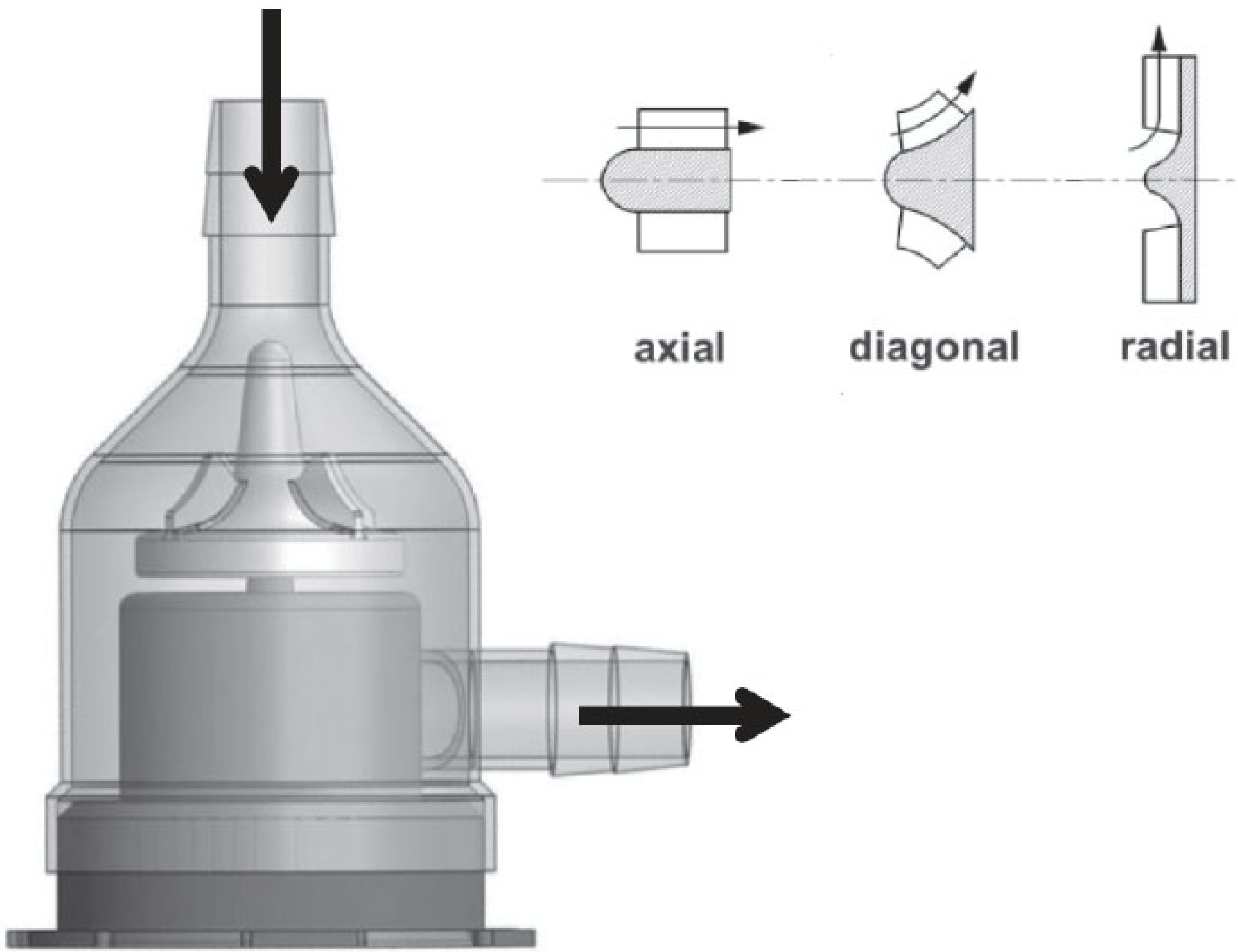
Biomedicus, Medtronic®
(cones superposés)

Deltastream pump, MEDOS (16 ml)

Revolution, Sorin ®
(avec aubes vitesse moindre)




BIOLINE COATING


axial
diagonal
radial

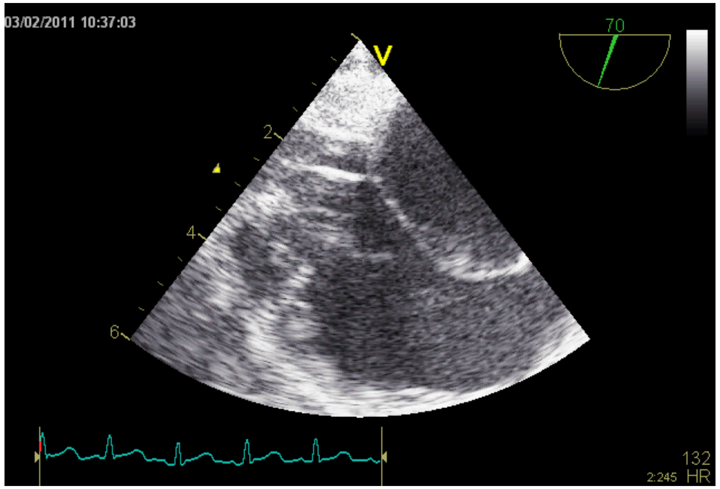
Biomedicus 560, Medtronic

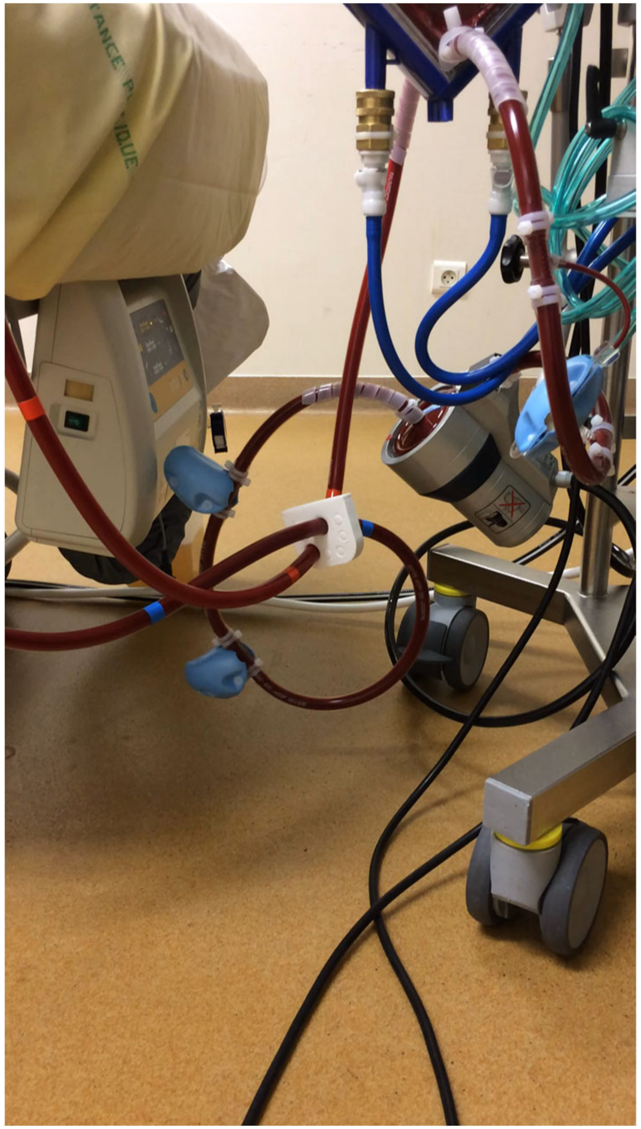
Biomedicus 550, Medtronic

Maquet Cardiopulmonary

Stockert centrifugal pump console

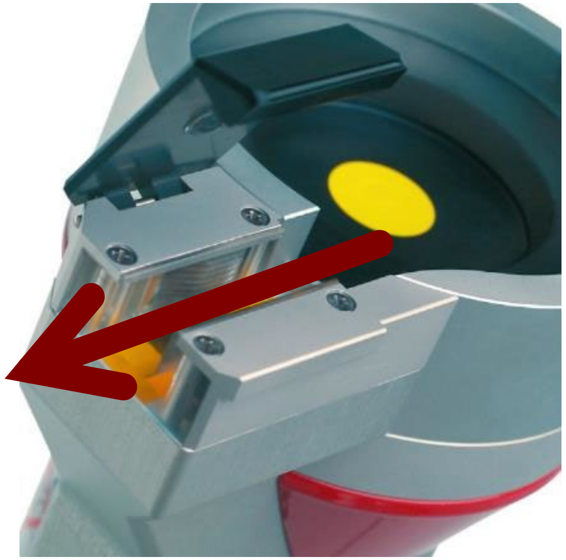
Approuvée pour une utilisation de 7 jours, mode pulsatile

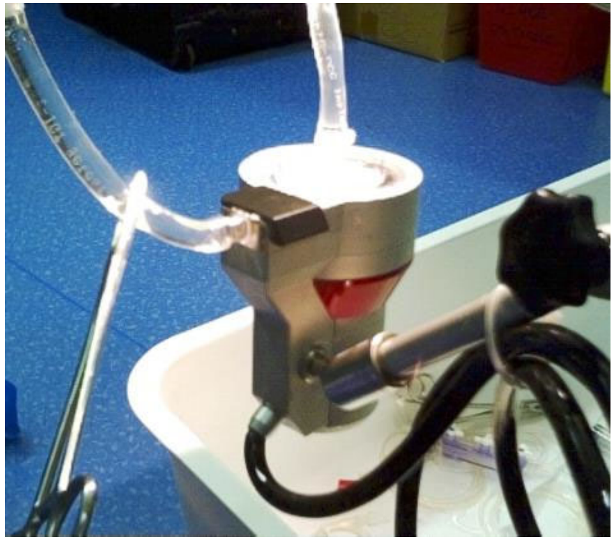




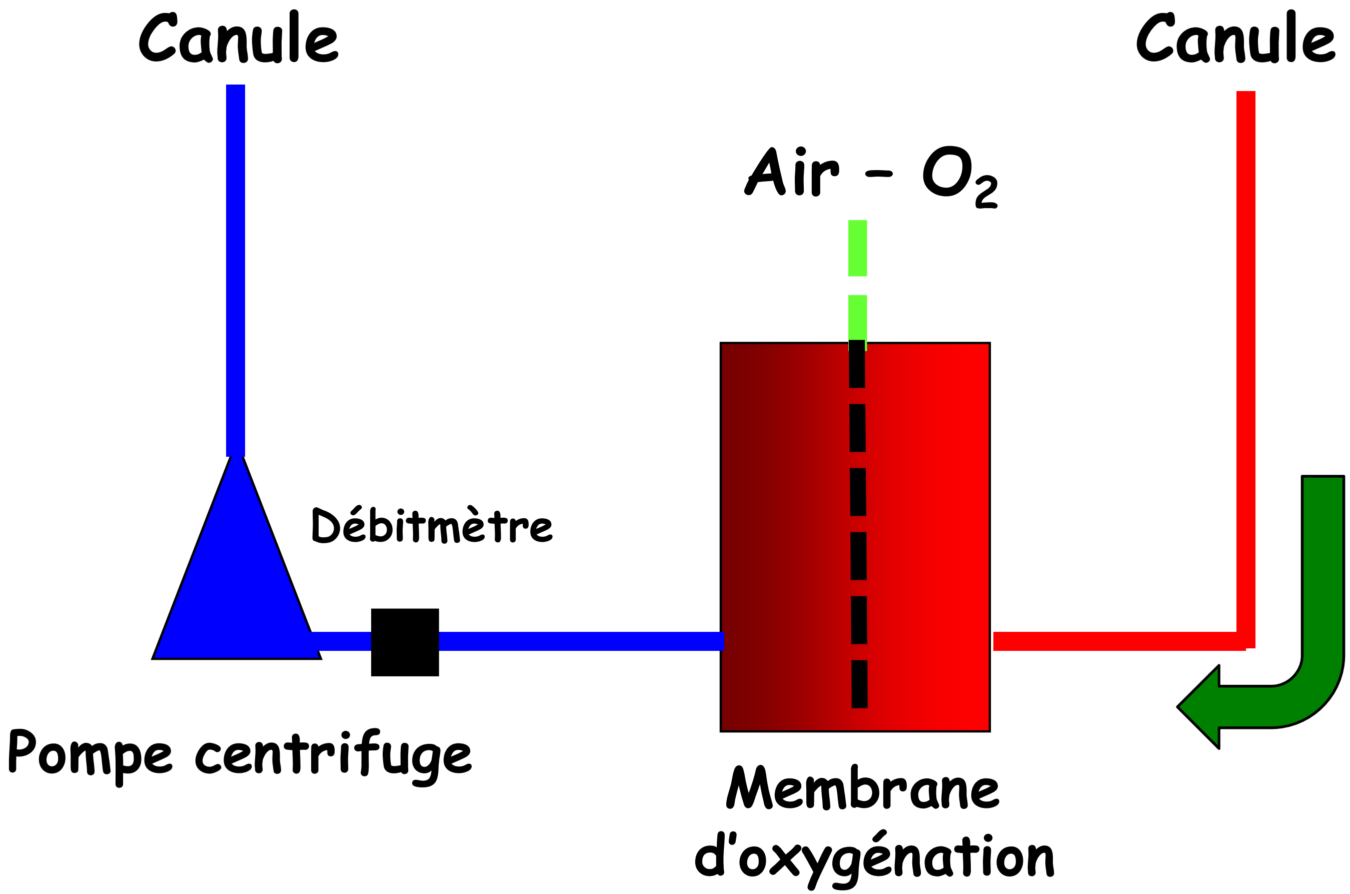
Decrease pump speed (and thus flow), fluid loading if possible or gently pull back canula

MESURE IMPÉRATIVE DU DÉBIT SANGUIN (EFFET DOPPLER)





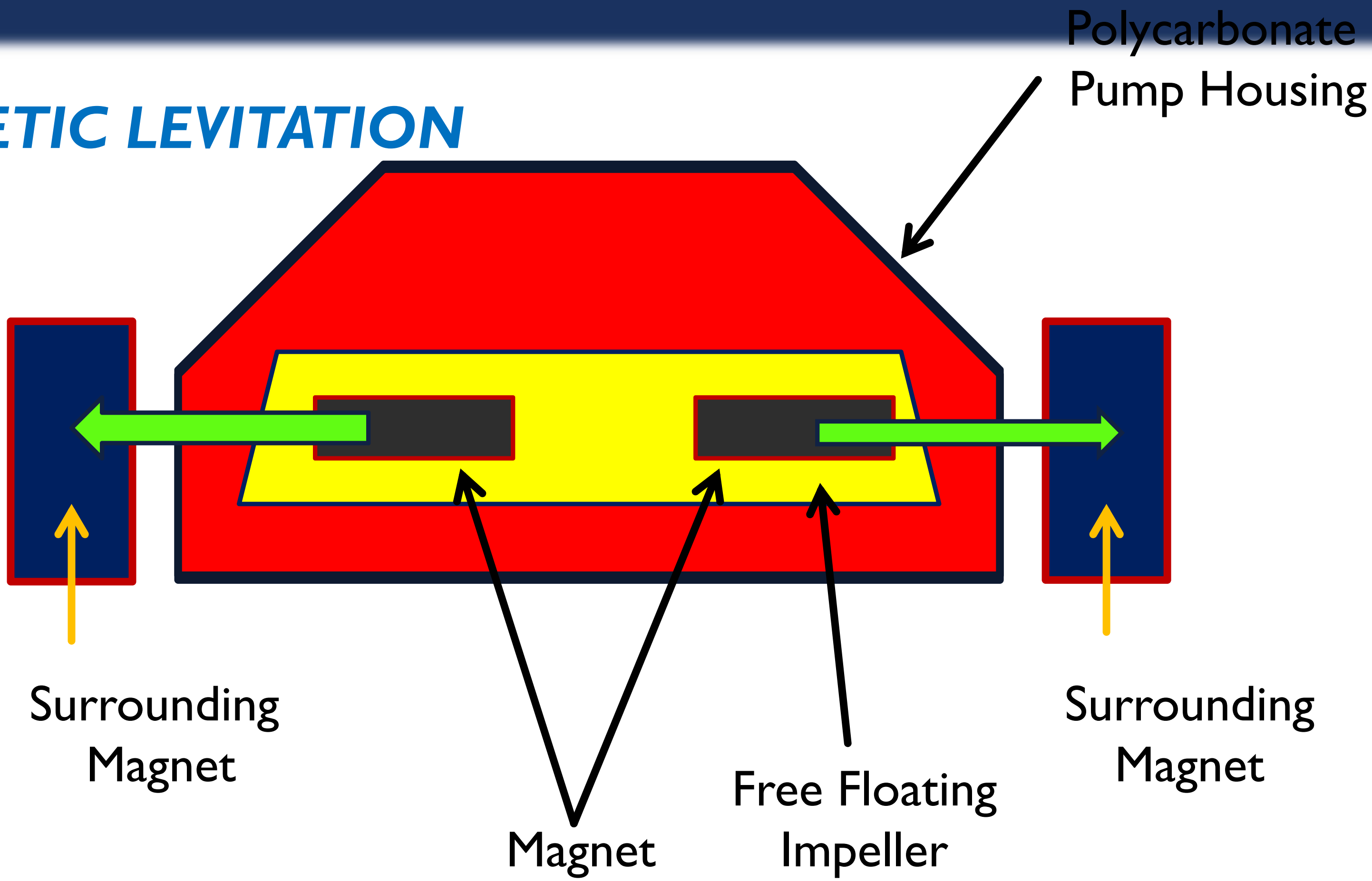
BACKFLOW (SPEED < 1500 TRM)



Clamp imperatively arterial line if speed is profoundly decreased +++

Magnetically levitated pump

MAGNETIC LEVITATION



SYSTEM COMPONENTS – 2ND GEN

Centrifugal pump

Motor

Console

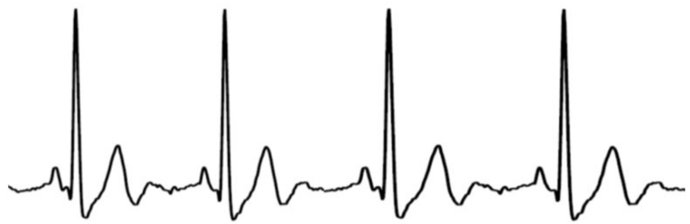

THORATEC
3200
3.82
-57
-208
151
CentriMag
toro

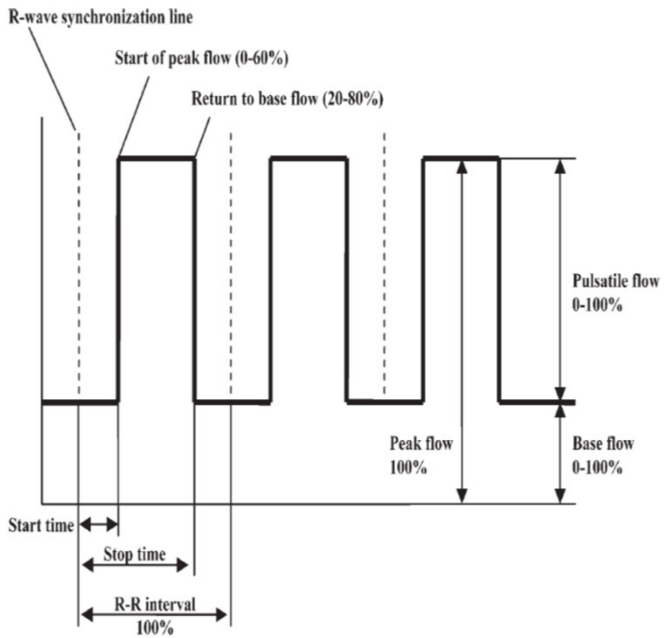
BENEFITS OF PULSATILE ECLS

- Add diastolic pulsatility
- Improve coronary blood flow (diatolic delivery)
- ECG-synchronized pulse flow (pulse delivery in diastole)
  - Avoid conflict between pulse-wave from intrinsic activity of failing heart and ECLS-generated pulse-waves
  - Modulation of ECLS by the patient’s own autonomic nervous system

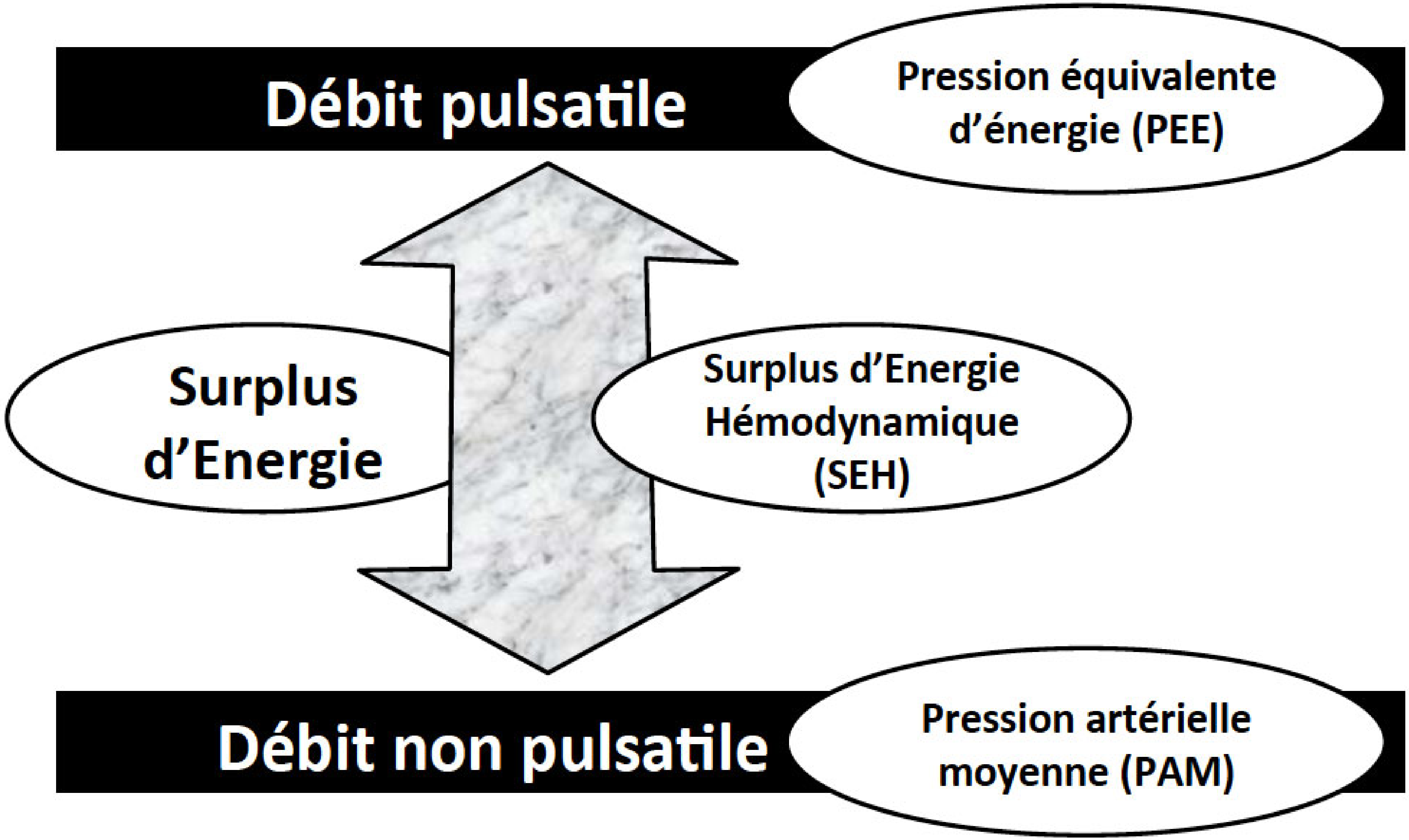
R-wave ECG synchronisation

- Width of pulsatility 200 msec
- Trigger pulsatile mode (assist frequency 1:1 to 1:2)
- Differential speed value 2000-4000 trm
- Pulsatile must represent at least 20% of cardiac cycle (R-R interval)

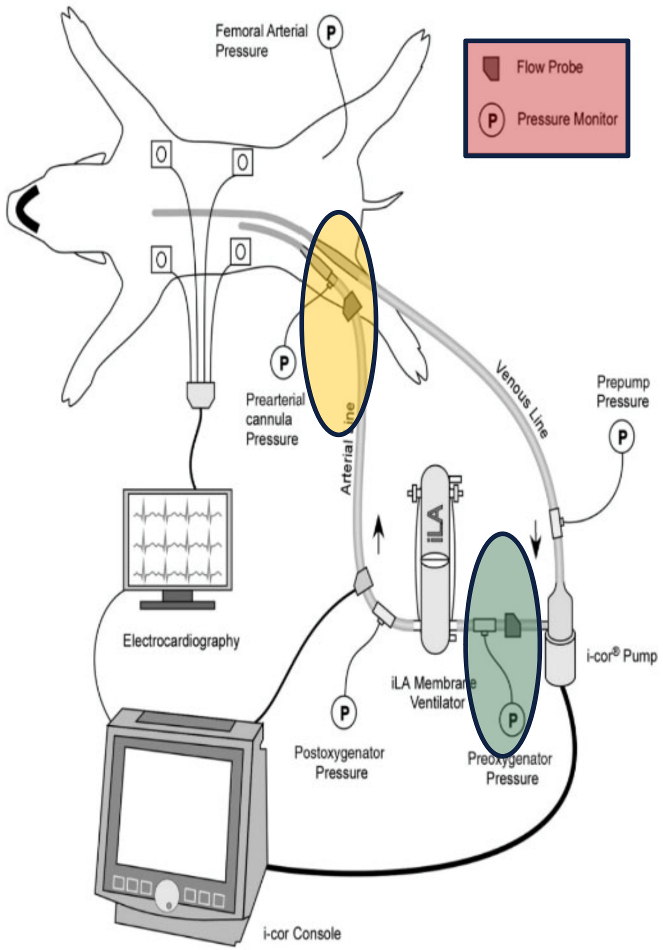


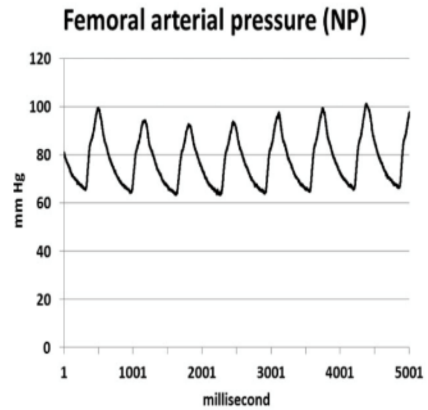


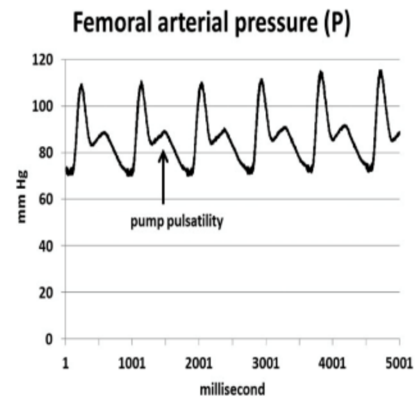
SEH = PEE - PAM

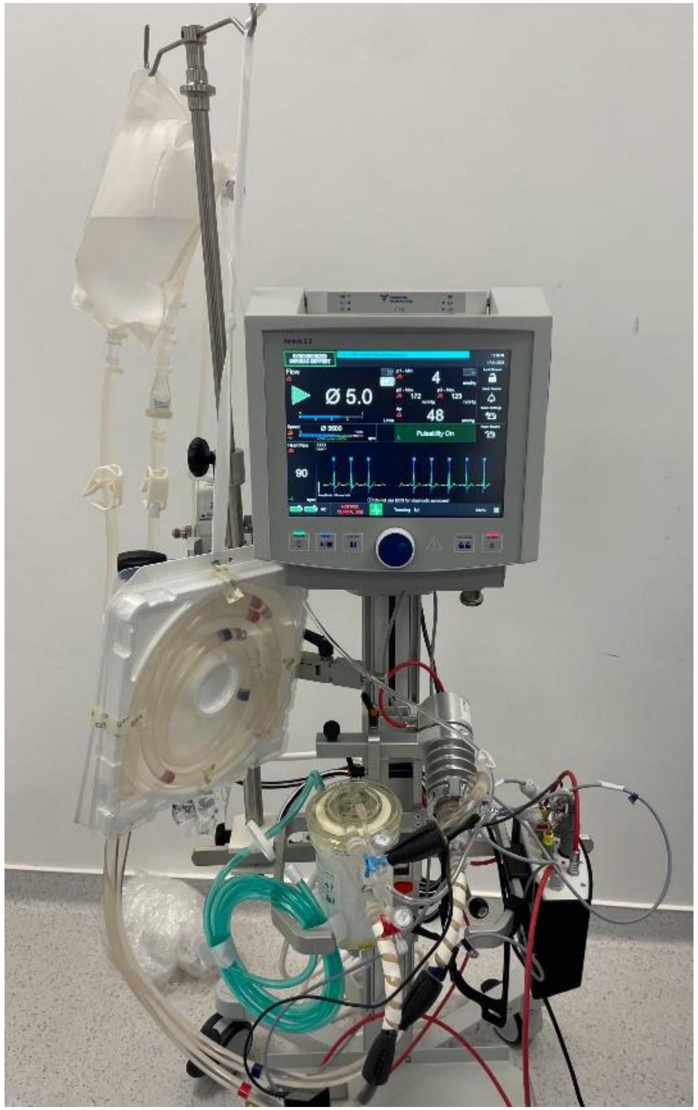

Débit pulsatile
Pression équivalente d'énergie (PEE)
Surplus d'Energie
Surplus d'Energie Hémodynamique (SEH)
Débit non pulsatile
Pression artérielle moyenne (PAM)

Wang S et al. Arti Organs 2015;39:E90-E101









UMR-1034 INSERM
UNIVERSITY OF BORDEAUX
Biology of Cardiovascular Diseases

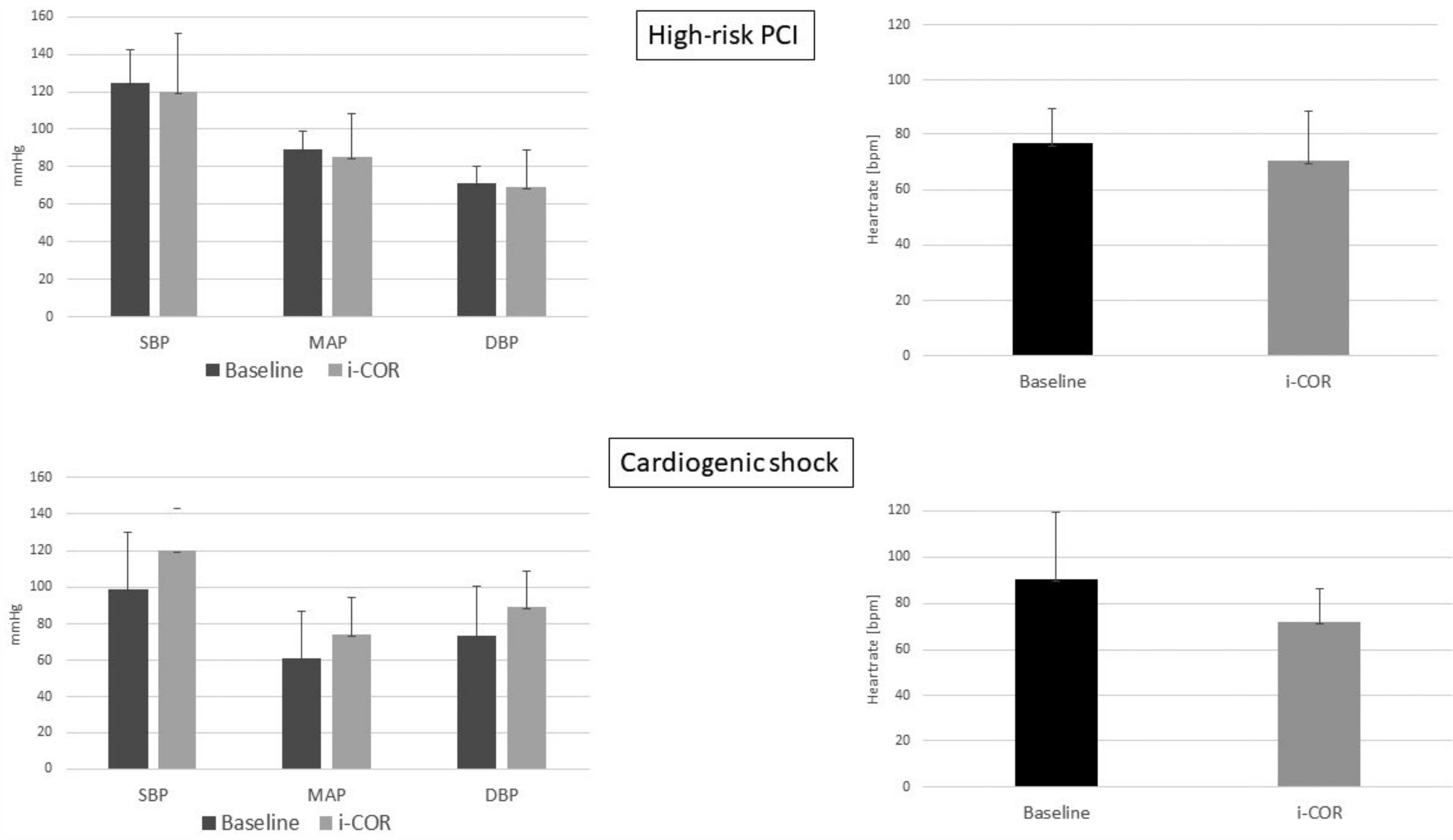
Inserm
université de BORDEAUX

CLINICAL TRIAL

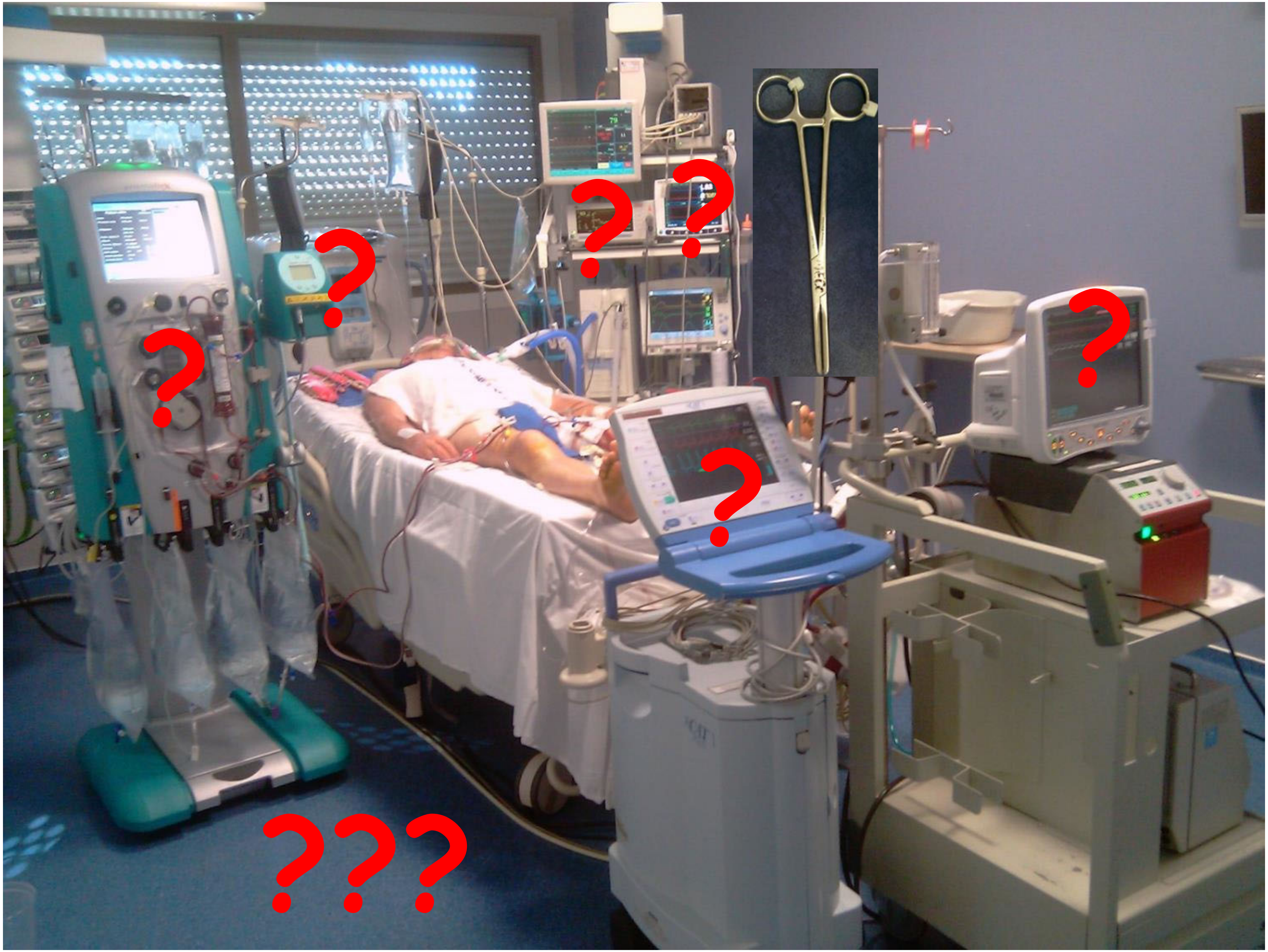
Artificial Organs

WILEY

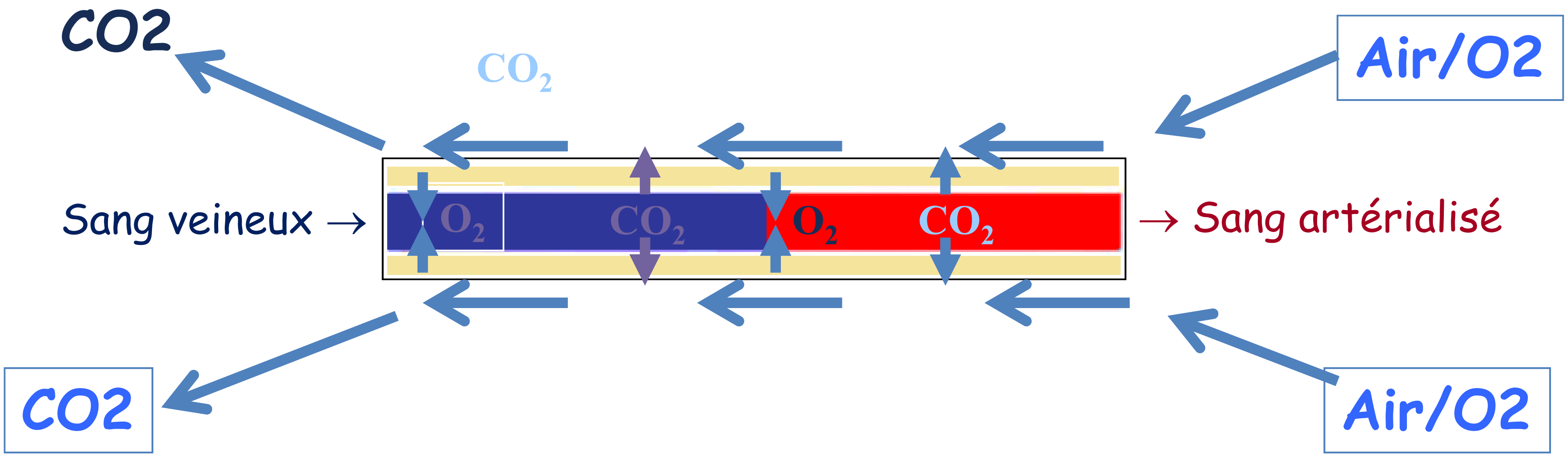
Efficacy and safety of ECG-synchronized pulsatile extracorporeal membrane oxygenation in the clinical setting: The SynCor Trial

