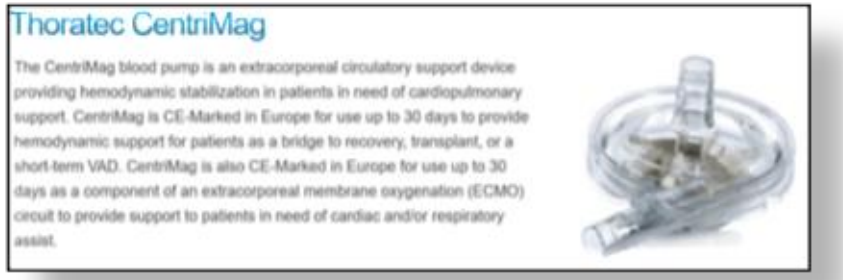
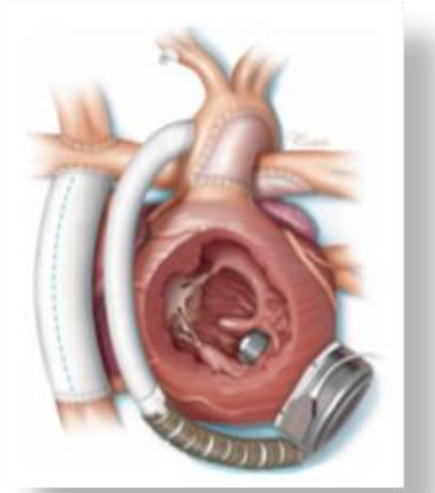


Assistances Circulatoires et Cardiopathies de l'Enfant

DIU Réanimation des Cardiopathies Congénitales

Dr Stephane LE BEL

DARP Hopital Timone Enfant

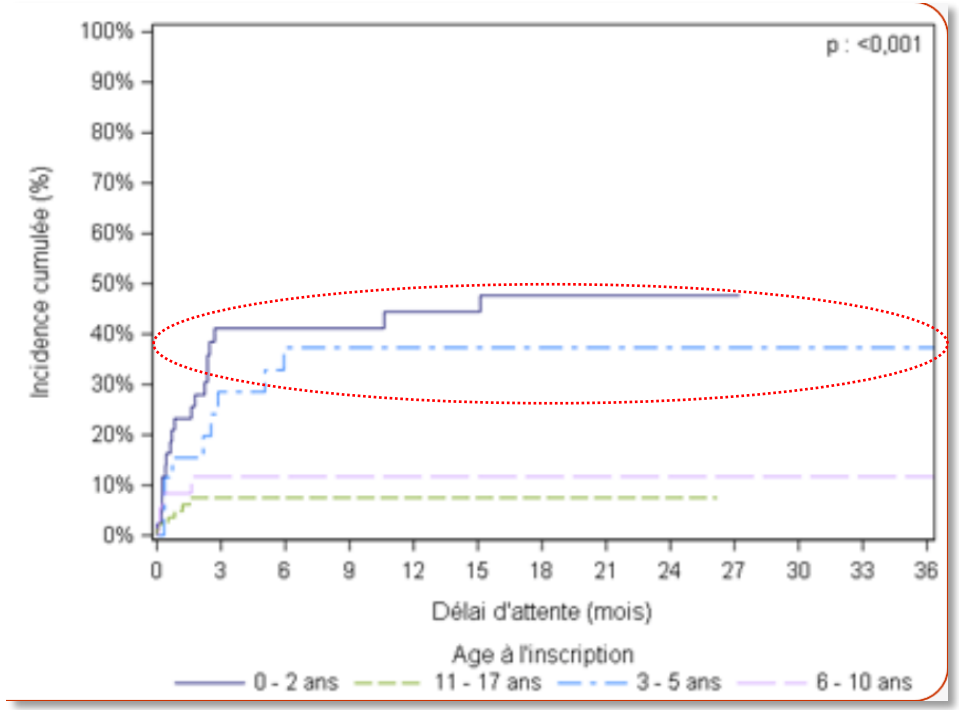


Pourquoi parle-t-on d'assistance aujourd'hui?

Le rapport médical et scientifique
de l'**Agence de la biomédecine** **2017**

- Durée médiane d'attente d'un greffon = 3mois
- En 2017 36 nouveaux candidats pédiatriques à la transplantation cardiaque
- Incidence cumulée de transplantation à 6 mois = 64%.
  - 58% des nouveaux inscrits sont en Réanimation-USC.
  - 22% sont ventilés.
  - 19% sont sous ECMO.
  - 8% ont une assistance ventriculaire.
  - 53% ont un soutient inotrope.

Incidence cumulée de décès en attente ou sortie pour aggravation avec prise en compte du risque concurrent de greffe cardiaque



Historique

- 1970: 1ère ECMO Veino-Artérielle pour choc cardiogénique.
- 1976: ECMO Veino-Artérielle avec pompe centrifuge.
- 1980: Assistance Mono-Biventriculaire avec pompe centrifuge.
- 1990: Les 1ers VAD bricolés pour la pédiatrie
- 1996: The « Red Book »
- 2000: Assistance Ventriculaire pulsatile pédiatrique dédiée.
- 1990-2010: Les début d'une évaluation « sérieuse ».
- 2010: Nouvelles assistances ventriculaires:
  - De courte durée.
  - De longue durée.
- ? Cœur artificiel

« Assister » pour quel projet thérapeutique?

- **ECMO:**
  - Bridge to recovery
  - Bridge to bridge
  - Bridge do transplantation
  - Bridge to nowhere
- **VAD:**
  - Bridge to recovery
  - Bridge do transplantation
- **Les nouvelles assistances:**
  - Bridge to recovery
  - Bridge do transplantation
  - ***Bridge to destination ???***

Destination therapy with ventricular assist devices for patients with dystrophinopathies: A new way of life

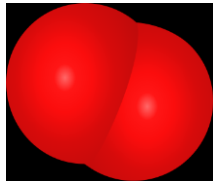
Christian Pizarro, MD

J Thorac Cardiovasc Surg 2017;153:667-8

Physiologie appliquée à L’assistance cardio-pulmonaire.

- Physiologie du transport des gaz.
- Relation DO2 / VO2.
- SvO2 et ses différents paramètres.
- Conséquences techniques pour l’ECMO.
- Comment promouvoir le récupération myocardique/pulmonaire sous ECMO.
- Concept de « bridge to recovery »

O_2



$$DO_2 = CO \times \{(BO_2 \times ceHb \times sO_2) + (PaO_2 \times 0.03)\}$$

Maximal oxygen-carrying capacity of the blood (ml/g of Hb): normally, 1.39ml/g

% saturation of effective haemoglobin

Rate of oxygen delivery in ml/min

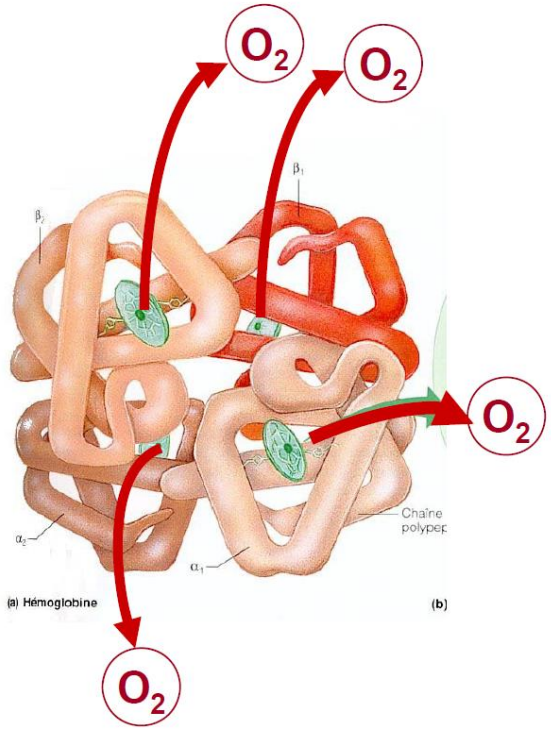
Cardiac output in L/min

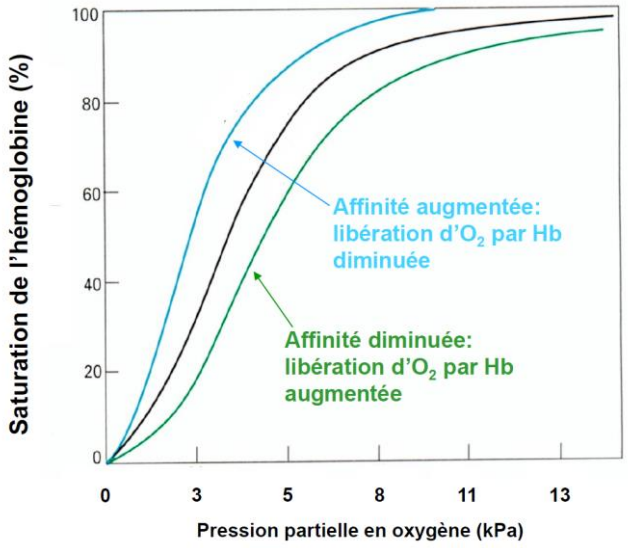
Concentration of effective haemoglobin (i.e. excluding dyshaemoglobin species)

Solubility constant for oxygen at 37° - normally, 0.03ml/L/mmHg

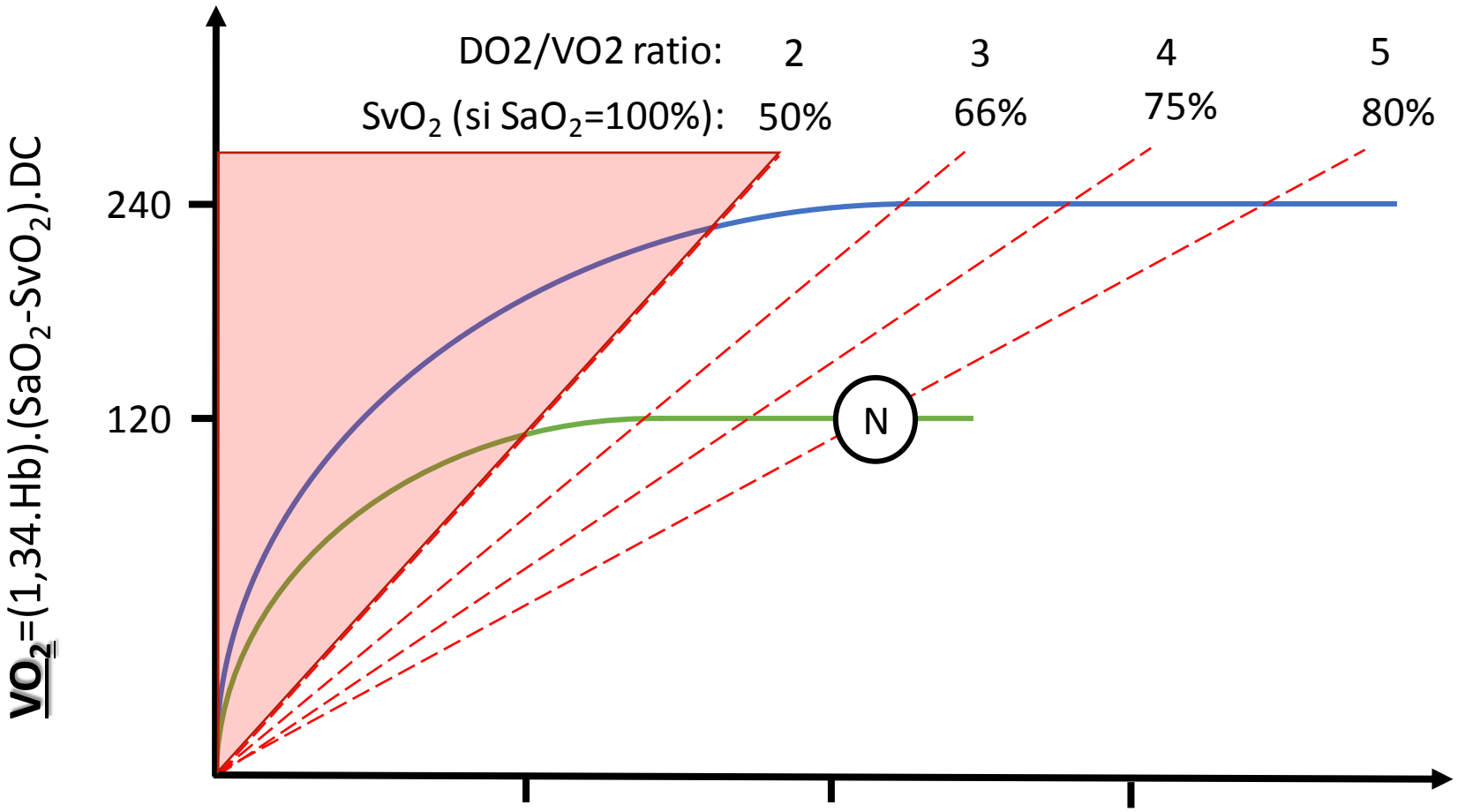
Partial pressure of oxygen

- Transport de l'oxygène essentiellement sous forme combinée (97%).
- Faible quantité dissoute (3%) dans le plasma et le cytoplasme des hématies.

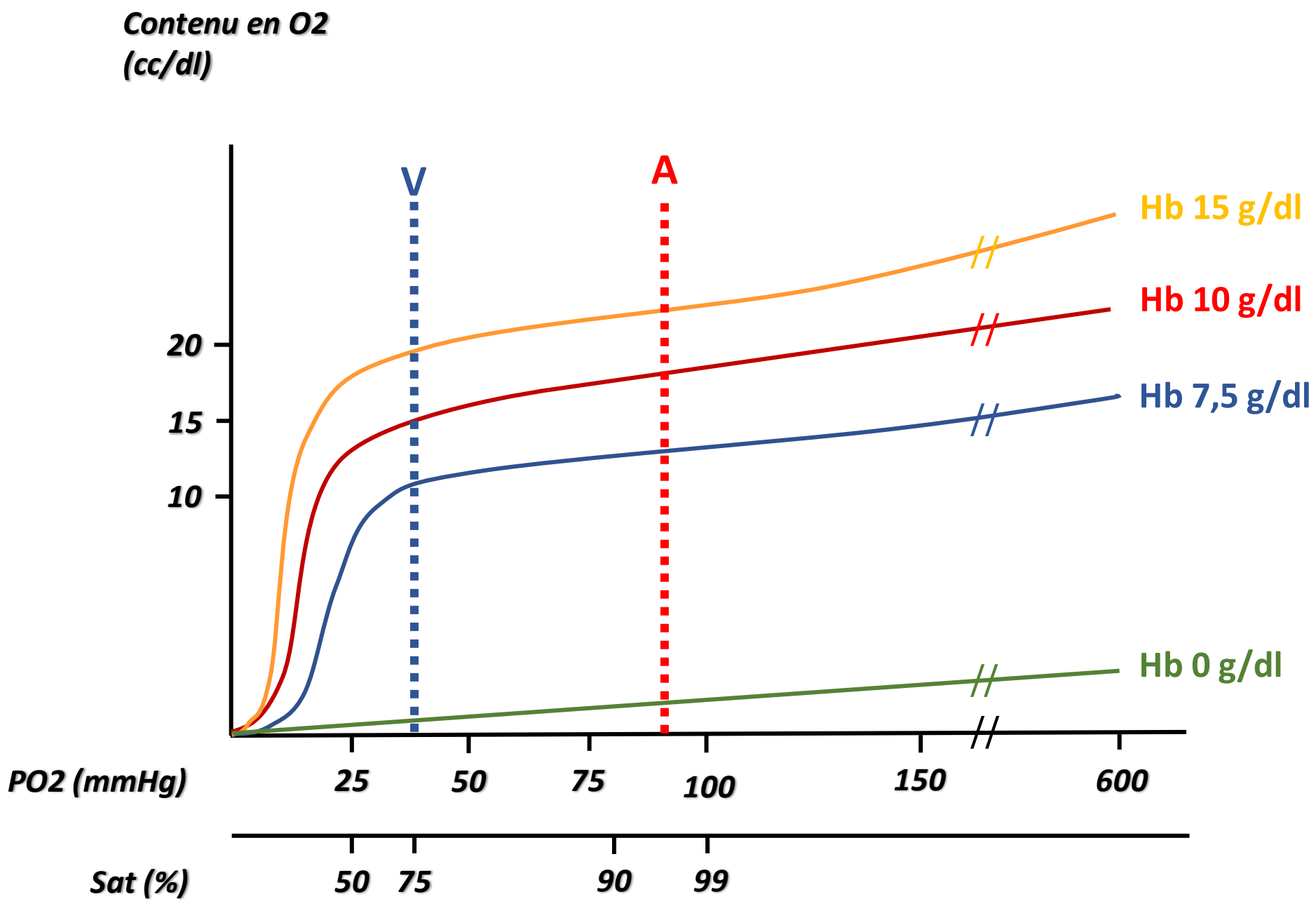




Relation DO_2 / VO_2 avec VO_2 normale et augmentée (Sepsis par exemple…)

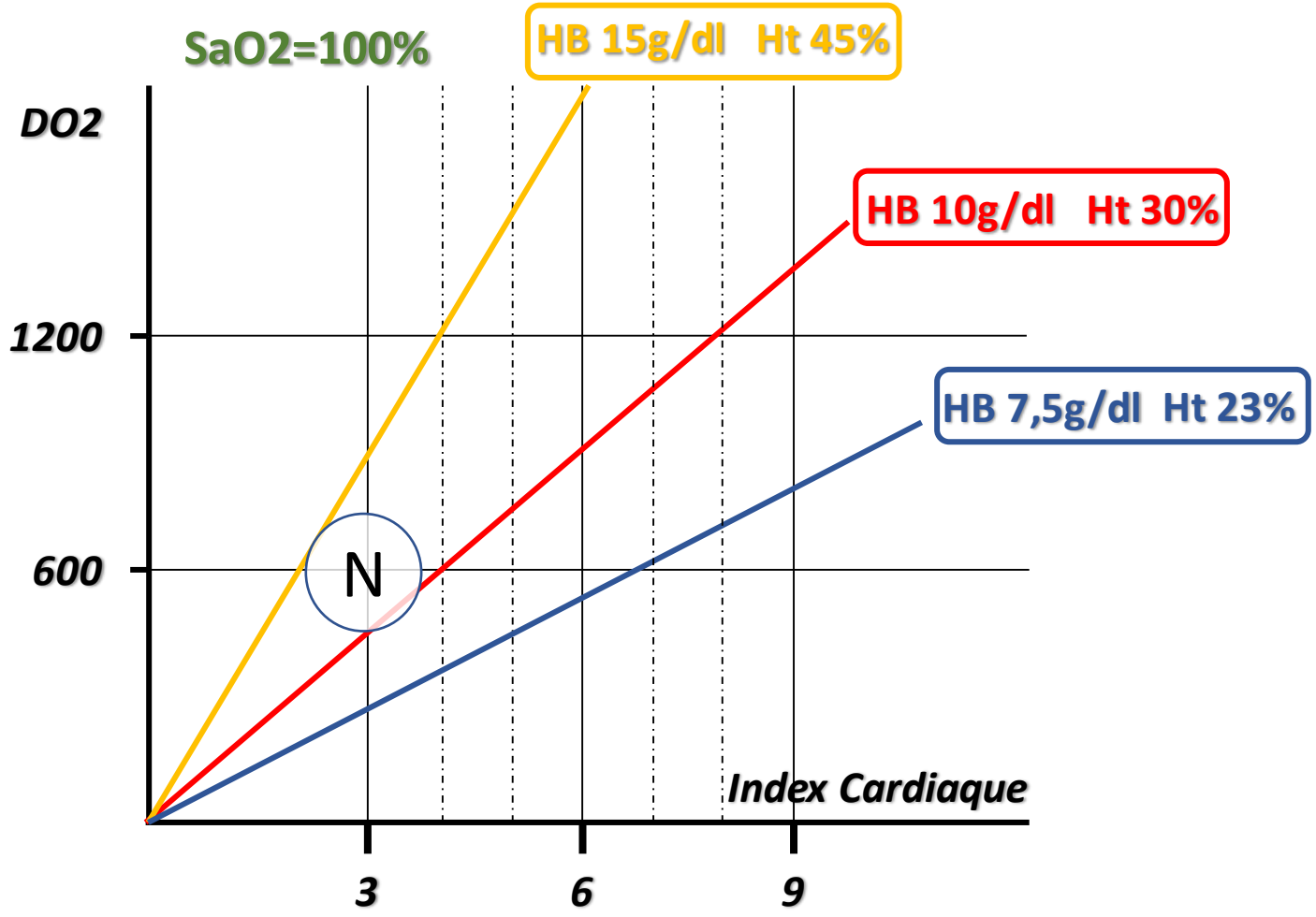


DO_2=[(1,34.Hb). SaO_2].DC ≃ *10 ml/kg/mn ou 500 ml/min/m²*


Contenu en O2
(cc/dl)
V
A
Hb 15 g/dl
Hb 10 g/dl
Hb 7,5 g/dl
Hb 0 g/dl
20
15
10
PO2 (mmHg)
25
50
75
100
150
600
Sat (%)
50
75
90
99

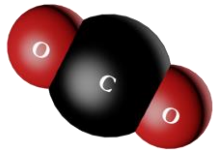
Importance respective des déterminants de la DO_2

$DO_2=[(1,34.Hb).\ SaO_2].DC$



- Le débit cardiaque et l'hémoglobine sont les 2 facteurs majeurs du transport d'oxygène .
- A SpO2 et PaO2 normale (100%), le CaO2 peut être très diminué à cause d'une anémie.