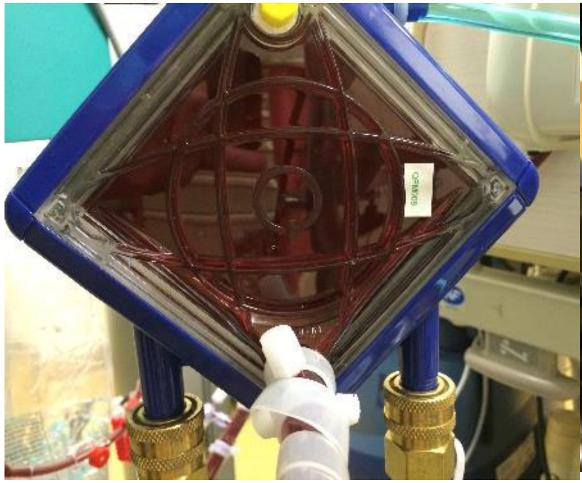


Rescue procedure

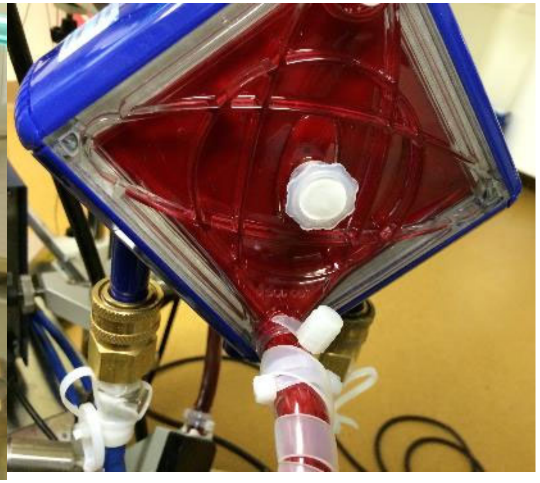


OXYGENATOR MEMBRANE





Venous compartiment

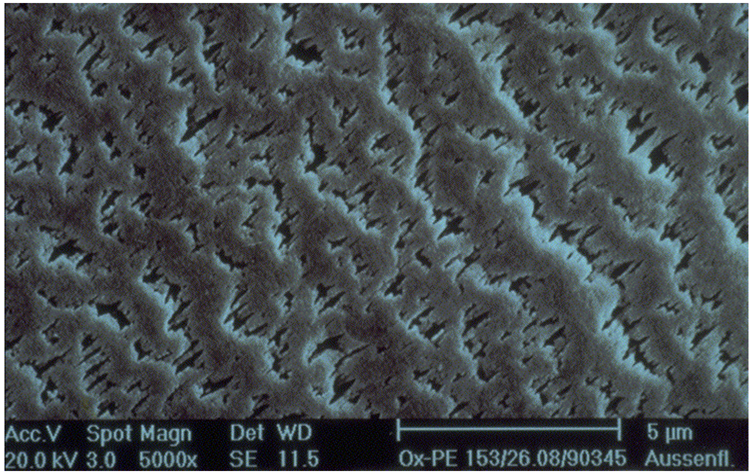


Arterial compartiment

Different color means that membrane works very well (blood gas analysis may be performed)

Micropores Membrane (CEC)

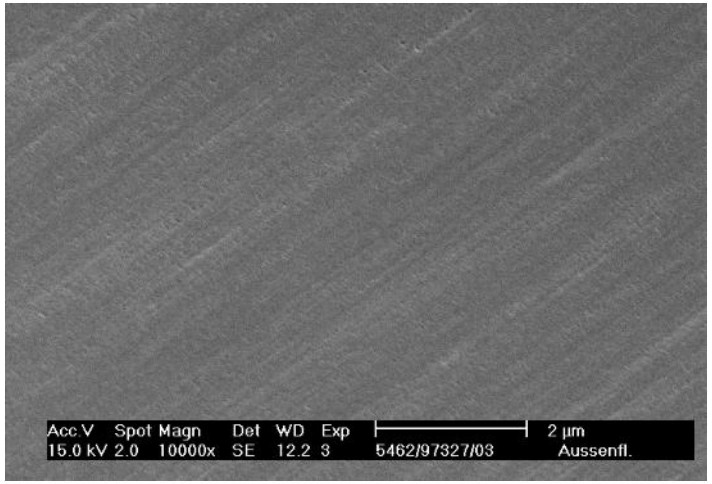
(Polypropylène)



Micropores for gas exchange

Diffusion Membrane (ECMO)

(Polyméthylpentène)



Diffusion of gas through the permeable membrane (human lung)

Better transfert

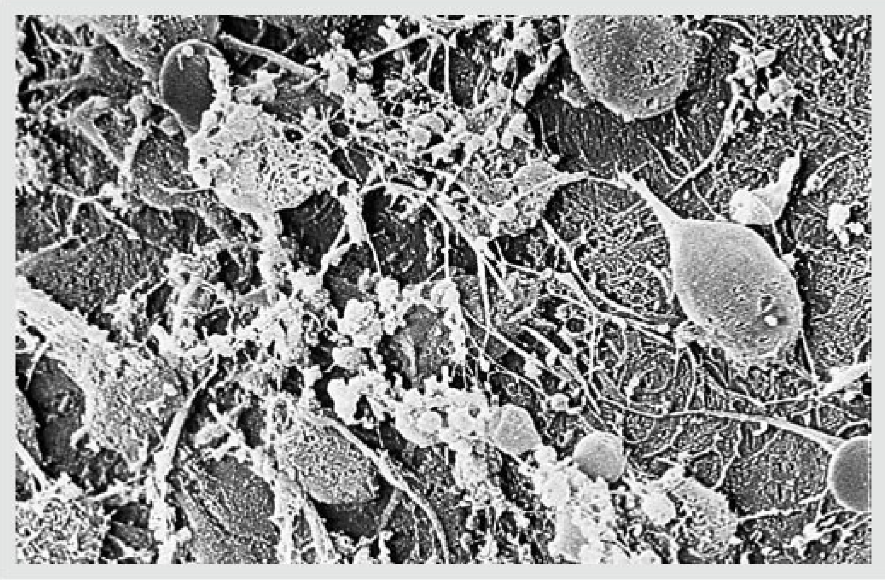
Impermeable for plasma

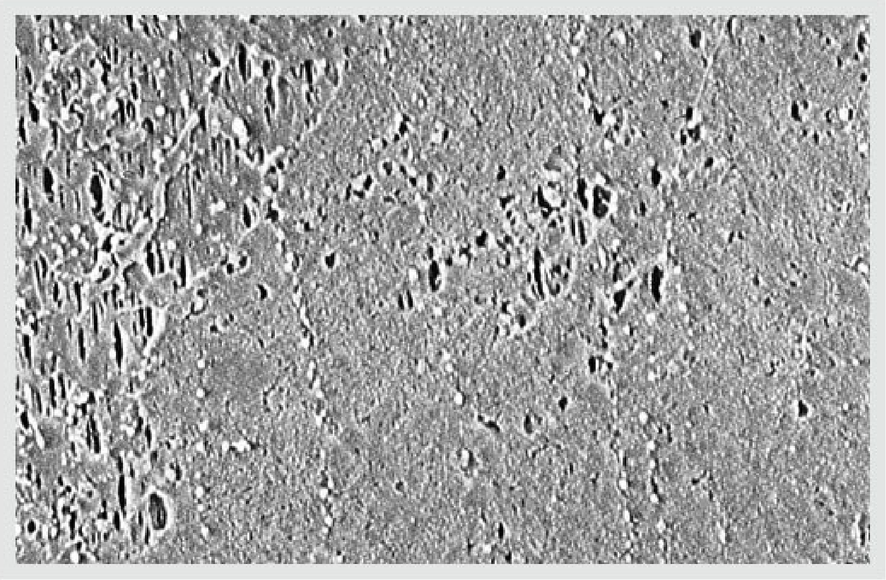
Possible coating

No plama leakage

Duration of use (label CE 14 days)

Surface coating

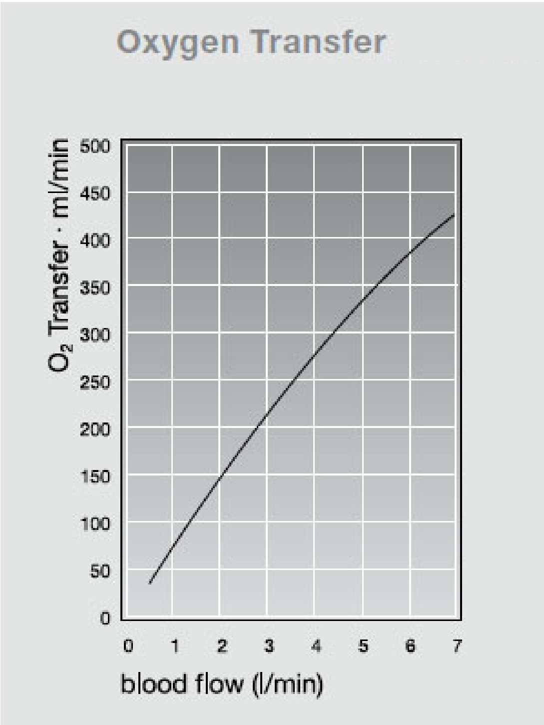


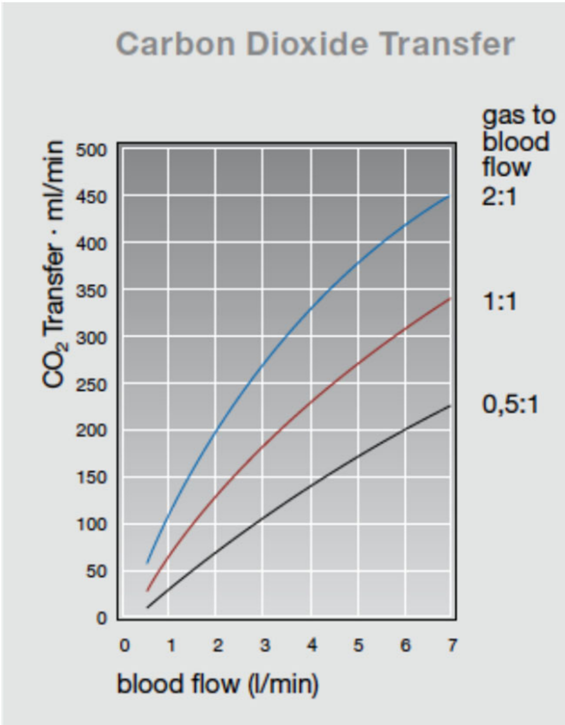


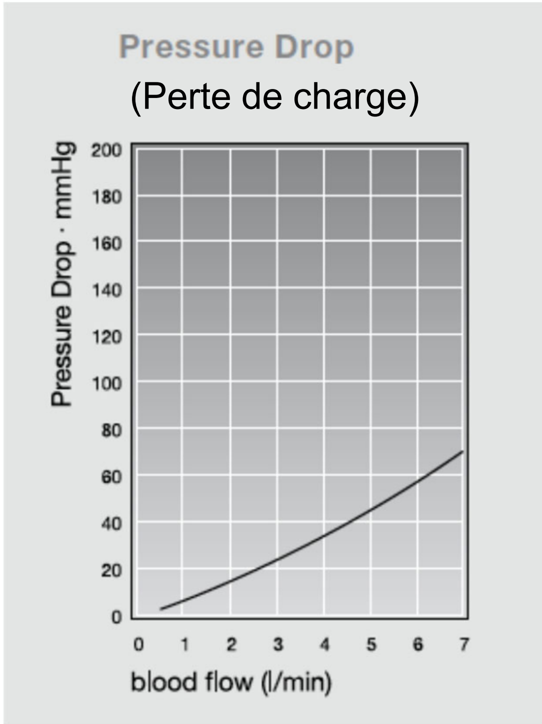
Membrane surface without SAFELINE treatment: Uncoated membrane with depositions potentially leading to high pressure drop phenomena.

QUADROX membrane surface with SAFELINE treatment: The advantage of the SAFELINE treatment under the electron microscope: significant reduction in surface deposition on the QUADROX membrane. The typical transmembrane pressure increase is minimized consistently.

Membrane's characteristics



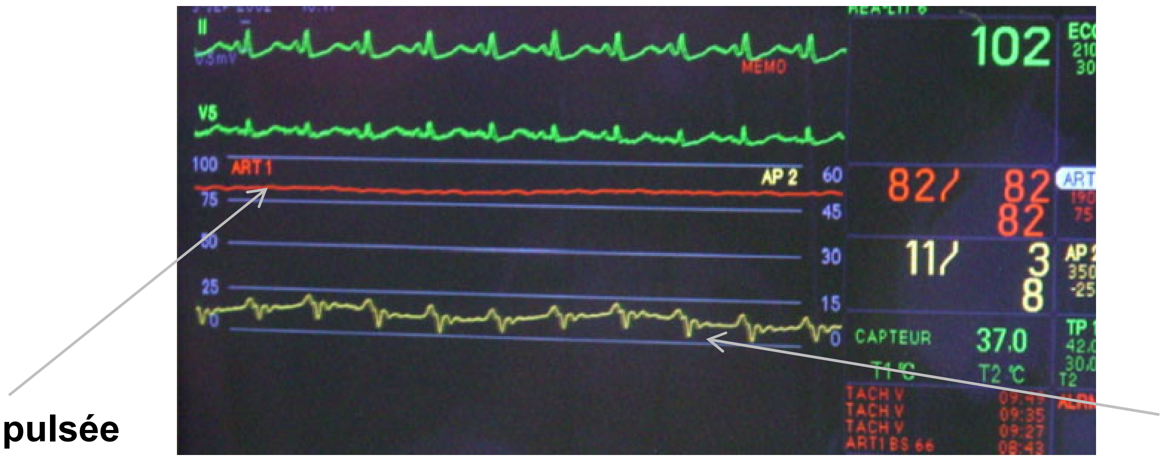




Bloc thermique

MONITORAGE HÉMODYNAMIQUE I

- Pression artérielle moyenne
  - KT radial droit +++ (sang cœur natif)
  - Oxygénation cérébral et myocardique
  - PAM 60-70 mmHg (post-charge dépendance)
  - Aspect linéaire = absence de récupération
- Pression veineuse centrale (décharge cavités droites)



Monitorage Hémodynamique II

- Cathéter de Swan-Ganz
  - Saturation veineuse mêlée O_2 (SvO_2)
  - Index cardiaque (appréciation de la qualité de décharge cavités droites)
  - PAP = maintien d'une pression diastolique minimale (flux intra vasculaire)
  - Evaluation de PAPO (PTDVG) risque d'OAP (PAPO < 18 mmHg)
  - Phase de sevrage

- Echographie (quotidienne ETO> ETT)
  - Prudence traumatisme induit ++++ (ETT)
  - Positionnement canules veineuse et artérielle (si centrale)
  - Décharge cavités Dte et Gche
  - Evaluation pressions de remplissage
  - Evaluation de la fonction systolique (FE, Tei index, Strain rate,…)
  - Recherche d'un épanchement péricardique
  - Thrombus intra-cavitaire
  - Valvulopathie (IM, IA)
  - Aspect aorte descendante

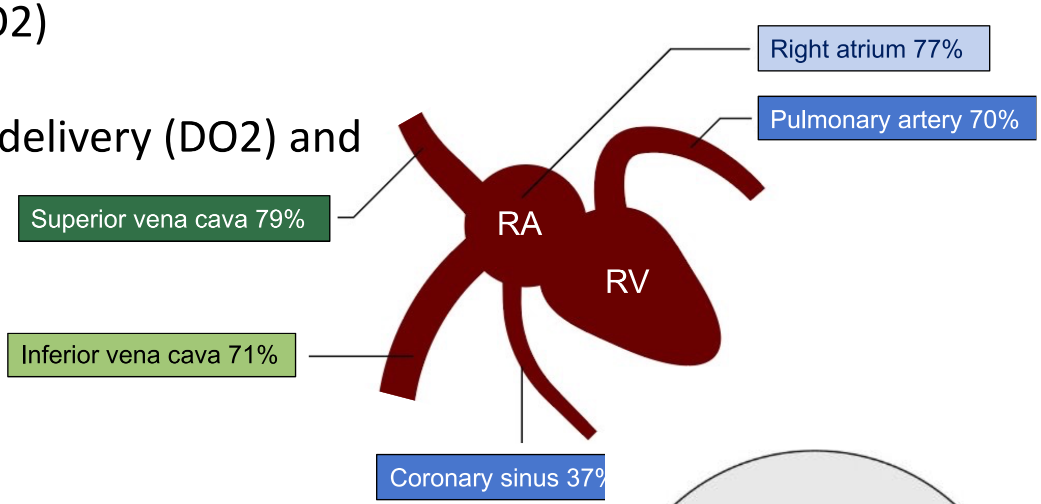
MINIMAL BLOOD FLOW TO MEET THE METABOLIC DEMAND DO_2/VO_2

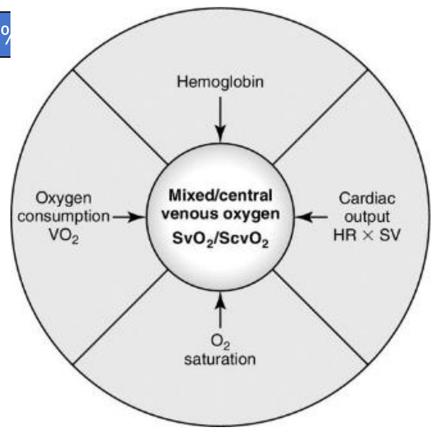
Mixed venous oxygen saturation (SVmO2)

Parameter of balance between oxygen delivery (DO2) and demand (VO2)

Increased oxygen extraction (O2ER)

Goal therapy 70±5 %





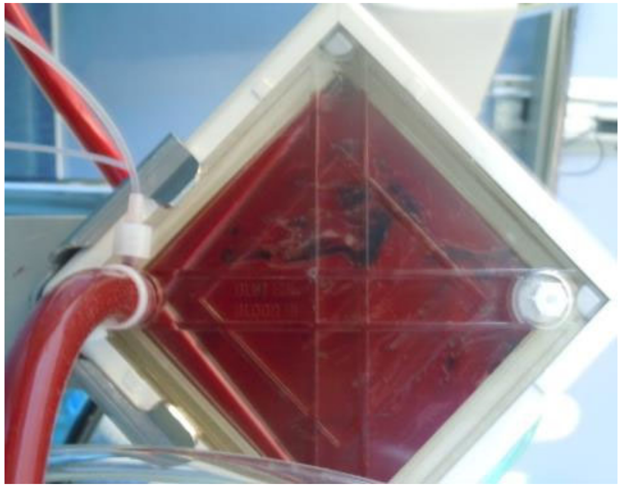
$$O_2ER = \frac{SaO2-SvO2}{SaO2} = 1-SvO2$$

Adapted from Reinhart K 1988

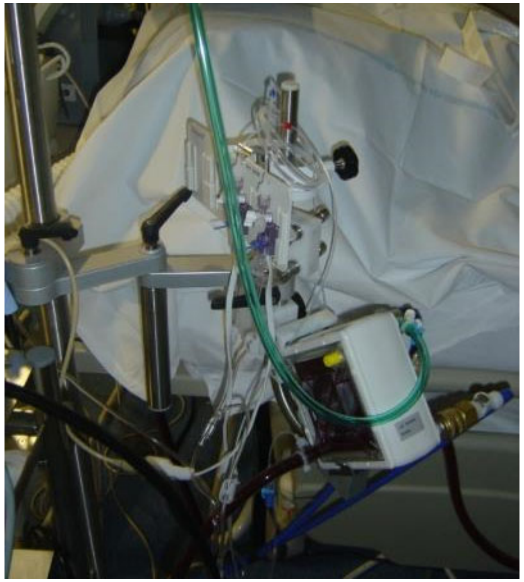
CIRCUIT D'ECLS

- Perfusionniste (/ 24 à 48h) et personnel de réanimation (MD et IDE)
- Aspect des canules et lignes
  - Caillots, plicature, efficacité du sertissage
  - Ligne de reperfusion +++
  - Aspect des orifices
  - Battement canule veineuse (mauvais drainage)
- Membrane et pompe
  - Recherche de caillots (discuter le changement)
  - Purge circuit gaz frais (condensation)
- Console
  - Meilleur débit avec le moindre de TRM
- Changement de circuit si:

  - Caillots,
  - hémolyse importante,
  - Défaut oxygénation P/F < 150-200 mmHg,
  - Systématique (> 14 j)



Monitorage pressions pré- et post-filtre

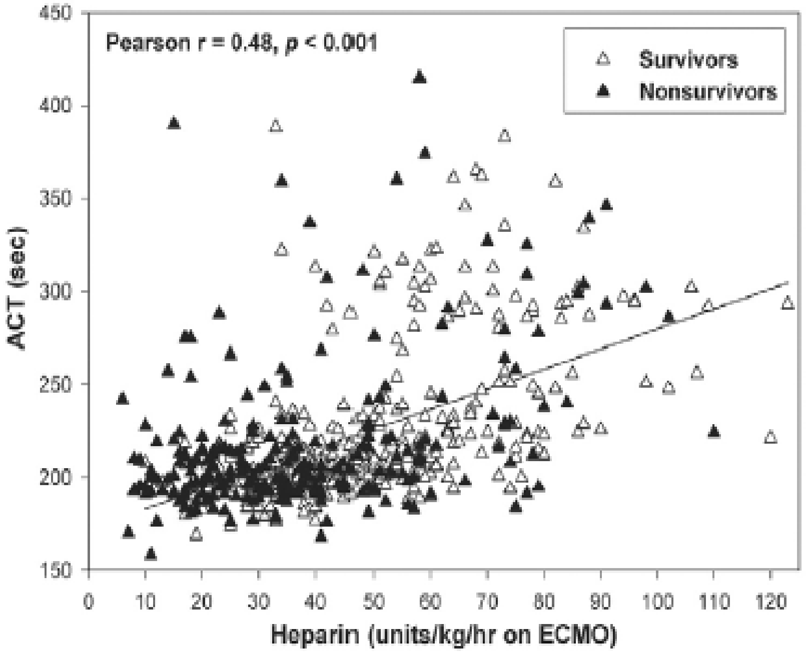


Intérêts:

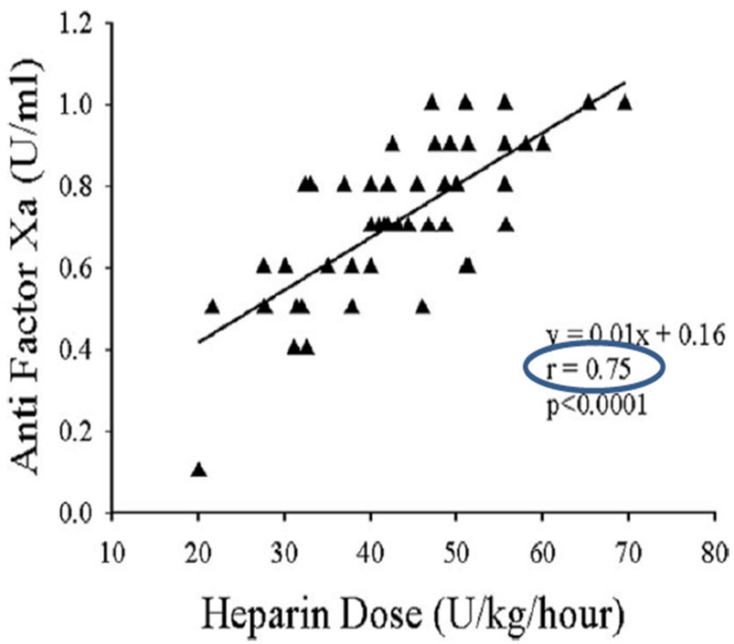
- Suspicion thrombose de filtre si gradient augmente
- Signes évocateurs récupération VG (oscillations pré-filtre)
- Valeurs max 300 mmHg

Faible corrélation ACT avec la dose HNF perfusée

L'activité antiXa est mieux corrélée à la dose



Ann Thorac Surg 2007 83



Nankervis CA et al. ASIAO Journal 2007

Objectif anti-Xa entre 0,2-0,4 UI/ml

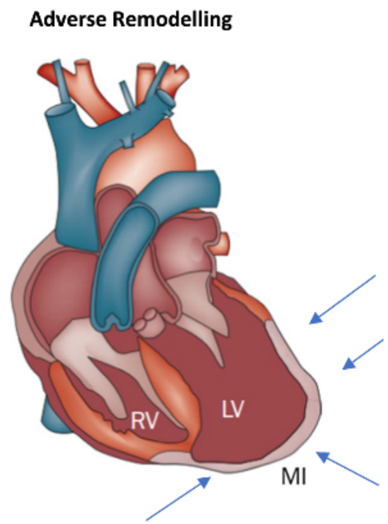
MAIN OBJECTIVES OF SHORT-TERM MECHANICAL CIRCULATORY SUPPORT

- Restore end-organ perfusion for limiting multi-organ failure (**supply**)
  - ✓ Blood flow, systemic pressure, oxygenation
  - ✓ Cerebral, coronary, renal, hepatic and mesenteric perfusion…
  - ✓ Poor prognostic of multi-organ failure

- Limit ventricular congestion (**assist**)
  - ✓ Volume and pressure unloading +++
  - ✓ Reduce risk of pulmonary edema (prolonged MV, VAP…) **[short term]**
  - ✓ Reduce the risk of ventricular remodeling **[Mild or long-term]**

VENTRICULAR REMODELING

- 30% of patients after MI (infarct size is the principal risk factor)
- Main origin of chronic heart failure after MI
- Increased parietal stress (+++) and myocardial work
- Increased myocardial oxygen consumption
- Decreased coronary blood flow (+++)
- Increased compliance of infarcted zone
  - Thinning of myocardial wall
  - Left ventricular dilation

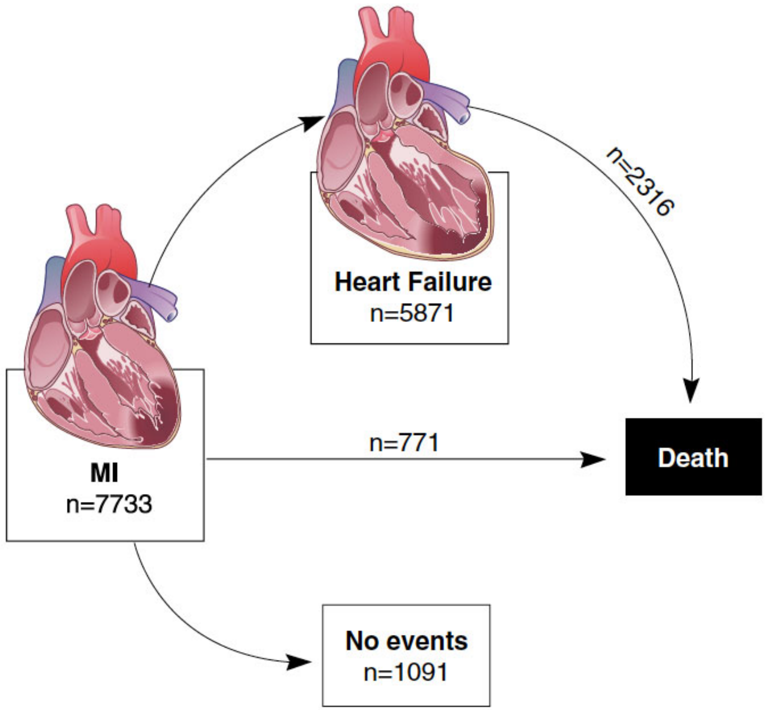


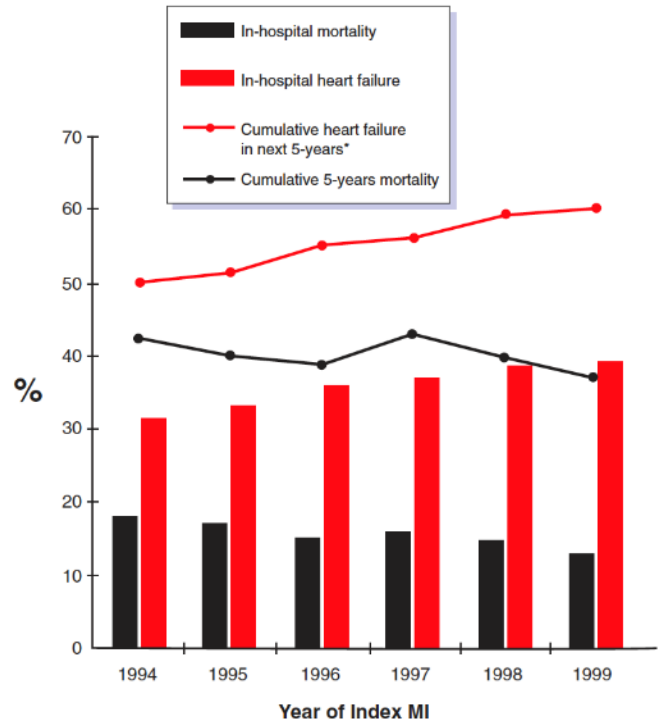
Deja MA et al. Circulation 2012; 125:2639-48

Michler RE et al. J Thorac Cardiovasc Surg 2013;146:1139-45

Jackson BM JACC 2002; 40:1160-7

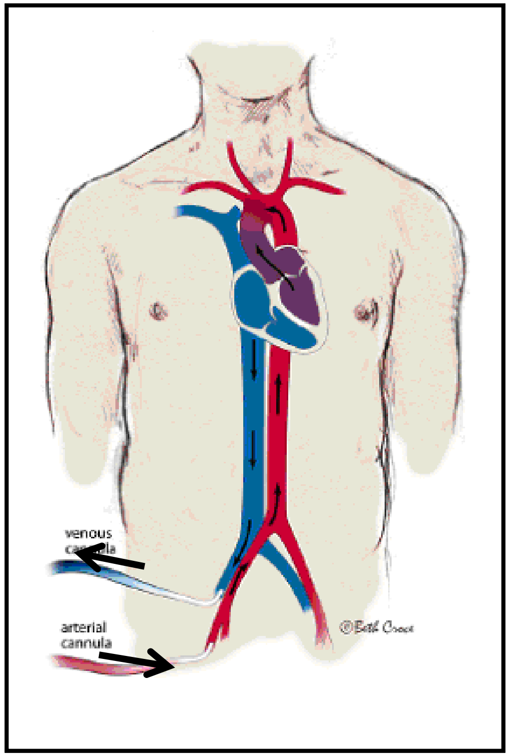
CHRONIC HEART FAILURE ATFER MYOCARDIAL INFARCTION



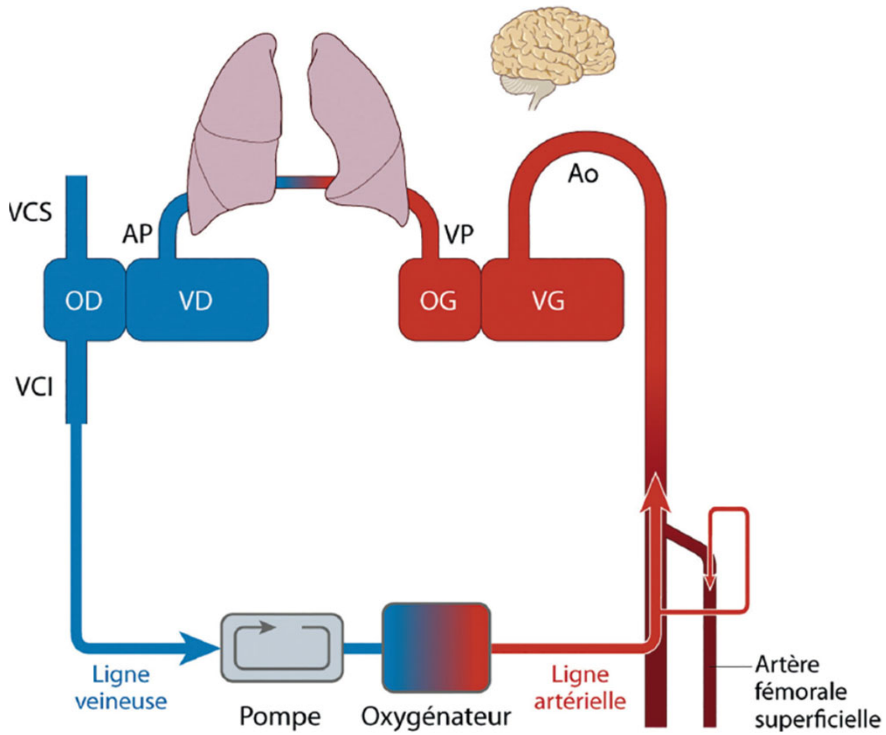


Ezekowitz JA et al. J Am Coll Cardiol 2009;53:13-20

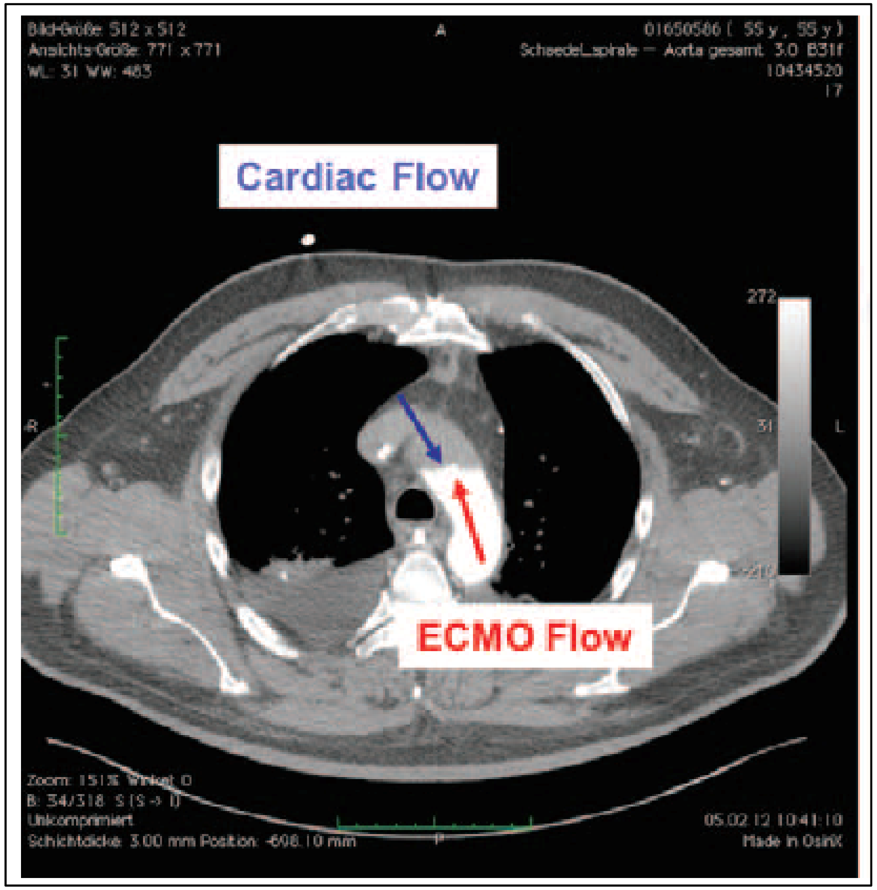
INTERACTION BETWEEN PERIPHERAL VENO-ARTERIAL ECLS AND NATIVE FAILING HEART

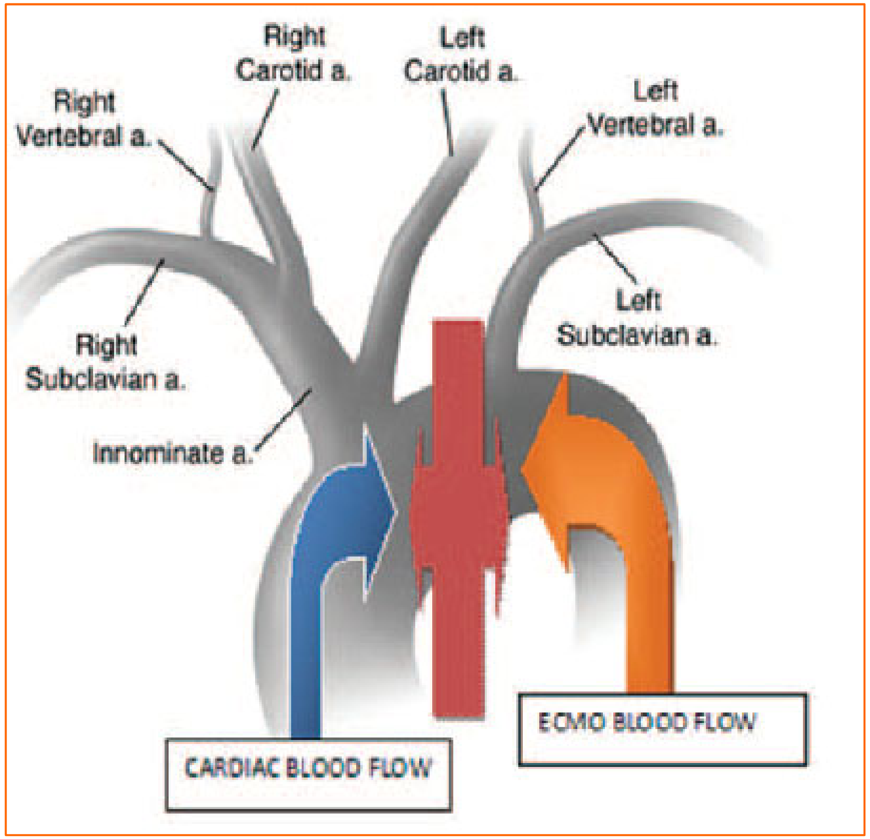


Retrograde aortic flow in total competition with native stream



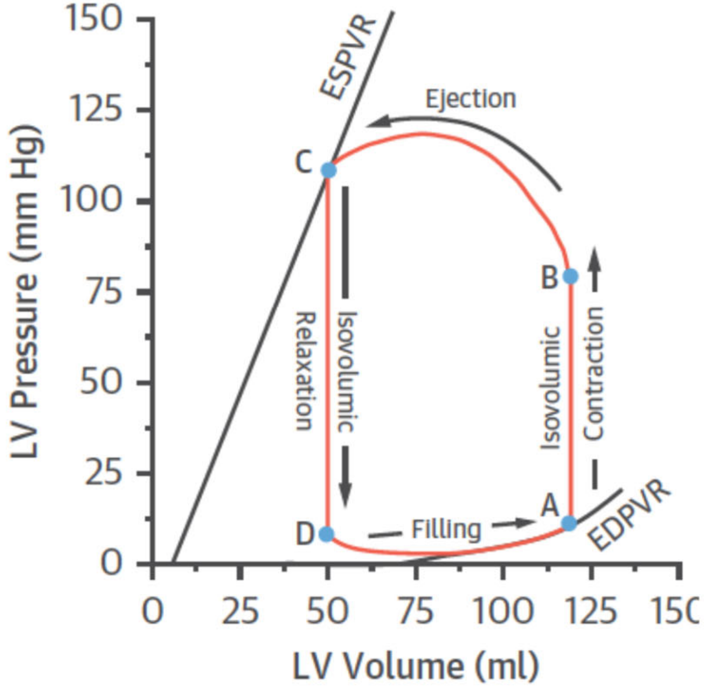
Calderon J et al. Traité Anesthésie-Réanimation O. Fourcade (4ème Edition)