CO_2



Transport artériel sous 3 formes

because of the following technical difficulty: Carbon dioxide diffuses through the respiratory membrane so rapidly that the average P_{CO_2} in the pulmonary blood is not far different from the P_{CO_2} in the alveoli—the average difference is less than 1 mm Hg—and with the available techniques, this difference is too small to be measured.

- **Dissout 5-%**

le CO_2 est 20 fois plus soluble que l'O_2 (0,067ml.dl^{-1}.mmHg^{-1}).

- **Bicarbonates 90%:**

$$CO_2 + H_2O \overset{[AC]}{\leftrightarrow} H_2CO_3 \leftrightarrow H^+ + HCO^{3-}$$

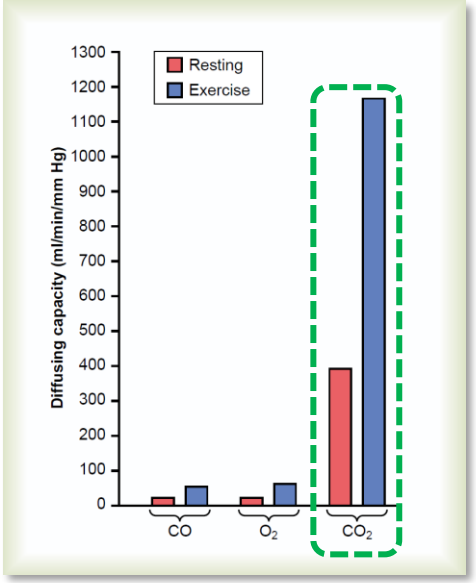
« Chlorid shift ».

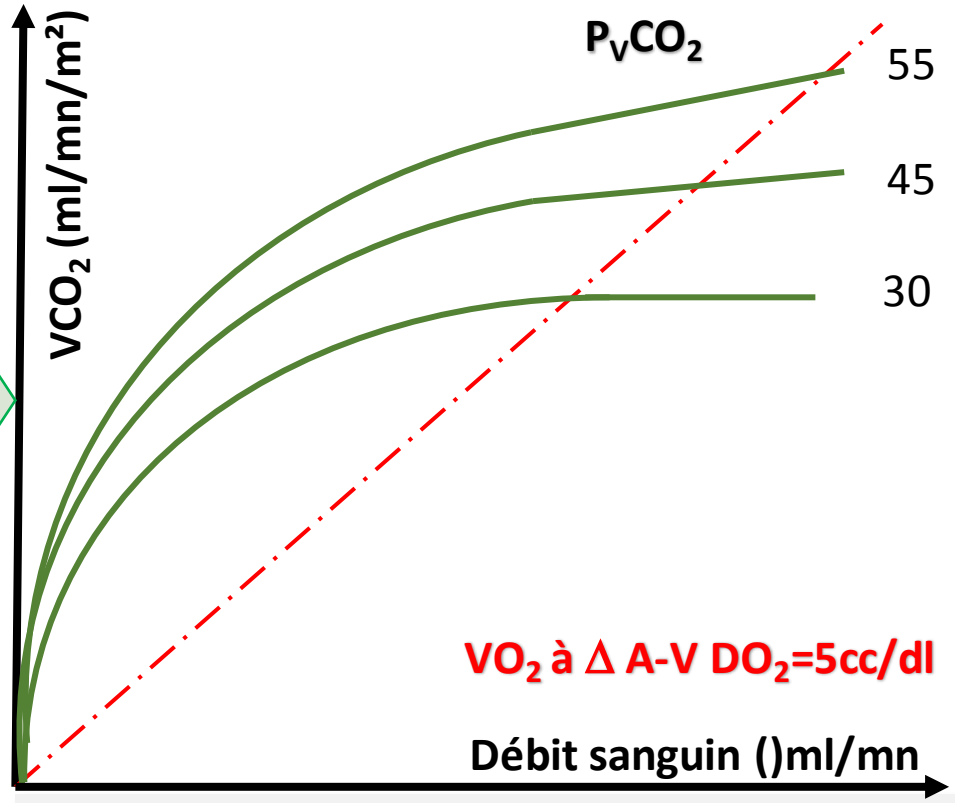
Effet Haldane.

- **Combiné à des protéines 5%:**

Globine de l'Hb+++

$$Hb.NH_2 + CO_2 \leftrightarrow Hb.NH.COOH$$

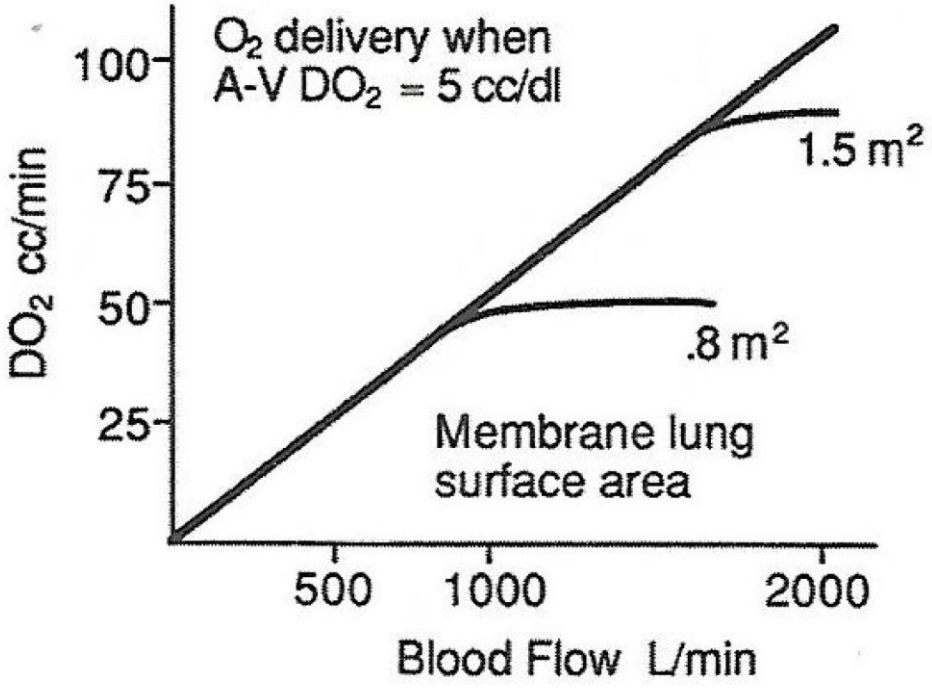




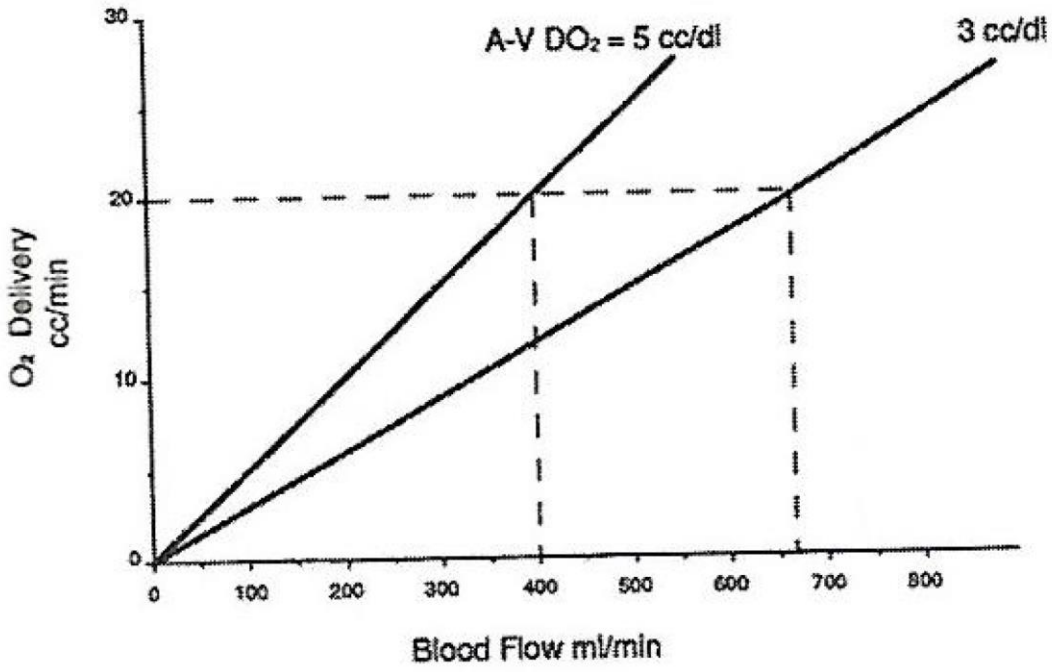
Pour cet oxygénateur, l'épuration du CO2 dépasse l'oxygénation a chaque niveau de débit.

Conséquences pour l'assistance

Le transport d'oxygène pour un oxygénateur donnée dépend de sa S²et de sa géométrie



Quant un oxygénateur est utilisé en dessous du débit maximal autorisé, le transport d'oxygène est inversement proportionnel à la SvO2



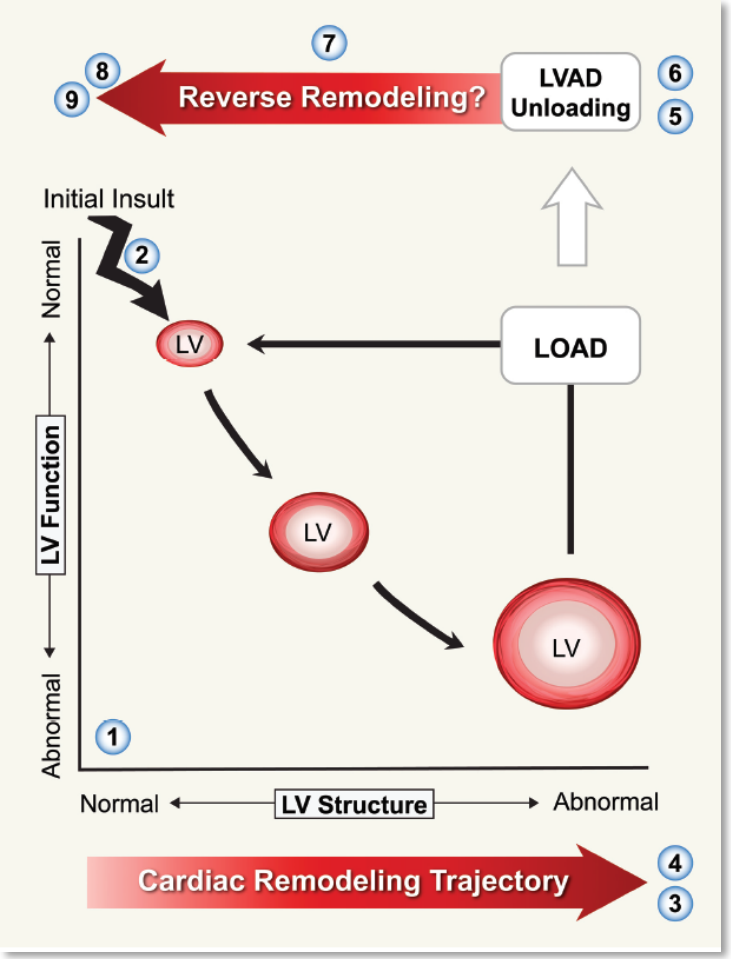
Advances in Mechanical Circulatory Support

Bridge to Recovery

Understanding the Disconnect Between Clinical and Biological Outcomes

Drakos SG et al. Circulation 2012;126(2):230-41.

1. Existe-t-il une correspondance entre la structure et la fonction myocardique?
2. Quel est l'impact de l'étiologie dans la possibilité de récupération myocardique?
3. Existe-t-il une durée d'insuffisance cardiaque au-delà de laquelle toute récupération est impossible?
4. L'importance du « remodeling » avant implantation joue-t-il un rôle dans la capacité de récupération?
5. Comment « bien » décharger le cœur? Pulsatile vs Continuous vs counterpulsion.
6. Quels thérapeutiques adjuvantes? (IEC-β-bloquants…).
7. Quel protocole de surveillance pendant l'assistance?
8. Existe-t-il une durée optimale d'assistance (un loading?)
9. Quels sont les indices de récupération myocardique pérenne?



DIU de réanimation des Cardiopathies Congénitales oblige…

- L'ECMO veino-artérielle est la technique de référence de l'assistance cardiaque mécanique.

- Nous ne parlerons pas de l'ECMO veino-veineuse
  - Technique non conventionnelle en chirurgie cardiaque pédiatrique.
  - Privilège des centres particulièrement expérimentés…
  - …et uniquement dans des situations très spécifiques.

Nous n'envisagerons ici que les indications cardiogéniques…et donc l'ECMO V-A!

- Echec de sevrage de la CEC.
- Arrêt cardiaque.
- Choc cardiogénique.
- Dégradation progressive de la fonction cardiaque avec défaillance viscérale.
- Syndrome de bas débit cardiaque postopératoire ne répondant pas au *traitement médical maximal*.

Quels bénéfices attend-t-on d'une ECMO?

1. ***Rétablissement d'un transport d'oxygène*** normal chez un patient incapable de l'assurer par insuffisance cardiaque aigue.

2. ***Assurer une oxygénation du sang adéquate et une décarboxylation efficace*** dans les situation d'insuffisance respiratoire aigue.

3. ***Prévention des complications liés aux traitement:***
   - Volo/barotraumatisme pulmonaire.
   - Interactions cardio-pulmonaires pathologiques.
   - Excès de demande énergétique cardiaque par surdosage en inotropes.
   - Aggravation des défaillances viscérales par surdosage en vasopresseurs.

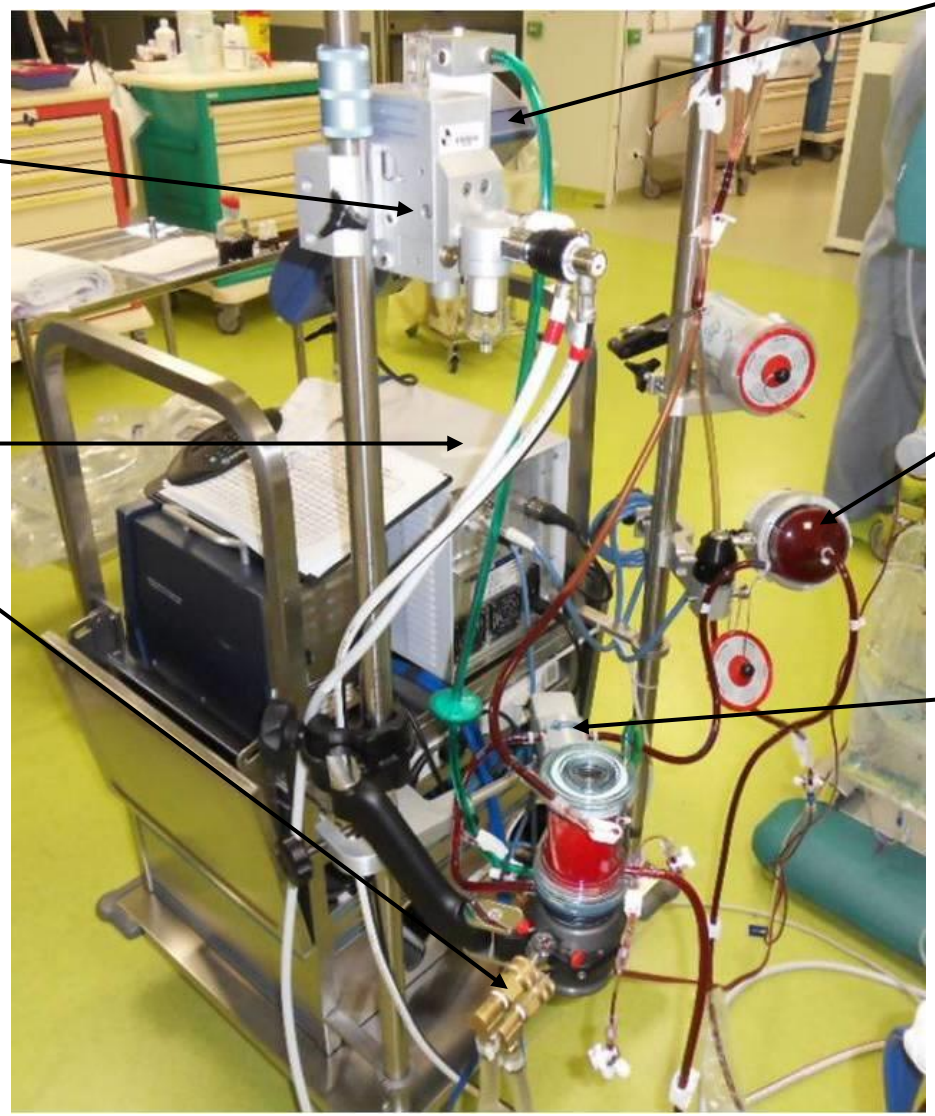
4. ***Sécurisation de certaines procédures:***
   - Chirurgie trachéale.
   - Cathétérisme cardiaque à risque.
   - Rétablissement de la normothermie.
   - Promouvoir l'épuration de substances.
   - Maintien de la perfusion d'organe chez le donneur d'organe.