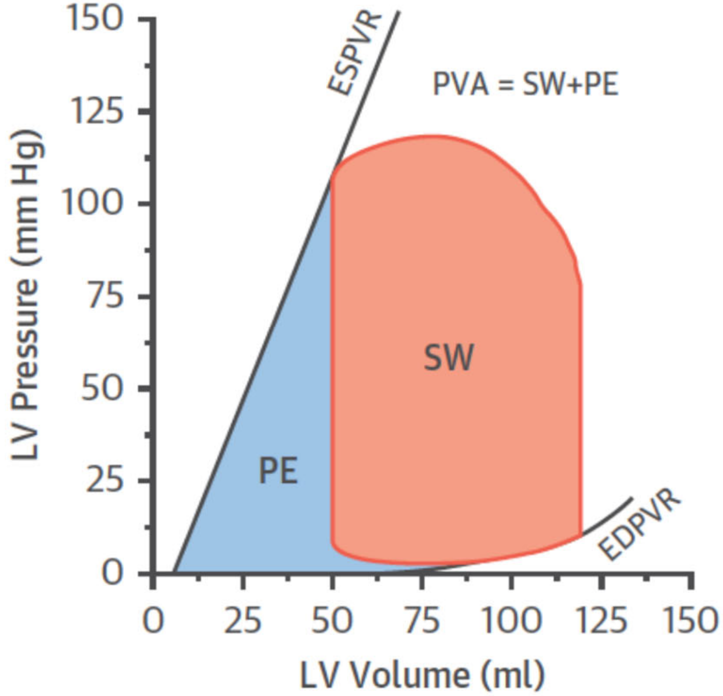




Rupprecht L et al. ASAIO Journal 2013;59:547-53

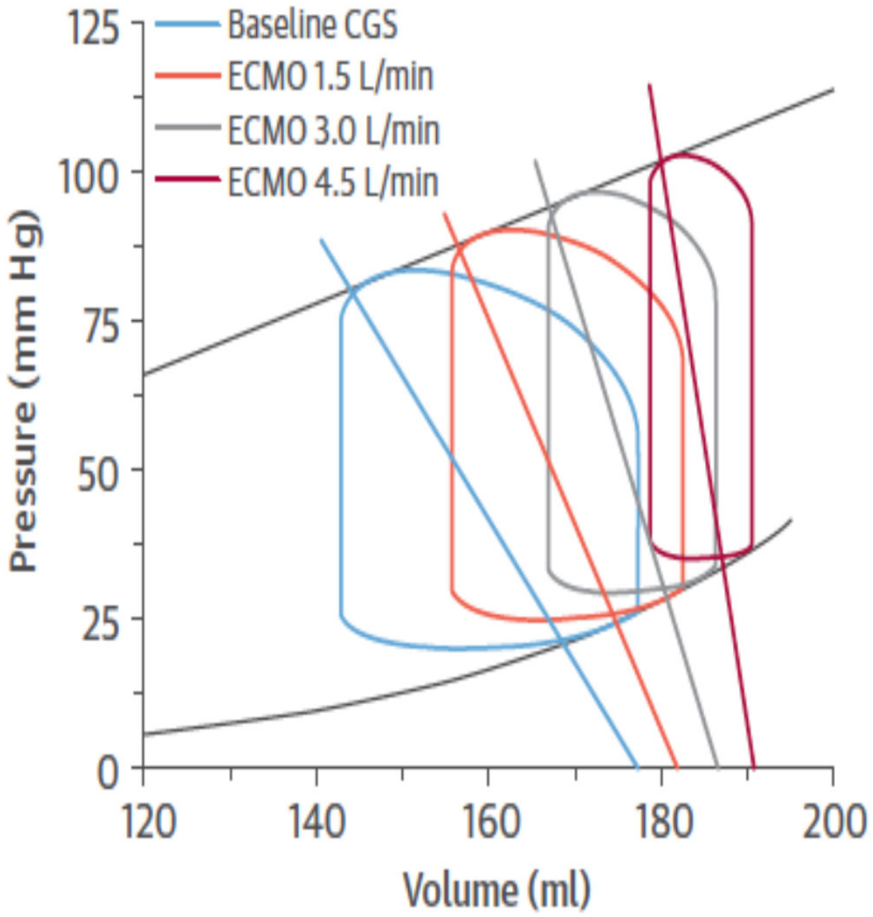
Pressure-volume area, mechanical work of LV and MvO_2

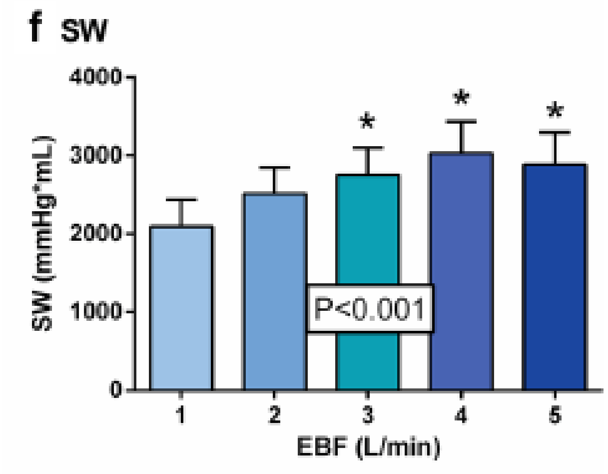


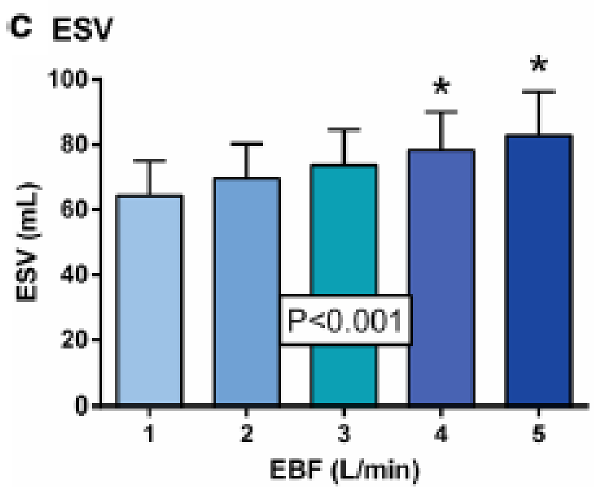


The PVA represents the total mechanical work of LV and may be assessed as the sum of Potential Energy (PE) and stroke work (SW). A relationship exists between PVA and MvO_2

Uriel N et al. J Am Coll Cardiol 2018;72:569-80







Burkhoff et al. JACC 2015; 66:2663-74

Ostadal.P et al, J Transl Med 2016

Kawashima D et al. ASAIO Journal 2011; 57:169-76

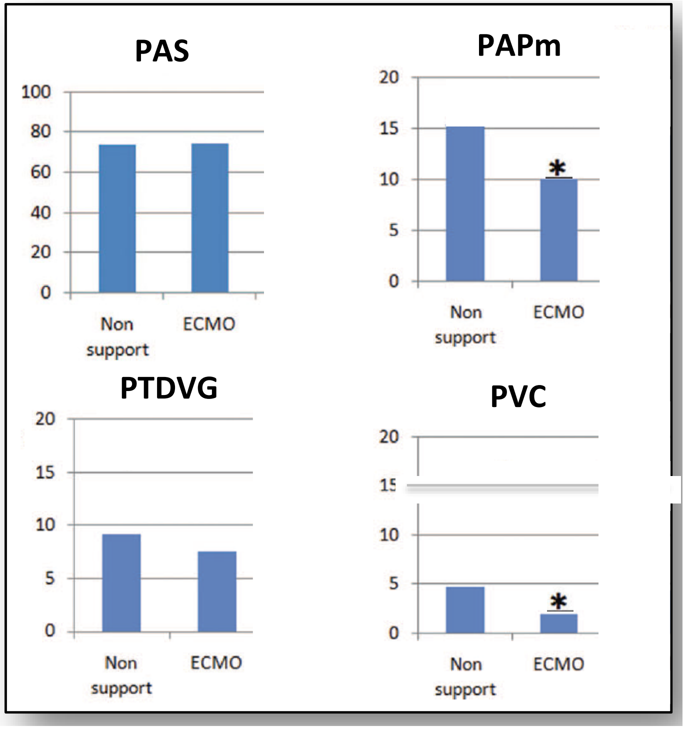
Left Ventricular Mechanical Support with Impella Provides More Ventricular Unloading in Heart Failure Than Extracorporeal Membrane Oxygenation

Basic research in dogs

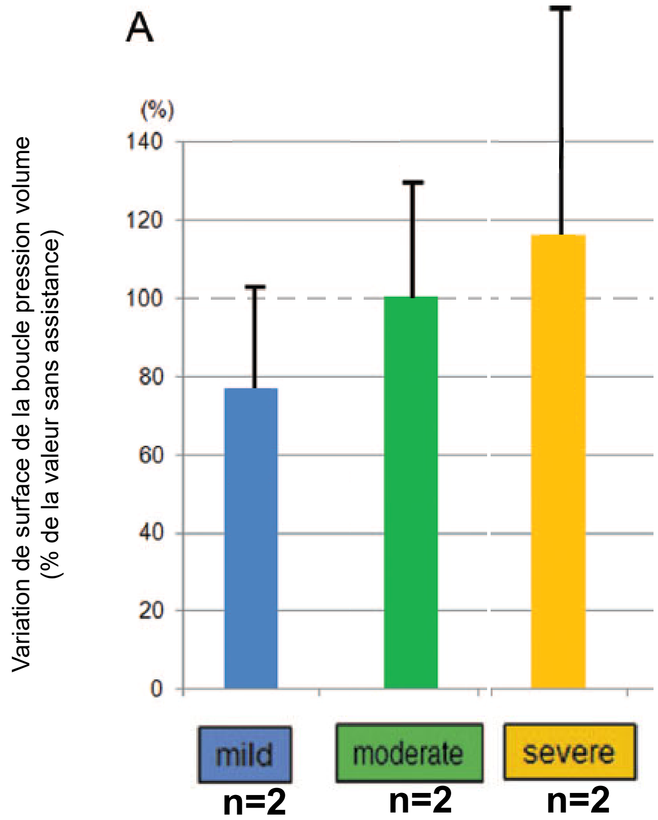
Haemodynamic monitoring (AP, Swan-Ganz catheter, Millar)

Cardiogenic shock after MI by coronary banding

Peripheral ECLS (10 Fr AF/28 Fr OD)



Total myocardial work
(PV curve under ECLS)

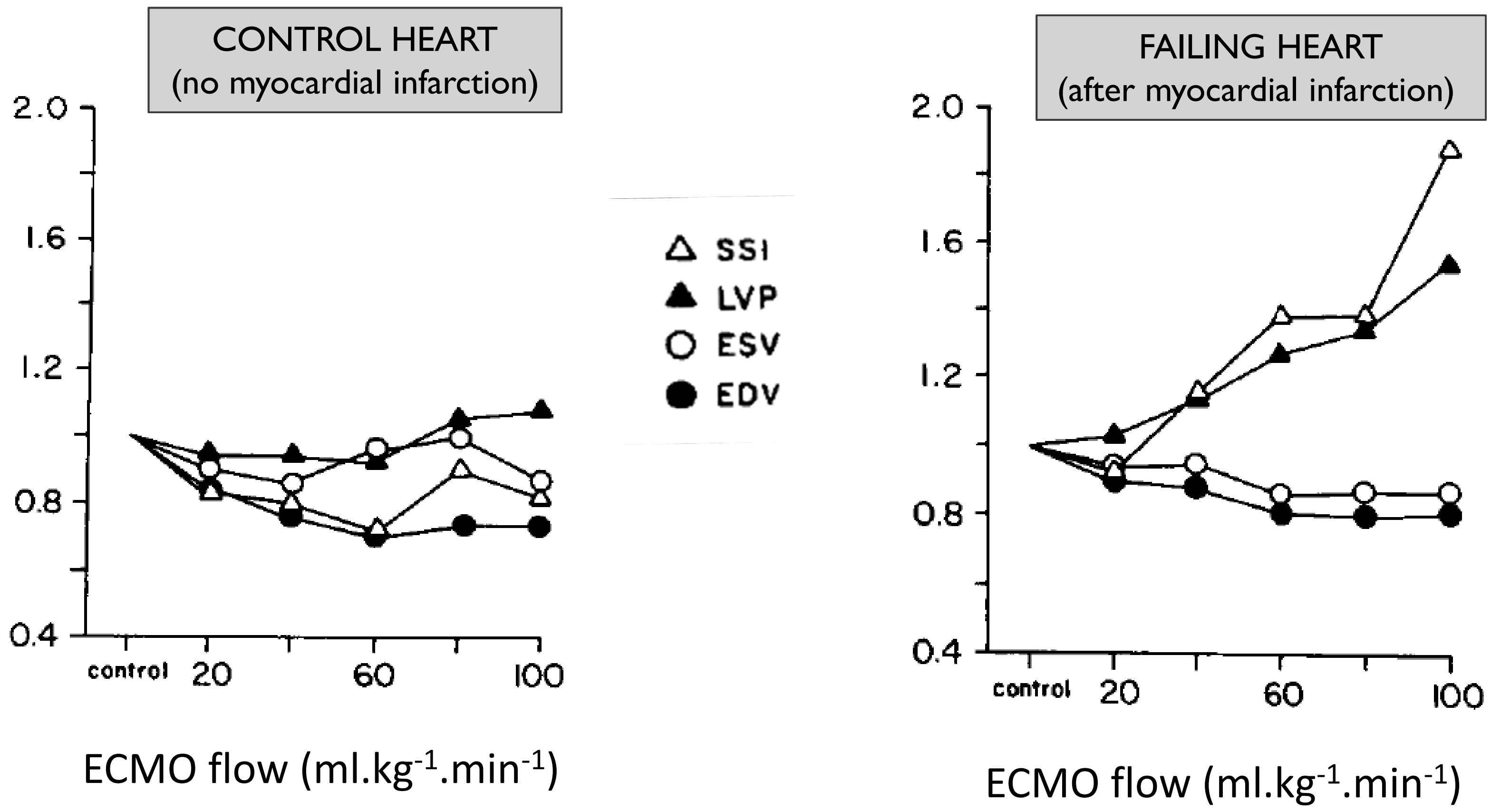


Myocardial ischemia model by aortic clamping (30 min) and reperfusion (30 min) under CPB in sheep (n=14)

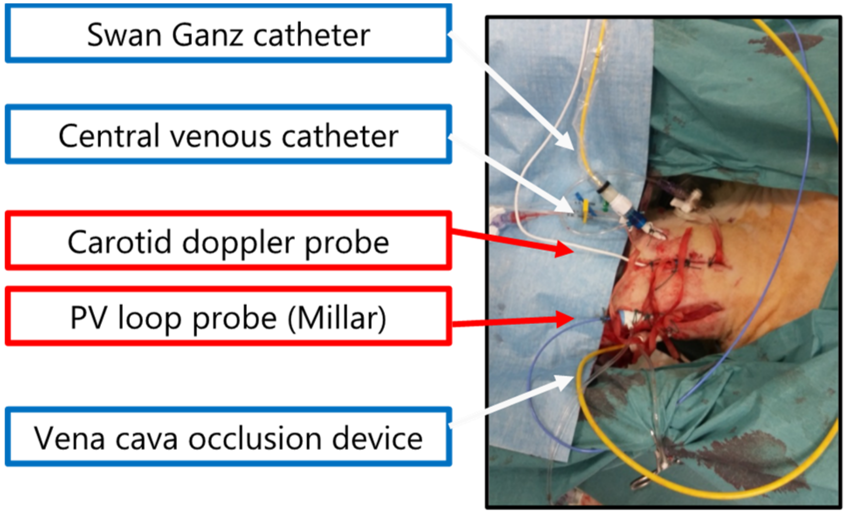
LV cavity pressure monitoring (Millar catheter)

ECLS was then instituted with increasing flow (from 20 to 100 $ml.kg^{-1}.min^{-1}$)

LV circumferential stress (Systolic Stress index=SSI) correlated to **myocardial oxygen consumption**



Bavaria JE et al. Ann Thorac Surg 1988; 45:526-32



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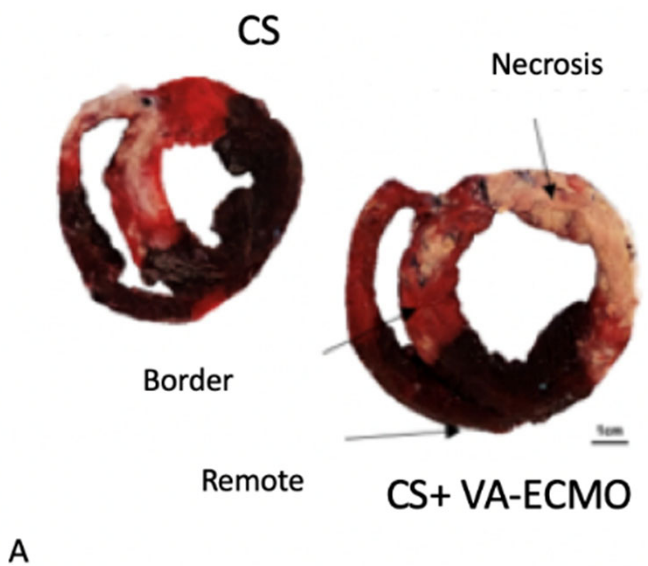
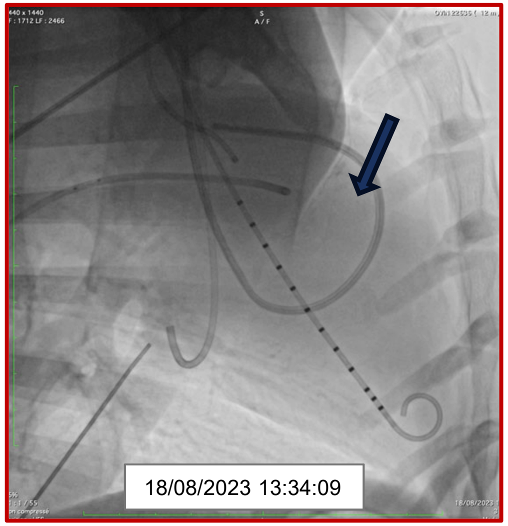
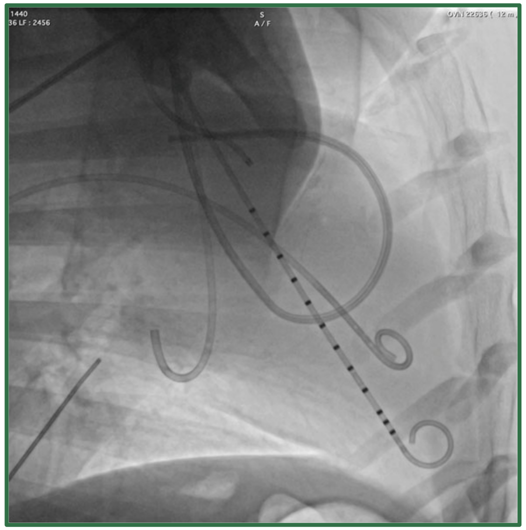
A total closed chest sheep model of cardiogenic shock by percutaneous intracoronary ethanol injection

Mario Rienzo[1,2,9], Julien Imbault[1,2,9], Younes El Boustani[1,2], Antoine Beurton[1,2], Carolina Carlos Sampedrano[3,4], Philippe Pasdois[3,4], Mathieu Pernot[1,5], Olivier Bernus[3,4], Michel Haïssaguerre[3,4,6], Thierry Couffinhal[1,7] & Alexandre Ouattara[1,2,8]✉

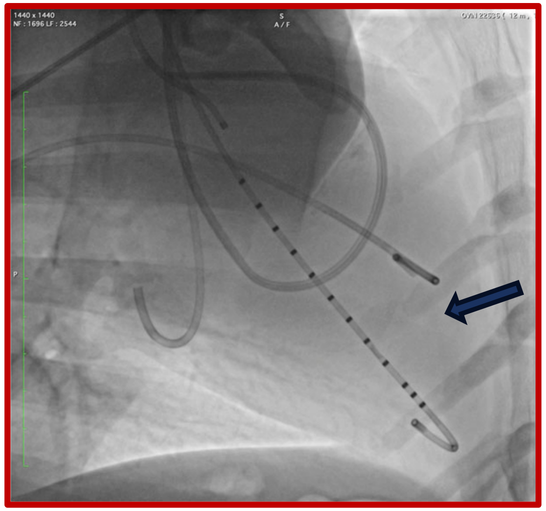


Proximal occlusion of LAD coronary artery



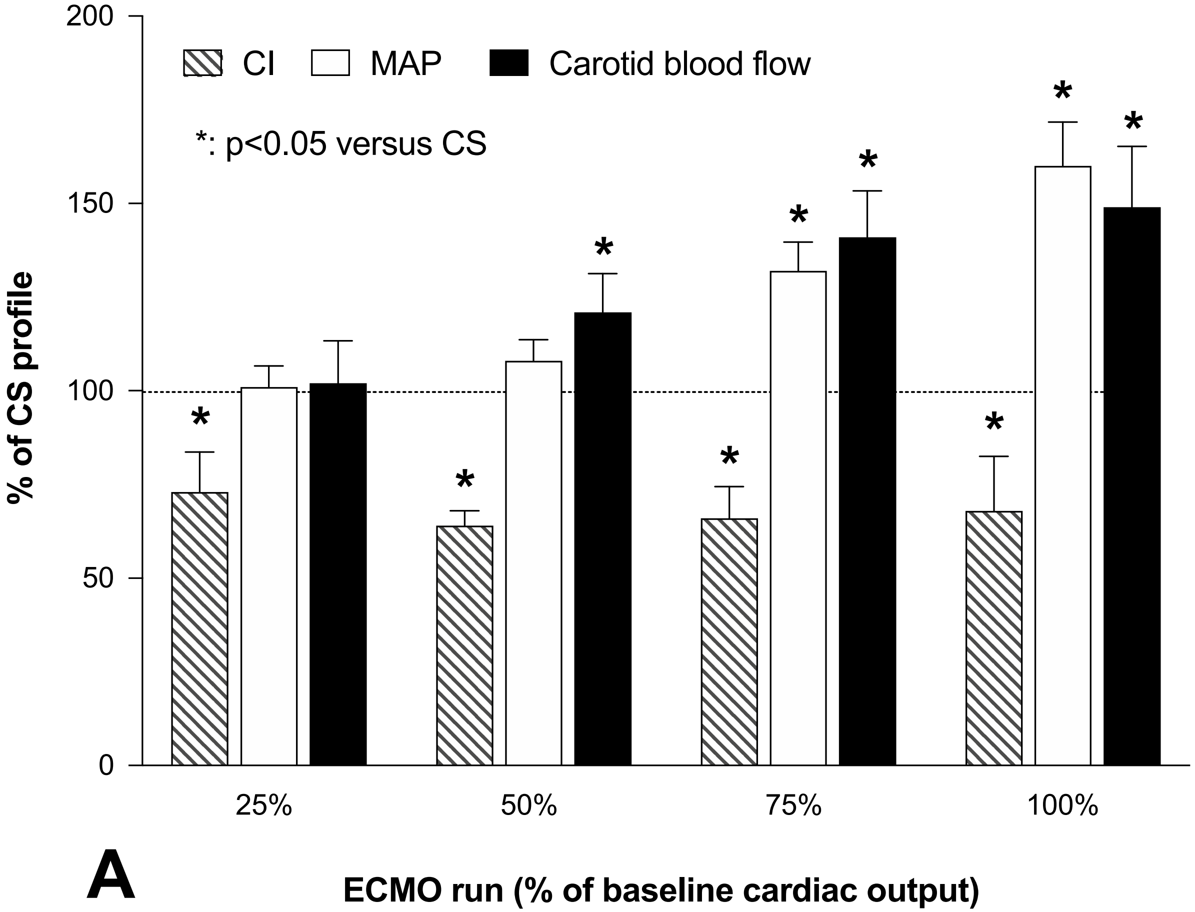


Left ventricular anterior wall akinesia



Systemic Hemodynamics, Cardiac Mechanics, and Signaling Pathways Induced by Extracorporeal Membrane Oxygenation in a Cardiogenic Shock Model

Antoine Beurton,*† Maxime Michot,† François-Xavier Hérion,*† Mario Rienzo,‡ Claire Oddos,* Thierry Couffinhal,† Julien Imbault,*† and Alexandre Ouattara*†



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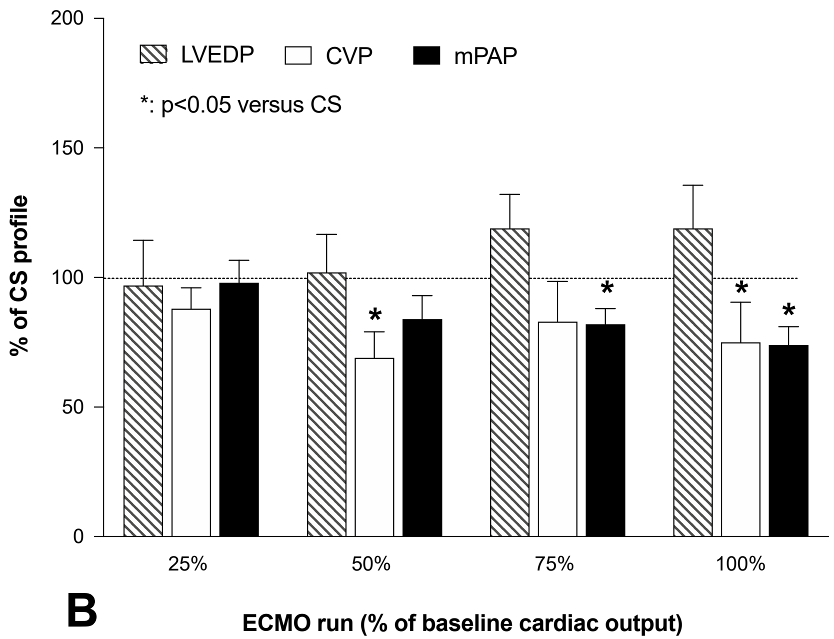
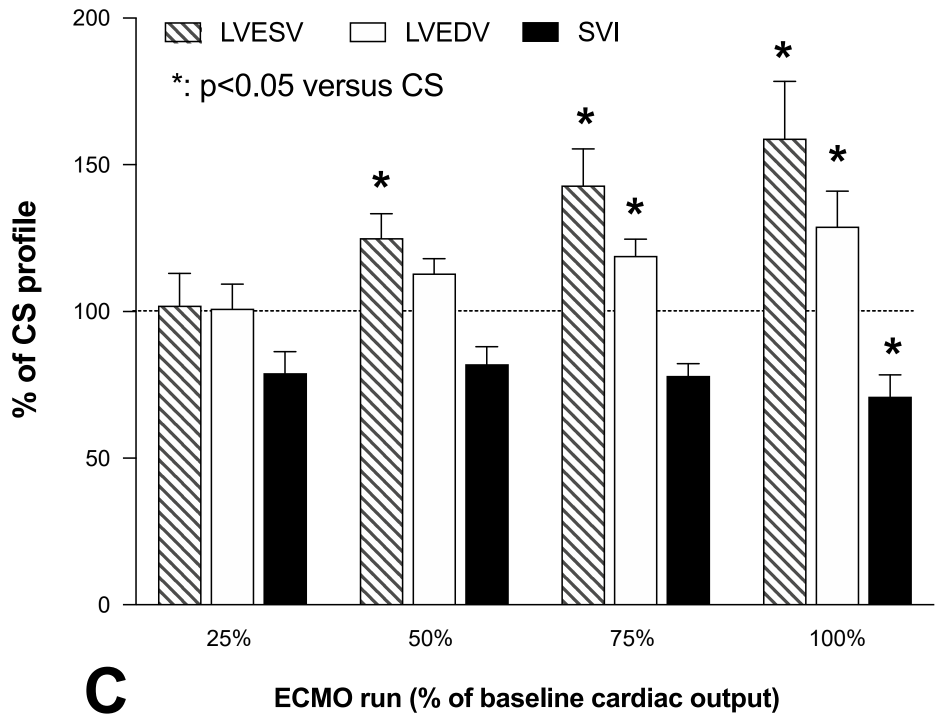




Beurton A et al. ASAIO Journal 2024 (in press)

Experimental study in pigs (n=14)

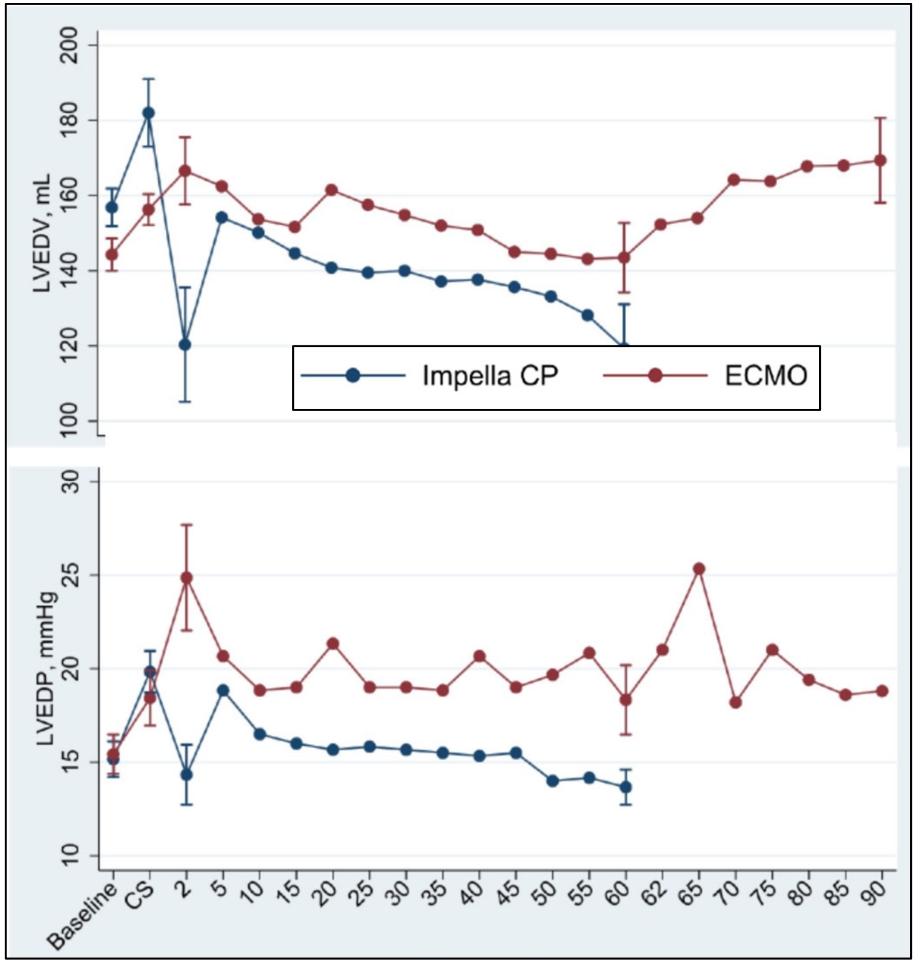
Closed-chest profound cardiogenic shock model (microspheres)

PV catheter (LVEDV, LVEDP, EDPVR, ESPVR, PVA...)