Le Matériel…rapidement

La machine d'ECMO

Console

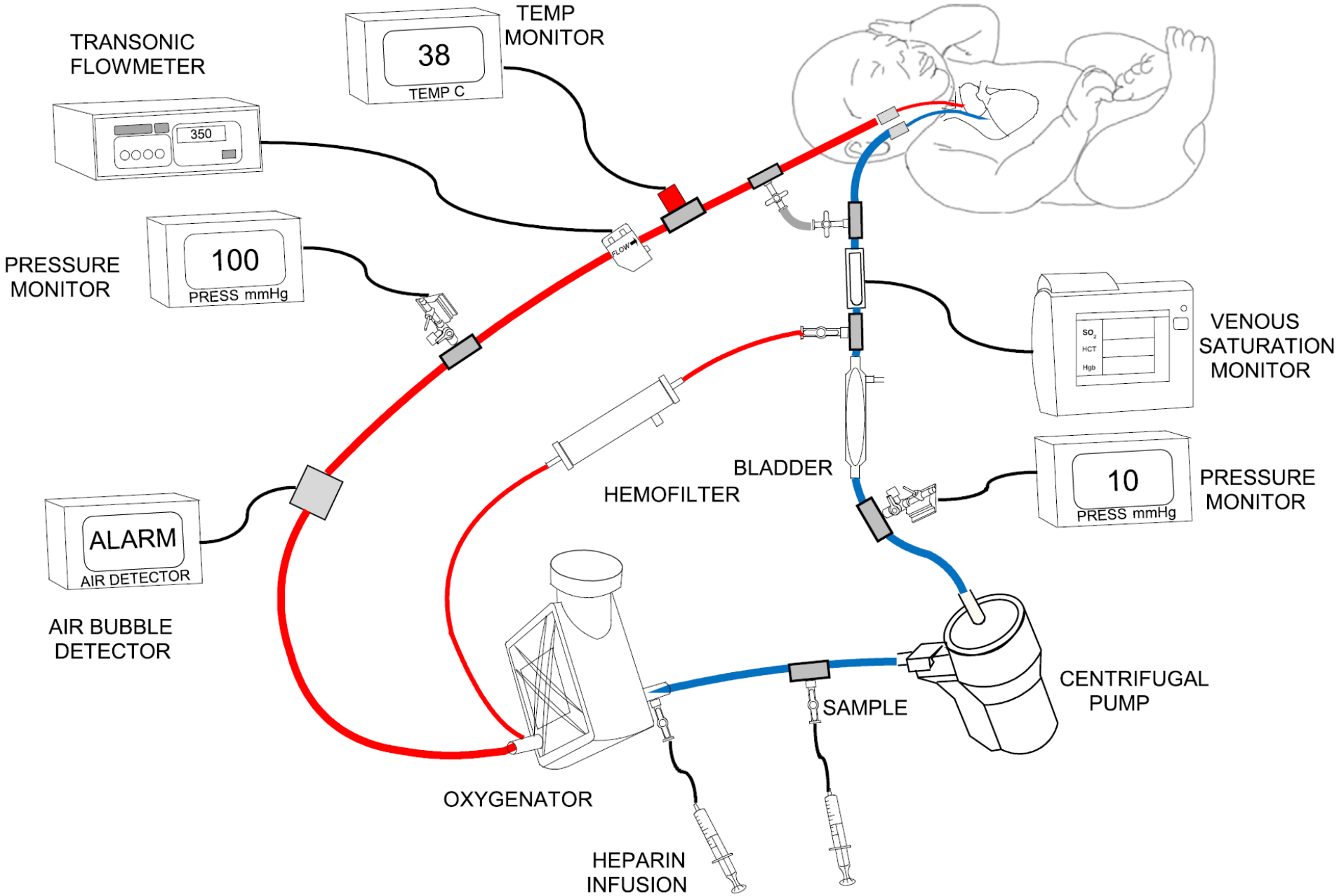
Mélangeur de gaz



Bloc chaud-froid

Pompe

Débimètre


TRANSONIC FLOWMETER
350
TEMP MONITOR
38
TEMP C
PRESSURE MONITOR
100
PRESS mmHg
FLOW
VENOUS SATURATION MONITOR
SO2
HCT
Hgb
BLADDER
HEMOFILTER
10
PRESSURE MONITOR
PRESS mmHg
ALARM
AIR DETECTOR
AIR BUBBLE DETECTOR
CENTRIFUGAL PUMP
SAMPLE
OXYGENATOR
HEPARIN INFUSION

$$q_v = \frac{\pi r^4}{8\eta L} \times (P_1 - P_2)$$

Le drainage veineux

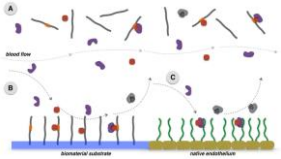
- Le débit est proportionnel au gradient de pression multiplié par la puissance 4 du rayon du conduit divisé par la longueur du conduit.
- ⚠ Veine = résistance de Starling.
- Importance du diamètre de la canule veineuse…
- …de sa position (dans l'OD)…
- …de la vitesse de la pompe centrifuge…
- …ou de la position du sac de recueil si pompe à galet.
- Site variable:
  - Jugulaire.
  - Fémorale.
  - Les 2!
  - Oreillette droite.
- Chirurgical ou percutané.

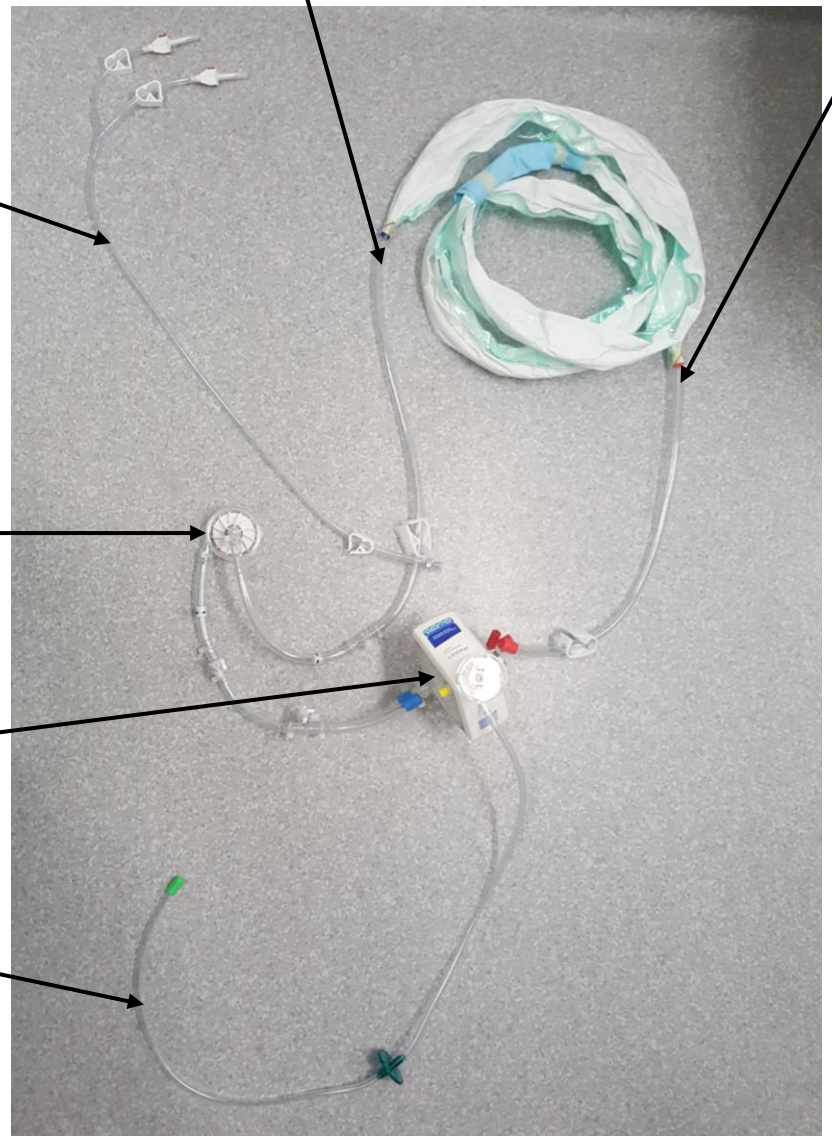
Débit théorique (ml/mn)	Canule Artérielle	Canule Veineuse
400	6	8
450		
500	8	10
550		
600		
650		
700	10	12
750		
800		
850		
900		
950		
1000	12	14
1100		
1200		
1300		
1400	14	15
1500		
1600		
1700		
1800	15	17
1900		
2000		
2100		
2200		
2300		

Débit théorique (ml/mn)	Canule Artérielle	Canule Veineuse
2400	17	19
2500		
2600		
2700		
2800		
2900		
3000		
3200	19	21
3400		
3600		
3800		
4000		
4200	21	
4400		
4600		
4800		
5000		

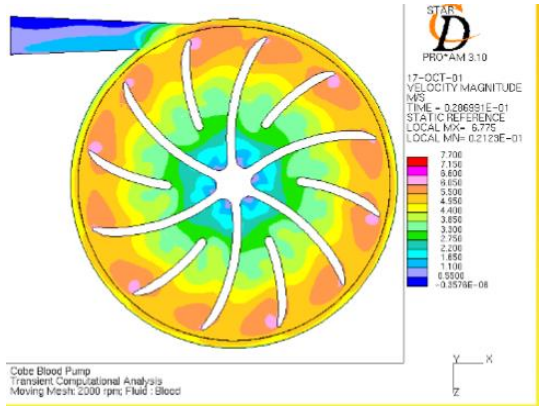
Le circuit d'ECMO

- Tube de PVC de diamètre variable
  - ¼ inch ➔ néonatal
  - ⅜ inch ➔ pédiatric
  - ½ inch ➔ adolescent (big ones…) – adulte.
- The shorter the better
  - Resistance à l 'écoulement.
  - S^2de contact sang/S^2 artificielles.
  - Perte de chaleur
  - V3 du priming.
- The fewer connector the better
  - Flux turbulent sur les variations de Ø.
  - Connexion scellées.
- Traitement de S^2
  - Albumine ➔ Carmeda® BioActive surface.
  - Efficacité clinique?



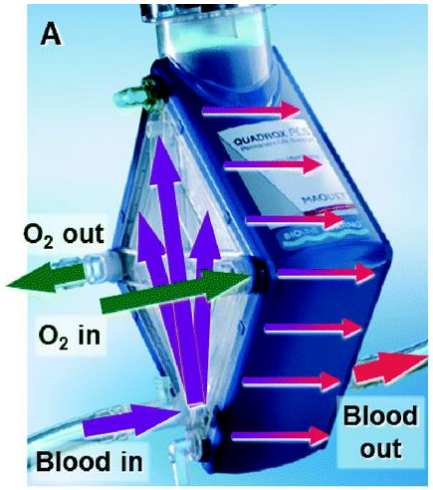


La Pompe

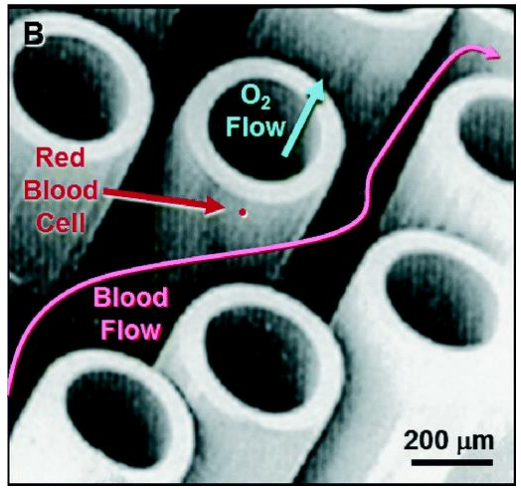


- Centrifuge +++
- Energie nécessaire à la mobilisation du sang moins importante.
- On règle un nombre de trs/mn.
- On mesure un débit…
- …qui dépend aussi de la précharge et de la postcharge.
- Attention au coudure de circuit et à tous les facteurs de résistance.
- Hémolyse possiblement plus importante à bas débit (nouveau-nés).

- Nouveau-né: 100 ml/kg/mn.
- Enfant 80 ml/kg/mn.
- Adulte 60 ml/kg/j.



L'Oxygénateur

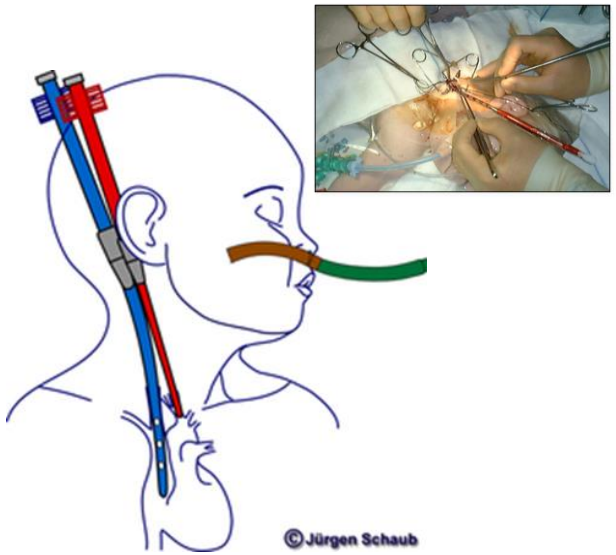


- Oxygénateurs à membranes +++.
- Traitement de surface.
- Moins d'activation de la coagulation.
- Meilleurs échanges gazeux / unité de S^2.
- Moindre résistance à l 'écoulement…
- …donc moins d'hémolyse.

- L'oxygénation dépend:
  - de la FiO2
  - du débit d'ECMO.
  - S^2 oxygénateur.
  - La fonction d'oxygénation d'un oxy. est non linéaire.
- La décarboxylation dépend:
  - S^2 oxygénateur.
  - Débit de gaz.

Les sites de canulation

- Périphériques:
  - Percutané vs Chirurgicale
  - Deux sites privilégiés
  1. Jugulo-carotidienne
     - ➢ obstruction carotidienne.
     - ➢ Complications neurologiques.
  2. Fémoro-fémoral.
     - ➢ Taille des canules.
     - ➢ Ischémie de membre inférieur.
- Centrale:
  - ➢ Sternotomie.
  - ➢ Drainage veineux « idéal ».
  - ➢ Canula Aortique de bon diamètre.
  - ➢ Risque hémorragique.
  - ➢ Risque infectieux.



Débit théorique (ml/mn)	Canule Artérielle	Canule Veineuse
400 450	6	8
500 550 600 650 700 750 800 850 900 950	8 10	10 12
1000 1100 1200 1300	12	14
1400 1500 1600 1700 1800	14	15
1900 2000 2100 2200 2300	15	17
2400 2500 2600 2700 2800 2900 3000	17	19
3200 3400 3600 3800 4000	19	21
4200 4400 4600 4800 5000	21	

ECMO et Norwood

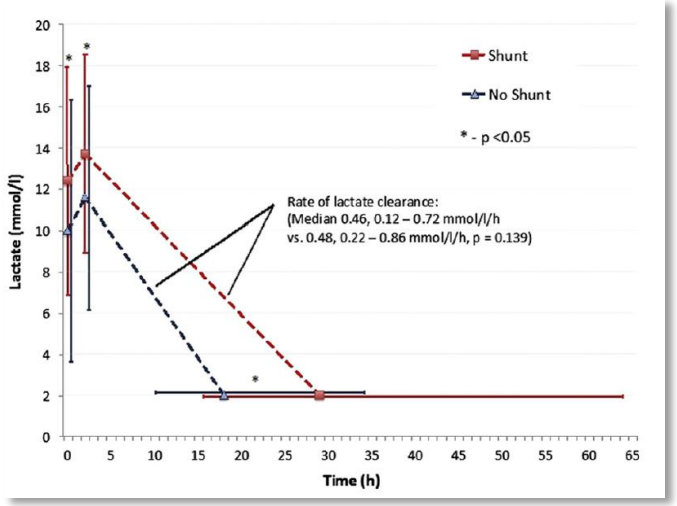
Extracorporeal membrane oxygenator support in infants with systemic-pulmonary shunts

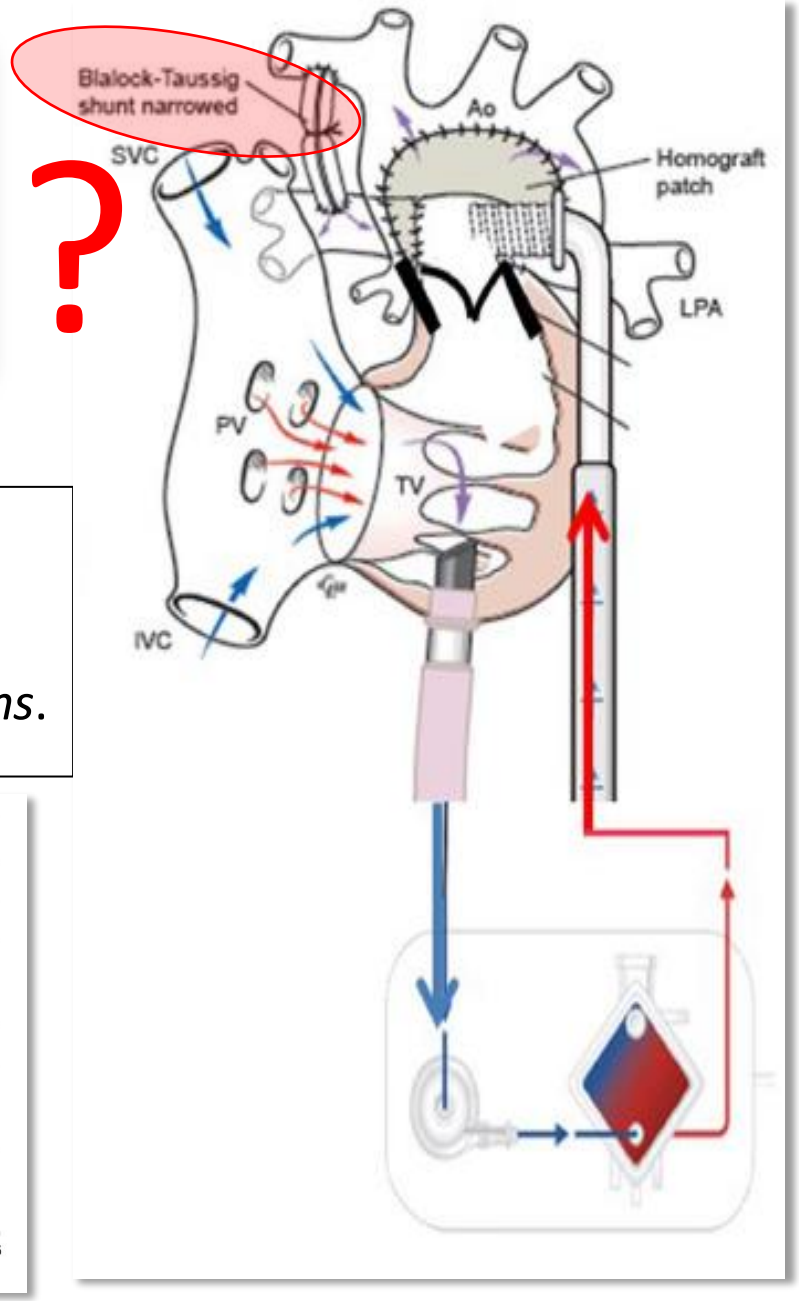
Phil Botha. **The Journal of Thoracic and Cardiovascular Surgery • September 2016**

TABLE 1. Patient demographic data

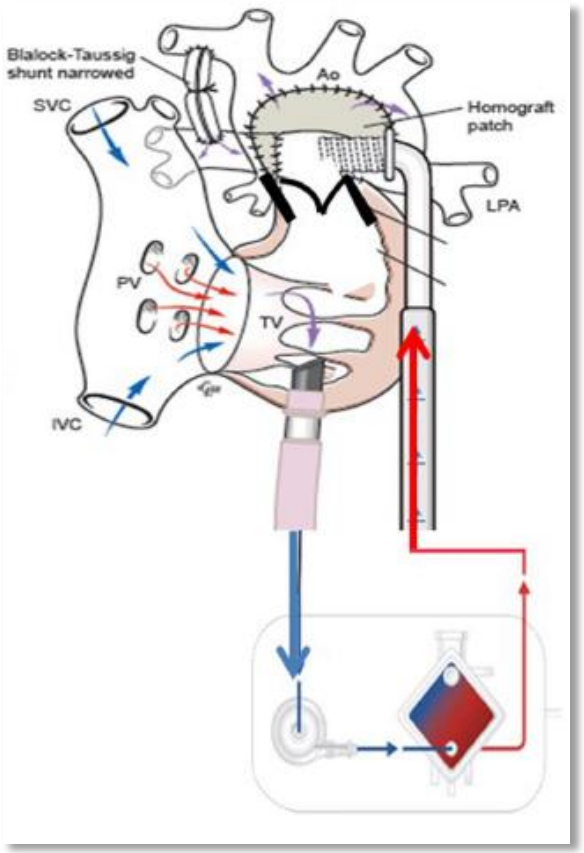
	Shunt group (n = 51)	Nonshunt group (n = 118)	*P* value
Age, d, median (IQR)	15 (8-38)	19 (7-109)	NS
Weight, kg, median (IQR)	3.3 (2.7-3.8)	3.6 (2.9-5.4)	.010
Postoperative, n (%)	48 (94.1)	90 (76.3)	.005
Norwood stage 1, n (%)	16 (31.4)	28 (23.7)	NS
ECPR, n (%)	37 (72.5)	56 (47.5)	.003
Indication for ECMO, n (%)			
Inability to wean from CPB	2 (3.9)	13 (11.01)	
Cardiac arrest	19 (37.3)	37 (31.4)	
CV instability	16 (31.4)	38 + 7 (38.1)	
Hypoxia	6 (11.8)	11 (9.3)	
Respiratory arrest	7 (6.1)	3 (2.5)	
Concern for shunt thrombosis	5 (9.8)	0	

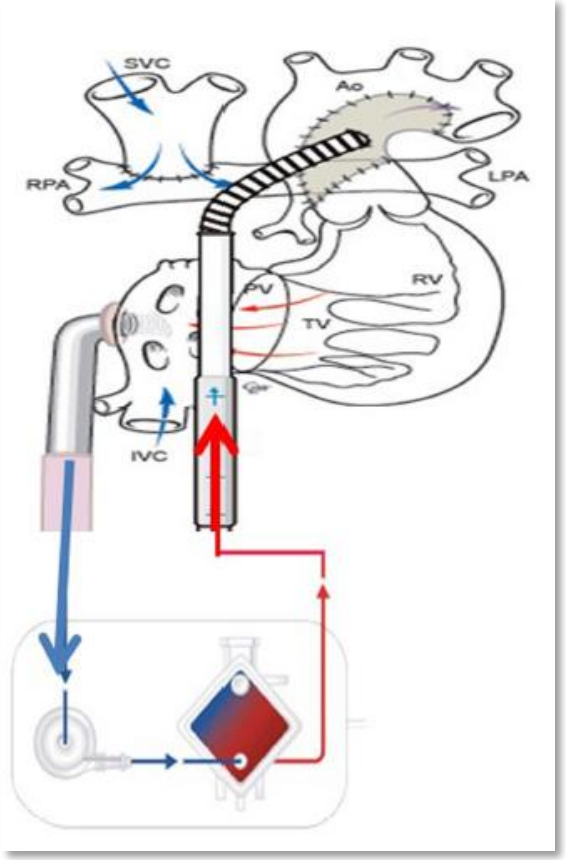
- Débit ECMO 161±43 $_{sht}$ vs 134±41ml/mn $_{nosht}$.
- Survie 49%$_{sht}$ vs 48.3%$_{nosht}$ *ns*.

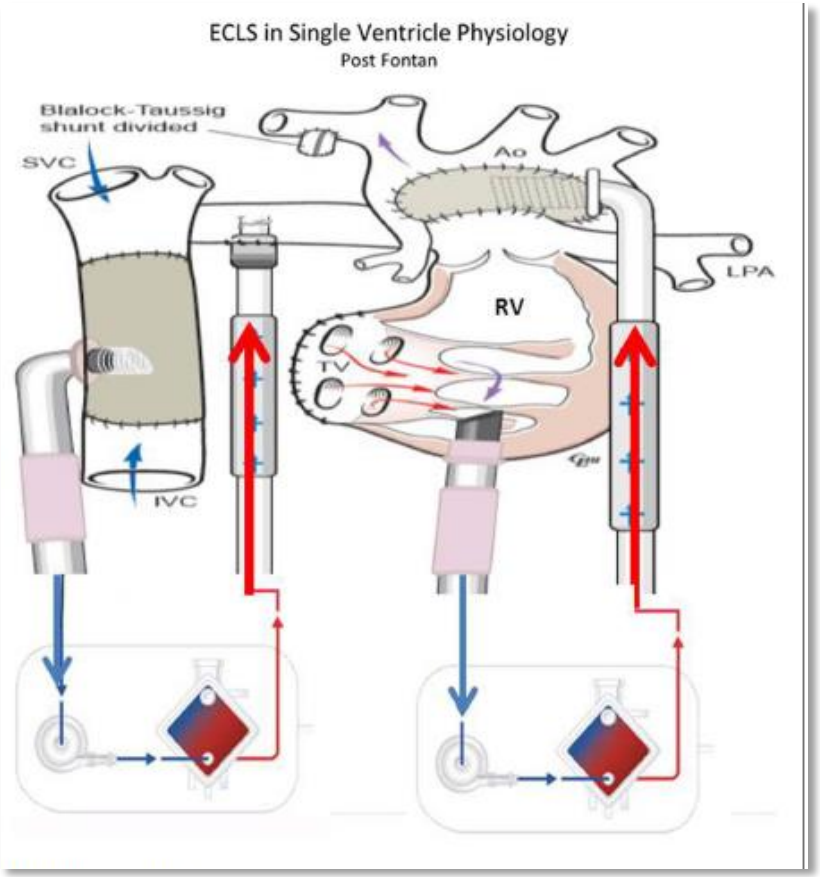




ECMO et cardiopathie univentriculaire







Effets hémodynamiques et métaboliques de l'ECMO

Considérations hémodynamiques générales

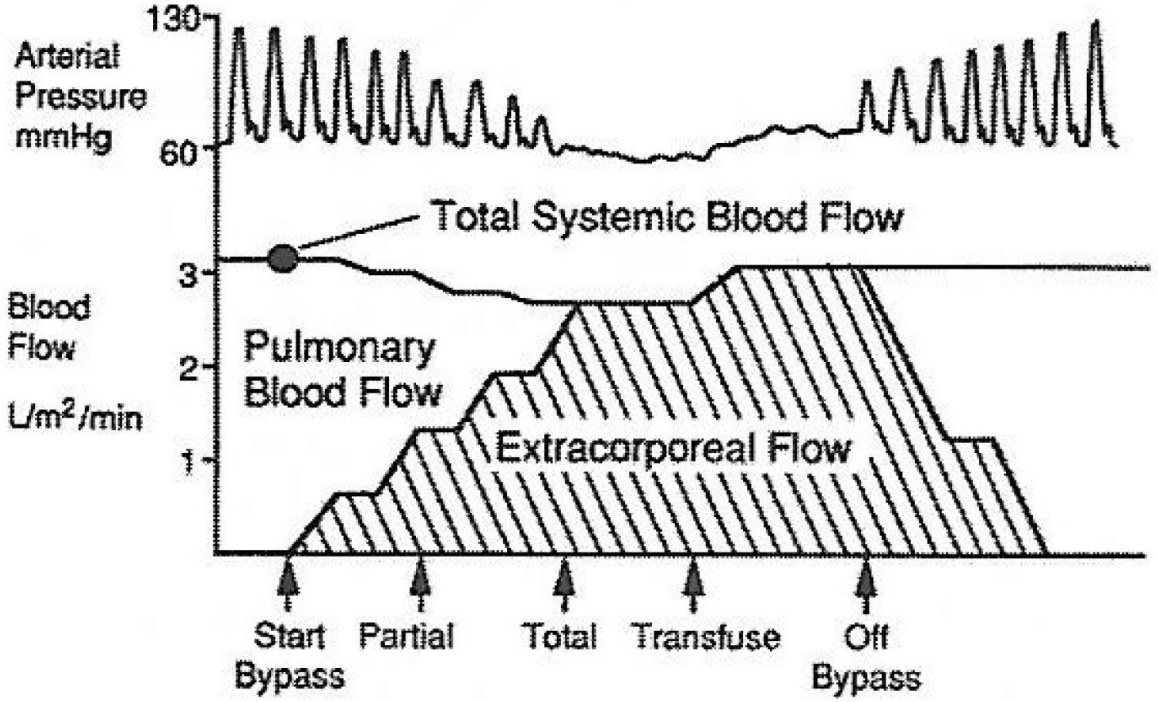
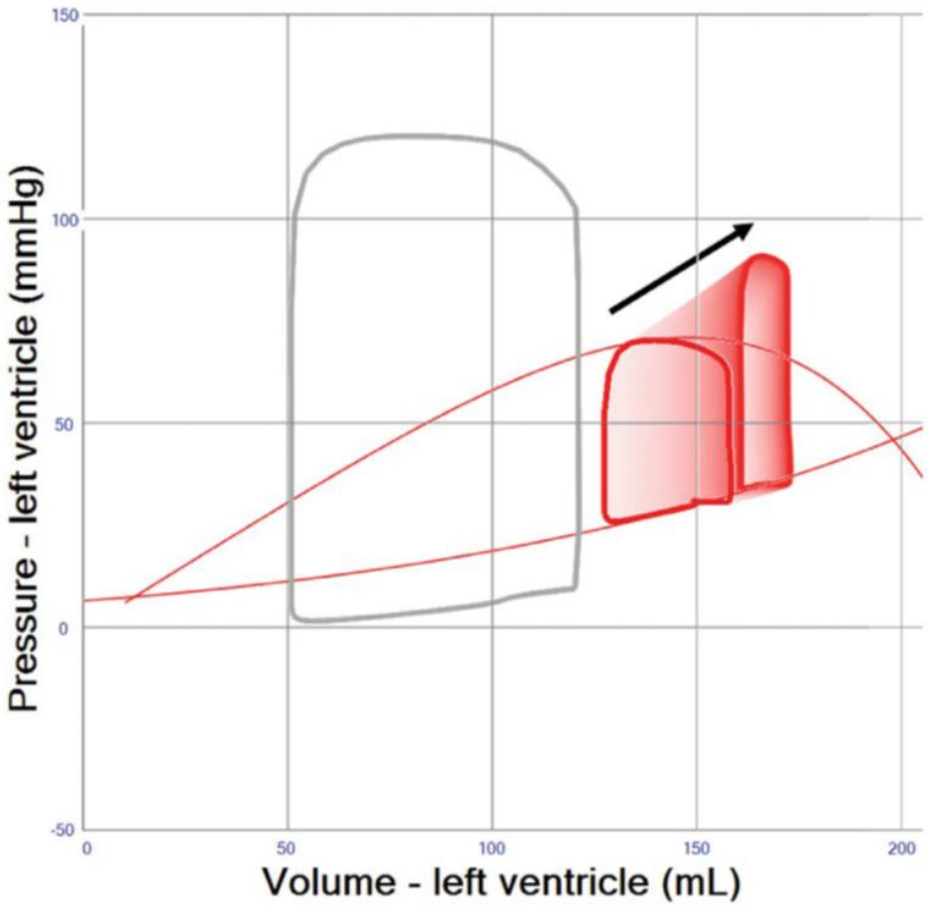


Figure 12. As extracorporeal flow increases, systemic pulse pressure decreases. In this example, total CPB is associated with a flat systemic pulse contour.

Left Ventricular Unloading During Veno-Arterial ECMO: A Simulation Study

Dirk W. Donker,* Daniel Brodie,† José P. S. Henriques,‡ and Michael Broomé§¶‖

- Adulte de 70kg
- IC congestive
  - V^3_{sg} 5600 ml ➔ 6400 ml
- Défaillance VG systolique
  - Index Card 3,9 ➔ 1,7 l/mn/m²
  - Poap 30 mmHg
- ECMO
  - Cannulation fémoro-fémorale
  - Q_{ecmo} 0➔4 l/mn



Individualized real-time clinical decision support to monitor cardiac loading during venoarterial ECMO

Michael Broomé[1,2,3*] and Dirk W. Donker[4]

Broomé and Donker *J Transl Med* (2016) 14:4

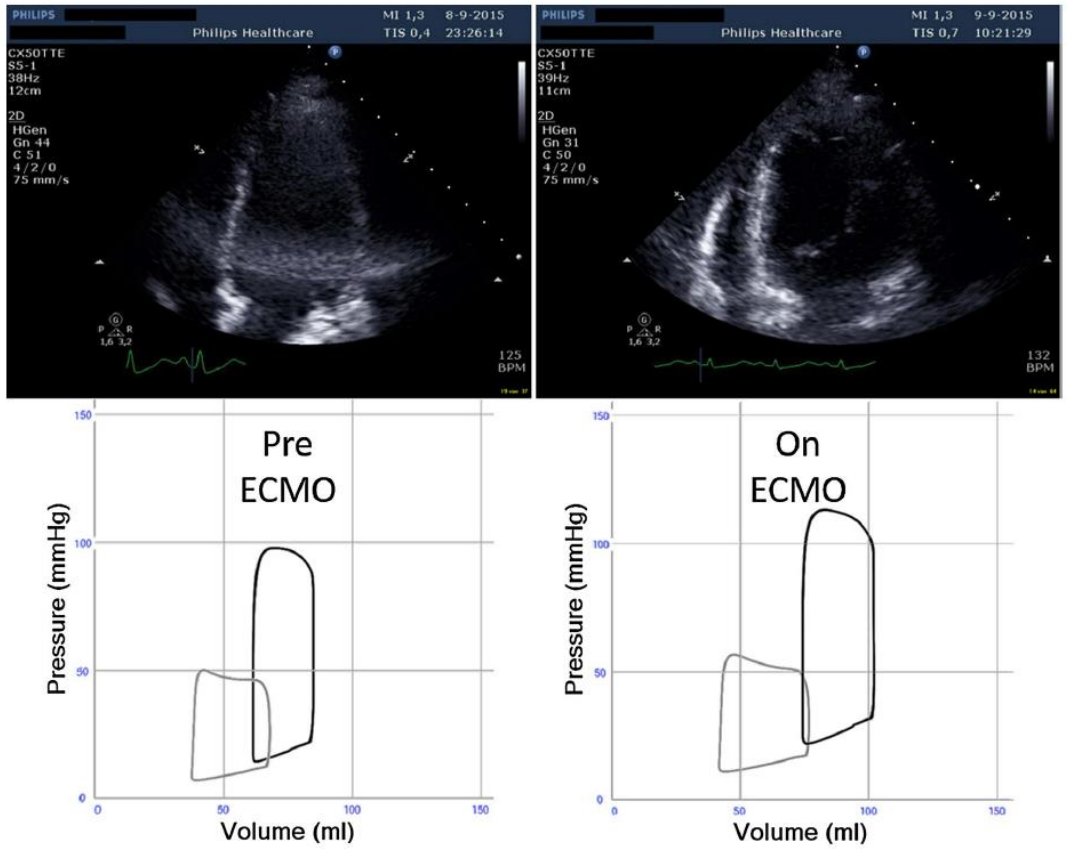
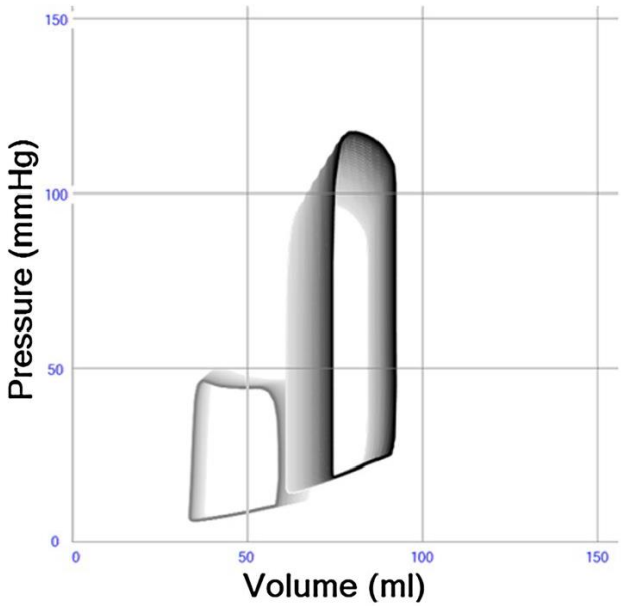


Fig. 2 Comparison of end-diastolic transthoracic echocardiograms in upper panel shows dilatation of the left ventricle after initiation of VA ECMO (*right*) as compared to baseline before initiation of VA ECMO (*left*). The lower panel shows simulated left (*black*) and right (*gray*) ventricular pressure–volume loops before (*left lower*) and after adjustment of heart rate, systemic vascular resistance and absence of tricuspid regurgitation (*right lower*) in accordance with available clinical data



ECMO induced LV loading

Fig. 3 Effects of simulated increase of VA-ECMO from 0 to 2.1 L/min left (*black*) and right (*gray*) ventricular pressure–volume loops. All other model parameters such as cardiac contractility, intravascular blood volume, systemic and pulmonary vascular resistance are unchanged. The results indicate an increase in left ventricular loading, that is represented by movement of loops upward (higher pressures) and rightward (higher volumes)

Left Ventricular Unloading During Veno-Arterial ECMO: A Simulation Study

Dirk W. Donker,* Daniel Brodie,† José P. S. Henriques,‡ and Michael Broomé§¶‖

↘ Postcharge

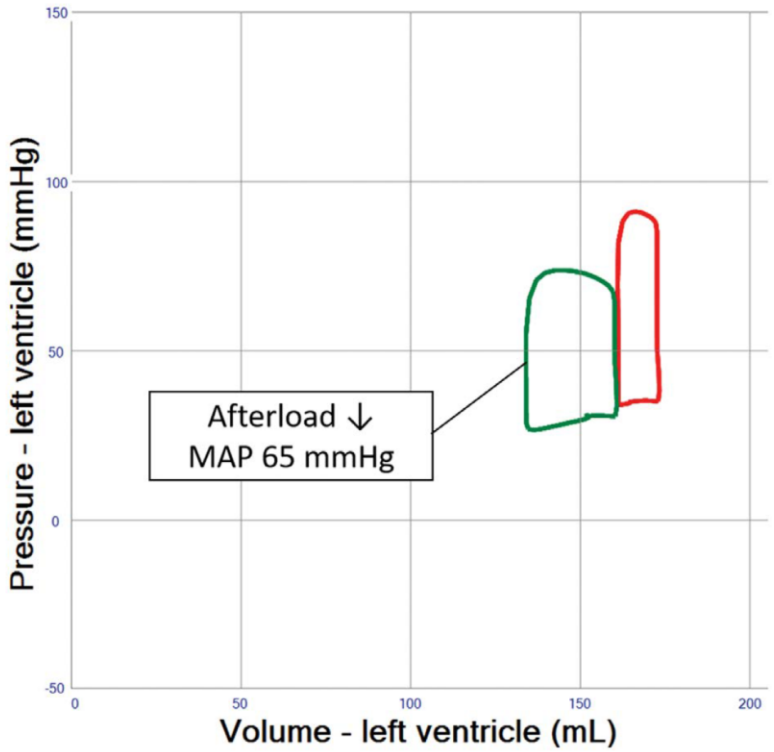


Figure 2. Pressure–volume loop analysis representing the effects of afterload reduction in left ventricular systolic failure supported by veno-arterial extracorporeal membrane oxygenation (VA ECMO) 4 L/min. Afterload (systemic vascular resistance) is reduced until systemic mean arterial blood pressure (MAP) reaches 65 mm Hg, an accepted target in clinical care for patients with cardiogenic shock providing a reasonable compromise between low afterload, systemic and coronary perfusion pressure.