Comparison of effects on intracardiac haemodynamics and end-organ perfusion

1) pECLS (3.2 $L.min^{-1}$ during 60 min and increased to maximum flow during 30 min)

2) IMPELLA (via femoral artery, P8 ≈ 3.2 $L.min^{-1}$) during 60 min)

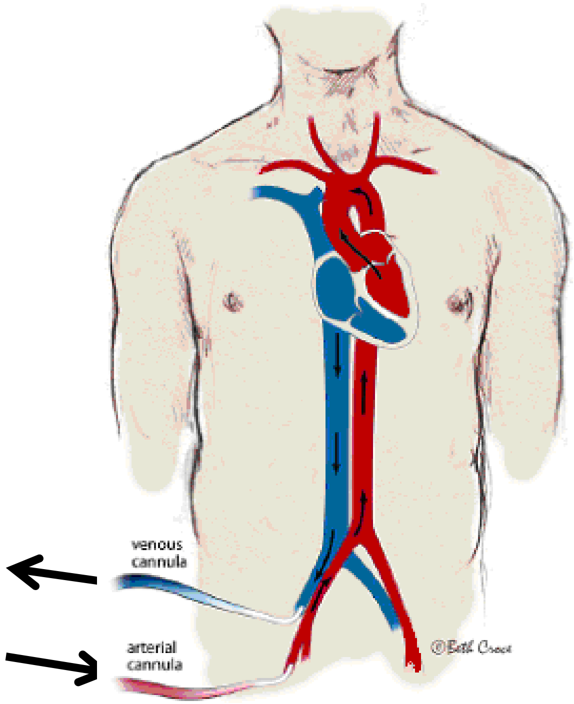


Moller-Helgestad OK et al. EuroIntervention 2019;14:e1585-92

Left ventricular overloading

- Continuous filling of left cardiac cavities
  - Residual pulmonary arterial flow
  - Bronchial circulation (broncho-pulmonary shunts)
  - Thebesian vein (myocardial wall veins draining into the left ventricle)
  - Increase in LV afterload (increase in end-systolic volume)
- Overloading of left ventricle (severe failing heart+++)
- Ventricular dilation and increase in parietal stress
- Subendocardial coronary hypoperfusion

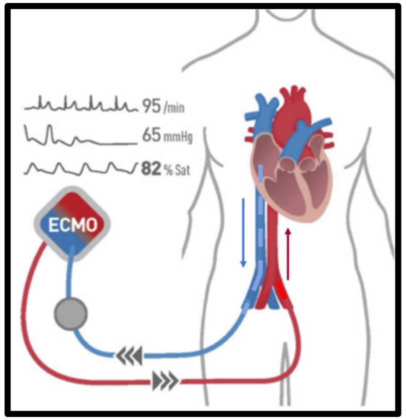
Hydrostatic pulmonary edema

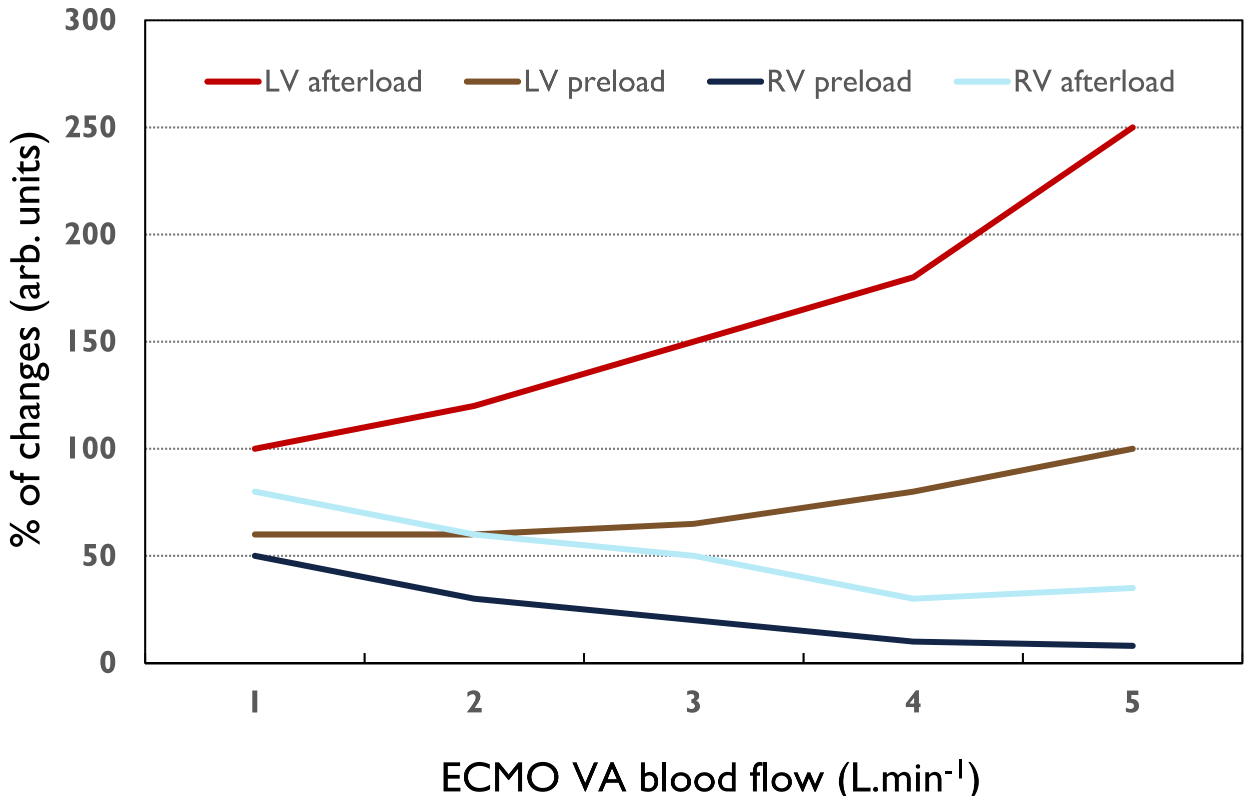


Peripheral ECLS

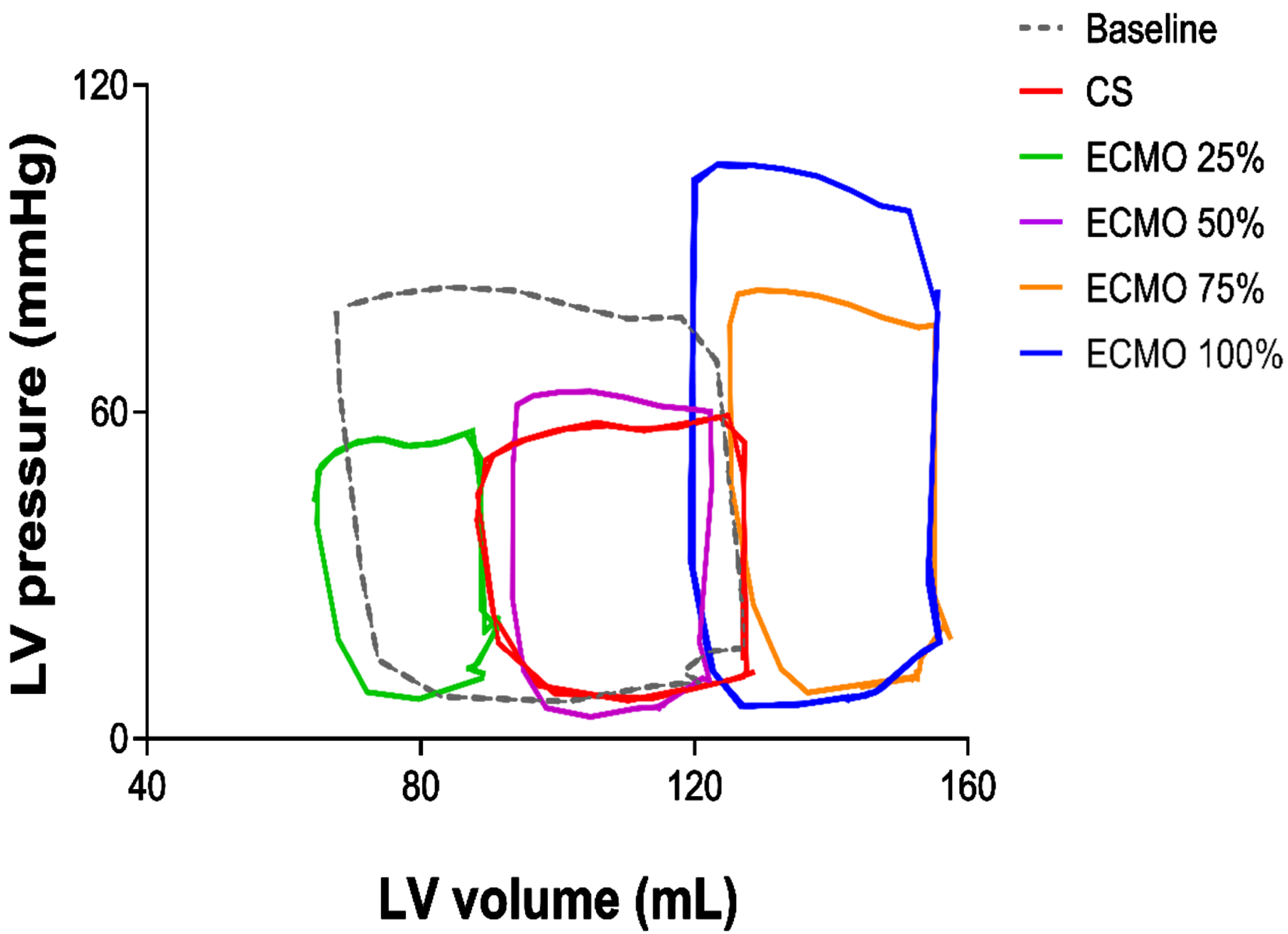
- Changes in ventricular loading conditions (increase afterload)
- Technical and anatomy dispositions
- Increase in parietal stress
- Risk of pulmonary edema (pulmonary morbidity)
- Alteration of sub-endocardial myocardial perfusion
- Alteration of myocardial recovery
- Increased risk when profound LV dysfunction (no « wash-out ») and in presence of MR ou AR

IMPACT OF VA-ECMO ON CARDIAC (LEFT AND RIGHT) LOADING CONDITIONS

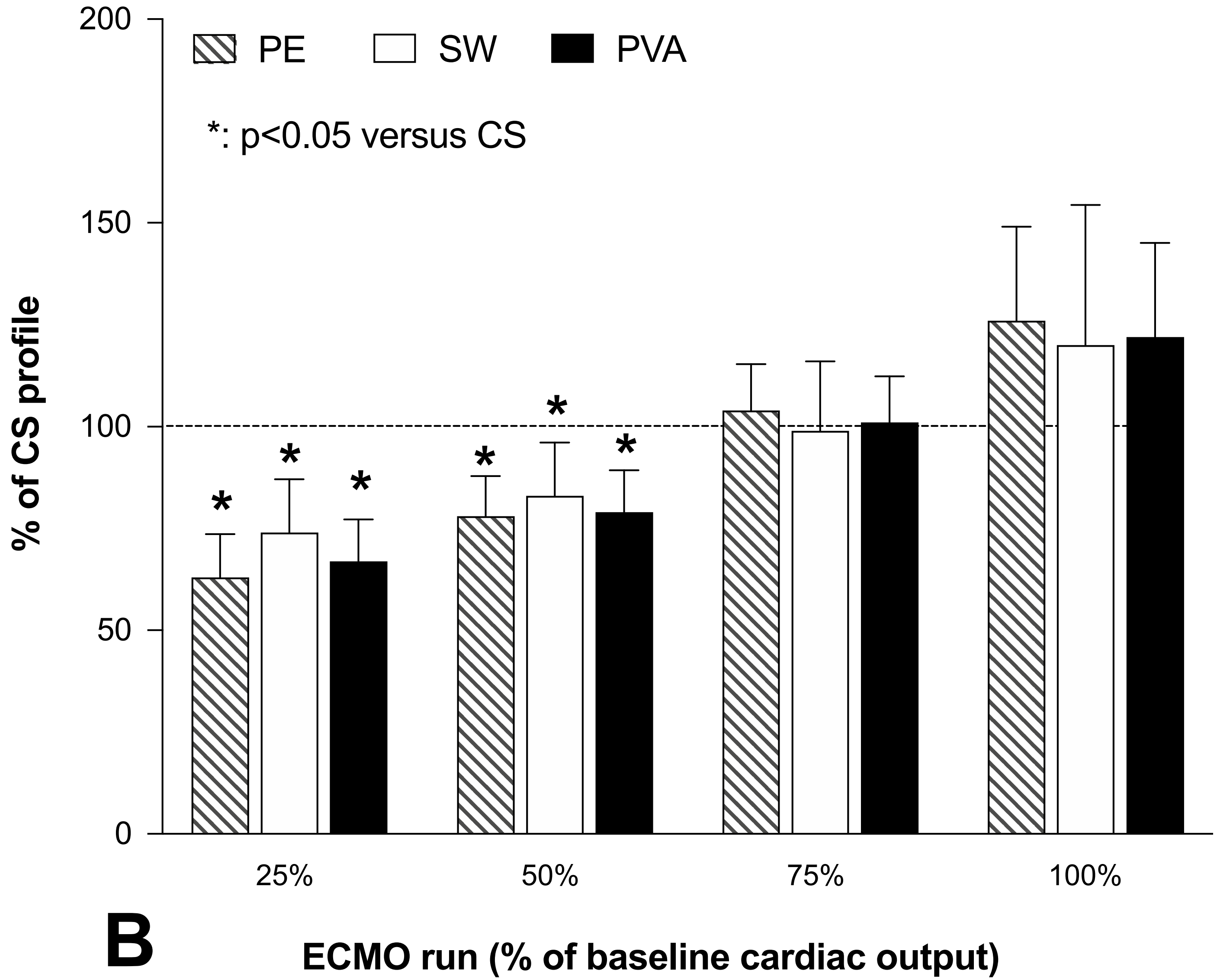




Beurton A et al. ASAIO Journal 2024 (in press)

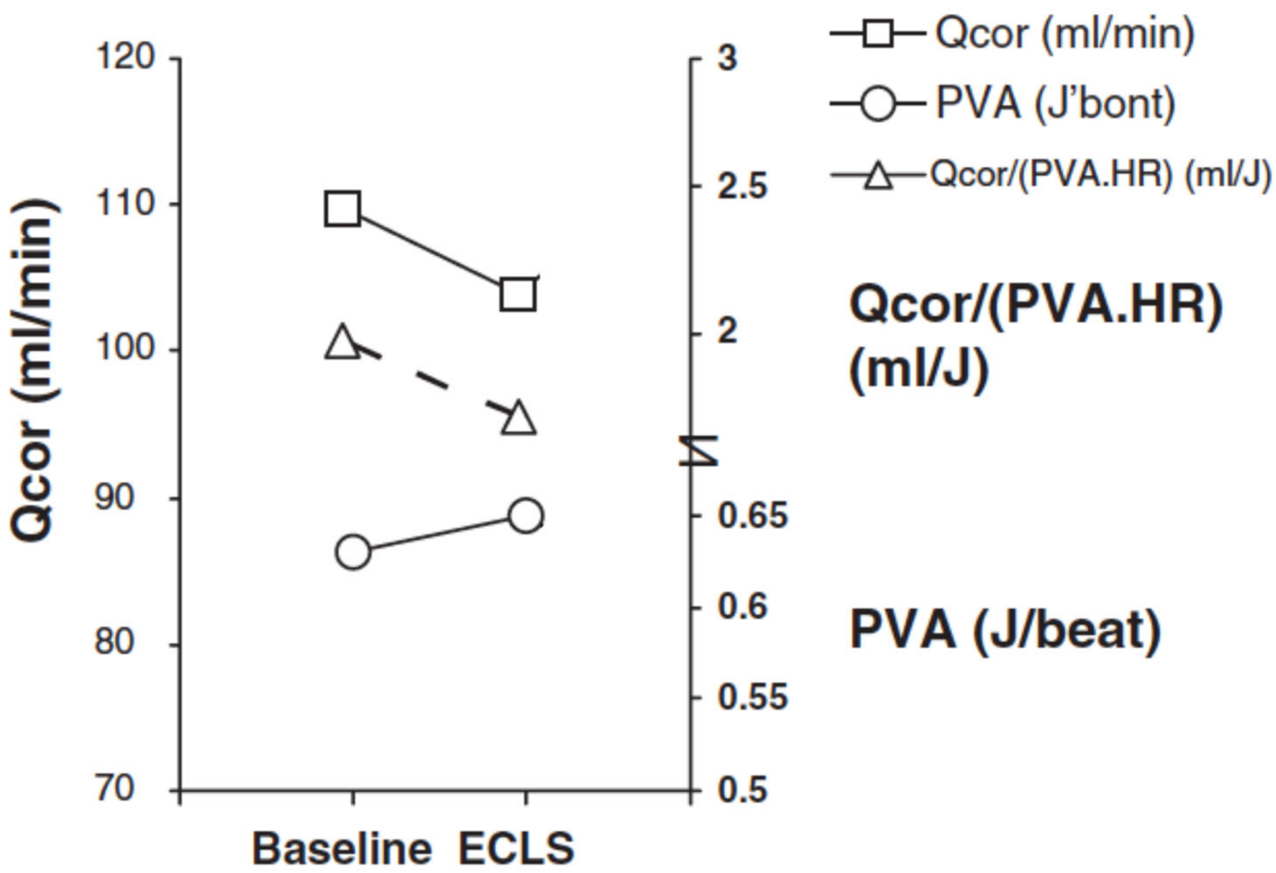


Beurton A et al. Am J Resp Crit Care Med (in submission)

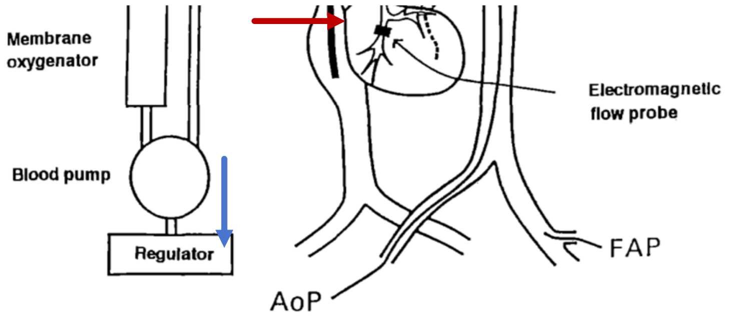


PE
SW
PVA
*: p<0.05 versus CS
% of CS profile
200
150
100
50
0
25%
50%
75%
100%
B
ECMO run (% of baseline cardiac output)

ECLS and coronary perfusion



Sauren LDC et al. Artificial Organs 2007;31:31-8



. Schematic diagram of the VA-ECMO circuit and experimental model. Note the placement ‹
›magnetic flow probe on the coronary artery and the cannulation sites for hemodynamic mea

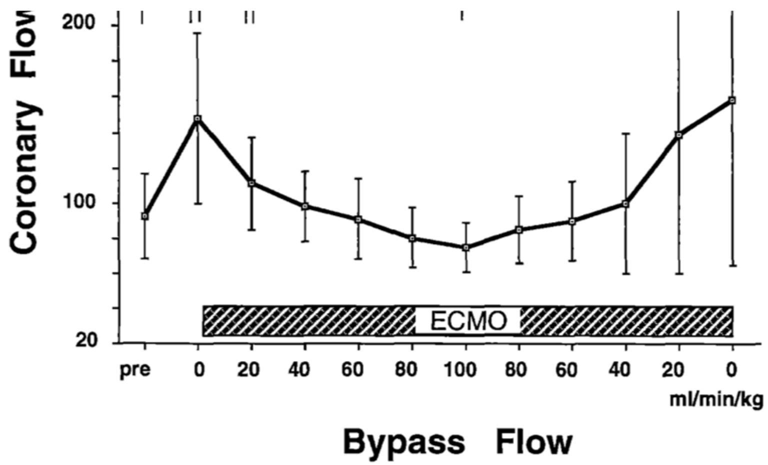
of 0.5 m^2 (MERASILOX-S; Senkoh Ika
›kyo, Japan). A pair of sack-type pumps are
‹nation by compressed air under automatic
ECMO flow, which is monitored with an
ic flowmeter, is automatically regulated by

Methods. The animals were anesthetized
lal sodium (10 mg/kg). They were then intu
lated, and subjected to general endotrache
with continuous intravenous ketamine chlori
per hour) and pancuronium bromide (0.

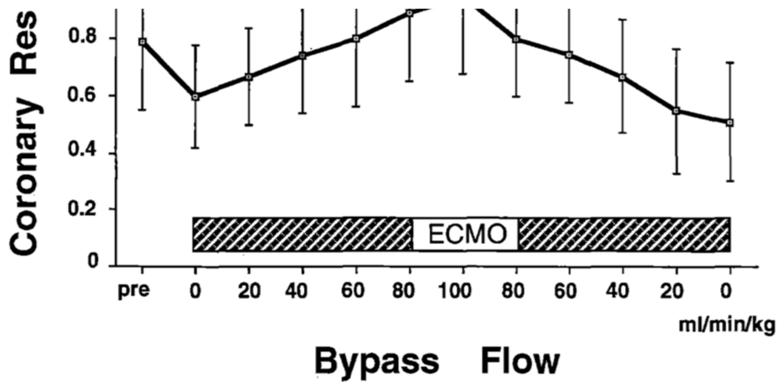
ncreased in 20 ml · min^{-1} · kg^{-1} increments to a maxi-
num bypass flow of 100 ml · min^{-1} · kg^{-1}. In nine of the
4 animals, the flow was then decreased in 20 ml ·
nin^{-1} · kg^{-1} increments to a bypass flow of zero. All
neasurements were made after a 5-minute stabilization
›eriod at each flow rate.

Statistical analysis. Results are expressed as mean ±
tandard deviation. Analysis of variance and the paired
test were used to analyze the data. Differences were
onsidered statistically significant at a p value less than
05.

other hand, Pao_2 in the left ventricle and ascenc
ing aorta did not change significantly. The dispa
ity in Pao_2 at the different sites became mor
prominent as the ECMO flow was increased t
100 ml · min^{-1} · kg^{-1}. The difference in Pac
between the left ventricle and ascending aorta wa
not significant. The ascending aorta was th
perfused by blood that had been ejected by th
left ventricle. There were no significant changes i
arterial carbon dioxide tension at the differe



;. **2.** CAF as a function of bypass flow. Ventilation settings were reduced to 10 cm H_2O peak inspirato
:ssure and 10 breaths/min respiratory rate between period before VA-ECMO *(pre)* and the initiation
\-ECMO. CAF increased significantly with reduced ventilator settings and decreased significantly shor
er the initiation of ECMO. CAF continued to fall with increases in the ECMO flow. As the ECMO flo
s decreased from the maximum of 100 ml · min^{-1} · kg^{-1} to 20 ml · min^{-1} · kg^{-1}, CAF increased to t
ne level as before VA-ECMO. *gLV,* Grams of left ventricle, wet weight; *SD,* standard deviation.

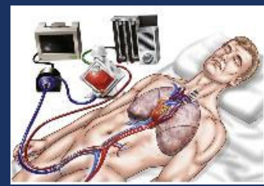


. **4.** Coronary resistance as a function of bypass flow. The coronary resistance decreased with reduced
tilator settings and increased with increases in bypass flow. The difference in coronary resistance
ween the peak ECMO flow (100 ml · min^{-1} · kg^{-1}) and minimal ECMO flow (20 ml · min^{-1} · kg^{-1})
statistically significant ($p < 0.01$). The coronary resistance returned to baseline as the bypass flow was
reased. *gLV,* Grams of left ventricle, wet weight; *SD,* standard deviation.

ronary flow with increases in LVEDP, ated by an extracorporeal circuit may also

Kato J et al. J Thorac Cardiovasc 1996;111:630-6

CARDIAC HAEMODYNAMIC AND VA-ECMO



- Decrease RV loading conditions
- Blood flow dependent increase in LV loading conditions (pre and after load)
- Blood flow dependent increase in total parietal stress
- Blood flow dependent increase in myocardial work and thus MvO2
- Decreased coronary blood flow

Anaesth Crit Care Pain Med 37 (2018) 195–196

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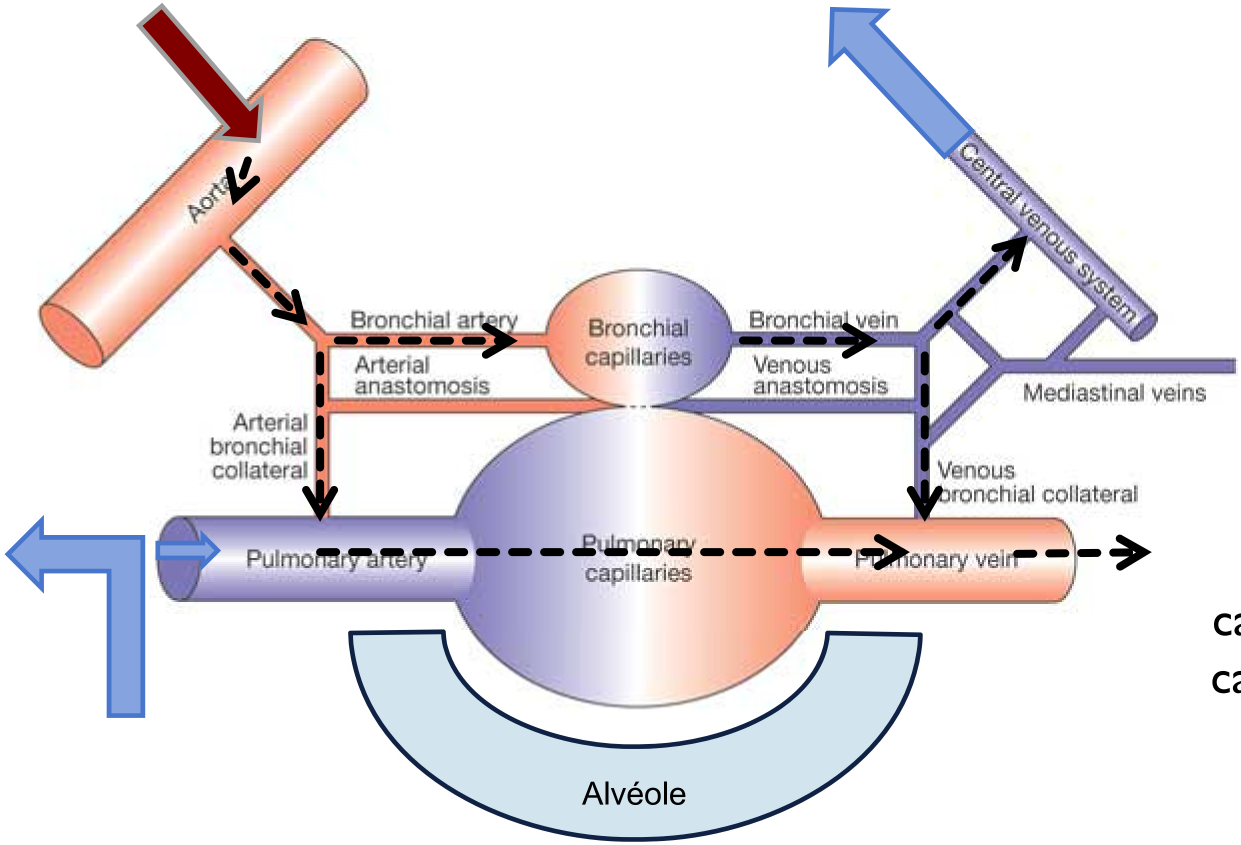
Société Française d'Anesthésie et de Réanimation

Editorial

ExtraCorporeal Life support for refractory cardiogenic shock: "An efficient system support of peripheral organs more than real ventricular assist device..."

Alexandre Ouattara[a,b,*], Alain Rémy[b], Astrid Quessard[b]
[a]*Université Bordeaux, Inserm, UMR 1034, biology of cardiovascular diseases, 33600 Pessac, France*
[b]*CHU Bordeaux, department of anaesthesia and critical care, Magellan Medico-Surgical Centre, 33000 Bordeaux, France*

Broncho-pulmonary shunt…

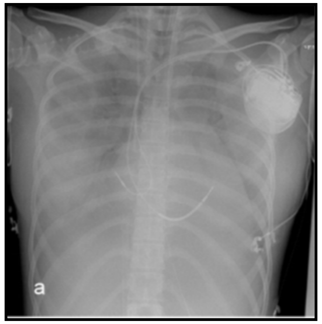


Left cardiac cavities

de Leval MR. Nature Clin Pract Cardiovasc Med 2005; ***2****:202-8*

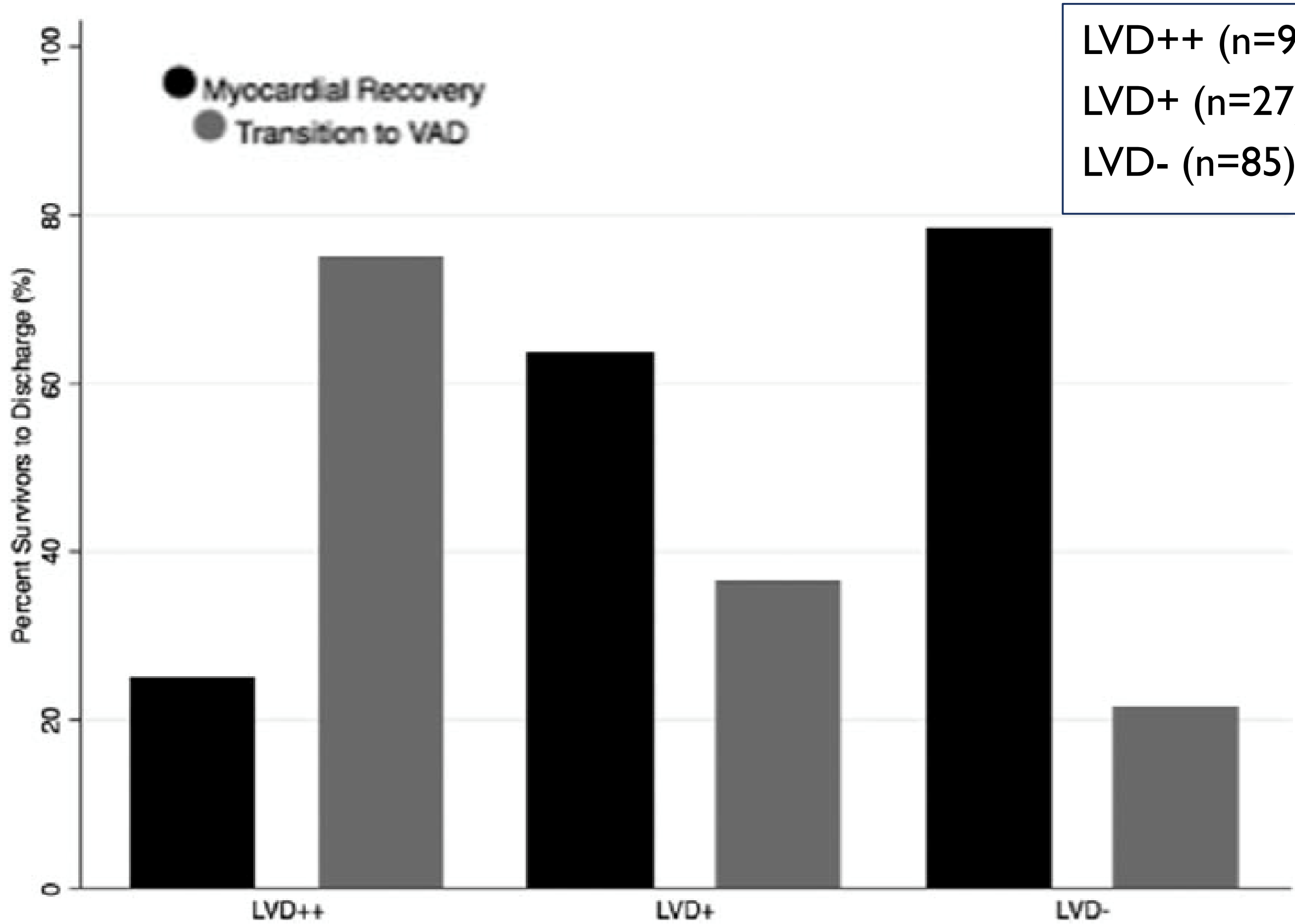
Table 2. Comparisons of intensive care unit events between survivors and nonsurvivors

Parameter	Survivors (n = 34)	Nonsurvivors (n = 47)	*p*
ECMO duration, days, median (IQR)	7 (5–10)	4 (1–12)	.04
Patients on MV, n (%)	30 (88)	47 (100)	.03
MV duration, days, median (IQR)	17 (8–25)	3 (2–10)	.0002
ICU stay, days, median (IQR)	21 (12–31)	4 (2–15)	<.0001
LVAD or BiVAD after ECMO, n (%)	5 (15)	1 (2)	.03
Heart transplant after ECMO, n (%)	7 (21)	2 (4)	.03
Day 3 SOFA score, mean ± SD	12 ± 5	17 ± 4	<.0001
Day 7 SOFA score, mean ± SD	10 ± 5	7 ± 6	<.0001
Packed red cells, n, mean ± SD	15 ± 11	11 ± 9	.05
Patients transfused, n (%)	34 (100)	43 (91)	.03
Renal replacement therapy, n (%)	13 (38)	36 (77)	.03
Major complication, n (%)	22 (65)	24 (51)	.27
Major bleeding	12 (35)	14 (30)	.60
Femoral vein thromboses	6 (18)	2 (4)	.06
Arterial ischemia	8 (24)	7 (15)	.39
Vena cava thrombosis	4 (12)	2 (4)	.24
Surgical wound infection	6 (18)	8 (17)	.99
Overt pulmonary edema	1 (3)	4 (9)	.39
Stroke	4 (12)	3 (6)	.44



Combes A et al. Crit Care Med 2008; 36:1404-11

LV DILATION ASSOCIATED WITH A WORSE PROGNOSIS

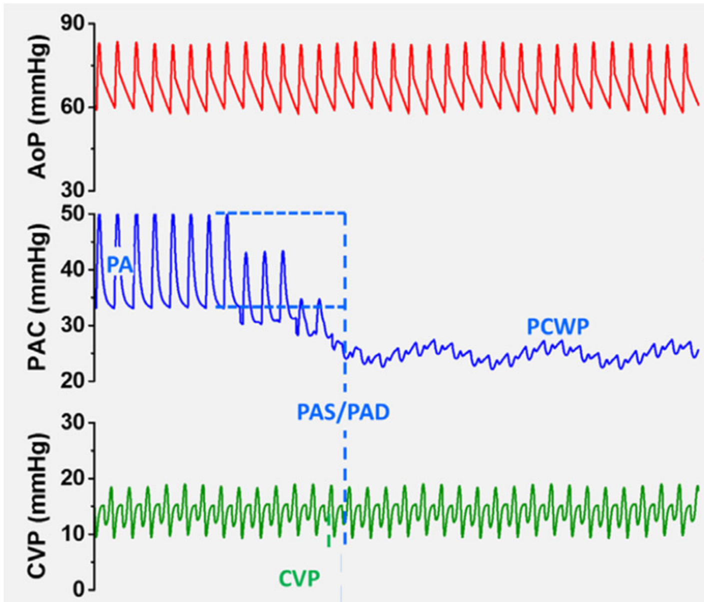


LVD++ (n=9)= clinical
LVD+ (n=27)= subclinical LVD
LVD- (n=85)= no signs of LVD

Truby LK et al. ASAIO Journal 2017;63:257-65

ASSESSMENT OF LV PRELOAD

- Pulmonary capillary wedge pressure (PCWP) or pulmonary artery occlusion pressure (PAOP)
- Estimation of LA pressure
- Upper limit 18 mmHg



WHITE PAPER

Value of Hemodynamic Monitoring in Patients With Cardiogenic Shock Undergoing Mechanical Circulatory Support

Abhinav Saxena, MD
A. Reshad Garan, MD
Navin K. Kapur, MD
William W. O'Neill, MD
JoAnn Lindenfeld, MD
Sean P. Pinney, MD
Nir Uriel, MD
Daniel Burkhoff, MD, PhD
Morton Kern, MD

SUMMARY

"PACs should be used in all patients undergoing MCS to monitor effectiveness, optimize device settings , assess the need for escalation and guide timing and rate of weaning…"

Circulation 2020; 141:1184-97

ELSO Interim Guidelines for Venoarterial Extracorporeal Membrane Oxygenation in Adult Cardiac Patients

« A pulmonary artery catheter should be considered during VA ECMO, as it allows detection of elevated left-sided filling pressures, which may prompt the use of adjunct LV unloading techniques… »

« …PAC-based continuous cardiac output monitoring during VA ECMO is inaccurate but it may provide an indication of pulmonary artery flow and aid in weaning… »

Table 8. Clinical Monitoring During Venoarterial Extracorporeal Membrane Oxygenation

Invasive arterial blood pressure monitoring/right radial artery
- Pulse pressure—measure of native contractility *vs.* ECMO blood flow
- Oxygen saturation—measure of oxygenation in proximal aortic arch/detection of differential oxygenation

Pulse oximetry/right hand
- Oxygen saturation—measure of oxygenation in proximal aortic arch/detection of differential oxygenation

Pulmonary artery catheter
- Detect elevated left-sided filling pressure
- Support indication for adjunct LV unloading
- Continuous cardiac output monitoring as indication of residual pulmonary artery flow (alternatively, residual pulmonary artery flow can be monitored by measuring end-tidal CO_2)

Echocardiography
- Early cardiac diagnostics and identification of contraindications to VA ECMO
- Visualization of proper vascular access and guidance cannulation
- Optimal tailoring of ECMO support
- Serial assessment of hemodynamic and cardiac conditions
- Cardiac assessment during weaning trial

Electrocardiography
- Consider continuous, multilead electrocardiographic monitoring

NIRS
- Monitoring of limb (single and bilateral comparison) and brain perfusion

ECLS, extracorporeal life support; LV, left ventricular; NIRS, near-infrared spectroscopy; VA ECMO, venoarterial extracorporeal membrane oxygenation.

Lorusso R et al. ASAIO Journal 2021

TO ASSESS RIGHT CAVITIES UNLOADING AND RESIDUAL PULMONARY FLOW

- Central venous pressure < 10 mmHg
- Diastolic pulmonary partial pressure < 20 mmHg
- Cardiac index between 1.0 and 2.0 $L.min^{-1}.m^{-2}$

Merkle J et al.Thorac Dis 2019; 11(Suppl 6): S946–56

CLINICAL IMPLICATIONS

- Avoid over-assistance (blood flow to meet the metabolic demand (SvO_2)
- Screening risk of pulmonary edema (TTE, Swan-Ganz catheter PCWP < 16-18 mmHg...)