↘ Postcharge + Inotropes

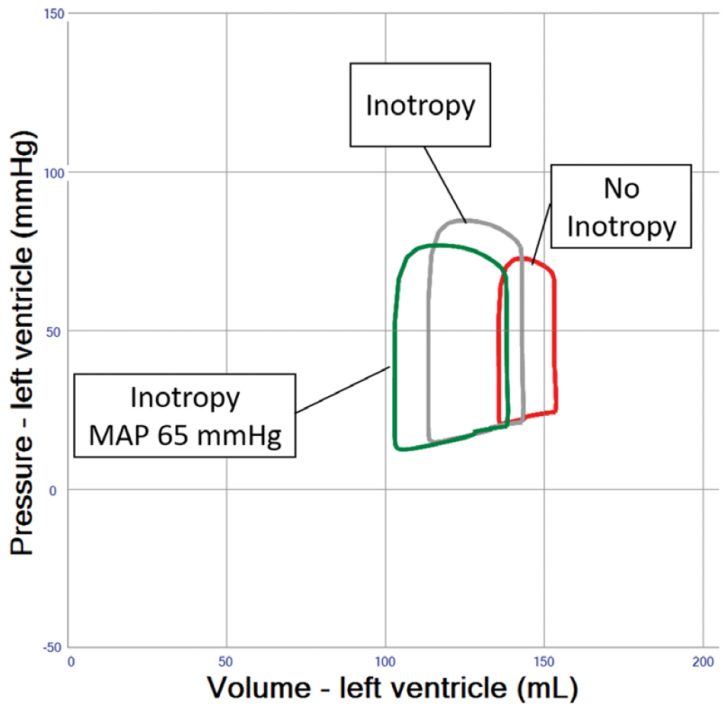


Figure 4. Pressure–volume loop analysis of inotropic drug effects in left ventricular failure and veno-arterial extracorporeal membrane oxygenation (VA ECMO) 4 L/min. Inotropy only (gray loop) reduces end-diastolic volume and increases stroke volume as well as systemic mean arterial blood pressure (MAP) as compared with no inotropy (red loop). Systemic vascular resistance is finally readjusted down to an MAP of 65 mm Hg, providing further unloading (green loop).

Left Ventricular Unloading During Veno-Arterial ECMO: A Simulation Study

Dirk W. Donker,* Daniel Brodie,† José P. S. Henriques,‡ and Michael Broomé§¶‖

Atrio-septostomie

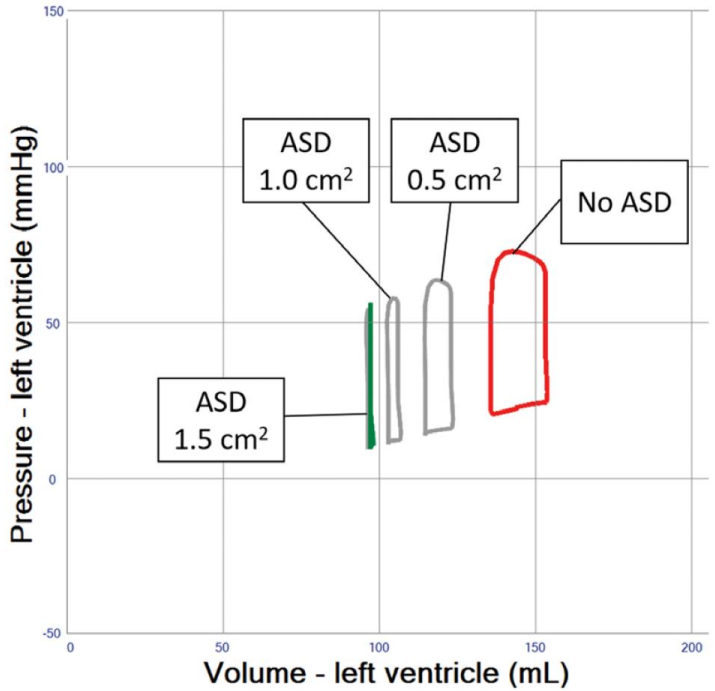


Figure 7. Pressure–volume loop analysis of atrial septostomy in left ventricular (LV) systolic failure and veno-arterial extracorporeal membrane oxygenation (VA ECMO) 4 L/min. The LV is efficiently unloaded with atrial septal defect (ASD) sizes of 0.5, 1, and 1.5 cm². A nonejecting LV is created with the largest defect.

Impella

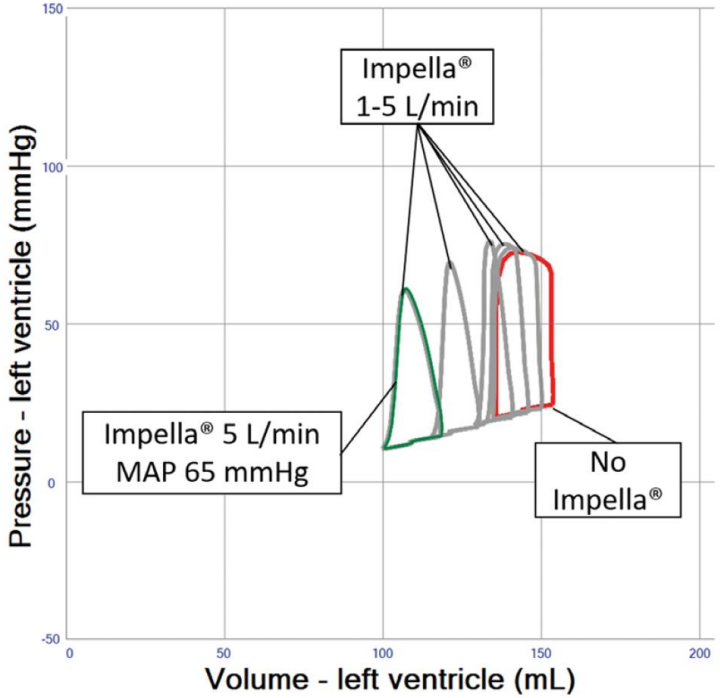


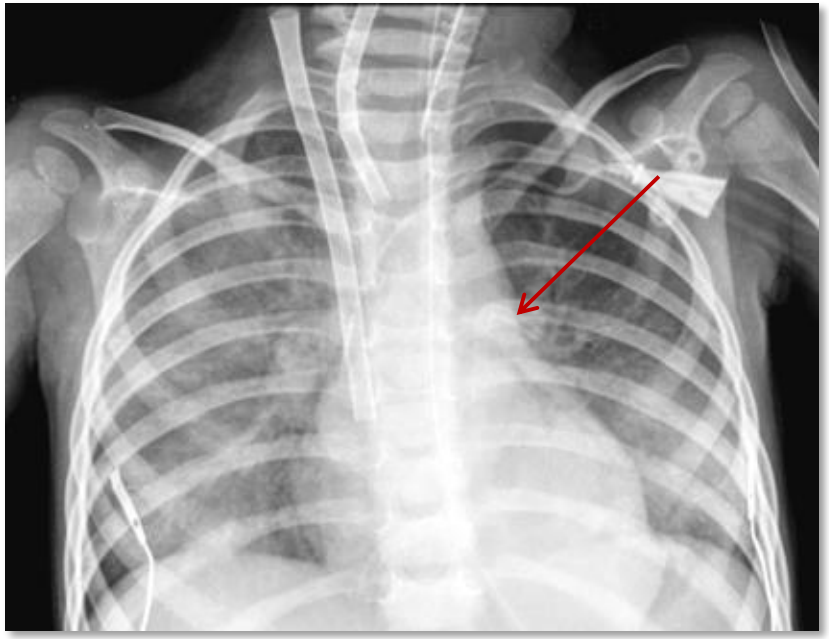
Figure 6. Pressure–volume loop analysis of Impella effects in left ventricular systolic failure and veno-arterial extracorporeal membrane oxygenation (VA ECMO) 4 L/min. Device flows of 1–5 L/min are shown in gray loops. Systemic vascular resistance is finally readjusted down to systemic mean arterial blood pressure (MAP) 65 mm Hg, resulting in further unloading as indicated in the green loop.

La décharge gauche

- L'un des objectifs de l'ECMO, peut être le principal, est de promouvoir la récupération myocardique.
  - En maintenant une perfusion et une oxygénation coronarienne efficace…
  - …et des pressions télédiatoliques ventriculaires basses.
- En cas de dysfonction ventriculaire gauche très sévère, la décharge ventriculaire peut être insuffisante.
- Une tentation est d'augmenter le débit d'ECMO.
  - Mais augmentation de la postcharge ventriculaire et de la perfusion vasculaire bronchique et majoration de la surcharge ventriculaire.
  - Ischémie myocardique; thrombose intraVG; Œdème pulmonaire hémorragique.

La décharge gauche

- FOP.
- CIA.
- Atrio-septostomie percutanée.
- « Vent » dans l'OG.
- « Vent » dans l'artère pulmonaire.



Left Anterior Descending Coronary Artery Blood Flow and Left Ventricular Unloading During Extracorporeal Membrane Oxygenation Support in a Swine Model of Acute Cardiogenic Shock

Artif Organs, Vol. 39, No. 2, 2015

- Modèle porcin (n=7;65-73 kg)
- Mesure du débit coronaire gauche par technique doppler
- ECMO V-A fémoro-fémorale
- Choc cardiogénique induit par esmolol 2mg/kg dans l'oreillette gauche, puis 500mg/kg/mn

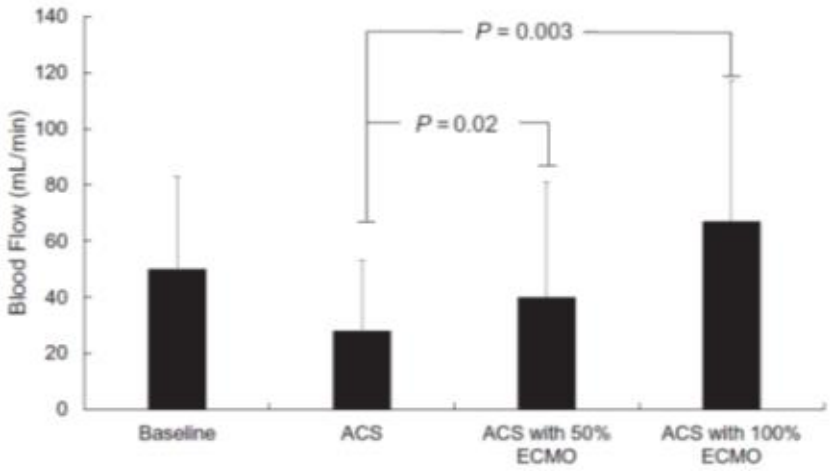


FIG. 2. LAD coronary artery blood flow (mL/min): at baseline conditions, with induction of acute cardiogenic shock (ACS), and with 50 and 100% ECMO support.

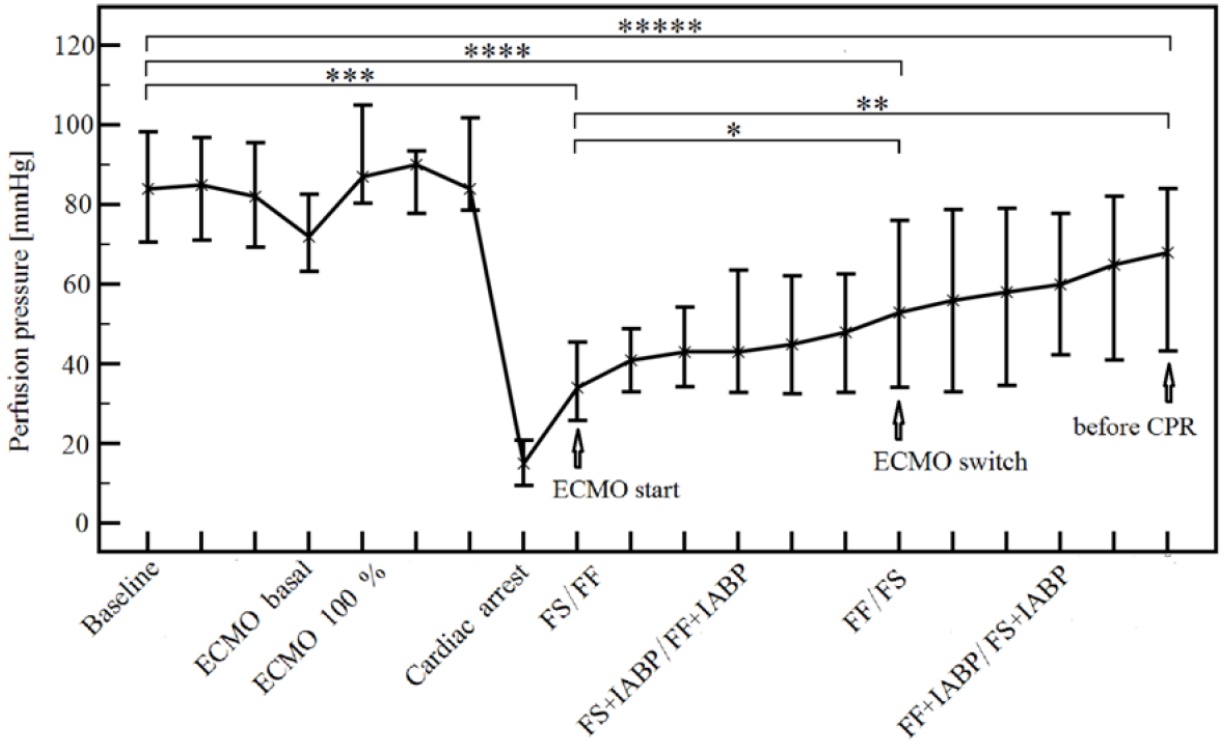
Condition 1	Baseline, normal heart in sinus rhythm
Condition 2	Induced acute cardiogenic shock without ECMO support in sinus rhythm
Condition 3	Induced cardiogenic shock with 50% ECMO support in sinus rhythm
Condition 4	Induced cardiogenic shock with 100% ECMO support

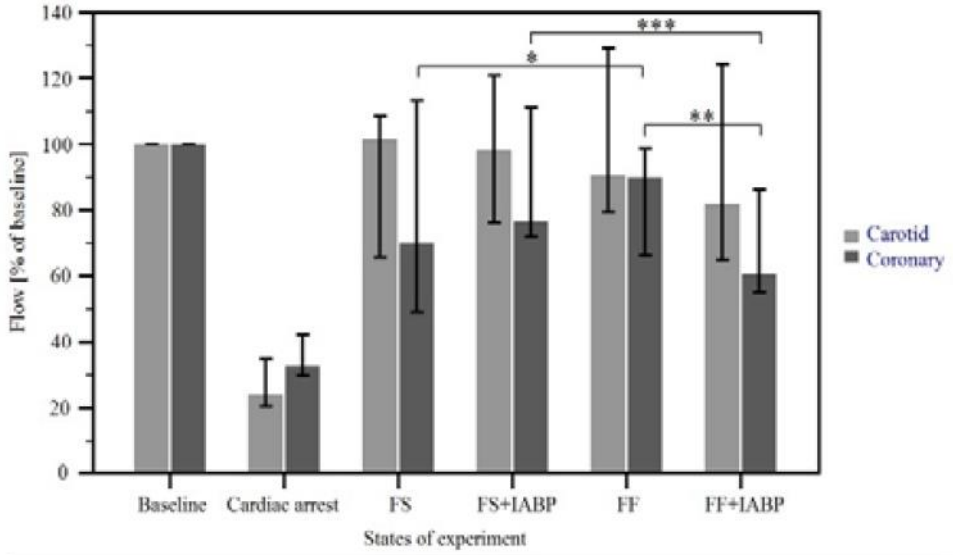
Coronary versus carotid blood flow and coronary perfusion pressure in a pig model of prolonged cardiac arrest treated by different modes of venoarterial ECMO and intraaortic balloon counterpulsation

Bělohlávek *et al. Critical Care* 2012, **16**:R50

L'ECMO permet le restauration d'une pression de perfusion coronaire, mais à un niveau < aux conditions de base.

En terme de débit coronarien, l'ECMO fémoro-fémorale, dans ce modèle est plus performante





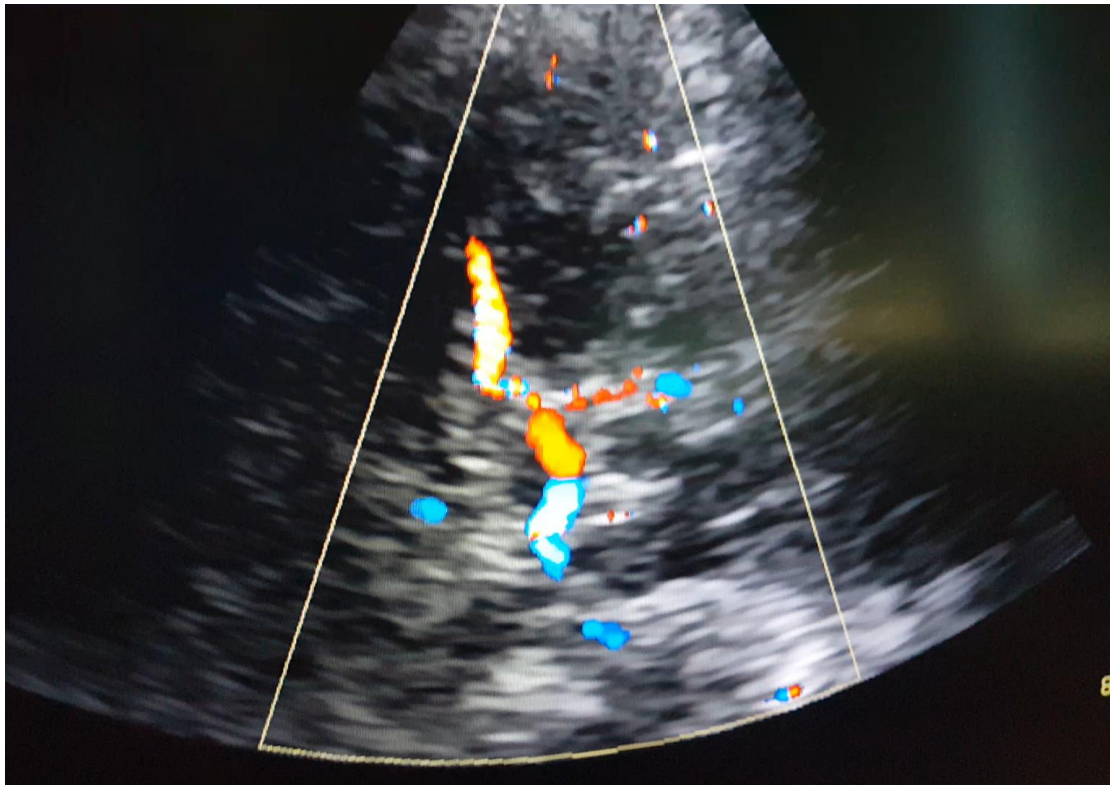
	P-values			
N = 11	FS vs. FF	FS vs. FS+IABP	FF vs. FF+IABP	FS+IABP vs. FF+IABP
Flow Velocity				
Carotid	0.095	0.87	0.16	0.87
Coronary	**0.039***	0.16	**0.004****	**0.026****

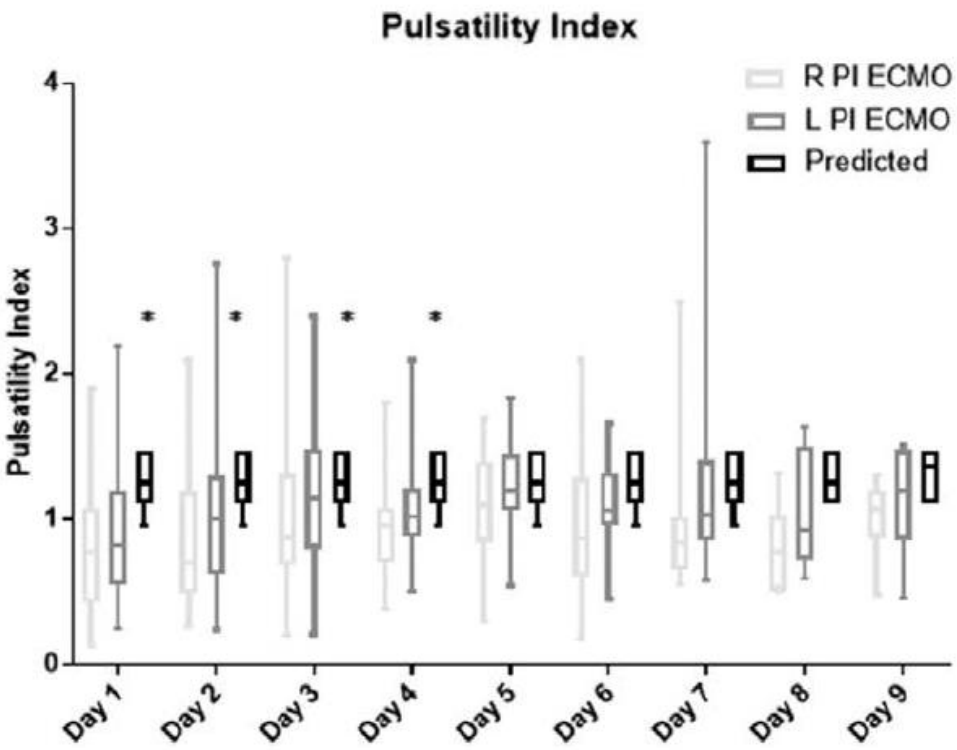
Perfusion Coronaire

- Objectif important si on espère un sevrage de l'ECMO
- Pression de perfusion « adéquate »
- Diminution des pressions intraventriculaire (décharge gauche)
- Dés qu'il existe une pulsatilité, s'assurer des performances du poumon natif de l'enfant.
- En cas de pulsatilité, le flux coronarien majoritaire est issu du ventricule gauche, et non pas de l'assistance.

Cerebrovascular Physiology During Pediatric Extracorporeal Membrane Oxygenation: A Multicenter Study Using Transcranial Doppler Ultrasonography*

February 2019 • Volume 20 • Number 2





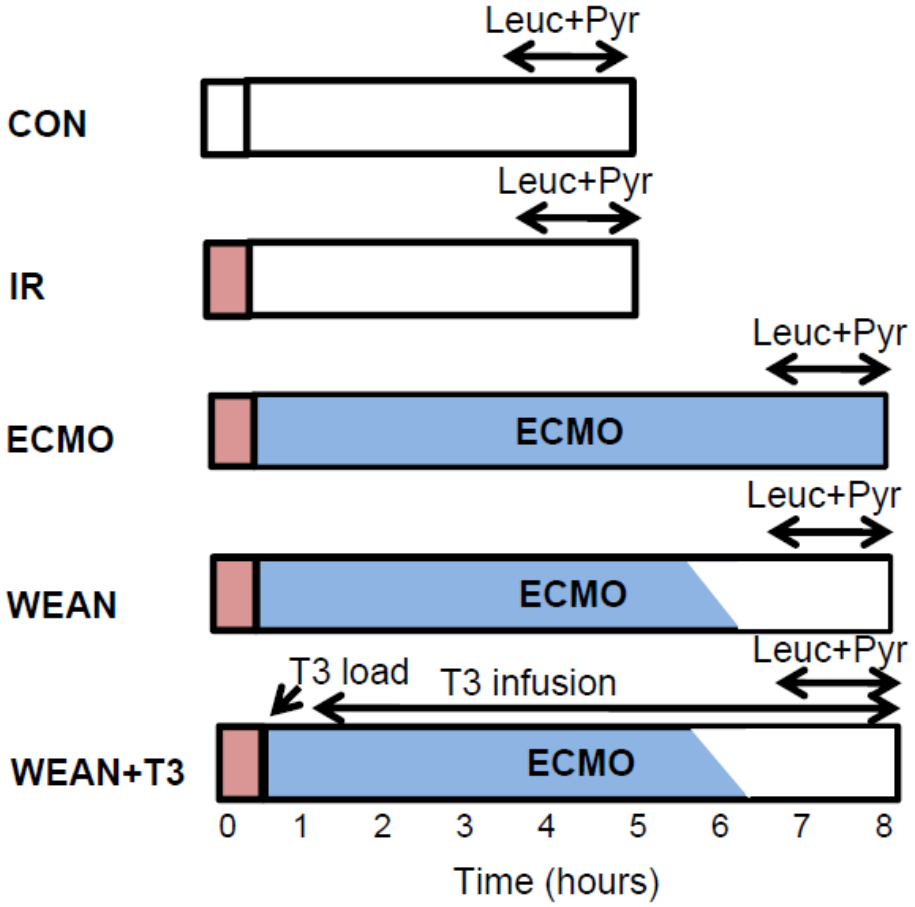
Triiodothyronine Facilitates Weaning From Extracorporeal Membrane Oxygenation by Improved Mitochondrial Substrate Utilization

Matthew D. Files, MD; Masaki Kajimoto, MD, PhD; Colleen M. O'Kelly Priddy, MD; Dolena R. Ledee, PhD; Chun Xu, PhD; Christine Des Rosiers, PhD; Nancy Isern, MS; Michael A. Portman, MD

- 36 porcelets (12-16,7kg).
- Ischémie-reperfusion myocardique par occlusion coronaire (≈Cor. Gche en aval de la 1ère diagonale) de la pendant 10 mn.
- ECMO V-A, centrale
- Perfusion intra-coronaire de Pyruvate et de

L-leucine marquée

- Analyse apex VG (marqueurs;RMN)
- 5 groupes d'étude



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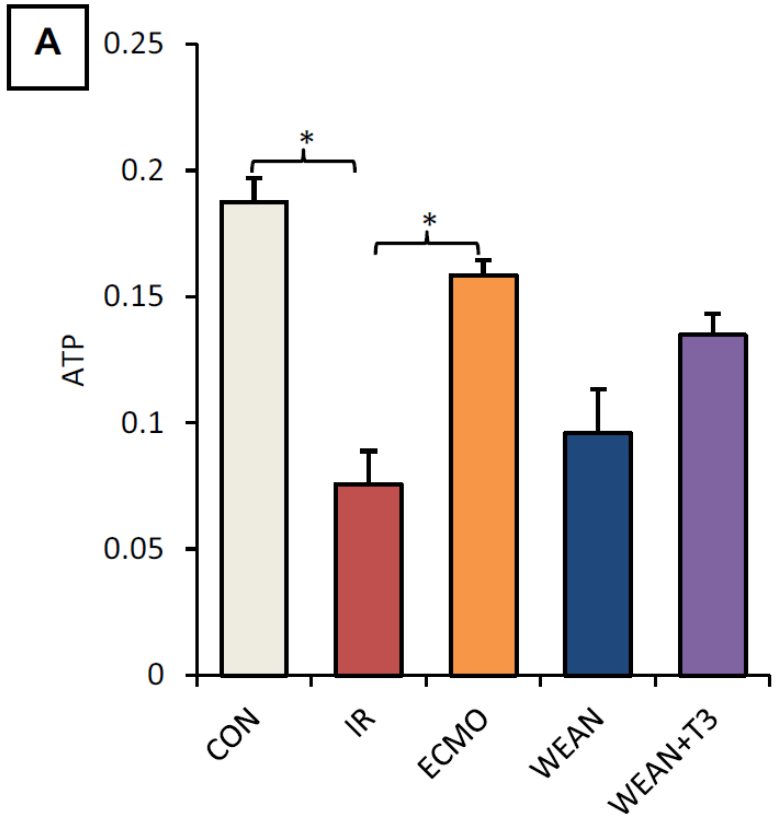
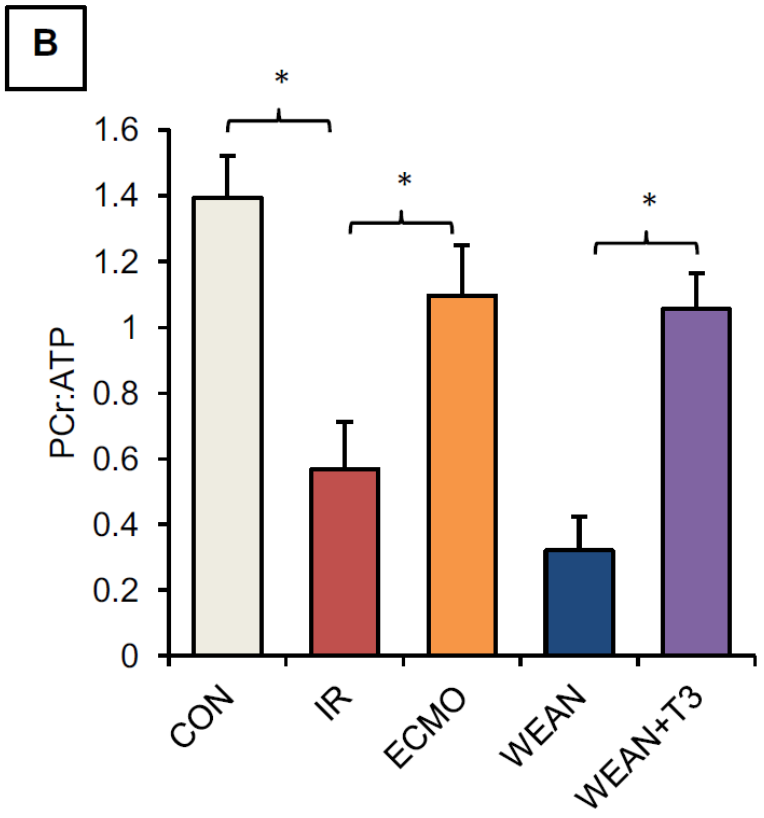
- L'ischémie réduit la [ATP]
- L'ECMO permet l'↗ de la [ATP]

L'ECMO restaure la capacité de phosphorylation du myocyte ischémique.





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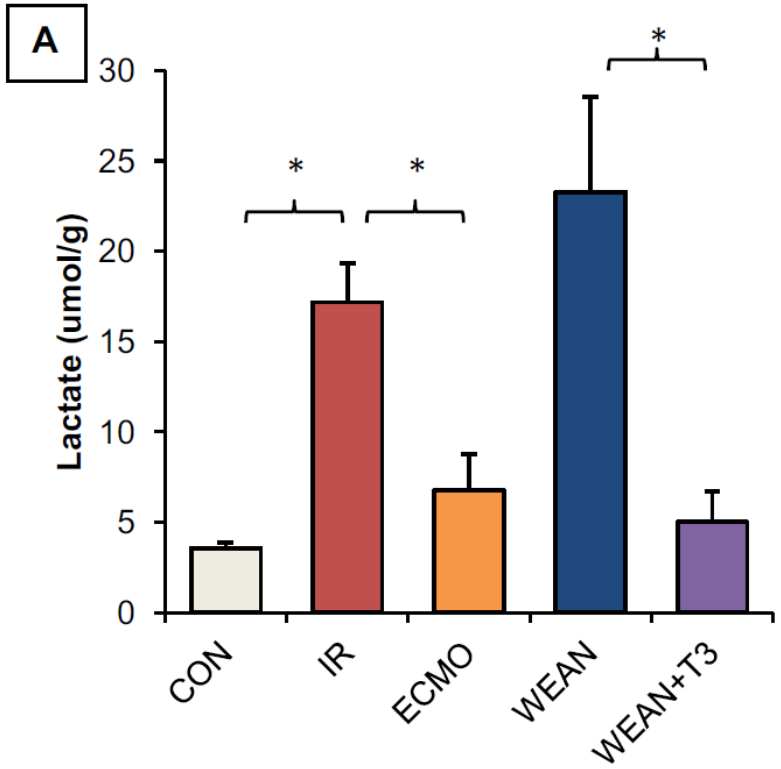
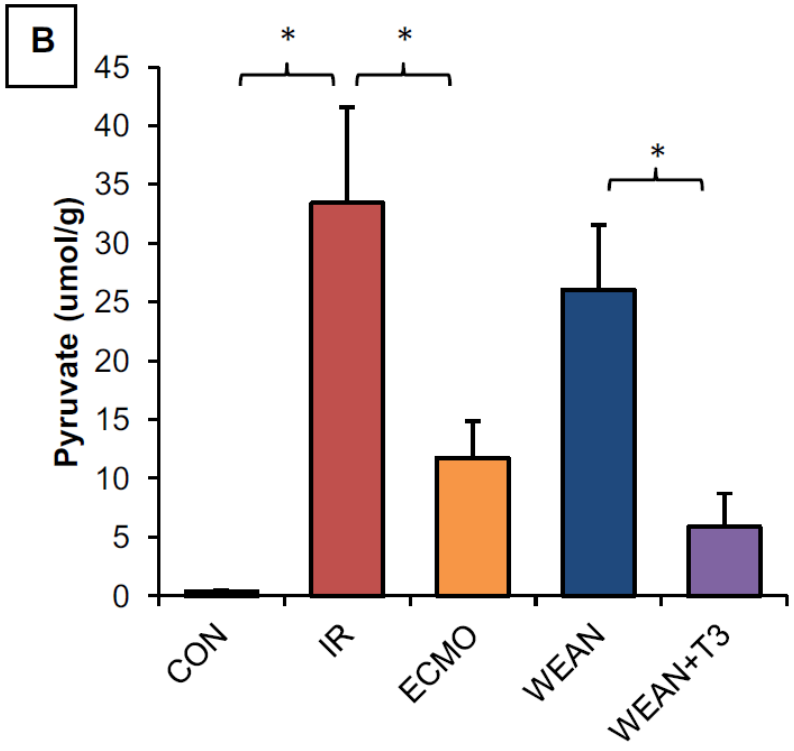
- **L'ECMO est associé à une ↘ [Lactates]**

- **L'ECMO est associé à une ↘ [Pyruvates]**





ECMO et conséquences

ECMO post-cardiotomie
Plusieurs situations

- Indication anticipée.
- Dysfonction ventriculaire post CEC avec sevrage de la CEC impossible ou déraisonnable.
  - Réparation techniquement bonne – problème de protection myocardique.
  - Geste chirurgical non adapté – lésions résiduelles – iatrogénie.
- SDRÄ postopératoire avec hypoxémie réfractaire.
- …et lorsque que la situation échappe à l’analyse.

La CEC n’est pas « sevrable »…

- S’assurer que la tentative de sevrage c’est faite dans de bonnes conditions.
  - Volémie
  - Soutien aminergique efficace et adapté.
  - Hémoglobine – PH - Ca2+ - T°.
- Essayer de trouver une explication à cette situation…
- …avec une règle d’or: **ne pas laisser de lésions résiduelles**.
  - Echo épicardique – ETO.
  - Cathétérisme si vous avez la chance d’avoir une salle hybride.

Residual lesions in postoperative pediatric cardiac surgery patients receiving extracorporeal membrane oxygenation support

Hemant S. Agarwal

J Thorac Cardiovasc Surg 2014;147:434-41

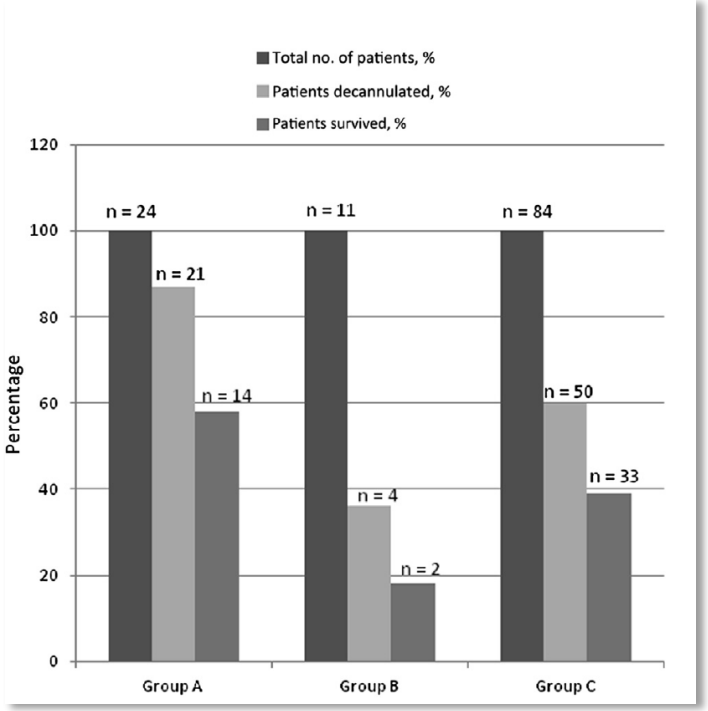


FIGURE 1. Outcome of postoperative pediatric cardiac surgery patients placed on extracorporeal membrane oxygenation (ECMO). In group A, early detection (≤3 days of ECMO duration) of residual lesions in postoperative pediatric cardiac surgery patients placed on ECMO is noted. In group B, late detection (>3 days of ECMO duration) of residual lesions in postoperative pediatric cardiac surgery patients placed on ECMO is noted. Patients not suspected of having residual lesions are indicated in group C.

Results: Residual lesions were evaluated in 43 of 119 postoperative patients placed on ECMO support. Lesions were detected in 35 patients (28%), predominantly in branch pulmonary arteries (n = 10), shunts (n = 7), and ventricular outflow tracts (n = 9). Echocardiography detected 7 residual lesions (20%) and cardiac catheterization detected 28 residual lesions (80%). Earlier detection of residual lesions during the first 3 days of ECMO support in 24 patients improved their rate of decannulation significantly ($P = .004$) and survival to hospital discharge ($P = .035$), compared with later detection (after 3 days of ECMO support) in 11 patients.

Intervention undertaken	n
Cardiac catheterization technique	
Early detection (≤3 d of ECMO duration)	
Sano shunt dilation	1
Balloon angioplasty of branch pulmonary arteries	1
Balloon septostomy of atrial septal defect	1
Angiojet and thrombolysis of clot in distal Blalock-Taussig shunt and descending aorta	1
Late detection (>3 d of ECMO duration)	
Stent placement in branch pulmonary artery	2
Balloon dilation of atrial septal defect	1
Surgical intervention*	
Early detection (≤3 d of ECMO duration)	
Sano/Blalock-Taussig shunt revision	4
Aortic arch revision	3
Branch pulmonary artery plasty	2
Right ventricular outflow tract/conduit revision	1
Ventricular septal defect revision	1
Patent ductus arteriosus ligation	1
Late detection (>3 d of ECMO duration)	
Branch pulmonary artery plasty	3
Blalock-Taussig shunt addition/revision	3
Right ventricular outflow tract/conduit revision	2
Atrioventricular valve repair	2
Pulmonary vein stenosis repair	1
Aortopulmonary collateral ligation	1

ECMO, Extracorporeal membrane oxygenation. *More than 1 intervention may have been performed per patient studied.