STATE OF THE ART

Puajara D et al. Semin Thoracic Surg 2015;27:17-23

The State of the Art in Extracorporeal Membrane Oxygenation

Pharmalocigal unloading

MANAGEMENT CONSIDERATIONS

Inotropic support and ventricular assist devices (eg, Impella, Abiomed; intra-aortic balloon pump; TandemHeart trans-septal cannula) should be maintained to facilitate the left-side chamber unloading if cardiac recovery is a possibility.

Cardiogenic shock in 2024: insight the complex reality of ECLS and left ventricular unloading strategies

Intensive Care Med. 2024;50:971-3

Aurore Ughetto[1*], Benedikt Schrage[2] and Clément Delmas[3,4]

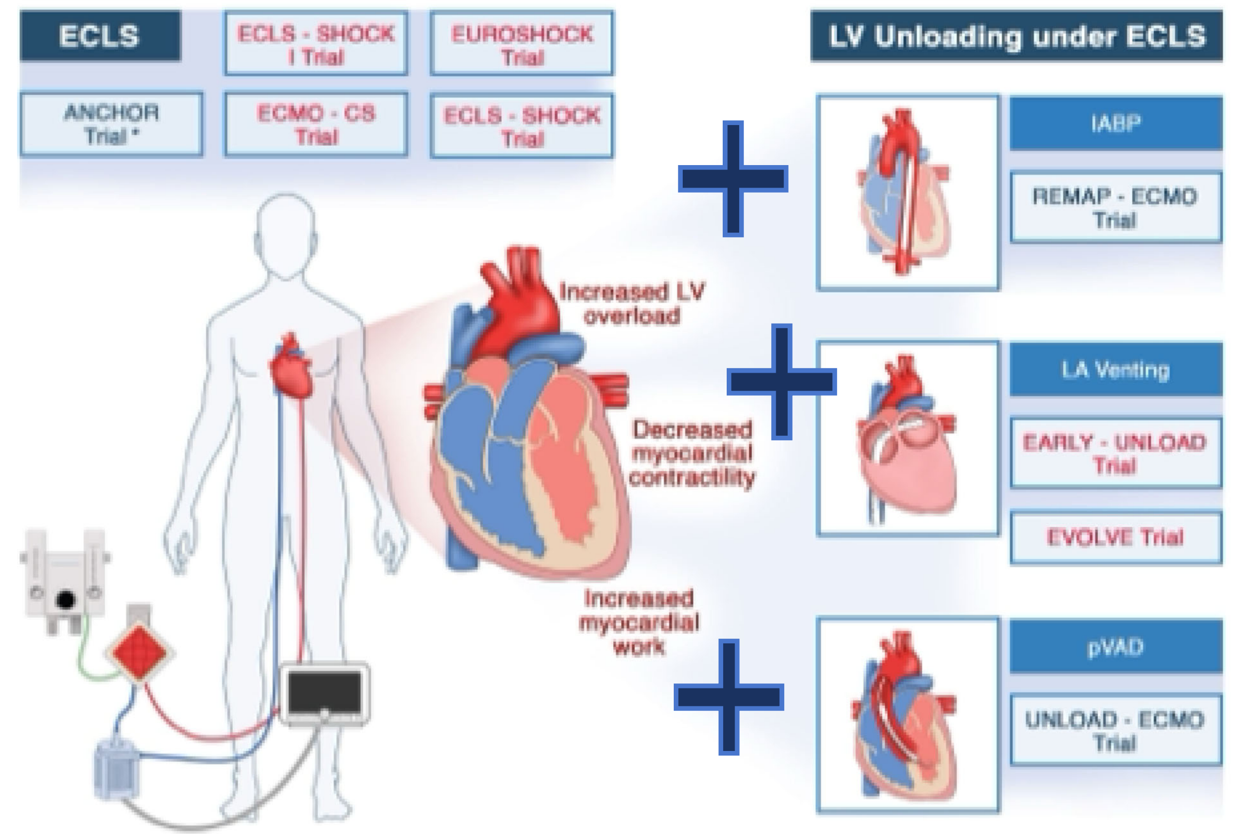
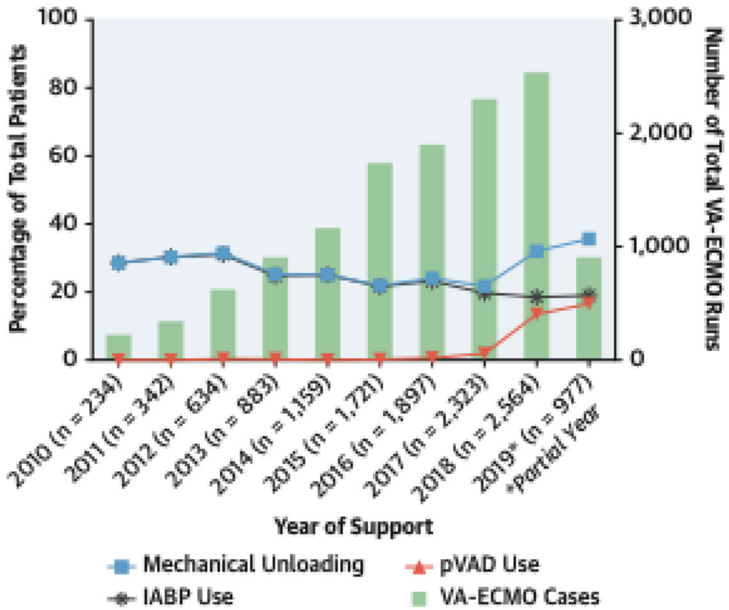
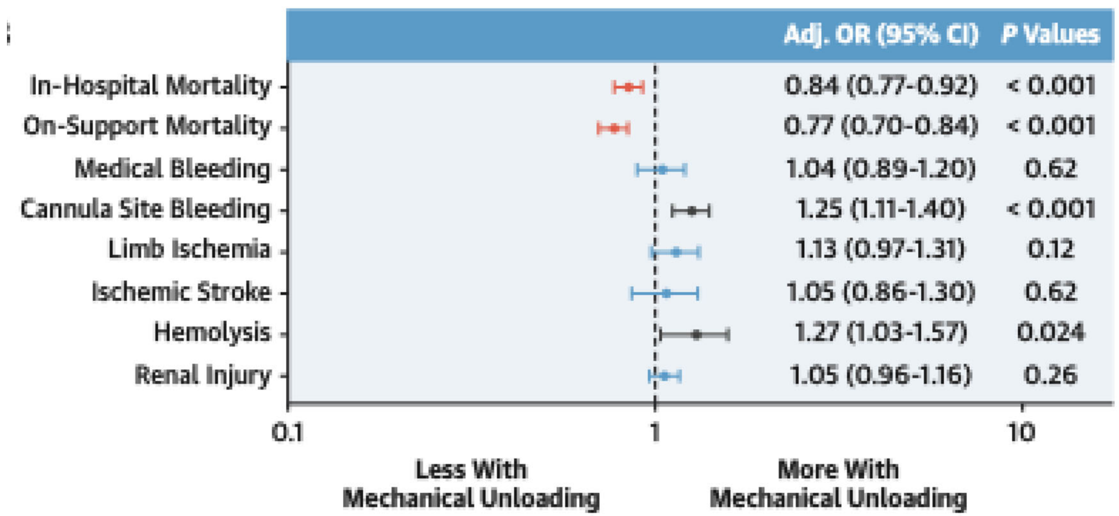


Fig. 1 Drawbacks of extracorporeal life support and techniques for left ventricular unloading with associated randomized controlled trials. *ECLS* extracorporeal life support, *IABP* intra-aortic balloon pump, *LV* left ventricle, *pVAD* percutaneous ventricular assist device

Grandin EW et al. J Am Coll Cardioll 2022;79:1239-50



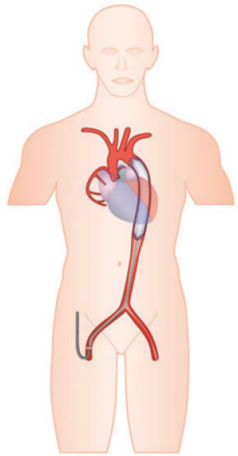
- ELSO registry 2010-2019 (**n=12 734**)
- 26.7% of patients with LV unloading
- No influence by timing (upfront versus delayed)

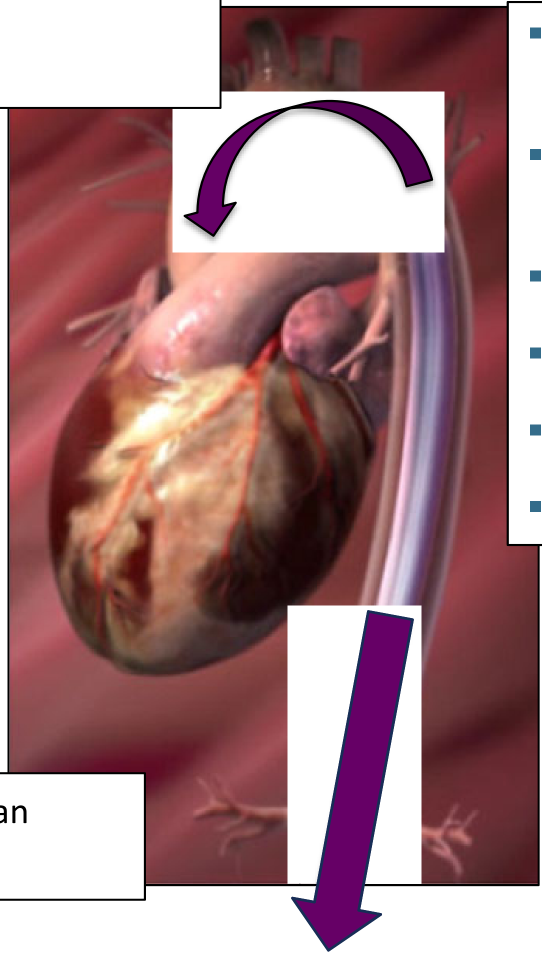


Intra-aortic balloon pump (IABP)

<u>Improvement energetic balance of myocardium</u>

- Decrease MvO_2 (loading conditions)
- Increase myocardial perfusion





- Increase diatolic aortic pressure 30 à 70% (rapid inflation r)
- Decrease systolic aortic pressure of 5-15% (rapid defletion)
- Decrease LV afterload
- Decrease LV preload
- Decrease HR (10%)
- Increase SV and CO (5-10%).

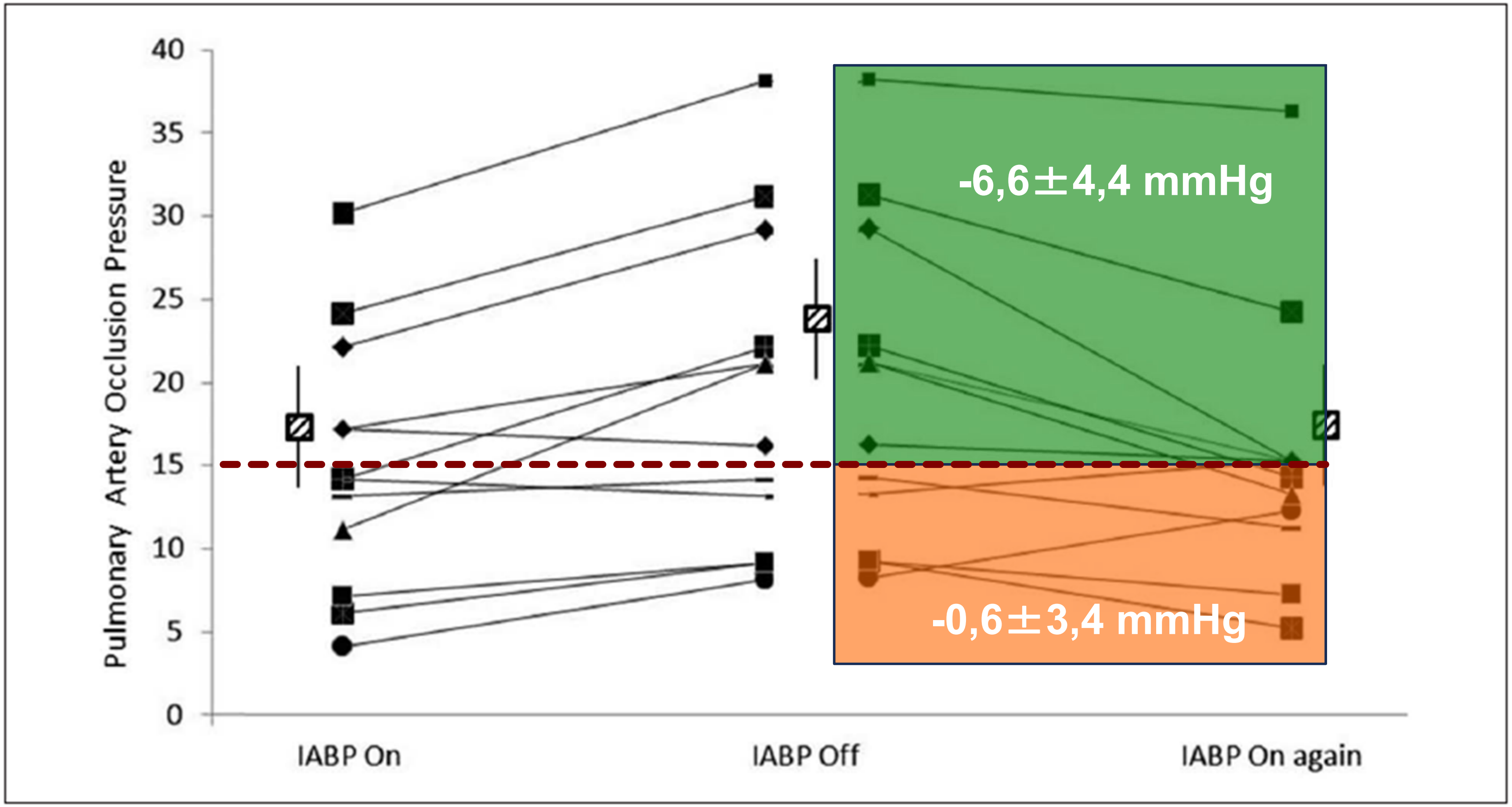
Improvement of end-organ perfusion (Pulsatility)

deWaha S et al. Vascular Pharmacology 2014;61:30-34

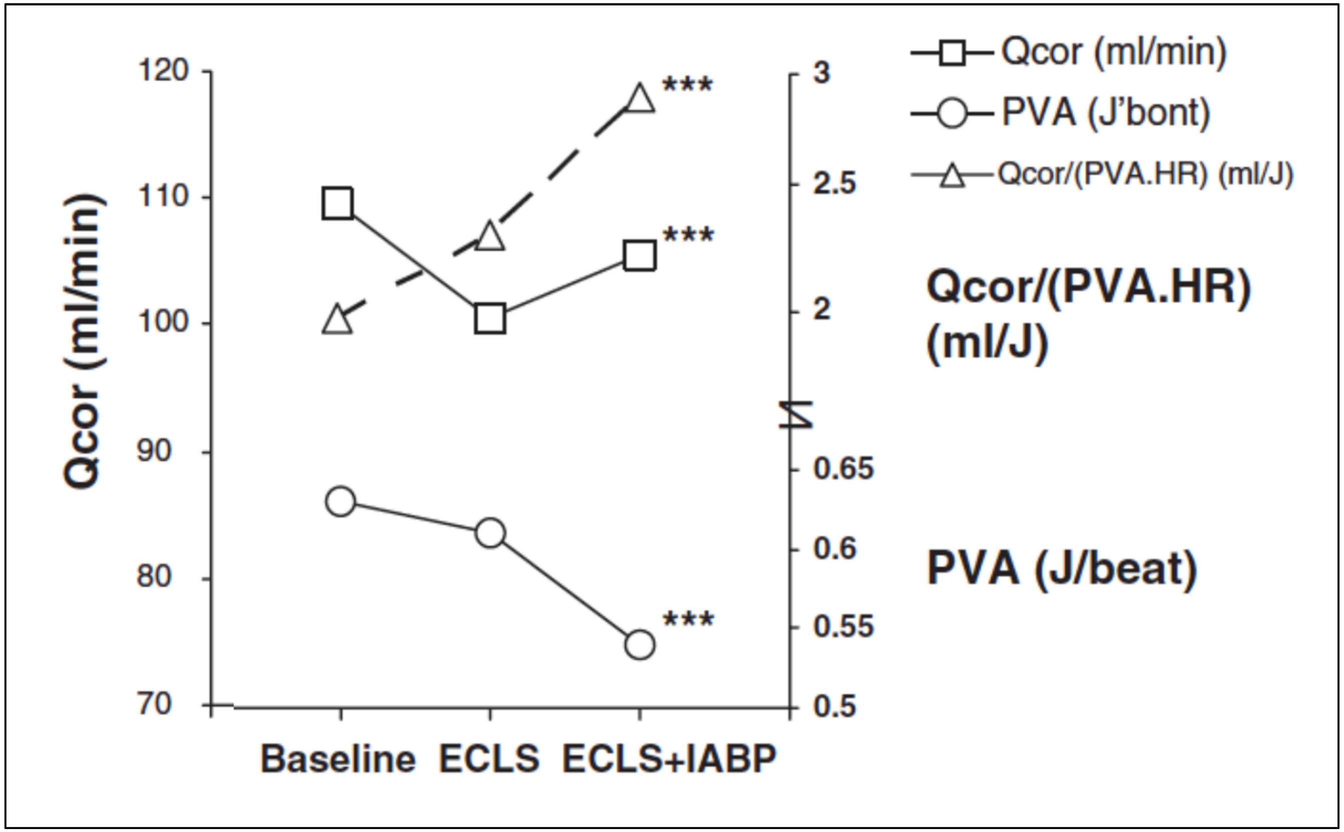
Ro SK et al. Eur J Cardiothorac Surg 2014; 46:186-92

Aso S et al. Crit Care Med 2016; 44:1974-9

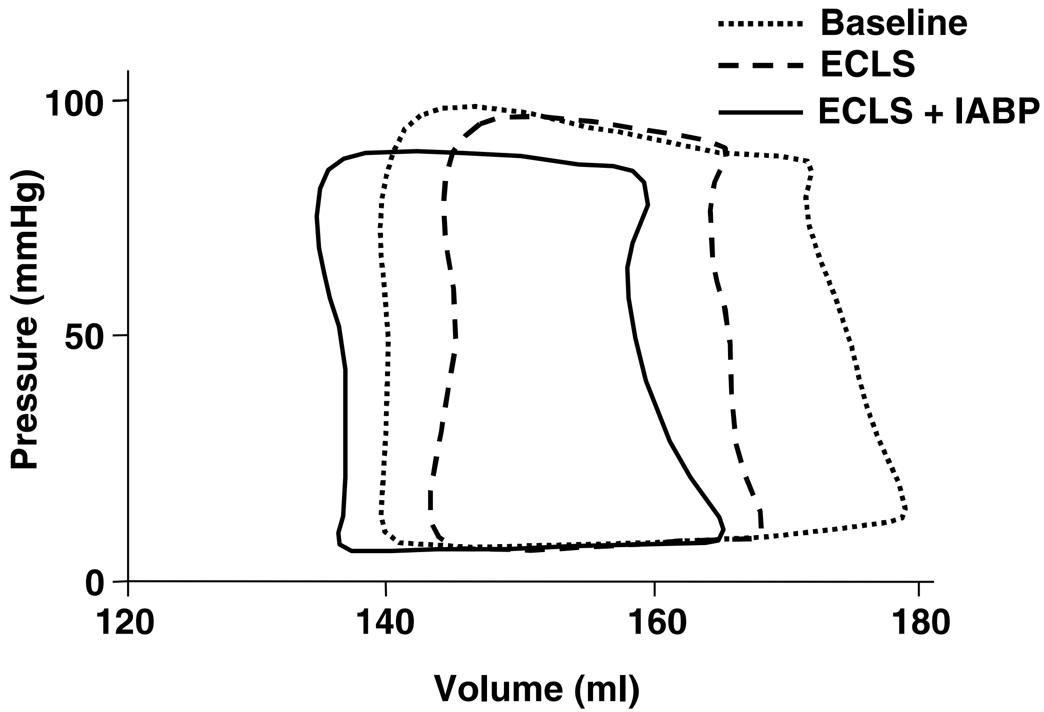
Changes in PCWP



Petroni T et al. Crit Care Med 2014; 42:2075-82

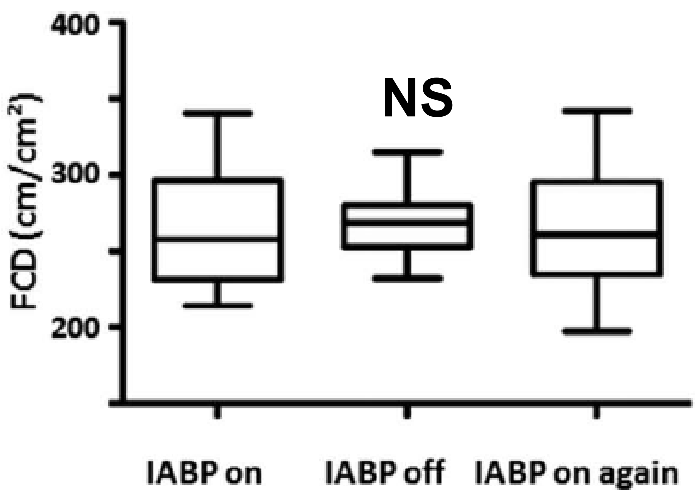


Sauren LDC et al. Artificial Organs 2007;31:31-8

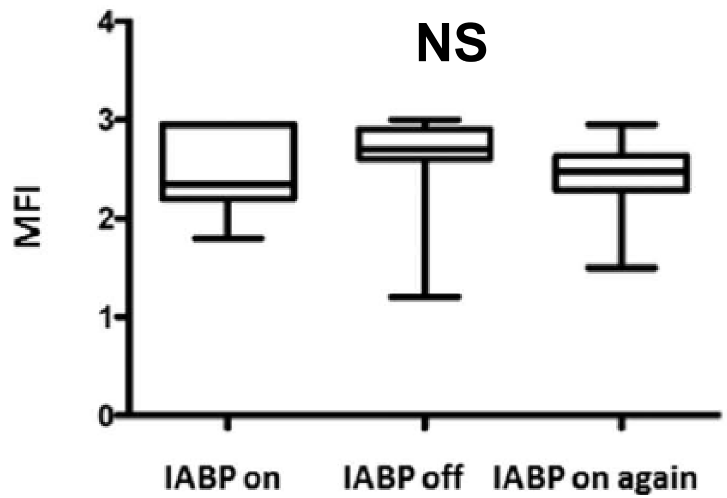


Decrease in LVEDP and LVEDV
Decrease in SV
Reduction of myocardial oxygen consumption

Sauren LDC et al. Artif Organs 2007; 31:31-8



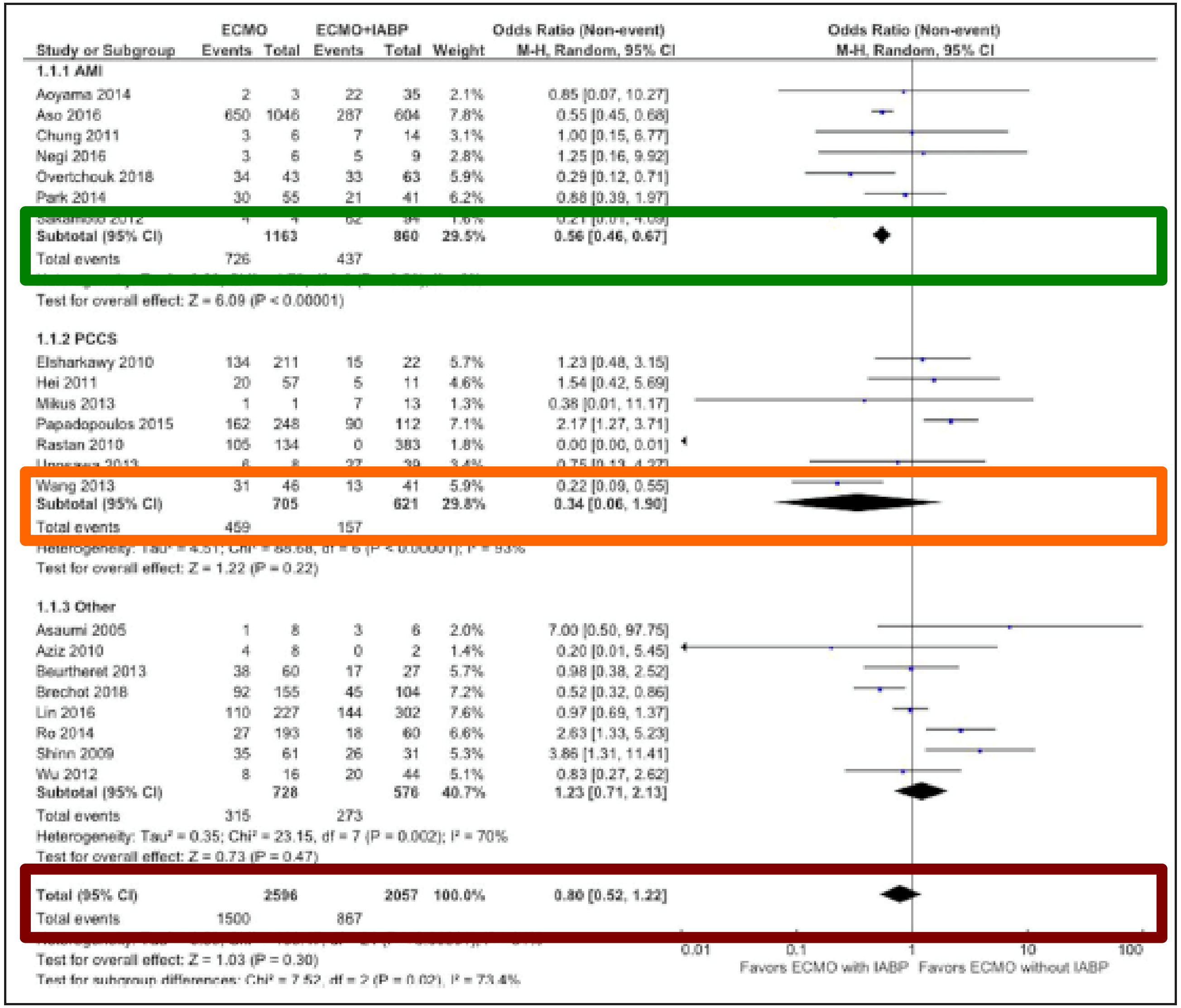
FCD = Functional capillary density



MFI = microvascular flow index

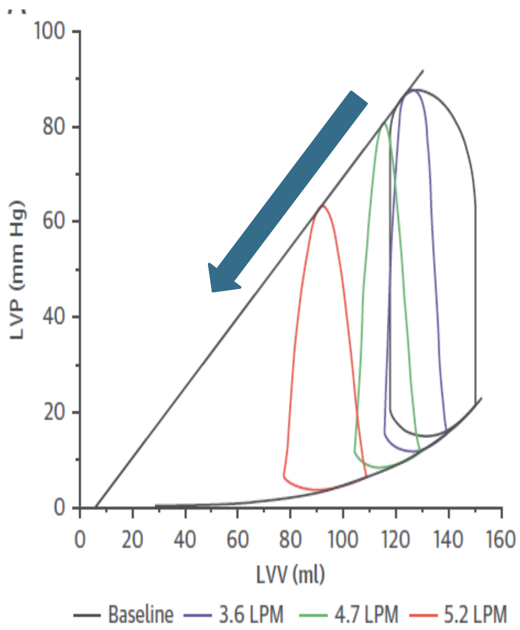
Petroni T et al. Crit Care Med 2014; 42:2075-82

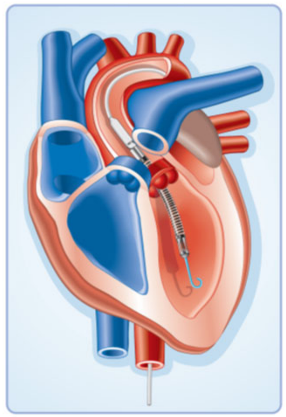
- Meta-analysis of 22 studies (2000-18, n= 4653). The IABP was used in nearly 44% of VA ECMO patients

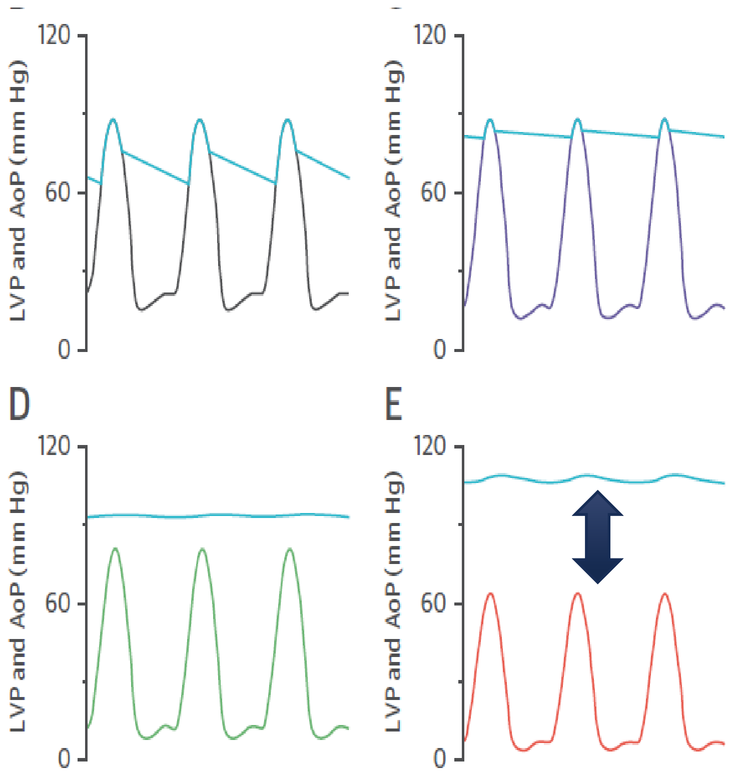


Study or Subgroup	ECMO Events	ECMO Total	ECMO+IABP Events	ECMO+IABP Total	Weight	Odds Ratio (Non-event) M-H, Random, 95% CI
1.1.1 AMI						
Aoyama 2014	2	3	22	35	2.1%	0.85 [0.07, 10.27]
Aso 2016	650	1046	287	604	7.8%	0.55 [0.45, 0.68]
Chung 2011	3	6	7	14	3.1%	1.00 [0.15, 6.77]
Negi 2016	3	6	5	9	2.8%	1.25 [0.16, 9.92]
Overtchouk 2018	34	43	33	63	5.9%	0.29 [0.12, 0.71]
Park 2014	30	55	21	41	6.2%	0.88 [0.39, 1.97]
Sakamoto 2012	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Subtotal (95% CI)		**1163**		**860**	**29.5%**	**0.56 [0.46, 0.67]**
Total events	726		437			
Test for overall effect: Z = 6.09 (P < 0.00001)						
1.1.2 PCCS						
Elsharkawy 2010	134	211	15	22	5.7%	1.23 [0.48, 3.15]
Hei 2011	20	57	5	11	4.6%	1.54 [0.42, 5.69]
Mikus 2013	1	1	7	13	1.3%	0.38 [0.01, 11.17]
Papadopoulos 2015	162	248	90	112	7.1%	2.17 [1.27, 3.71]
Rastan 2010	105	134	0	383	1.8%	0.00 [0.00, 0.01]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Wang 2013	31	46	13	41	5.9%	0.22 [0.09, 0.55]
Subtotal (95% CI)		**705**		**621**	**29.8%**	**0.34 [0.06, 1.90]**
Total events	459		157			
Test for overall effect: Z = 1.22 (P = 0.22)						
1.1.3 Other						
Asaumi 2005	1	8	3	6	2.0%	7.00 [0.50, 97.75]
Aziz 2010	4	8	0	2	1.4%	0.20 [0.01, 5.45]
Beurtheret 2013	38	60	17	27	5.7%	0.98 [0.38, 2.52]
Brechot 2018	92	155	45	104	7.2%	0.52 [0.32, 0.86]
Lin 2016	110	227	144	302	7.6%	0.97 [0.69, 1.37]
Ro 2014	27	193	18	60	6.6%	2.63 [1.33, 5.23]
Shinn 2009	35	61	26	31	5.3%	3.86 [1.31, 11.41]
Wu 2012	8	16	20	44	5.1%	0.83 [0.27, 2.62]
Subtotal (95% CI)		**728**		**576**	**40.7%**	**1.23 [0.71, 2.13]**
Total events	315		273			
Heterogeneity: Tau² = 0.35; Chi² = 23.15, df = 7 (P = 0.002); I² = 70%						
Test for overall effect: Z = 0.73 (P = 0.47)						
Total (95% CI)		**2596**		**2057**	**100.0%**	**0.80 [0.52, 1.22]**
Total events	1500		867			
Test for overall effect: Z = 1.03 (P = 0.30)						
Test for subgroup differences: Chi² = 7.52, df = 2 (P = 0.02), I² = 73.4%						

INTRA-CARDIAC HAEMODYNAMIC EFFECTS OF IMPELLA DEVICE







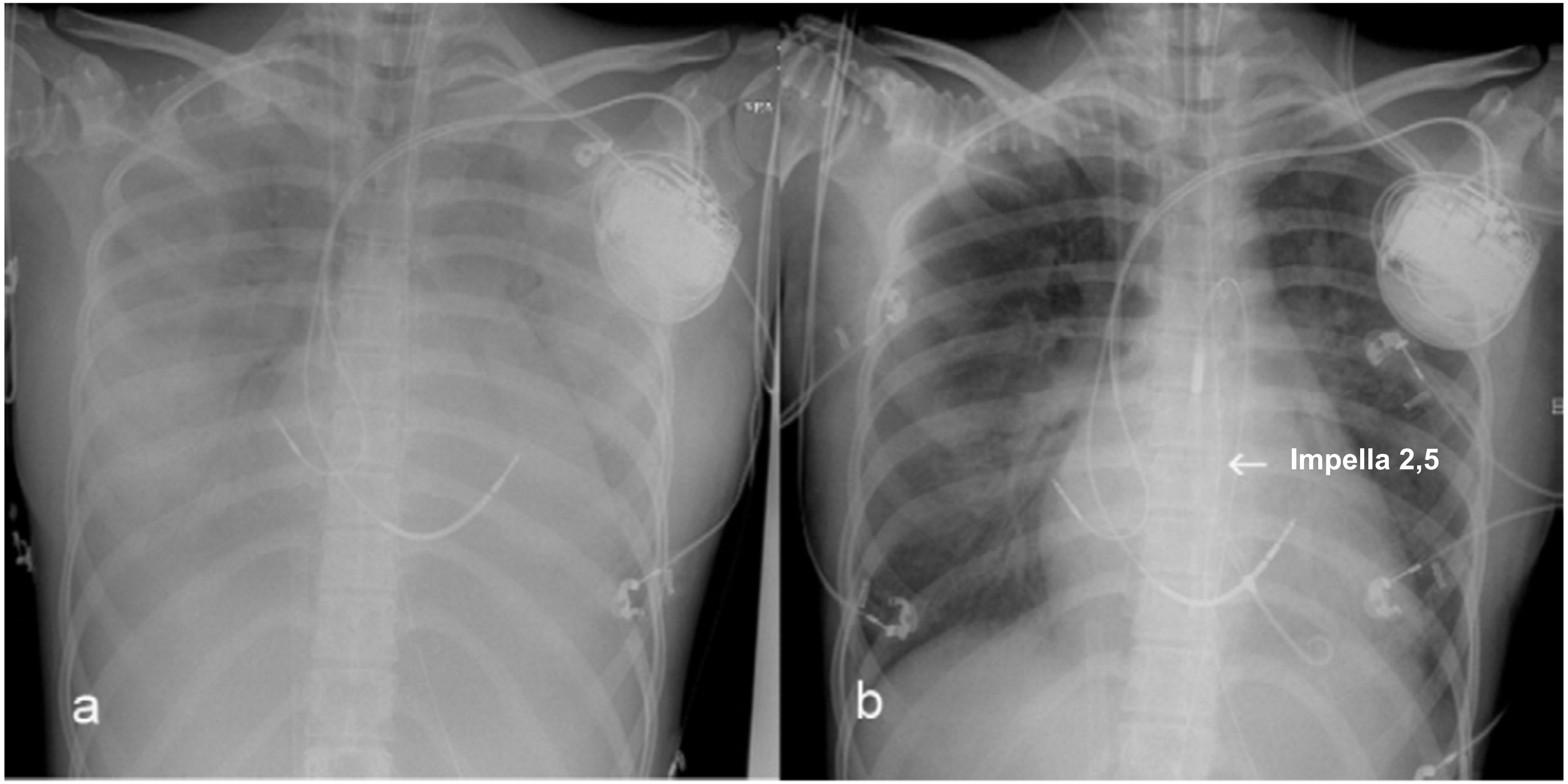
LV unloading and reduction of myocardial work

Arterio-Ventricular decoupling

Uriel N et al. J Am Coll Cardiol 2018;72:569-80

Successful left ventricular decompression following peripheral extracorporeal membrane oxygenation by percutaneous placement of a micro-axial flow pump

Jouan J et al. J Heart Lung Transplant 2010;29:135-6



Concomitant implantation of Impella® on top of veno-arterial extracorporeal membrane oxygenation may improve survival of patients with cardiogenic shock

Papparlardo F et al. Eur J Heart Failure 2016

Retrospective multicenter trial (n=2) including **Propensity Score adjustment**

ECLS alone versus ECLS + IMPELLA (2.5 or CP)

Table 1 Comparison of baseline characteristics between patients treated with veno-arterial extracorporeal membrane oxygenation (ECMO) and Impella and patients treated with veno-arterial ECMO only in the original unmatched population (*n* = 157)

Parameter	Total (*n* = 157)	ECMO + Impella (*n* = 34)	ECMO (*n* = 123)	*P*-value	Absolute standardized difference[a]
Age, years	55 (46–64)	54 (47–66)	55 (45–64)	0.9	0.0217
Males, *n* (%)	130 (83)	28 (82)	102 (83)	0.9	0.0263
CPR, *n* (%)	100 (64)	14 (41)	86 (70)	0.002	0.6101
STEMI, *n* (%)	85 (54)	15 (44)	70 (57)	0.2	0.2622
PCI, *n* (%)	56 (36)	16 (47)	40 (33)	0.10	0,2887
pH	7.23 (6.98–7.39)	7.36 (7.08–7.41)	7.16 (6.95–7.37)	0.02	0.5087
Lactates, mmol/L	9.55 (4.40–15.35)	8.96 (3.10–16.25)	10.26 (4.97–15.24)	0.4	0.1173
Concomitant IABP, *n* (%)	54 (34)	8 (24)	46 (37)	0.10	0.2852

CPR, cardiopulmonary resuscitation; IABP, intra-aortic balloon pump; STEMI, ST-segment elevation myocardial infarction.
[a]0–0.2 small effect size; 0.2–0.5 medium effect size; 0.5–0.8 large effect size; 0.8–1 very large effect size.

Concomitant implantation of Impella® on top of veno-arterial extracorporeal membrane oxygenation may improve survival of patients with cardiogenic shock

Papparlardo F et al. Eur J Heart Failure 2016

Retrospective multicenter trial (n=2) including **Propensity Score adjustment**

ECLS alone versus ECLS + IMPELLA (2.5 or CP)

Table 3 **Comparison of major outcomes between patients treated with veno-arterial extracorporeal membrane oxygenation (ECMO) and Impella and patients treated with veno-arterial ECMO only in the propensity score matching sample (*n* = 63)**

Parameter	Total (*n* = 63)	ECMO + Impella (*n* = 21)	ECMO (*n* = 42)	*P*-value
Hospital mortality, *n* (%)	41 (65)	10 (48)	31 (74)	0.04
Bridge to next therapy or recovery, *n* (%)	28 (44)	13 (62)	15 (36)	0.048
Weaning from MCS, *n* (%)	26 (41)	10 (48)	16 (28)	0.047
Bridge to recovery, *n* (%)	19 (30)	8 (38)	11 (26)	0.3
Bridge to VAD, *n* (%)	8 (13)	4 (19)	4 (9.5)	0.5
Bridge to cardiac transplantation, *n* (%)	0	0	0	
Duration of ECMO, h	120 (36–234)	148 (72–239)	73.5 (29–217)	0.2
Duration of MV, h	93 (29–228)	163 (90–228)	48 (17–265)	0.04
CVVH, *n* (%)	18 (29)	10 (48)	8 (19)	0.02
Haemolysis, *n* (%)	30 (48)	16 (76)	14 (33)	0.004
Major bleeding, *n* (%)	20 (32)	8 (38)	12 (29)	0.6
Minor bleeding, *n* (%)	14 (22)	4 (19)	10 (24)	0.8
LVEF at weaning, %	45.5 (30–55)	52.5 (47–55.5)	37.5 (25–50)	0.13

CVVH, continuous veno-venous haemofiltration; MCS, mechanical circulatory support; MV, mechanical ventilation; VAD, ventricular assist device.

ORIGINAL RESEARCH ARTICLE

Left Ventricular Unloading Is Associated With Lower Mortality in Patients With Cardiogenic Shock Treated With Venoarterial Extracorporeal Membrane Oxygenation

Results From an International, Multicenter Cohort Study

Variable	Matched study cohort VA-ECMO, matched (n=255)	ECMELLA (n=255)	*P* value
Bleeding complications			
Intracerebral bleeding	16/182 (8.8)	18/216 (8.3)	0.99
Hemorrhagic stroke	10/181 (5.5)	7/216 (3.2)	0.38
Severe bleeding	45/252 (17.9)	98/255 (38.4)	<0.01
Moderate bleeding	74/192 (38.5)	123/241 (51.0)	0.01
Intervention resulting from bleeding	33/201 (16.4)	47/251 (18.7)	0.61
Hemolysis	43/192 (22.4)	79/235 (33.6)	0.01
Ischemic complications			
Ischemic stroke	22/242 (9.1)	16/230 (7.0)	0.50
Intervention because of access site–related ischemia	31/252 (12.3)	55/255 (21.6)	<0.01
Laparotomy because of abdominal compartment	9/243 (3.7)	23/245 (9.4)	0.02
Laparotomy because of bowel ischemia	7/243 (2.9)	11/245 (4.5)	0.48
Other complications			
Hypoxic brain damage	19/179 (10.6)	29/216 (13.4)	0.49
Renal replacement therapy	99/253 (39.1)	148/253 (58.5)	<0.01
Sepsis	44/200 (22.0)	70/251 (27.9)	0.19

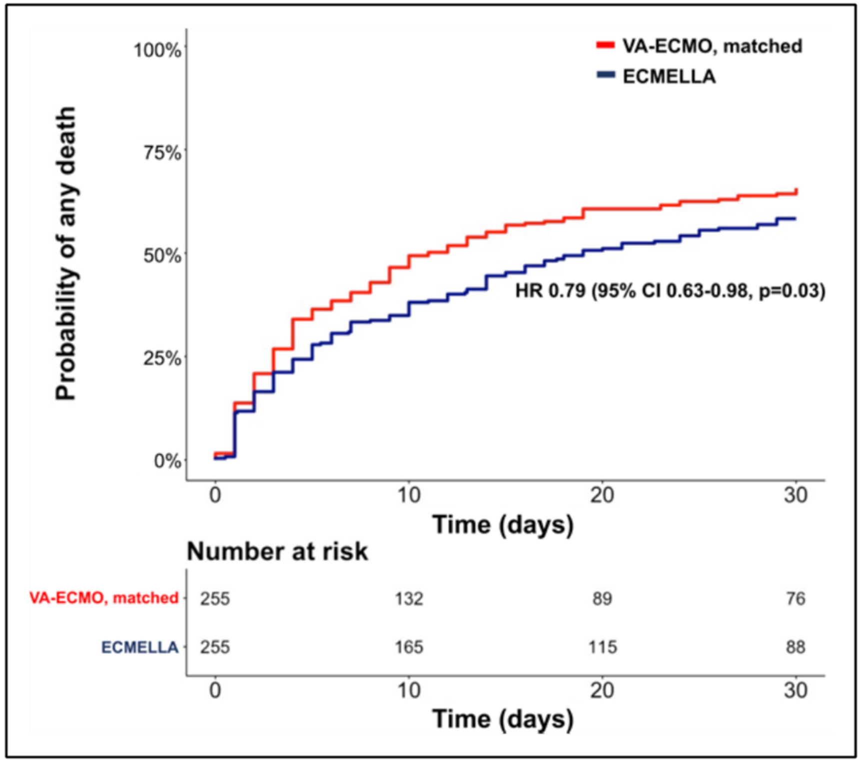


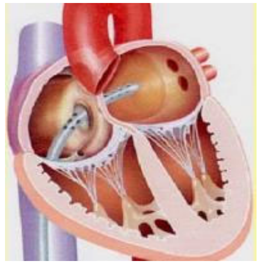
Figure 2. Kaplan-Meier curve of the matched study cohort. ECMELLA indicates Impella+extracorporeal membrane oxygenation; HR, hazard ratio; and VA-ECMO, venoarterial extracorporeal membrane oxygenation.

Schrage B et al. Circulation 2020; 142:2095-106

Decompression of the left atrium during extracorporeal membrane oxygenation using a transseptal cannula incorporated into the circuit*

Crit Care Med 2006 Vol. 34, No. 10

Ranjit M. Aiyagari, MD; Albert P. Rocchini, MD; Robert T. Remenapp, RN; Joseph N. Graziano, MD



Expérience d'une septotomie atriale percutanée (n=7)

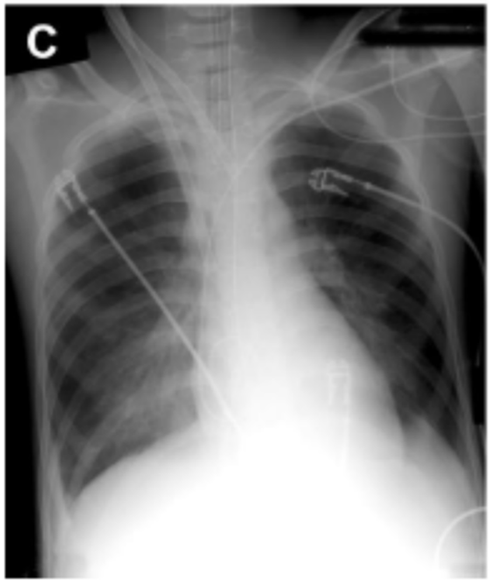
Délai médian 11 heures (6-130 heures)

POG = 31 mmHg (22-45)

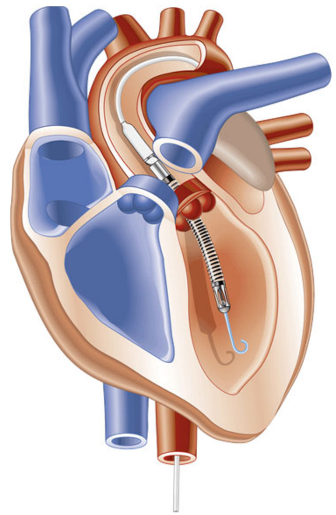
Durée de procédure 51 min (42-145)

Before

After



TEST OF RV FUNCTION IN RESPONSE TO CARDIAC OUTPUT RESTORATION



- Mono-ventricular axial pump
- Without oxygenation
- Restore systemic (and anterograde) blood flow
- Increase venous return (to the right heart)
- In vivo test of RV tolerance if LVAD is planned
- Opportunity for rehabilitation program (axillary insertion)

Short communication

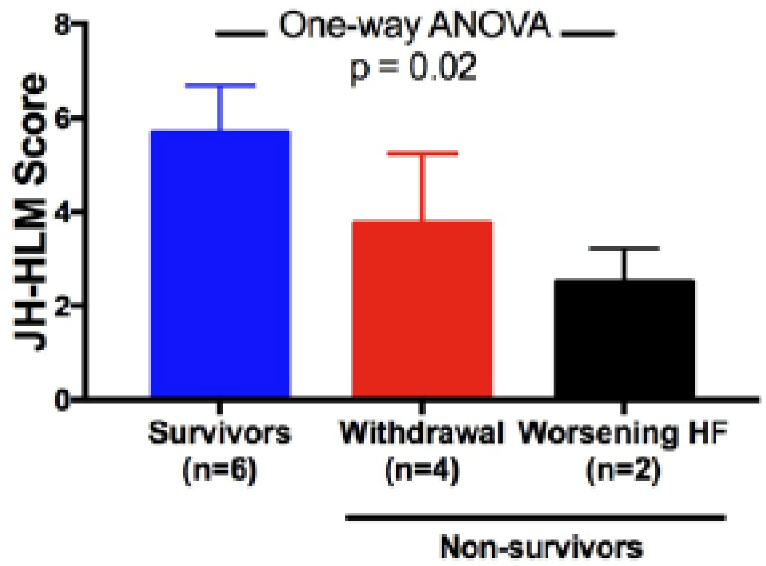
IJAO The International Journal of Artificial Organs

The International Journal of Artificial Organs
1–4

DOI: 10.1177/0391398817752575
journals.sagepub.com/home/jao
SAGE

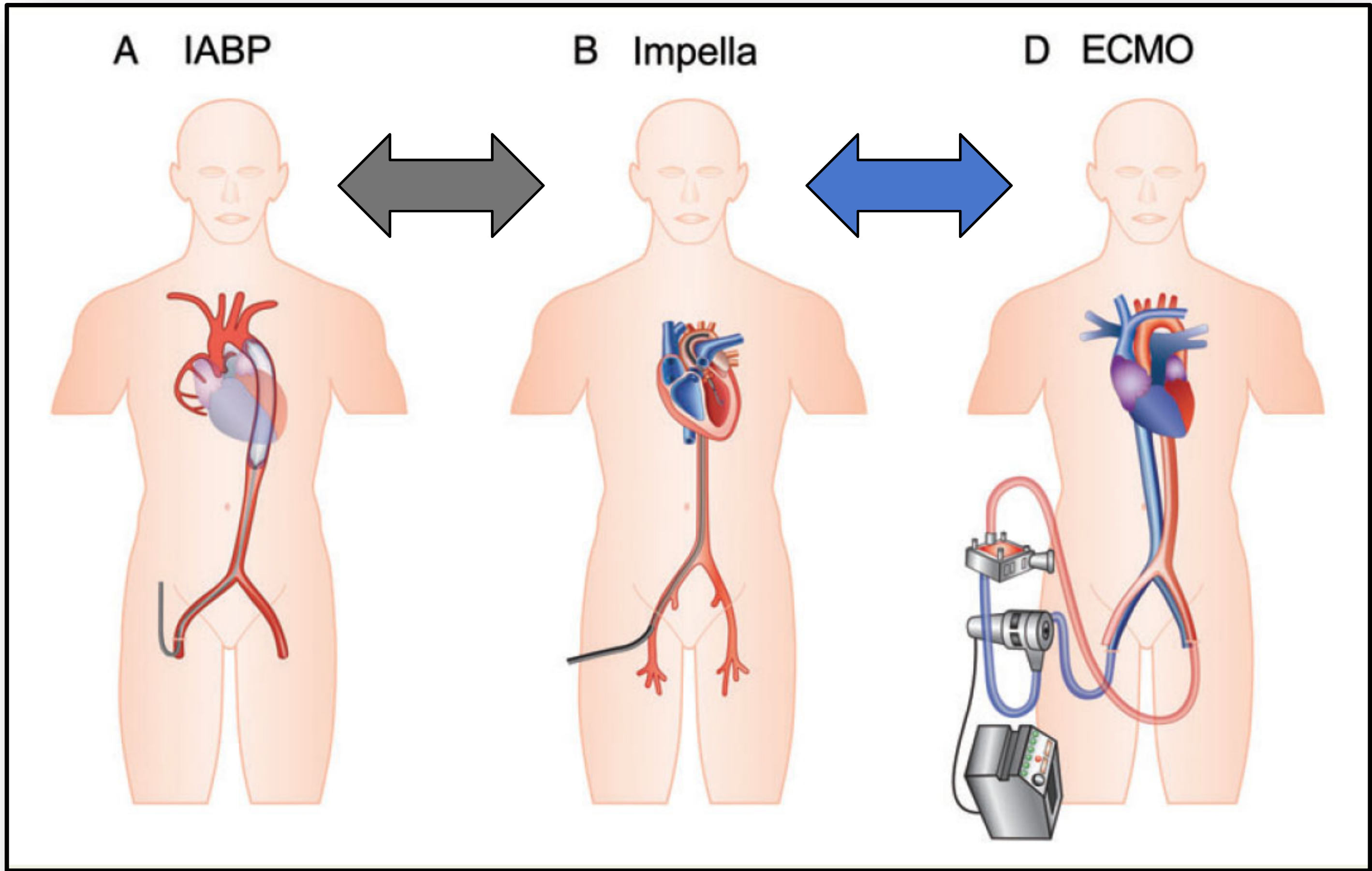
Maximum level of mobility with axillary deployment of the Impella 5.0 is associated with improved survival

Michele L Esposito, Janelle Jablonski, Allison Kras, Sara Krasney and Navin K Kapur

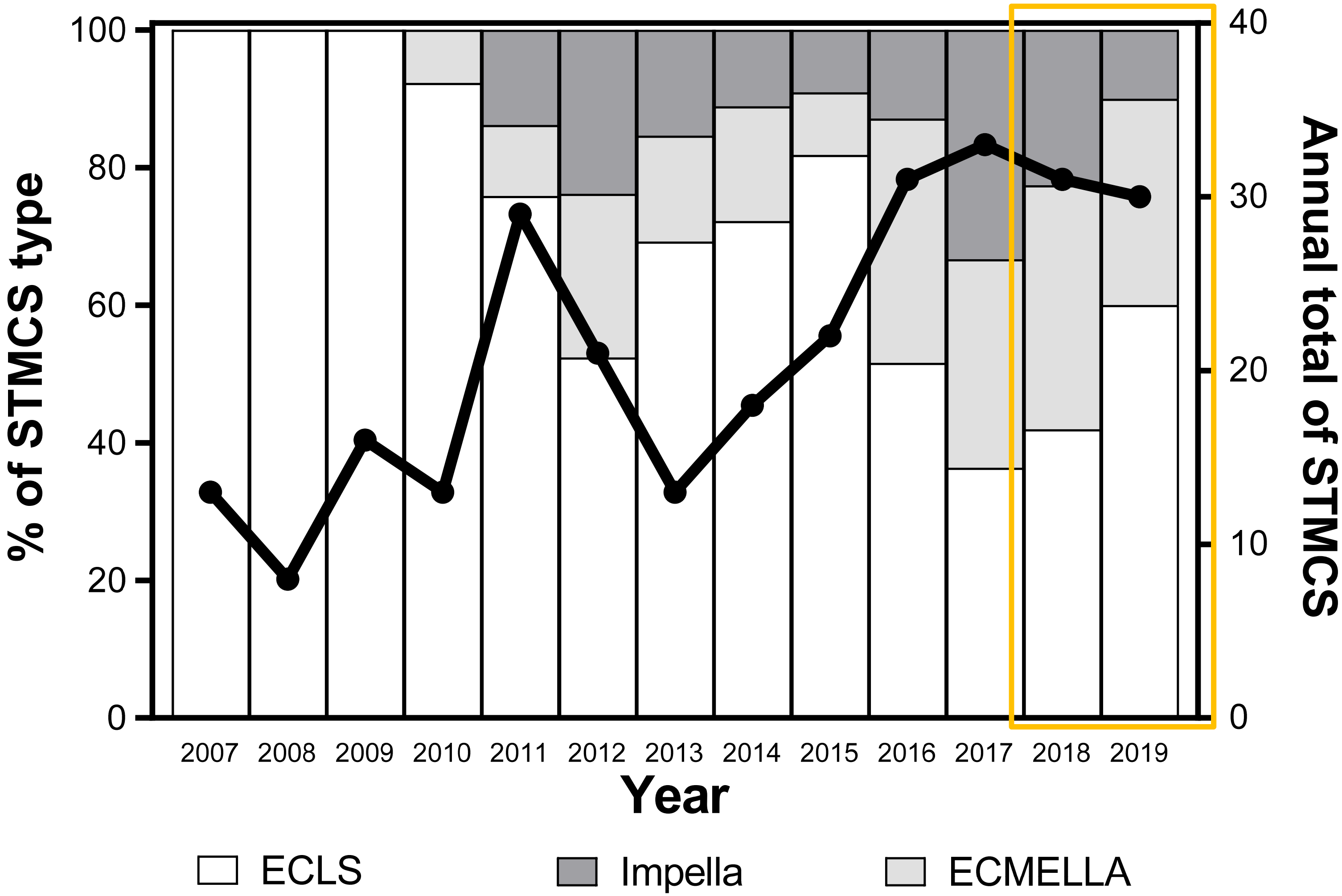


WHICH BEST STRATEGY?

Short-term mechanical circulatory support

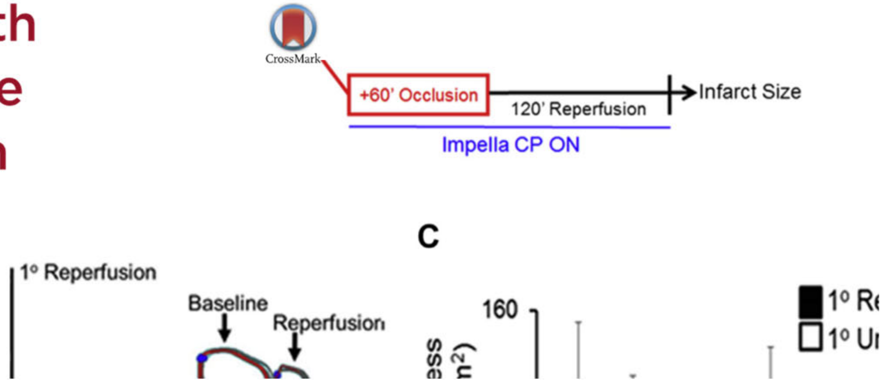


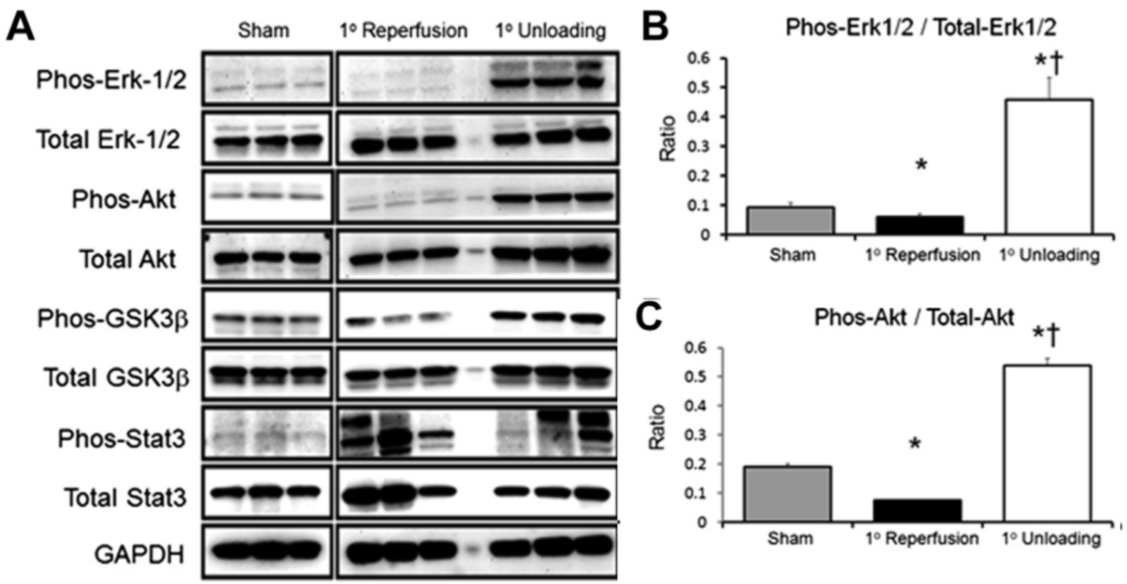
STMCS activity over the study period

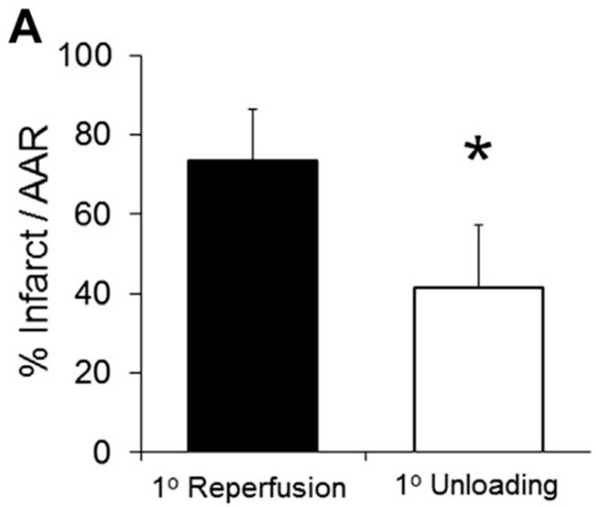


Henrion FX et al. (in submission)

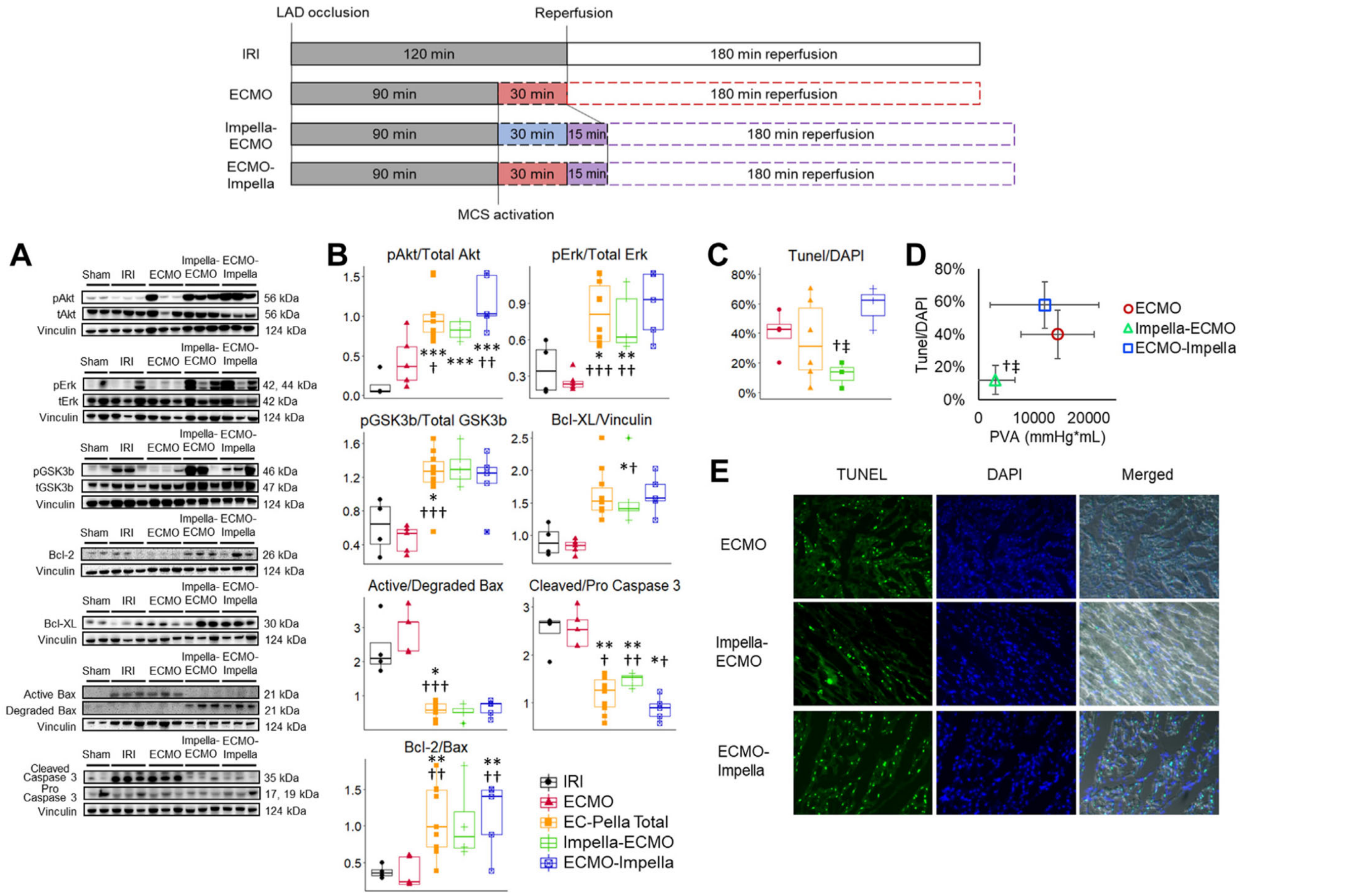
Mechanical Pre-Conditioning With Acute Circulatory Support Before Reperfusion Limits Infarct Size in Acute Myocardial Infarction



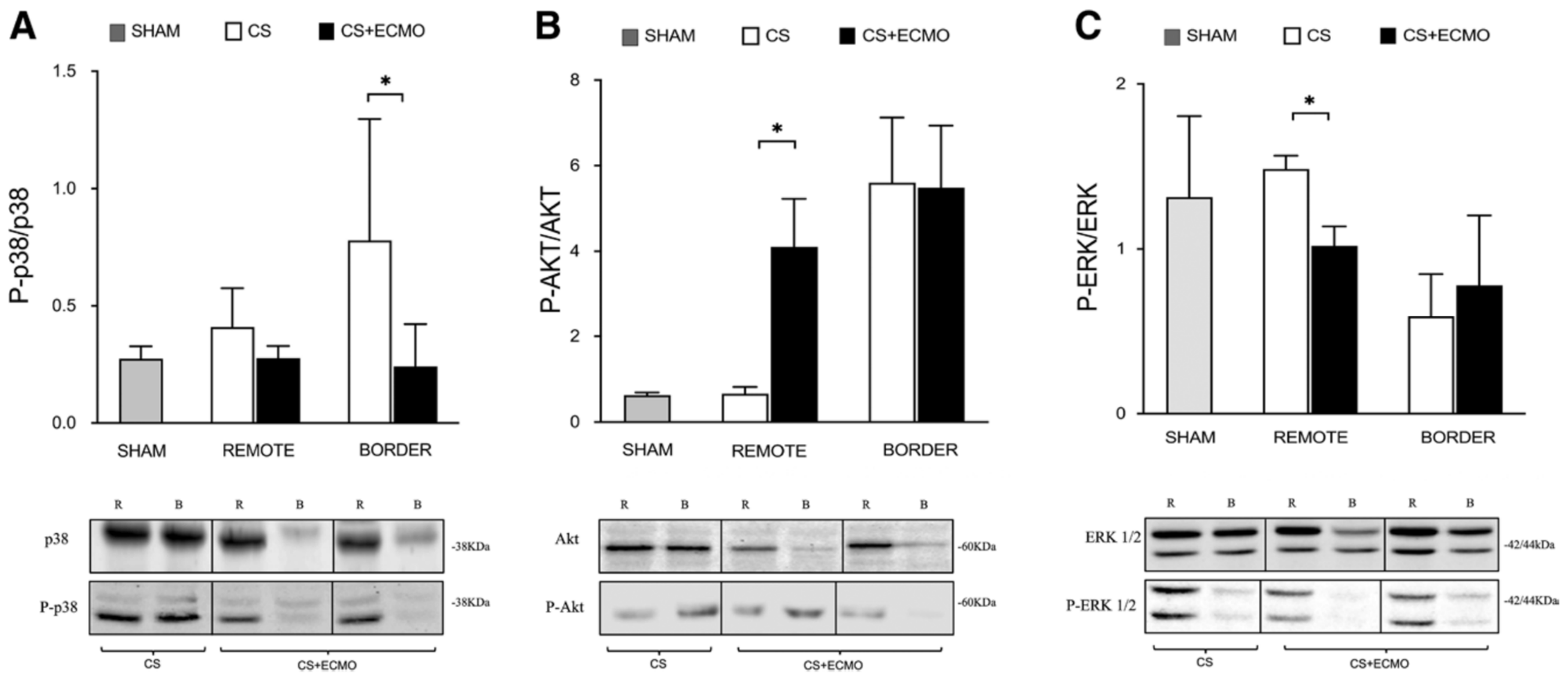




Kapur N et al. J Am Coll Cardiol HF 2015;3:873-82

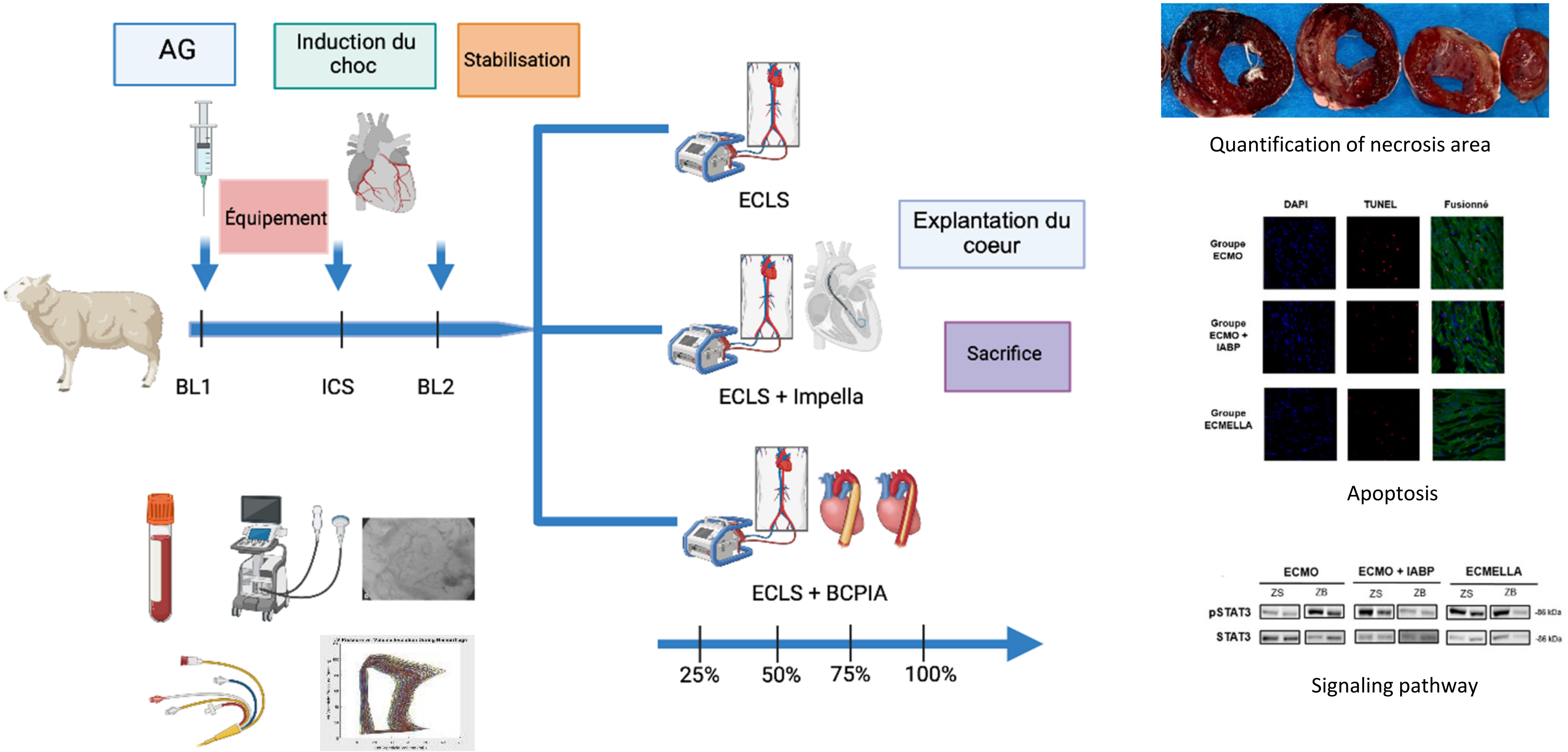

LAD occlusion
Reperfusion
IRI
120 min
180 min reperfusion
ECMO
90 min
30 min
180 min reperfusion
Impella-ECMO
90 min
30 min
15 min
180 min reperfusion
ECMO-Impella
90 min
30 min
15 min
180 min reperfusion
MCS activation
A
Sham IRI ECMO Impella-ECMO ECMO-Impella
pAkt 56 kDa
tAkt 56 kDa
Vinculin 124 kDa
pErk 42, 44 kDa
tErk 42 kDa
Vinculin 124 kDa
pGSK3b 46 kDa
tGSK3b 47 kDa
Vinculin 124 kDa
Bcl-2 26 kDa
Vinculin 124 kDa
Bcl-XL 30 kDa
Vinculin 124 kDa
Active Bax 21 kDa
Degraded Bax 21 kDa
Vinculin 124 kDa
Cleaved Caspase 3 35 kDa
Pro Caspase 3 17, 19 kDa
Vinculin 124 kDa
B
pAkt/Total Akt
pErk/Total Erk
pGSK3b/Total GSK3b
Bcl-XL/Vinculin
Active/Degraded Bax
Cleaved/Pro Caspase 3
Bcl-2/Bax
IRI
ECMO
EC-Pella Total
Impella-ECMO
ECMO-Impella
C
Tunel/DAPI
D
Tunel/DAPI
PVA (mmHg*mL)
ECMO
Impella-ECMO
ECMO-Impella
E
TUNEL
DAPI
Merged
ECMO
Impella-ECMO
ECMO-Impella

Survival signaling pathways



Beurton A et al. ASAIO Journal 2024 (in press)

WHAT IS THE IMPACT OF ASSOCIATION OF ECMO TO MECHANICAL LV UNLOADING?