Idéalement sevrer la CEC avant la mise en place de l'ECMO…

- Profiter de la CEC pour optimiser les conditions de charge.
- L'obtention de l'hémostase est un sujet cruciale:
  - ➢ Hémostase chirurgicale: prolène – colle biologique – pansement hémostatique.
  - ➢ Hémostase biologique: Fondamentale pour créer les conditions du succès –
    - PH / T° / Hb / C2+ -
    - Etude de l'hémostase au laboratoire – Point Of Care – PVI /CUP/ Cplx Prothrombinique/Fibrinogène/$fVII_a$

Excessive Postoperative Bleeding and Outcomes in Neonates Undergoing Cardiopulmonary Bypass

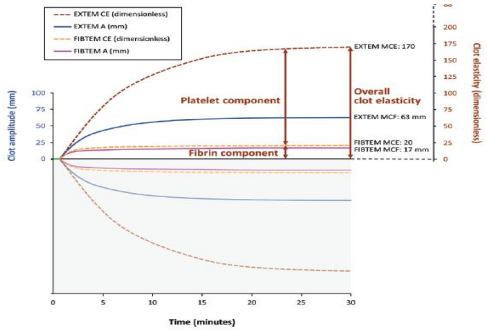
Anesth Analg 2014 Nina A. Guzzetta,

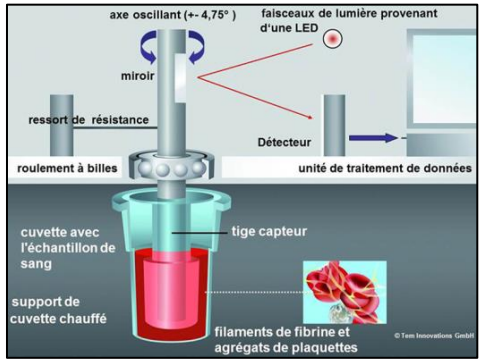
Table 6. Outcome Data Based on Bleeding Quartile and Adjusted Relative Risk

	CTO ≤75% (*n* = 124)	CTO >75% (*n* = 42)			
	Total (%)	Total (%)	RR[a]	95% CI	*P*
Renal dysfunction[b]	21 (17)	11 (26)	1.18	0.54–2.18	0.64
Dialysis	1 (1)	6 (14)	12.0	1.50–54.69	0.02
Thrombosis	9 (7)	4 (10)	0.82	0.17–2.87	0.78
ECMO	3 (2)	11 (26)	9.95	3.07–28.47	0.0008
In-hospital mortality	6 (5)	8 (19)	3.01	0.99–7.70	0.052

Thromboelastometry-guided intraoperative haemostatic management reduces bleeding and red cell transfusion after paediatric cardiac surgery

British Journal of Anaesthesia. 1 janv 2015;114(1):91-102.





Idéalement sevrer la CEC avant la mise en place de l'ECMO…

- Préparation du circuit d'ECMO.
- Installation des nouvelles canules éventuellement.
- Une fois les condition de pose de la CEC réunies:
  - Antagonisation complète de l'Héparine.
  - Support hémodynamique maximal
  - Hémostase chirurgicale.
  - Hémostase médicale et compensation des pertes.
  - PA limite inférieure de la normale.
- Débuter l'ECMO le plus tardivement possible, sur indication hémodynamique, pour permettre l'hémostase.
- Intérêt des circuits et des canules avec traitement de surface pour retarder ou diminuer la dose d'héparine initiale?

Réunir les conditions de récupération myocardique Préservation de la perfusion viscérale.

- Pressions télédiastolique intraventriculaire normale-basse.
  - Décharge gauche.
  - FOP.
  - Inotropes à doses raisonnables.
- Promouvoir la perfusion coronaire et l'oxygénation coronaire
  - Pression diastolique.
  - FiO2 sur le ventilateur.
- Essayer de maintenir / de rétablir une pulsatilité.
  - Facteur de longévité de l'assistance.
  - Meilleurs perfusion d'organe?

ECMO à distance de la chirurgie
Ce qu'on ma enseigné…et que j'ai pu vérifier

copyrights Pr Eduardo Da Cruz

A Faire	A ne pas Faire
• Travailler en équipe (Cardio-Réa-Chir).	Eviter les décisions solitaires.
• Utiliser une monitorage fiable de l'oxygénation tissulaire (SvO_2; Sv_cO_2; NIRS).	Etre trompé par une stabilité relative uniquement lié aux mécanismes d'adaptation physiologique.
• Suivre le principe de simplicité est souvent préférable à une solution complexe et hasardeuse.	Soumettre le cœur et les autres organes à des choix thérapeutiques délétères.
• Soigner le patient, pas l'echocardiographie.	Epuiser pharmacologiquement le cœur.
• Ne pas penser qu'au cœur. Penser aux autres organes.	Pousser le patient jusqu'à ses limites.
• Promouvoir l'anabolisme (c'est pas facile)	Accepter des objectifs et des résultats intermédiaires.
• Etre pro-actif: Poser l'indication de l'ECMO sur les tendances et non sur les évènements.	Accepter les défaillances d'organes.
• Information et soutien des familles.	Accepter l'hypothèse d'un arrêt cardiaque.
• Penser aux soins de réhabilitation dés le début	

Impact of Timing of ECMO Initiation on Outcomes After Pediatric Heart Surgery: A Multi-Institutional Analysis

Punkaj Gupta[1,2] Pediatr Cardiol (2016) 37:971–978

- 2908 patients – 42 hôpitaux US.
  - ECMO le jour de la chir-n=1738.
  - ECMO J ≥1 – n=1170.
  - ECMO J ≥2 (75th %) – n= 695.
  - ECMO J ≥11 (90th %) – n=304.
- 45% de décès.
- 18% décèdent sous ECMO.
- Absence de corrélation entre le $J0_{ECMO}$-$J0_{Chir}$ et la mortalité.

- ***Corrélation avec la morbidité***

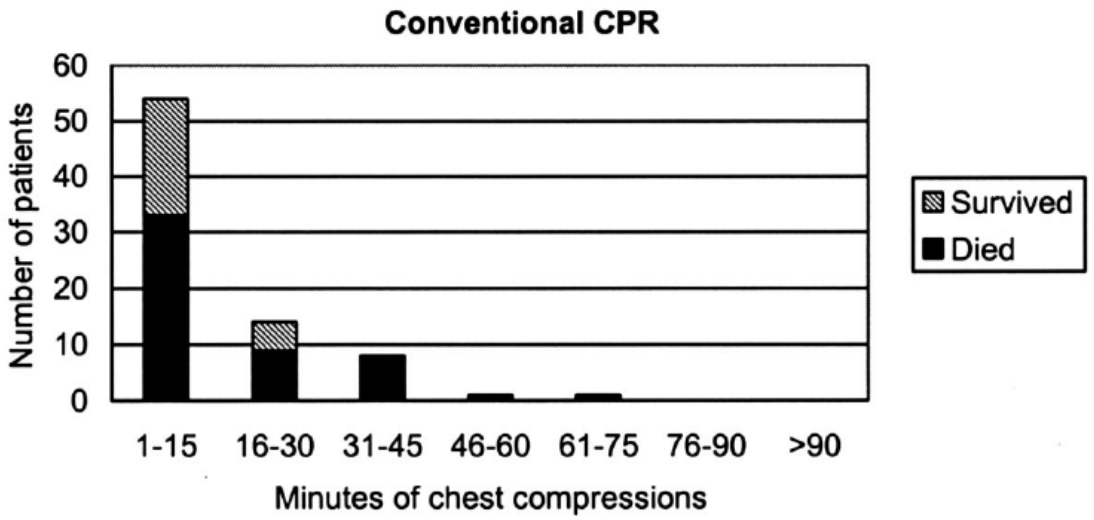
	Low-complexity operations		High-complexity operations	
	OR (95 % CI)	*P* value	OR (95 % CI)	*P* value
Composite poor outcome	1.01 (0.97–1.05)	0.69	1.02 (1.00–1.04)	0.02
Mortality	0.99 (0.97–1.00)	0.13	1.01 (1.00–1.02)	0.20
Prolonged length of ECMO	1.00 (0.99–1.00)	0.20	0.99 (0.97–1.00)	0.09
Prolonged length of ventilation	1.01 (1.00–1.02)	0.06	1.02 (1.00–1.03)	0.01
Prolonged length of ICU stay	1.03 (1.01–1.04)	<0.001	1.02 (1.00–1.04)	0.06
Prolonged length of hospital stay	1.03 (1.01–1.04)	<0.001	1.03 (1.02–1.05)	<0.001

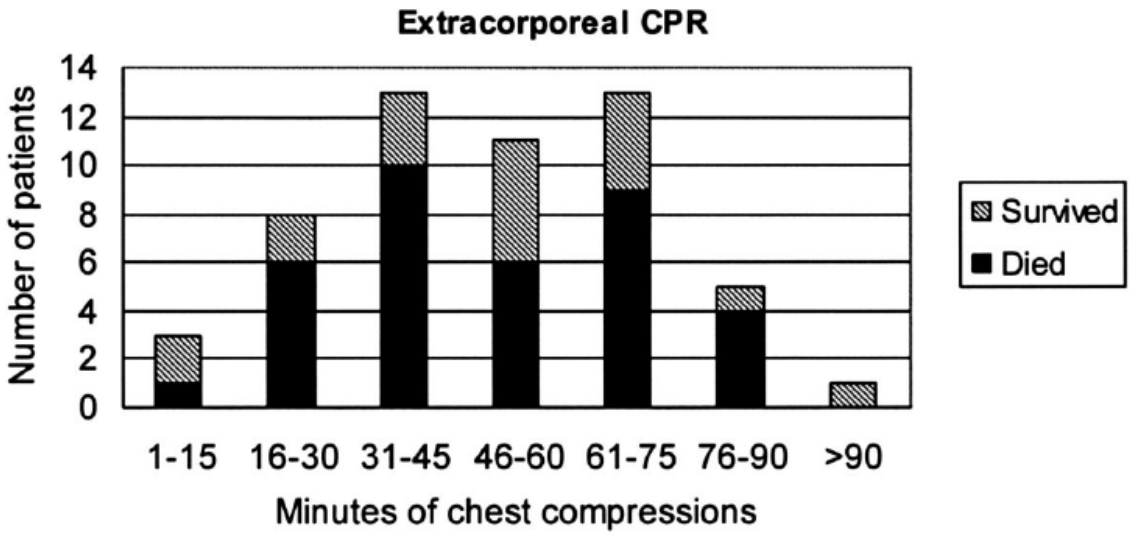
Low-complexity operations: RACHS-I categories 1, 2, and 3; high-complexity operations: RACHS-I categories 4, 5, and 6

CI confidence interval; *OR* odds ratio; *ECMO* extracorporeal membrane oxygenation; *ICU* intensive care unit

Survival outcomes after extracorporeal cardiopulmonary resuscitation instituted during active chest compressions following refractory in-hospital pediatric cardiac arrest*

Marilyn C. Morris, MD; Gil Wernovsky, MD; Vinay M. Nadkarni, MD, FAAP, FCCM





Extracorporeal Cardiopulmonary Resuscitation (E-CPR) During Pediatric In-Hospital Cardiopulmonary Arrest Is Associated With Improved Survival to Discharge

Circulation
2016;133:165-176;
Javier J. Lasa.

	All Patients (n=3756), n (%)		Propensity-Matched Patients (n=2178), n (%)		
	C-CPR (n=3165)	E-CPR (n=591)	C-CPR (n=1673)	E-CPR (n=505)	*P* Value
Age groups					
0–1 mo	667 (21)	123 (21)	320 (19)	91 (18)	0.002
1 mo–1 y	1688 (53)	331 (56)	914 (55)	297 (59)	
1–8 y	788 (25)	126 (21)	434 (26)	109 (22)	
>8 y	22 (<1)	11 (2)	5 (<1)	8 (2)	
Missing	0 (0)	0 (0)	0 (0)	0 (0)	
Illness category					
Medical, cardiac	491 (16)	119 (20)	325 (19)	106 (21)	<0.0001
Medical, noncardiac	1258 (40)	86 (15)	589 (35)	83 (16)	
Surgical, cardiac	628 (20)	349 (59)	496 (30)	282 (56)	
Surgical, noncardiac	282 (9)	18 (3)	114 (7)	16 (3)	
Newborn	506 (16)	19 (3)	149 (9)	18 (4)	
Missing	0 (0)	0 (0)	0 (0)	0 (0)	

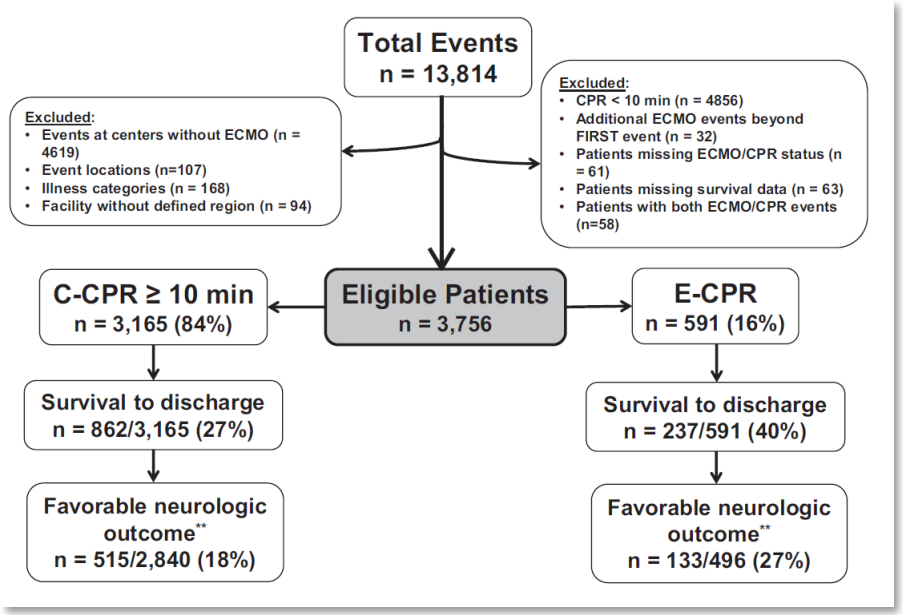


Table 4. Mode of CPR and Survival to Discharge and Favorable Neurological Outcome: Results From Subclassification on the Propensity Score

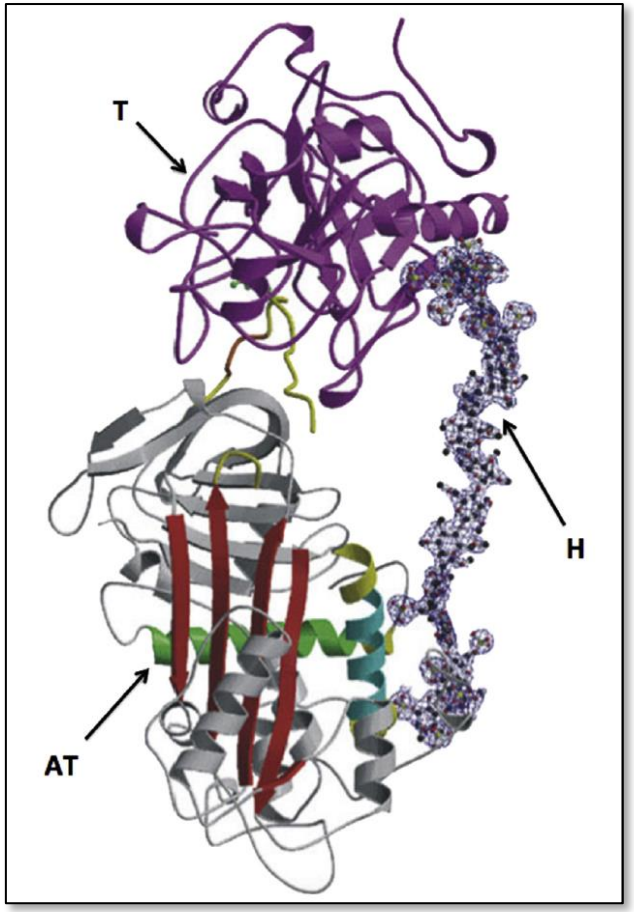
	Survival to Discharge (n=2178)					Favorable Neurological Outcome (n=1952)				
E-CPR/C-CPR	No (n=1539), n (%)	Yes (n=639), n (%)	OR	95% CI	*P* Value	No (n=1558), n (%)	Yes (n=394), n (%)	OR	95% CI	*P* Value
C-CPR	1233 (80)	440 (69)	1	…	…	1244 (80)	287 (73)	1	…	…
E-CPR	306 (20)	199 (31)	1.70	1.33–2.18	<0.0001	314 (20)	107 (27)	1.78	1.31–2.41	<0.001

CI indicates confidence interval; CPR, cardiopulmonary resuscitation; C-CPR, conventional cardiopulmonary resuscitation; E-CPR, extracorporeal cardiopulmonary resuscitation; and OR, odds ratio.