Beurton A et al. Cardiovascular Research (manuscript submitted under review)

ECMO and IABP

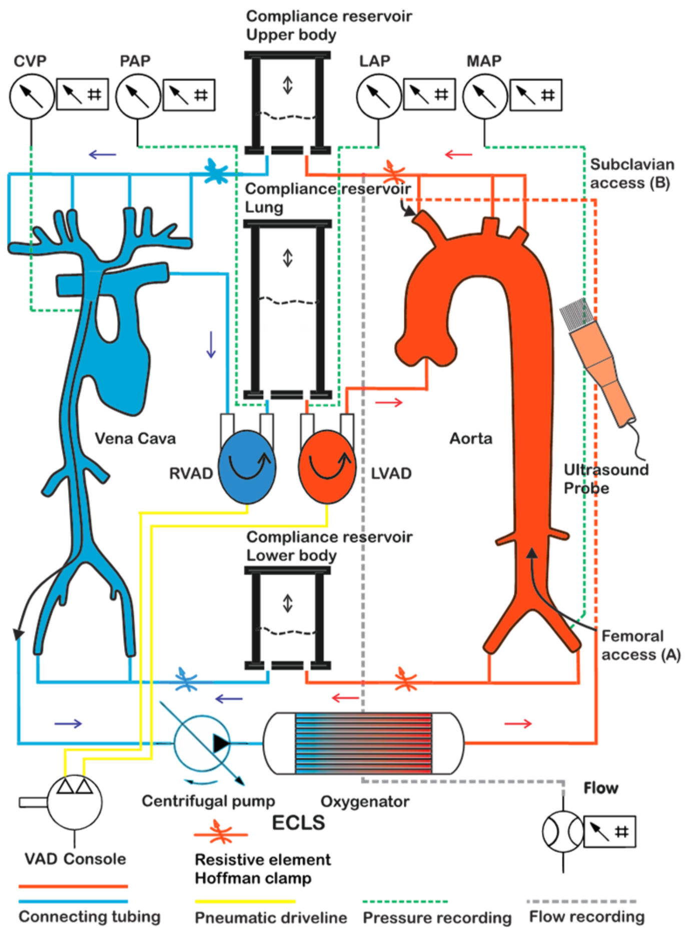
Myocardial oxygen balance

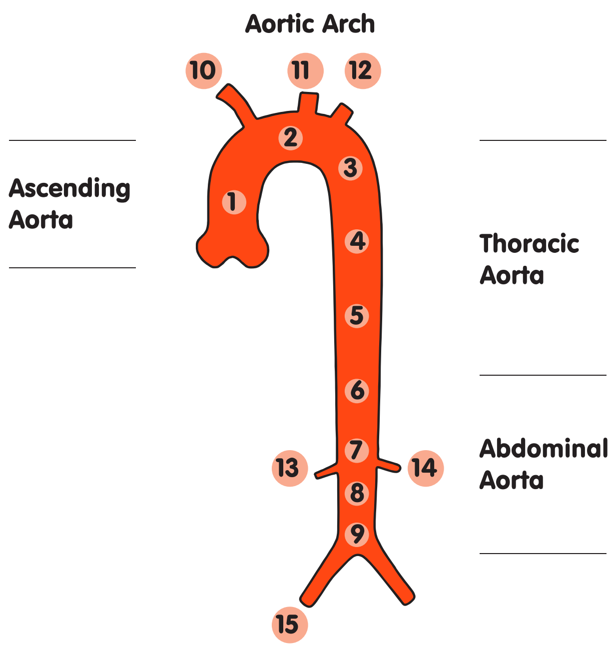
TABLE 1. *The hemodynamic effect of IABP during partial ECLS support*

		Central configuration		Peripheral configuration	
	Baseline	ECLS	ECLS + IABP	ECLS	ECLS + IABP
HR (bpm)	100 (10)	105 (10) $P = 0.176$	105 (10)* $P = 0.043$	95 (7)* $P = 0.028$	95 (7) $P = 1.00$
Plv,peak (mm Hg)	65 (16)	75 (25) $P = 0.091$	72 (25)* $P = 0.043$	72 (29) $P = 0.176$	67 (28)* $P = 0.018$
Pasc (mm Hg)	52 (10)	68 (24)* $P = 0.018$	72 (23)* $P = 0.018$	66 (26)* $P = 0.018$	67 (27)*** $P = 0.866$
LVO (L/min)	4.1 (1.0)	3.1 (0.9) $P = 0.091$	3.0 (1.0) $P = 0.237$	2.5 (1.1)* $P = 0.018$	2.7 (1.1)*,** $P = 0.018$
Qcor (mL/min)	110 (63)	104 (68) $P = 0.735$	114 (76)* $P = 0.018$ +9%	101 (59) $P = 0.499$	106 (62)* $P = 0.043$ +6%
EW (J/beat)	0.33 (0.13)	0.30 (0.13) $P = 0.462$	0.27 (0.12)* $P = 0.017$	0.24 (0.11)* $P = 0.018$	0.24 (0.14) $P = 0.394$
PE (J/beat)	0.30 (0.30)	0.35 (0.28) $P = 0.107$	0.32 (0.26)* $P = 0.027$	0.37 (0.33)* $P = 0.028$	0.30 (0.25)* $P = 0.027$
PVA (J/beat)	0.63 (0.41)	0.65 (0.39) $P = 0.735$	0.59 (0.36)* $P = 0.018$	0.61 (0.36) $P = 0.600$	0.54 (0.37)* ↓ $P = 0.028$
Qcor/(PVA·HR) (mL/J)	2.04 (1.32)	1.78 (1.23) $P = 0.063$	2.15 (1.52)* $P = 0.018$ +21%	2.38 (1.99) $P = 0.499$	2.92 (2.65)* $P = 0.018$ +22%
TTI (Pa·s)	16 (6)	20 (8)* $P = 0.018$	18 (8)* $P = 0.028$	20 (10)* $P = 0.018$	18 (10)* $P = 0.018$
DPTI (Pa·s)	14 (5)	19 (8)* $P = 0.018$	22 (8)* $P = 0.018$	22 (10)* $P = 0.018$	24 (11)*,*** $P = 0.018$
DPTI/TTI (%)	90 (19)	100 (20) $P = 0.310$	127 (29)* $P = 0.018$ +27%	110 (23) $P = 0.063$	136 (27)* $P = 0.018$ +24%

Sauren LDC et al. Artif Organs 2007; 31:31-8

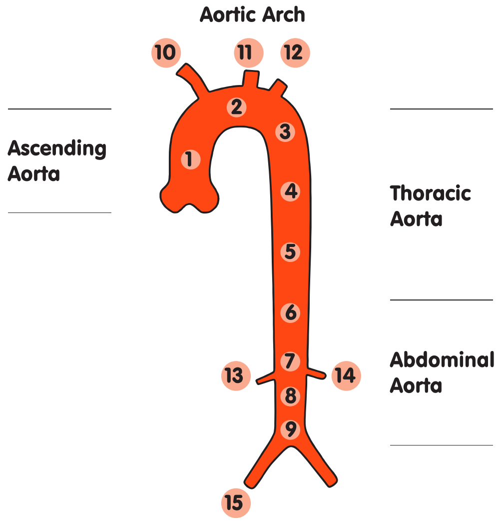
Watershed phenomena during extracorporeal life support and their clinical impact: a systematic in vitro investigation

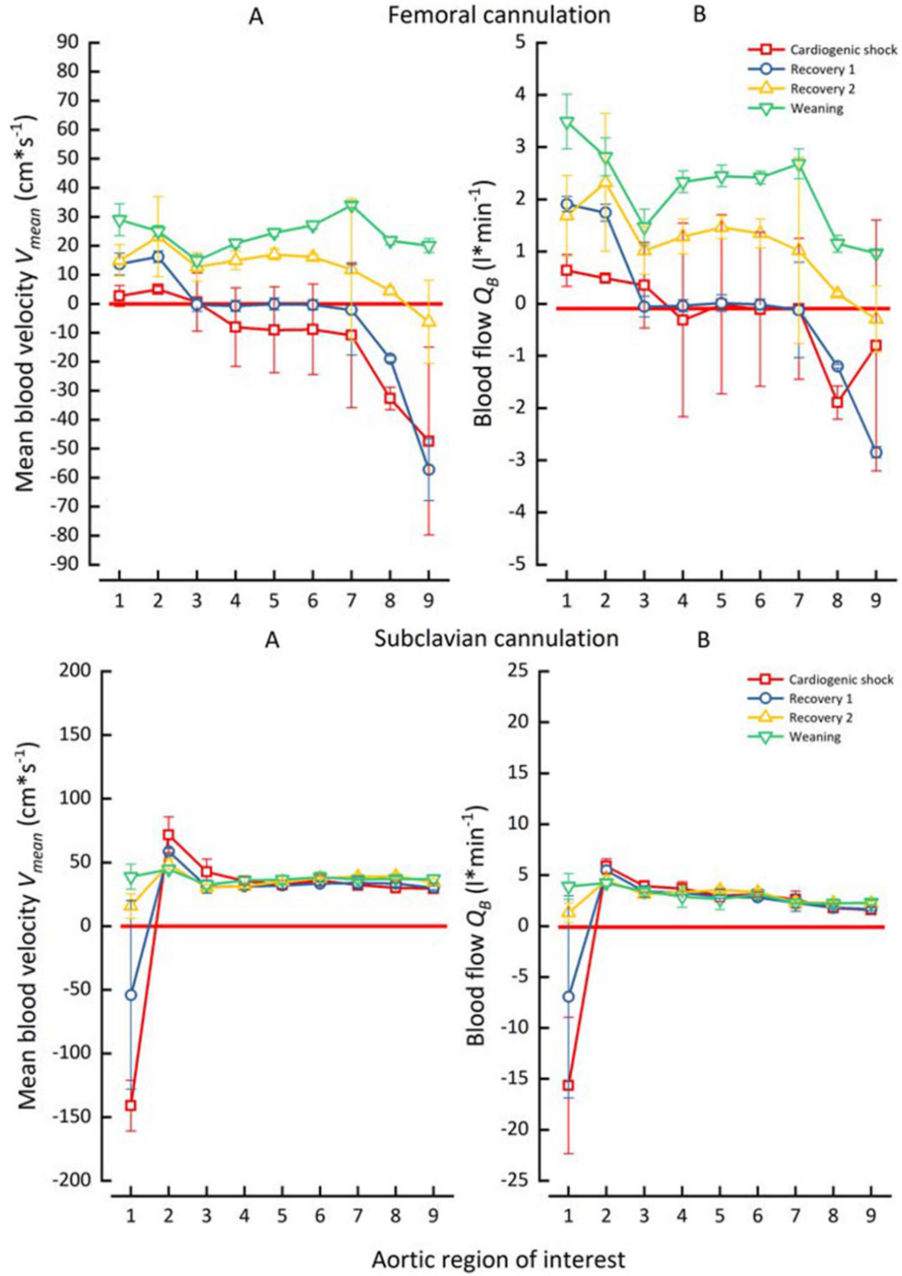




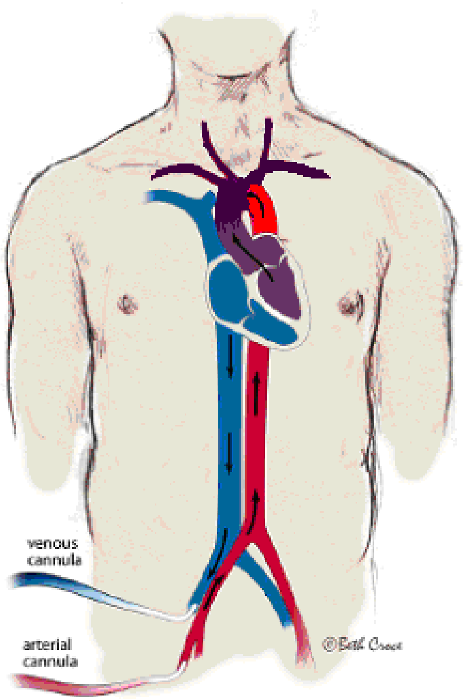
Gehron J et al. ESC Heart Failure 2020;7:1850-61

Gehron J et al. ESC Heart Failure 2020;7:1850-61





Refractory cardiogenic shock and ARDS

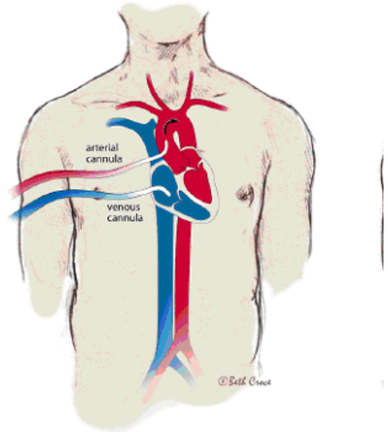


- Persistence of arterial pulmonary blood flow
- Loading of left atrium with hypoxic blood
- Perfusion of supra-aortic and coronary vessels
- Interface between hypoxemic blood and normoxic from ECLS depends:
  - Residual ventricular contractility
  - Level of supply by ECLS
  - Importance of pulmonary disease
- Arlequin Syndrome+++
- **Perform blood gas analysis from right artery radial ++++**

Marasco SF et al. Heart lung and Circulation 2008

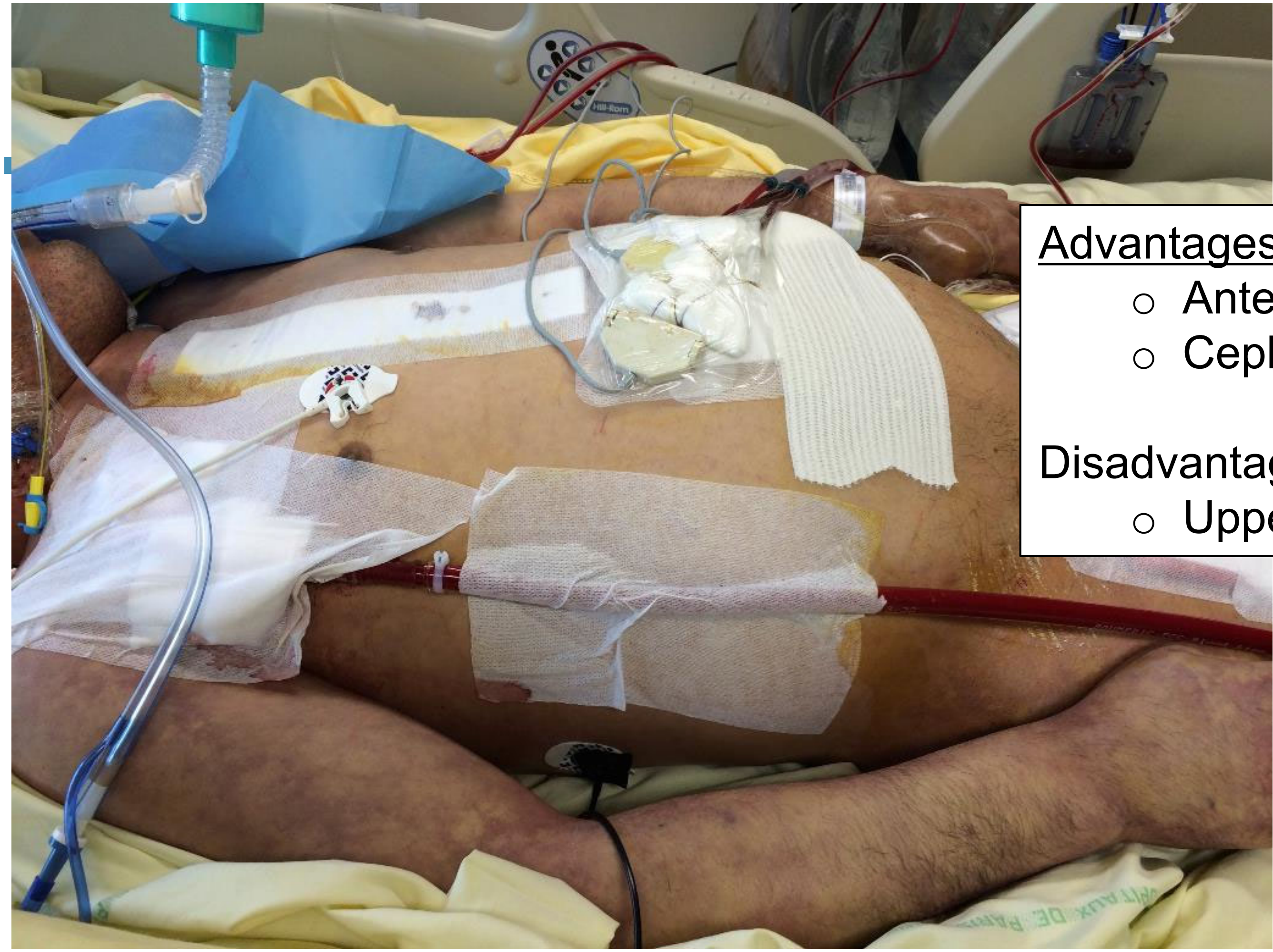
SOLUTIONS

- Centralisation
  - Heavy technology
  - Bleeding risk



- Axillary canulation

Stulak JM et al. Seminars Cardiothorac Vasc Anesth 2009;13:176-82



Advantages

- Anterograde flow
- Cephalic perfusion

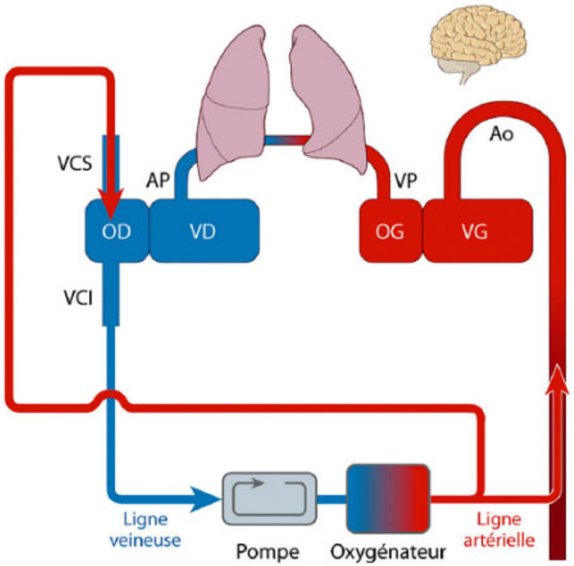
Disadvantages

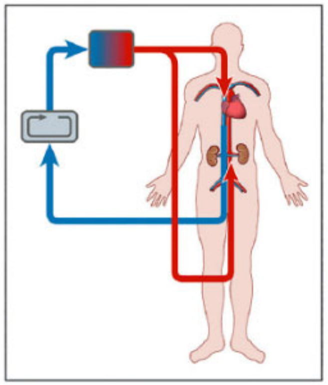
- Upper limb ischemia

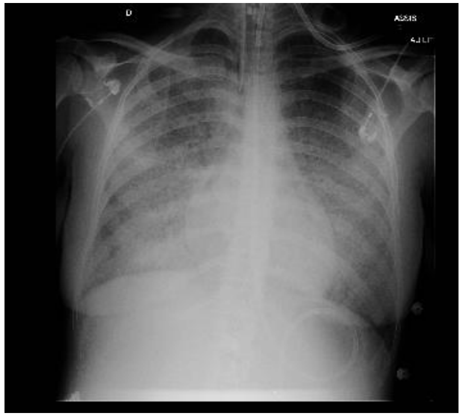
Moisan M et al. Ann Fr Anesth Réanim 2013;32:e71-75

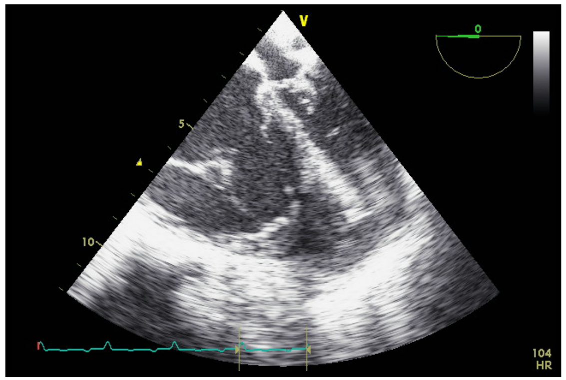
Case report

Pulmonary alveolar proteinosis requiring "hybrid" extracorporeal life support, and complicated by acute necrotizing pneumonia

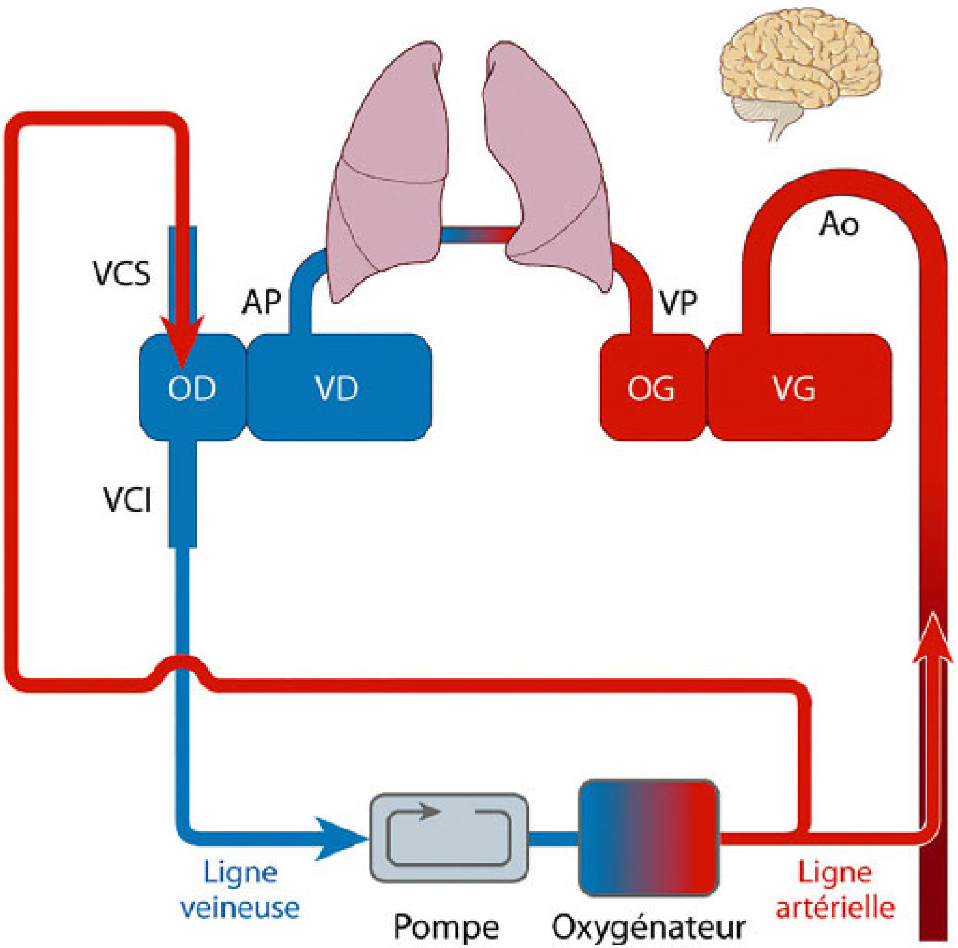


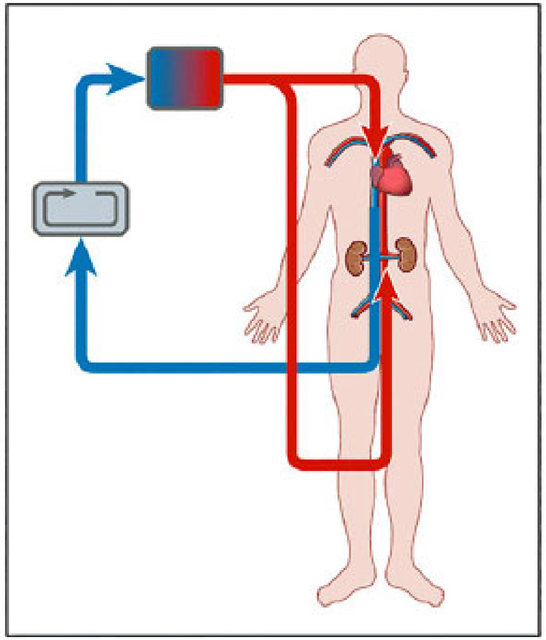


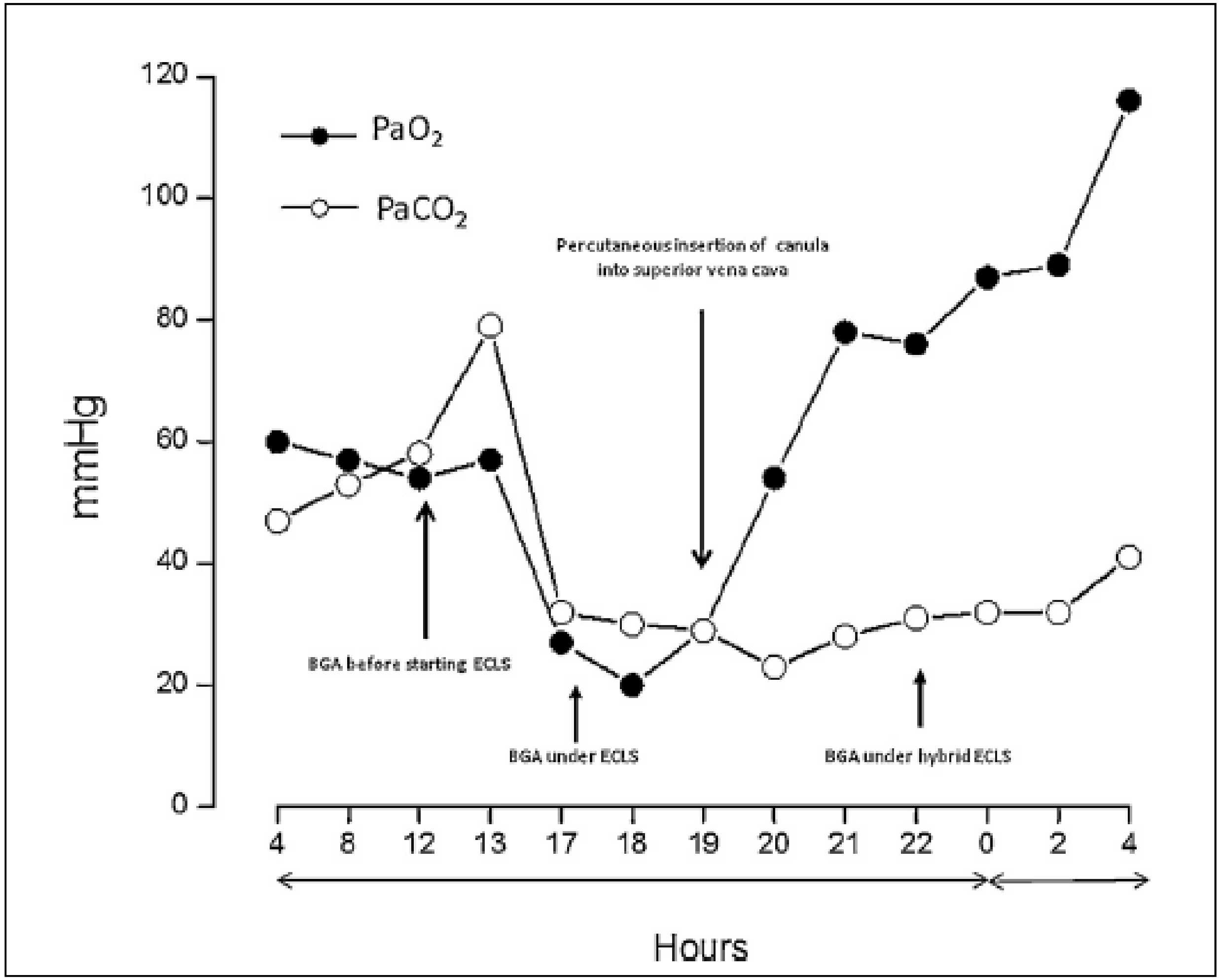


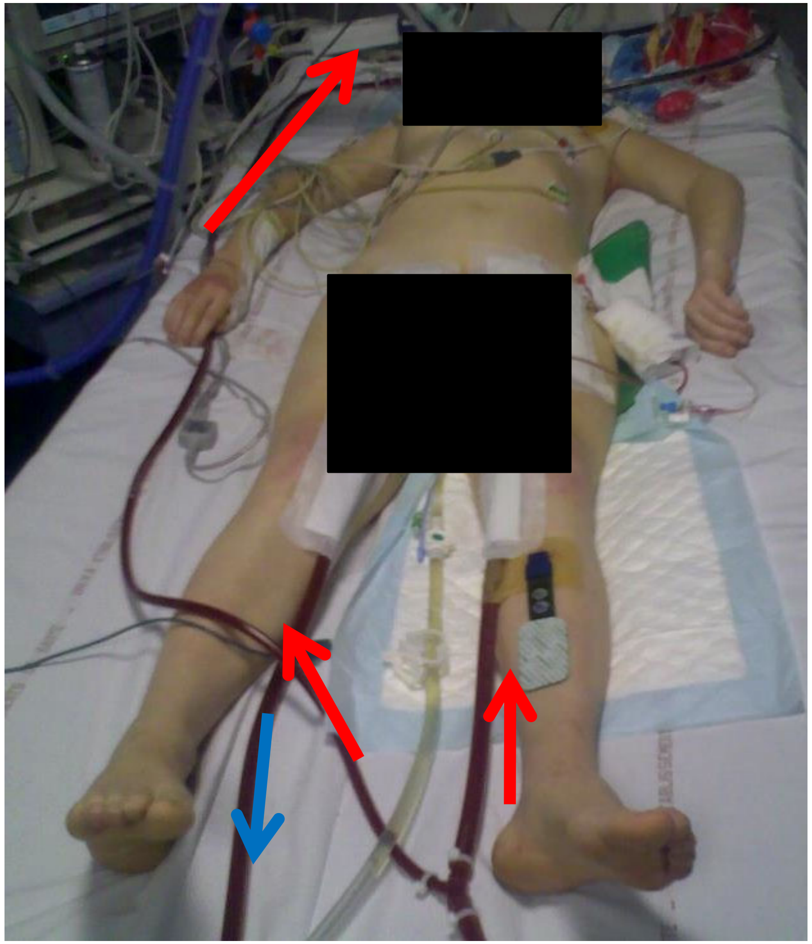


Precardiac oxygenation

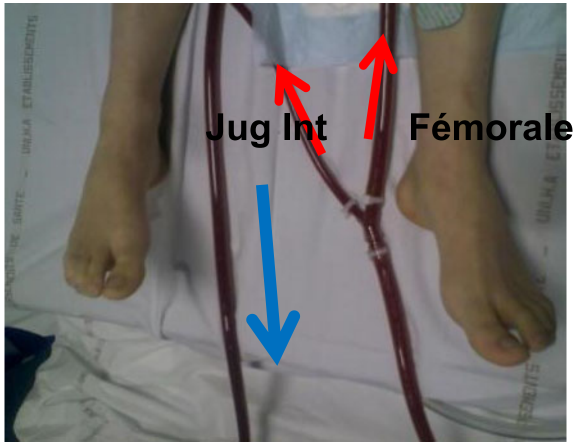





120
100
80
60
40
20
0
mmHg
PaO2
PaCO2
Percutaneous insertion of canula
into superior vena cava
BGA before starting ECLS
BGA under ECLS
BGA under hybrid ECLS
4
8
12
13
17
18
19
20
21
22
0
2
4
Hours



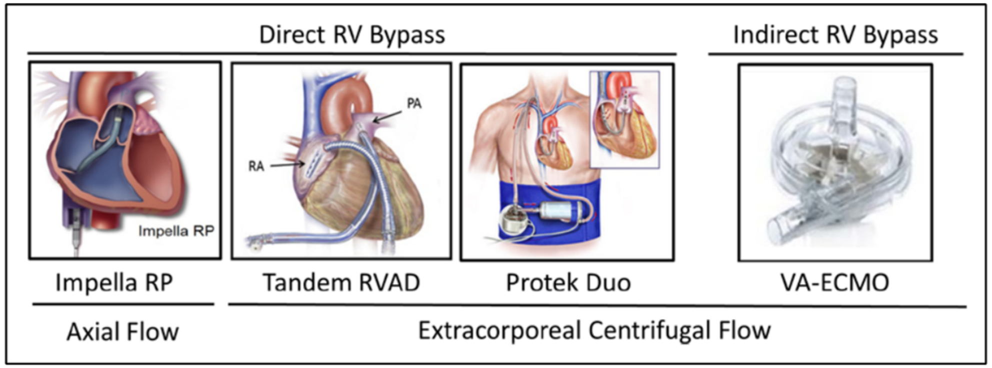
Re-infusion canula 17 Fr

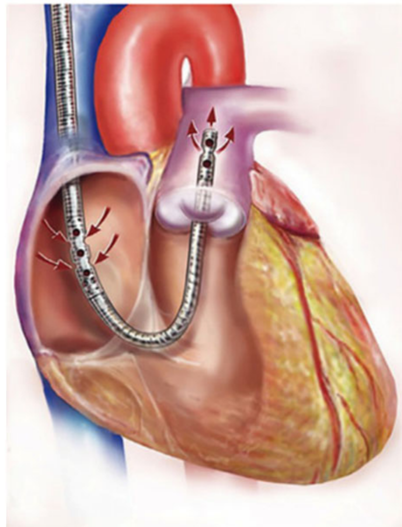


Connection 3/8-1/4 (arterial return)

Measurment of re-infusion flow by doppler

Mechanical Circulatory Support Devices for Acute Right Ventricular Failure





Kapur NK et al. Circulation 2017; 136:314-26

DEFINITION OF WEANING FROM ECLS

Weaning successful from ECLS is defined as: 1) device removal **and** 2) no further requirement for mechanical support because of recurring CS over the following **7 to 30 days (alive patients)**

Aissaoui N et al. Intensive Care Med 2015;41:902-5

Weaning from ECLS does not mean alive….

In-hospital mortality and successful weaning from venoarterial extracorporeal membrane oxygenation: analysis of 5,263 patients using a national inpatient database in Japan

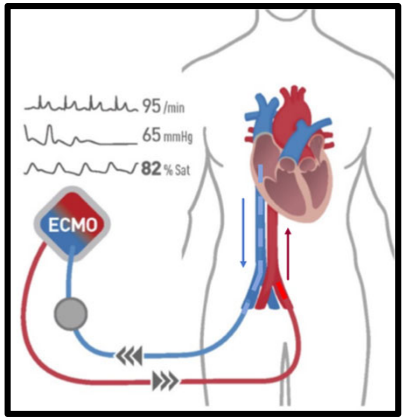
Aso S et al. Crit Care 2016; 20:80

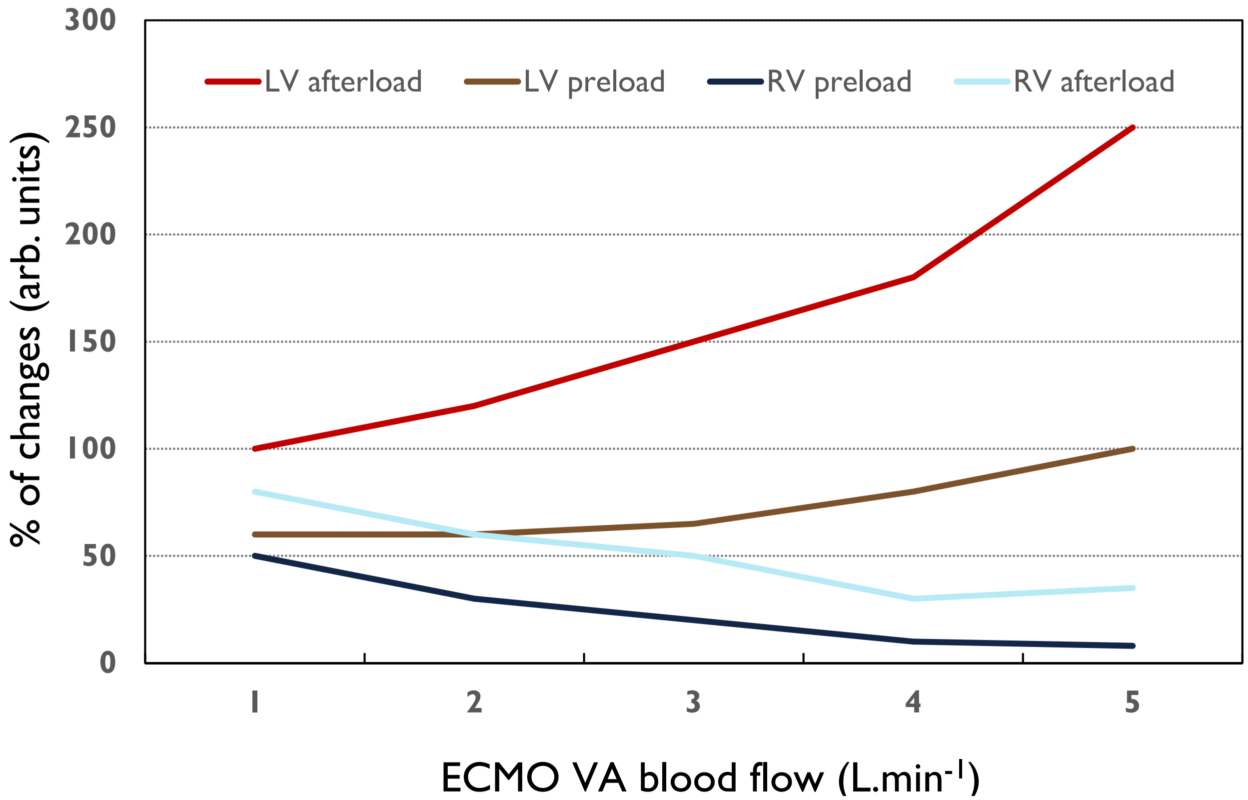
Table 2 In-hospital death and weaning from VA-ECMO among patients classified by six etiological categories

	All	Total in-hospital death		In-hospital death under VA-ECMO		Transferred to other hospitals with VA-ECMO		Weaning from VA-ECMO 64.4%			
								Discharged after weaning from VA-ECMO		In-hospital death after weaning from VA-ECMO	
All, *n* (%)	5263	3817	(72.5)	1823	(34.6)	51	(1.0)	1395	(26.5)	1994	(37.9)
Cardiogenic shock, *n* (%)	4658	3429	(73.6)	1554	(33.4)	44	(0.9)	1185	(25.4)	1875	(40.3)
Pulmonary embolism, *n* (%)*	353	226	(64.0)	151	(42.8)	7	(2.0)	120	(34.0)	75	(21.2)
Hypothermia, *n* (%)*	99	65	(65.7)	49	(49.5)	0	(0.0)	34	(34.3)	16	(16.2)
Poisoning, *n* (%)**	50	31	(62.0)	22	(44.0)	0	(0.0)	19	(38.0)	9	(18.0)
Trauma, *n* (%)*	103	66	(64.1)	47	(45.6)	0	(0.0)	37	(35.9)	19	(18.4)

*$p < 0.001$ for in-hospital death after weaning from venoarterial extracorporeal membrane oxygenation (VA-ECMO) vs. cardiogenic shock
**$p < 0.05$ for in-hospital death after weaning from VA-ECMO vs. cardiogenic shock

IMPACT OF VA-ECMO ON CARDIAC (LEFT AND RIGHT) LOADING CONDITIONS





Beurton A et al. ASAIO Journal 2024 (in press)

Weaning procedure from VA-ECMO

Changes in ventricular function parameters (Left **and** Right) in response to ECLS blood flow changes

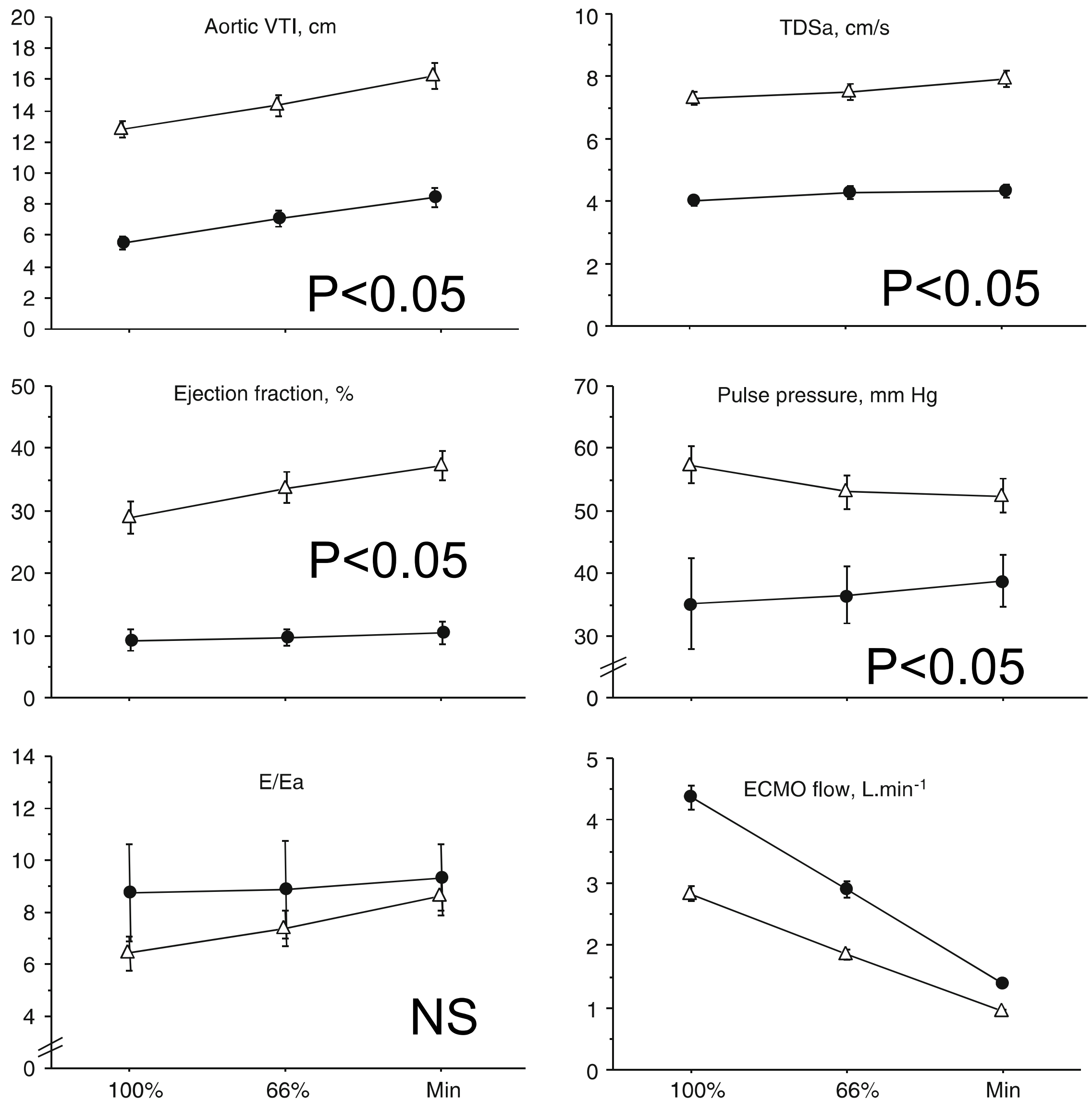
Assessment of ventricular function (Left **and** right) at the minimal ECLS flow

- Increase in **RV** preload
- Increase in **RV** afterload
- Decrease in **LV** afterload

∆ Weaned patients

● Non weaned patients

LV parameters...



Aissaoui N et al. Intensive Care Med 2011; 37:1738-45

Weaning test from ECLS

Step 1 : The etiology of cardiac failure must be compatible with myocardial recovery

Step 2 : Hemodynamic stability :
- The patient should have recovered from major metabolic disturbances
- The patient should have recovered a pulsatile arterial waveform for at least 24 hours
- Baseline MAP > 60 mmHg in the absence or with low doses of catecholamine

Step 3 : Pulmonary function should not be severely impaired
If PaO2/FiO2 <100 mmHg when FiO2 of the ECMO gas flow is set at 21%, consider bridging the patient from VA- to VV-ECMO

Step 4 : The patient must tolerate a full weaning trial
** Hemodynamic and Doppler-echocardiographic assessment whereas ECMO flow is gradually decreased to 66%, and to 33% of its baseline value and then to a minimum of 1–1.5 L/min*

If steps 1, 2, 3 and 4 are validated and the patient has under minimal ECMO support
LVEF of ≥ 20–25%, an aortic VTI of ≥ 12 cm and a TDSa ≥ 6 cm/s,

ECMO removal should be considered

60-75% of patients tolerated successfully the weaning from ECLS

Prognostic Implication of RV Coupling to Pulmonary Circulation for Successful Weaning From Extracorporeal Membrane Oxygenation

Kim D et al. J Am Coll Cardiol Imag 2021;14:1523-31

Unicenter study (n=79) between 2016 and 2019

Explore if right ventricular (RV) contractile function and its coupling pulmonary circulation were able to predict successful weaning from ECLS

At full ECLS blood flow +++ (avoid harmful haemodynamic effects)

TABLE 2 Comparisons of Echocardiographic Parameters Between Successful and Failed Weaning Groups

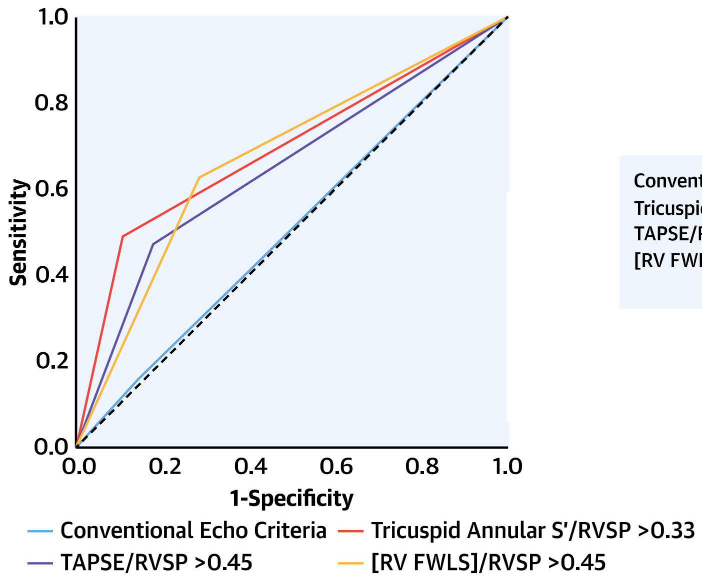
	Successful Weaning (n = 50)	Failed Weaning (n = 29)	p Value
ECMO flow at time of echocardiography, l/min	3.1 (3.0–3.5)	3.3 (3.0–4.0)	0.304
LV end-diastolic dimension, mm	52 (48–60)	56 (49–65)	0.122
LV end-systolic dimension, mm	42 (37–49)	48 (35–59)	0.232
LV ejection fraction, %	24 (19–35)	23 (15–37)	0.862
Transmitral E velocity, m/s	0.56 (0.44–0.68)	0.61 (0.55–0.83)	0.032
Transmitral A velocity, m/s	0.54 (0.36–0.69)	0.35 (0.39–0.57)	0.165
Lateral mitral S′ velocity, cm/s	4.6 (3.3–6.0)	4.6 (3.3–6.0)	0.309
Lateral e′ velocity, cm/s	4.4 (3.9–7.9)	4.4 (3.6–6.0)	0.617
E/Lateral e′	9.6 (6.6–18.3)	14.4 (10.8–18.3)	0.005
LVOT velocity-time integral, cm	8.5 (5.9–12.5)	7.4 (4.5–12.2)	0.338
RV end-diastole area, cm^2	13.1 (10.6–16.5)	16.2 (11.9–24.8)	0.073
RV end-systole area, cm^2	8.8 (7.1–11.6)	9.5 (7.8–18.1)	0.104
Indexed RV end-diastole area, cm^2	7.65 (6.09–9.42)	9.03 (7.07–12.9)	0.054
Indexed RV end-diastole area, cm^2	5.17 (4.20–6.12)	6.46 (4.50–8.85)	0.122
TAPSE, mm	12.8 (9.1–15.0)	11.3 (7.1–13.0)	0.243
Tricuspid annular S′ velocity, m/s	8.7 (6.0–10.7)	6.4 (5.1–8.3)	0.064
RV FAC, %	33.1 (24.2–38.6)	28.5 (19.5–38.7)	0.378
[RV FWLS], %	14.1 (8.7–19.8)	10.4 (7.9–14.6)	0.054
RVSP, mm Hg	27 (19–36)	33 (24–42)	0.040
Tricuspid annular S′/RVSP	0.32 (0.18–0.44)	0.21 (0.14–0.29)	0.004
RV FAC/RVSP	1.04 (0.73–1.59)	0.87 (0.53–1.31)	0.134
TAPSE/RVSP	0.45(0.29–0.68)	0.31 (0.25–0.40)	0.019
[RV FWLS]/RVSP	0.49 (0.32–0.82)	0.31 (0.22–0.48)	0.007

At full ECLS blood flow….!

TABLE 3 Predictors for Successful ECMO Weaning

	Univariable Analysis	
	OR (95% CI)	p Value
Age	1.02 (0.98-1.06)	0.286
Idiopathic-dilated cardiomyopathy	0.15 (0.40-0.64)	0.004
Continuous renal replacement therapy	0.28 0.11-0.75)	0.011
Extracorporeal CPR	2.81 (1.05-7.55)	0.040
LV venting	0.07 (0.02-0.19)	<0.001
Early venting (<12 h)	0.17 (0.04-0.70)	0.014
LV ejection fraction >20%	1.25 (0.46-3.42)	0.661
LVOT velocity-time integral ≥10 cm	1.25 (0.46-3.42)	0.664
Mitral annular S' ≥6 cm/s	2.37 (0.82-6.85)	0.113
FAC/RVSP ≥0.94	2.52 (0.98-6.52)	0.056
Tricuspid annular S'/RVSP >0.33	8.01 (2.15-29.92)	0.002
TAPSE/RVSP >0.45	4.09 (1.34-12.43)	0.013
[RV FWLS/RVSP] >0.45	4.21 (1.53-11.41)	0.005

Kim D et al. J am Coll Cardiol Img 2021;14:1523-31

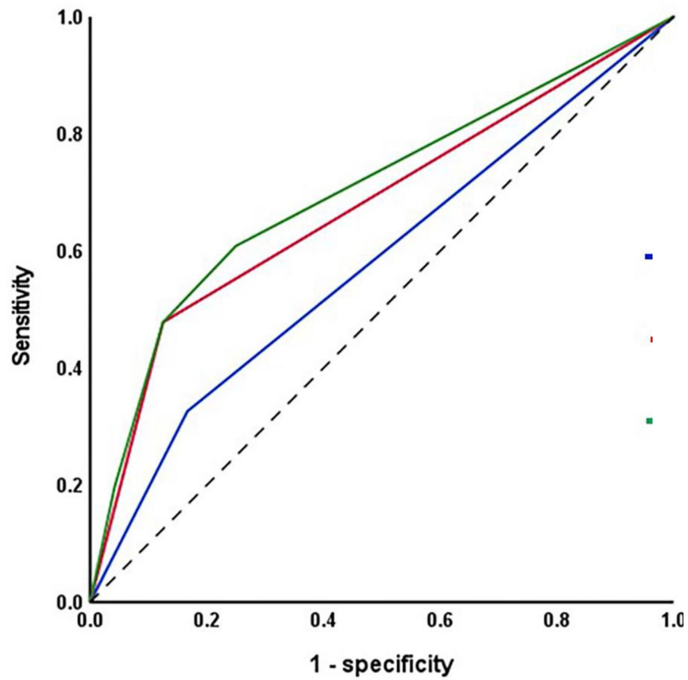


Conventional Echo Criteria: AUC = 0.507, 95% CI:0.373 - 0.641, p = 0.918
Tricuspid Annular S'/RVSP >0.33: AUC = 0.692, 95% CI: 0.574 - 0.809, p = 0.005
TAPSE/RVSP >0.45: AUC = 0.646, 95% CI: 0.522 - 0.770, p = 0.033
[RV FWLS]/RVSP >0.45: AUC = 0.671, 95% CI: 0.546 - 0.796, p = 0.012

Conventional echocardiographic criteria at minimal flow
(AUC=0.580, 95% CI:0.442-0.718, p=0.257)

Tricuspid annular S'/RVSP> 0.33 at full flow
(AUC=0.677, 95%CI: 0.549-0.804, p=0.016)

Tricuspid annular S'/RVSP> 0.33 at full flow
+Conventional echocardiographic criteria at minimal flow
(AUC=0.703. 95% CI: 0.579- 0.828, p=0.005)



Kim D et al. J am Coll Cardiol Img 2021;14:1523-31

Step 1: The **etiology** of cardiac failure must be compatible with myocardial recovery

Step 2: **Hemodynamic stability**:
- The patient should have recovered a pulsatile arterial waveform for at least 24 hours
- Baseline MAP >60 mmHg in the absence or with low doses catecholamine and/or pulsed pressure >
- The patient should have recovered from major metabolic disturbances

Step 3: **Pulmonary function** should not be severely impaired
If PaO2/FiO2 <100 mmHg when FiO_2 of the ECMO gas flow is set at 21%, consider bridging the patient from VA- to VV-ECMO

Step 4: The patient **must tolerate a full weaning** trial
* Hemodynamic and echocardiographic assessment whereas ECMO flow is gradually decreased to 66%, and to 33% of its baseline value and then to a minimum of 1–1.5 L/min

If steps 1, 2, 3 and 4 are validated and the patient has under minimal ECMO support:
- LVEF of ≥ 20–25%, an aortic VTI of ≥12 cm and a TDSa ≥6 cm/s
- 3D-RV ejection fraction (if feasible)>24.6%

ECMO removal should be considered

Tricuspid annular S'/RVSP >0.33
TAPSE/RVSP >0.45
[RV FWLS/RVSP] >0.45
at full ECLS blood flow

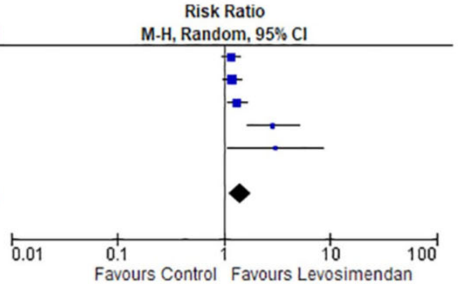
Adapted from Ortuno S et al. Ann Cardiothorac Surg 2019; 8(1):E1-8

Effects of levosimendan on weaning and survival in adult cardiogenic shock patients with veno-arterial extracorporeal membrane oxygenation: systematic review and meta-analysis

Analysis of risk of successful weaning from VA ECMO in patients treated with levosimendan

Study or Subgroup	Levosimendan Events	Levosimendan Total	Control Events	Control Total	Weight	Risk Ratio M-H, Random, 95% CI
Jacky 2018	24	26	30	38	27.8%	1.17 [0.96, 1.43]
Distelmaier 2016	144	179	41	61	28.2%	1.20 [0.99, 1.45]
Vally 2019	42	51	61	99	27.7%	1.34 [1.09, 1.63]
Zipfel 2018	24	37	11	49	11.6%	2.89 [1.63, 5.12]
Affronti 2013	5	6	3	11	4.7%	3.06 [1.09, 8.55]
Total (95% CI)		**299**		**258**	**100.0%**	**1.42 [1.12, 1.80]**
Total events	239		146			

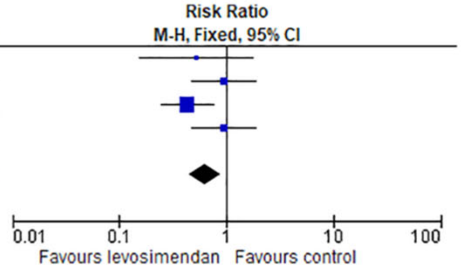
Heterogeneity: $Tau^2 = 0.04$; $Chi^2 = 13.58$, df = 4 (P = 0.009); $I^2 = 71\%$
Test for overall effect: Z = 2.86 (P = 0.004)



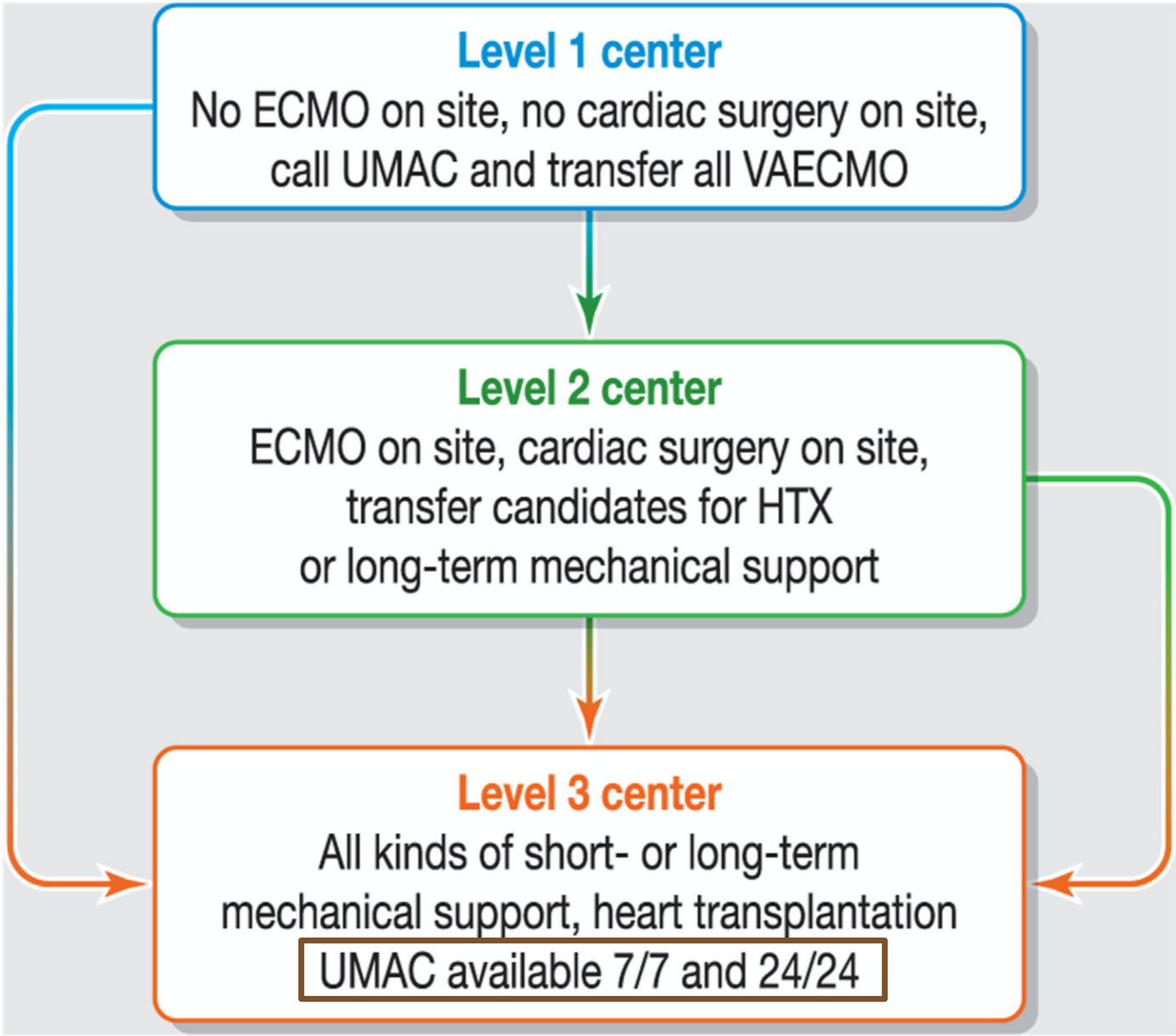
Analysis of risk of all-cause mortality in VA ECMO patients treated with levosimendan

Study or Subgroup	Levosimendan Events	Levosimendan Total	Control Events	Control Total	Weight	Risk Ratio M-H, Fixed, 95% CI
Affronti 2013	2	6	7	11	8.0%	0.52 [0.16, 1.77]
Jacky 2018	9	26	14	38	18.4%	0.94 [0.48, 1.84]
Vally 2019	11	51	50	99	55.1%	0.43 [0.24, 0.75]
Zipfel 2018	9	26	14	38	18.4%	0.94 [0.48, 1.84]
Total (95% CI)		**109**		**186**	**100.0%**	**0.62 [0.44, 0.88]**
Total events	31		85			

Heterogeneity: $Chi^2 = 4.70$, df = 3 (P = 0.20); $I^2 = 36\%$
Test for overall effect: Z = 2.68 (P = 0.007)



Burgos LM et al. Perfusion 2020



Flecher E et al. Arch Cardiovasc Dis 2019; 12:441-9

Intensive Care Med (2011) 37:824–830
DOI 10.1007/s00134-011-2158-8

ORIGINAL

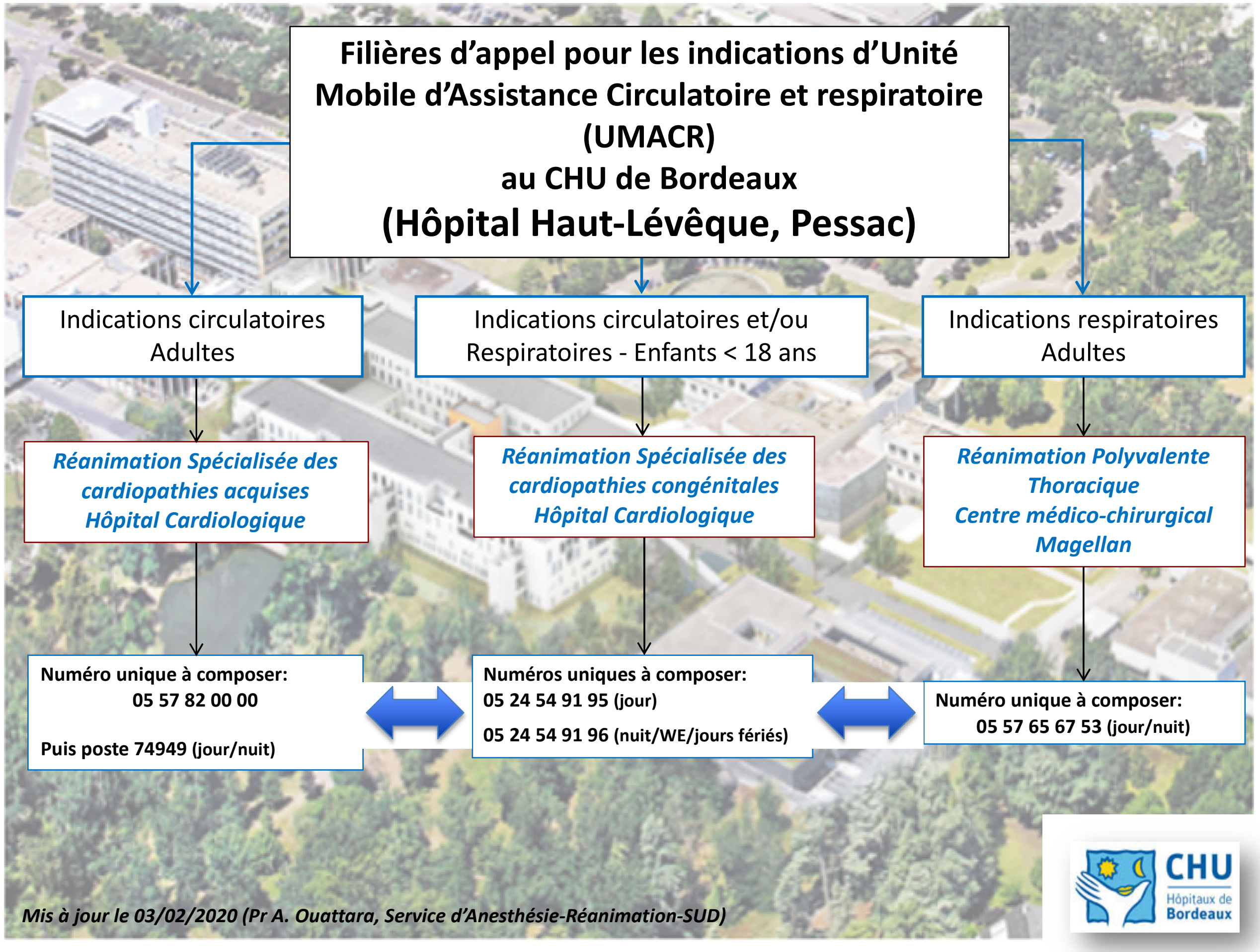
P. Forrest
J. Ratchford
B. Burns
R. Herkes
A. Jackson
B. Plunkett
P. Torzillo
P. Nair
E. Granger
M. Wilson
R. Pye

Retrieval of critically ill adults using extracorporeal membrane oxygenation: an Australian experience

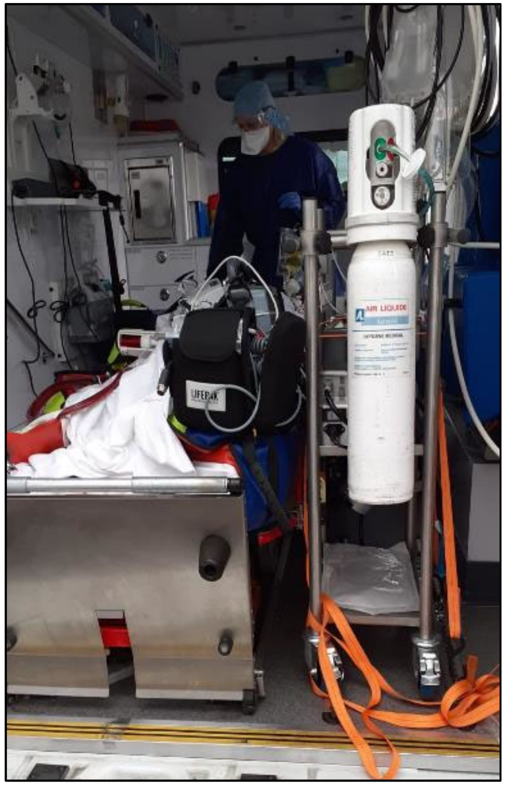
800 000 km^2 (X 1,5 F)
6 100 000 h


VARTA
VARTA
VARTA

DEPARTMENT OF ANAESTHESIA AND CRITICAL CARE OF HAUT-LEVEQUE HOSPITAL: REFERRAL ECMO CENTER



Mobile circulatory support unit



ROTAFLOW and

specific (smaller)

TROLLEY

(2020)

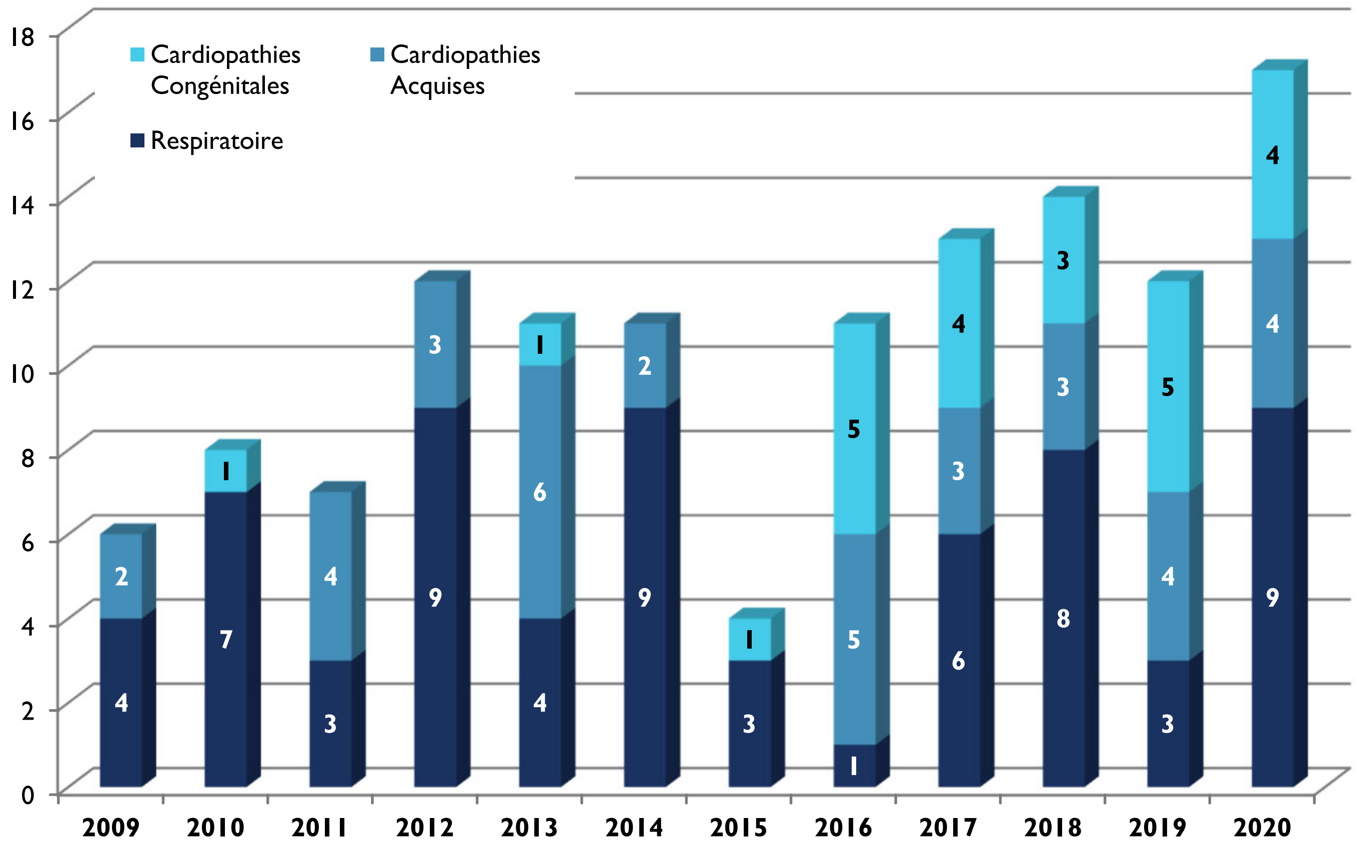
Miniaturisation…

CardioHelp (Maquet)

HLS Module Advanced 7.0:

- Oxygénateur à menbrane diffusion
- Pompe centrifuge innovante intégrée
- Marquage CE pour **30 J et le transport**
- Traitement de surface BIOLINE

Global activity (n=126)



Data from 126 patients managed by our Mobile assistance unit between 2009 and 2020

Age, year	33 [16-53]
Male, %	84 (67%)
Duration of ECMO, days	10 [2-23]
IGS II	52 [38-68]
In-hospital Mortality, %	46 (36.2%)
Distance, km	10 [10-146]

SHORT-TERM MECHANICAL CIRCULATORY SUPPORT…

- ✓ Rescue and temporary strategy to restore end-organ perfusion
- ✓ Intrinsic morbidity and even mortality (ischemia, bleeding,…)
- ✓ Impact on intra-cardiac haemodynamic (failing myocardium)
- ✓ Potentially harmful for myocardial recovery (ventricular remodeling)
- ✓ Multidisciplinary cardiogenic shock team approach
- ✓ Multimodal and evolutive strategy
- ✓ Further research still required to confirm and quantify outcome improvement
- ✓ And identify the best strategy regarding the severity of CS

INSERM, UMR 1034 Biology of cardiovascular diseases

Systemic and cardiac haemodynamics in acute heart failure

Program leaders

Professor Alexandre OUATTARA MD PhD (Anesthesia and Critical care)

Professor Thierry COUFFINHAL MD PhD (Cardiology)

Seniors

Associate Professor Julien IMBAULT MD

Associate Professor Mario RIENZO MD PhD

PhD Students

Antoine BEURTON MD MSc

MSc Students

FX HERION MD

Claire ODDOS MD

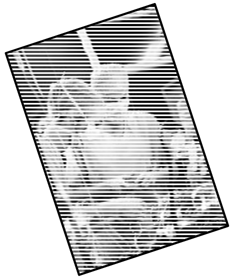
Elora BORDIER MD

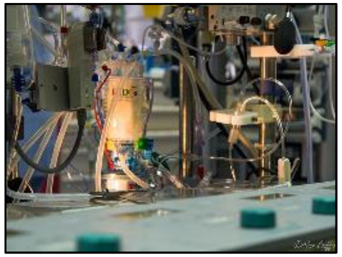
Simon VEYRET MD

UMR-1034 INSERM
UNIVERSITY OF BORDEAUX
Biology of Cardiovascular Diseases

Inserm

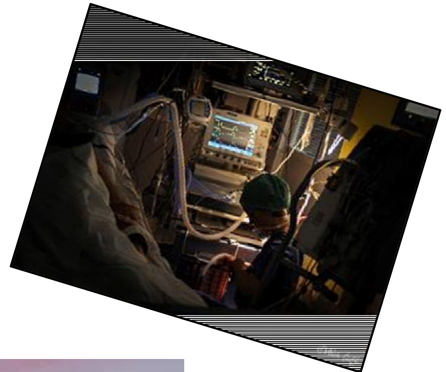
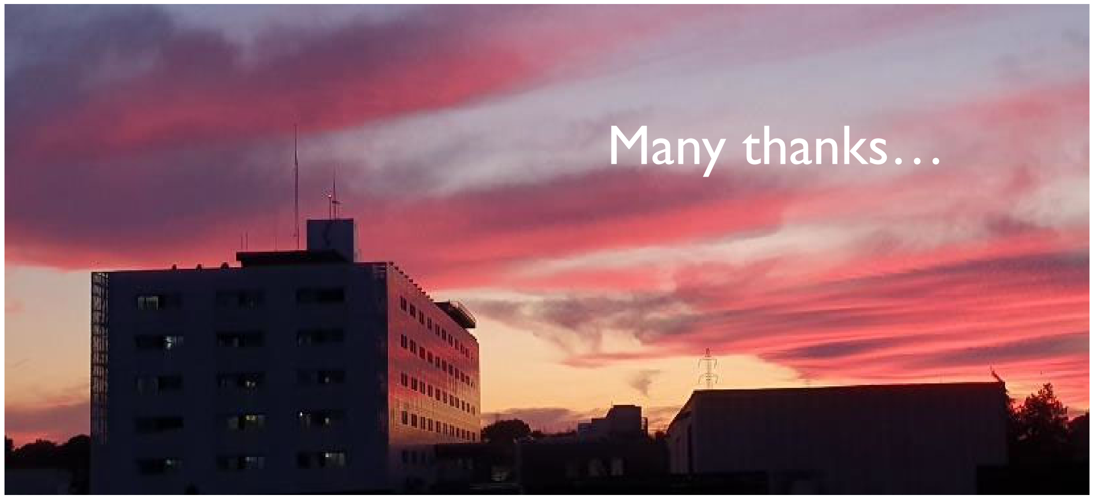
université BORDEAUX



SOL GLISSANT








Many thanks…