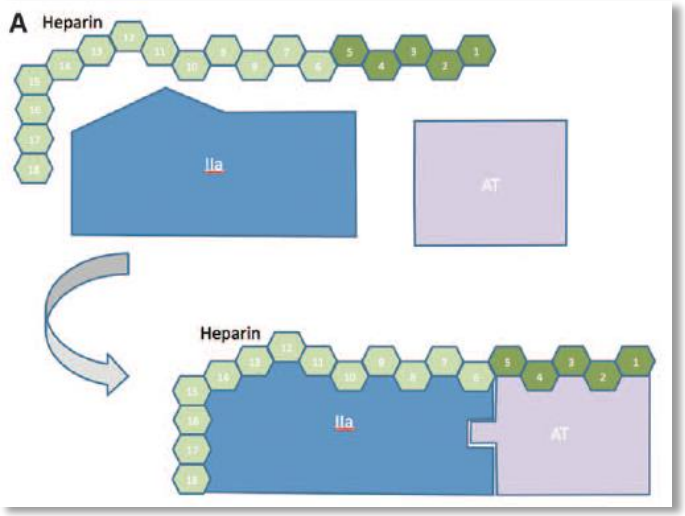
Un anticoagulant de référence

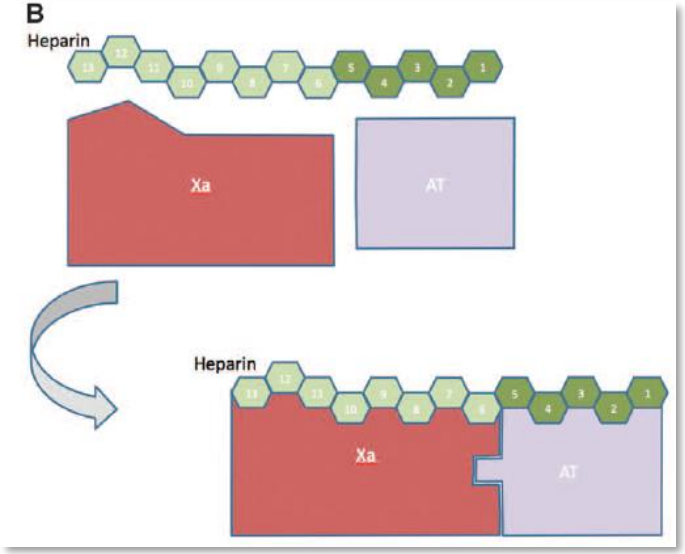
l'héparine…

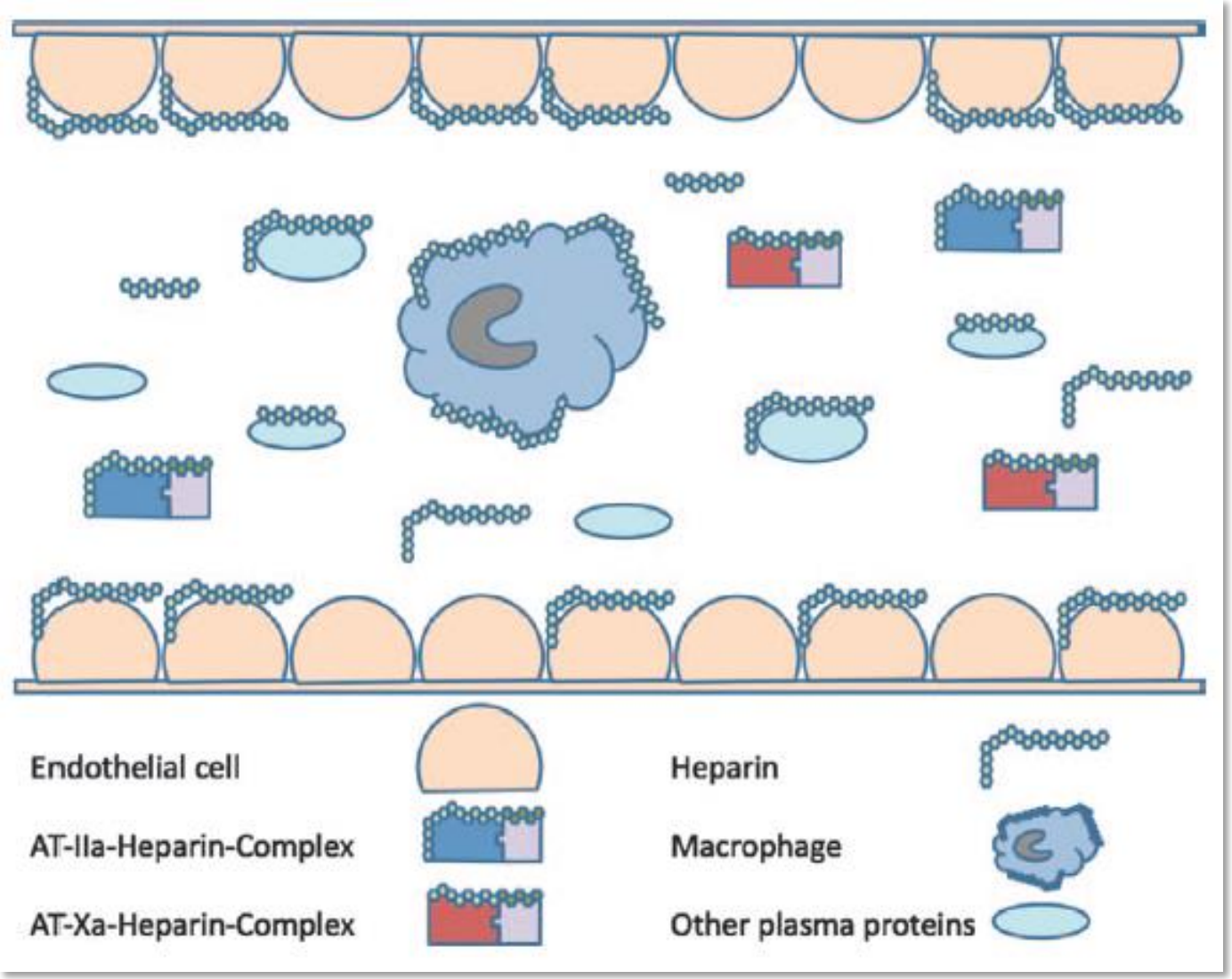
et son cofacteur, l'antithrombine



Un anticoagulant de référence: **l'héparine…**







Un double impératif!

Anticoaguler		**Prévenir les hémorragies graves**
• TCK=2-2,5x Témoin • 0,25 <Anti Xa< 0,4 • 180 < ACT< 250 • Antithrombine > 80%	ET ET	• Plqttes > 80-150 000 g/l • TP > 50% • Fibrinogène > 2g/l • Hb > 12 g/dl

Parler de l'anticoagulation dans le contexte de l'ECMO c'est…

- Poser le constat que nous ne sommes pas pleinement satisfaits de la conduite de l'anticoagulation au cours d'une ECMO.
- Poser le constat que nous ne disposons pas de l'anticoagulant idéal.
- Poser le constat que nous avons du mal à nous assurer de l'efficacité du traitement anticoagulant.
- Poser le constat que le bilan d'hémostase classique ne nous permet pas d'appréhender vraiment le statut hémostatique de nos patients.

Variability in anticoagulation management of patients on extracorporeal membrane oxygenation: an international survey

Melania M. Bembea

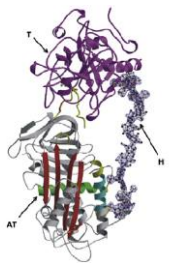
Pediatr Crit Care Med. 2013 February

- 121 centres / 187 qui sont affiliés à l'ELSO.
- 67% sont des centres pédiatriques.
- Tous les centres ont l'HNF comme anticoagulant en première intention.

What is the minimum UFH infusion rate allowed by your protocol? (n=115 respondents)	0 U/kg/h[a]	35 (30%)
	1–10 U/kg/h	62 (54%)
	11–25 U/kg/h	18 (16%)
	>25 U/kg/h	0
What is the maximum UFH infusion rate allowed by your protocol? (n=115 respondents)	No upper limit	83 (72%)
	50–75 U/kg/h	21 (18%)
	76–100 U/kg/h	8 (7%)
	101–125 U/kg/h[b]	3 (3%)
In the last six months, have you used non-UFH anticoagulation? (n=117 respondents)	Yes	10 (8%)
	No	107 (90%)
What non-UFH anticoagulation do/can you use in your ICU? (n=107 respondents)	Argatroban	48 (45%)
	Bivalirudin	10 (9%)
	Lepirudin	6 (6%)
	We never use any other pharmacologic anticoagulation besides UFH	50 (47%)
	Other	0

Antithrombin levels during pediatric cardiopulmonary bypass: Key to changing a decades-old paradigm for anticoagulation?

Dean B. Andropoulos, MD, MHCM,[a,b,c] and Charles D. Fraser, Jr, MD[b,d,e]



- « Cofacteur » de l'héparine.
- Une fois liée à l'héparine, les pouvoirs antithrombinique sont multiplié par 2000-4000.
- Antithrombine du nouveau né = 60% de l'activité observée chez un adulte.

Administration of Antithrombin Concentrate in Infants and Children on Extracorporeal Life Support Improves Anticoagulation Efficacy

ASAIOJ 2014

RYERSON *ET AL.*

- La perfusion d'antithrombine permet de diminuer les doses d'héparine et augmente le niveau d'antiXa.
- Absence d'effet adverse (notamment hémorragique).

Variability in anticoagulation management of patients on extracorporeal membrane oxygenation: an international survey

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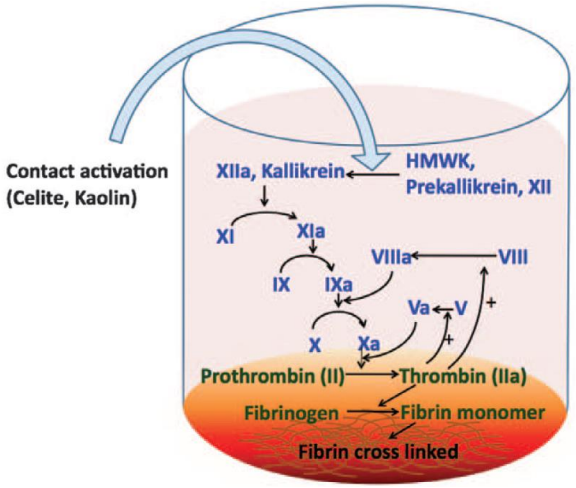
Pediatr Crit Care Med. 2013 February

ACT



ACT goal (sec) (n=116 respondents)	Minimum ACT goal, mean (SD)	183 (13), range 140–220
	Maximum ACT goal, mean (SD)	210 (15), range 170–240
	We do not follow ACT (n=3 respondents)	

Variability in anticoagulation management of patients on extracorporeal membrane oxygenation: an international survey

Melania M. Bembea

Pediatr Crit Care Med. 2013 February

Anti-factor Xa measurements (n=115 respondents)	Routinely	46 (40%)
	Occasionally	29 (25%)
	Never	40 (35%)
Anti-factor Xa monitoring frequency (n=66 respondents)	Every 1–8 h	15 (23%)
	Every 9–12 h	12 (18%)
	Every 13–24 h	27 (41%)
	Only as needed	12 (18%)

Anti-Factor Xa Assay Is a Superior Correlate of Heparin Dose Than Activated Partial Thromboplastin Time or Activated Clotting Time in Pediatric Extracorporeal Membrane Oxygenation*

Anna Liveris.

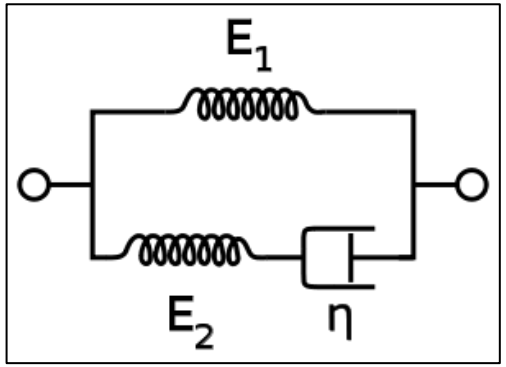
Pediatric Critical Care Medicine 2014

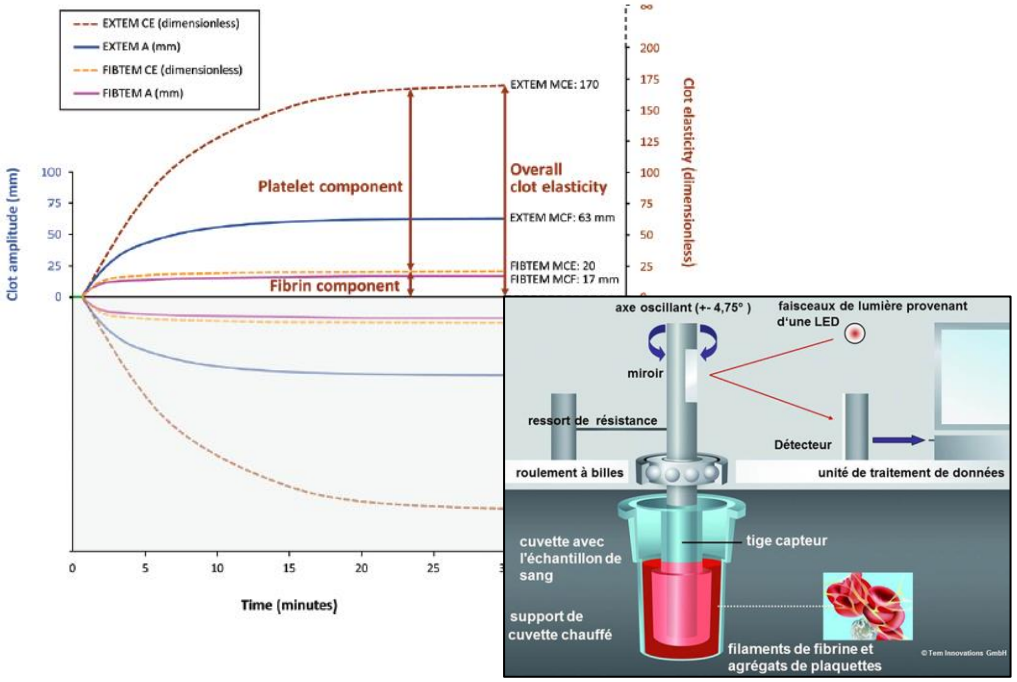
Variability in anticoagulation management of patients on extracorporeal membrane oxygenation: an international survey

Melania M. Bembea *Pediatr Crit Care Med.* 2013 February

TEG measurements (n=116 respondents)	Routinely	21 (18%)
	Occasionally	29 (25%)
	Never	66 (57%)

- Méthode viscoélastométrique de formation du caillot.
- Sur sang total.
- En situation de « no flow » (donc la plus thrombogène).





Prospective Observational Study of Hemostatic Alterations During Adult Extracorporeal Membrane Oxygenation (ECMO) Using Point-of-Care Thromboelastometry and Platelet Aggregometry

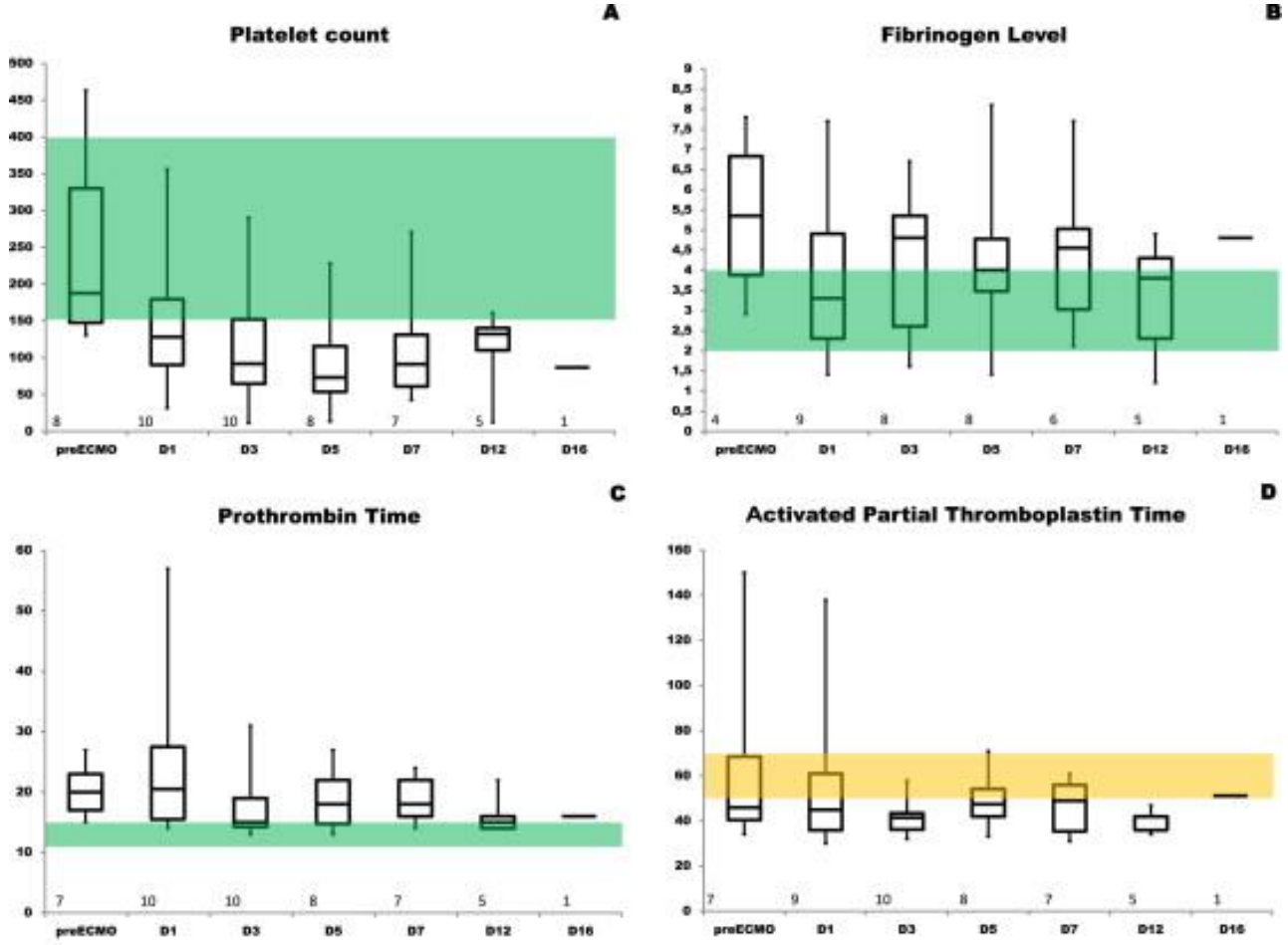
NAIR ET AL

Journal of Cardiothoracic and Vascular Anesthesia, Vol 29, No 2 (April), 2015: pp 288–296

- 10 ECMO adultes ➔ 110 jours ECMO.
- 7 ECMO VA / 3 ECMO VV.
- 6 survivants.

- Objectifs d'anticoagulation:
  - APTT 1,5 – 2 X Normal

- Etude observationnelle
  - Thromboélastométrie
  - Multiaggrégométrie



Prospective Observational Study of Hemostatic Alterations During Adult Extracorporeal Membrane Oxygenation (ECMO) Using Point-of-Care Thromboelastometry and Platelet Aggregometry

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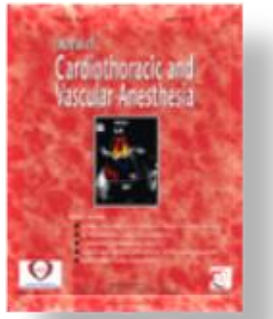
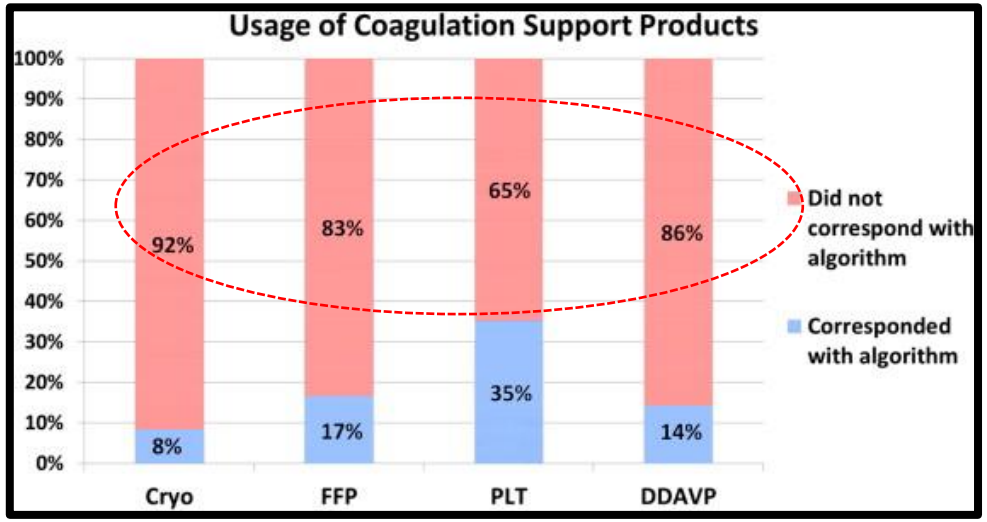


- Analyse des options thérapeutiques en réponse à une hémorragie portant sur la conduite de l'héparinothérapie et la transfusion de produits hémostatiques.
- Comparaison « fictive » avec un protocole validé guidé par le TEG.



Cette étude suggère que les réponses thérapeutiques à une hémorragie selon le protocole théorique thromboélastométrie ne correspond qu'assez rarement à la décision prise par le clinicien avec le protocole traditionnel.

Jeune Fille de16 ans

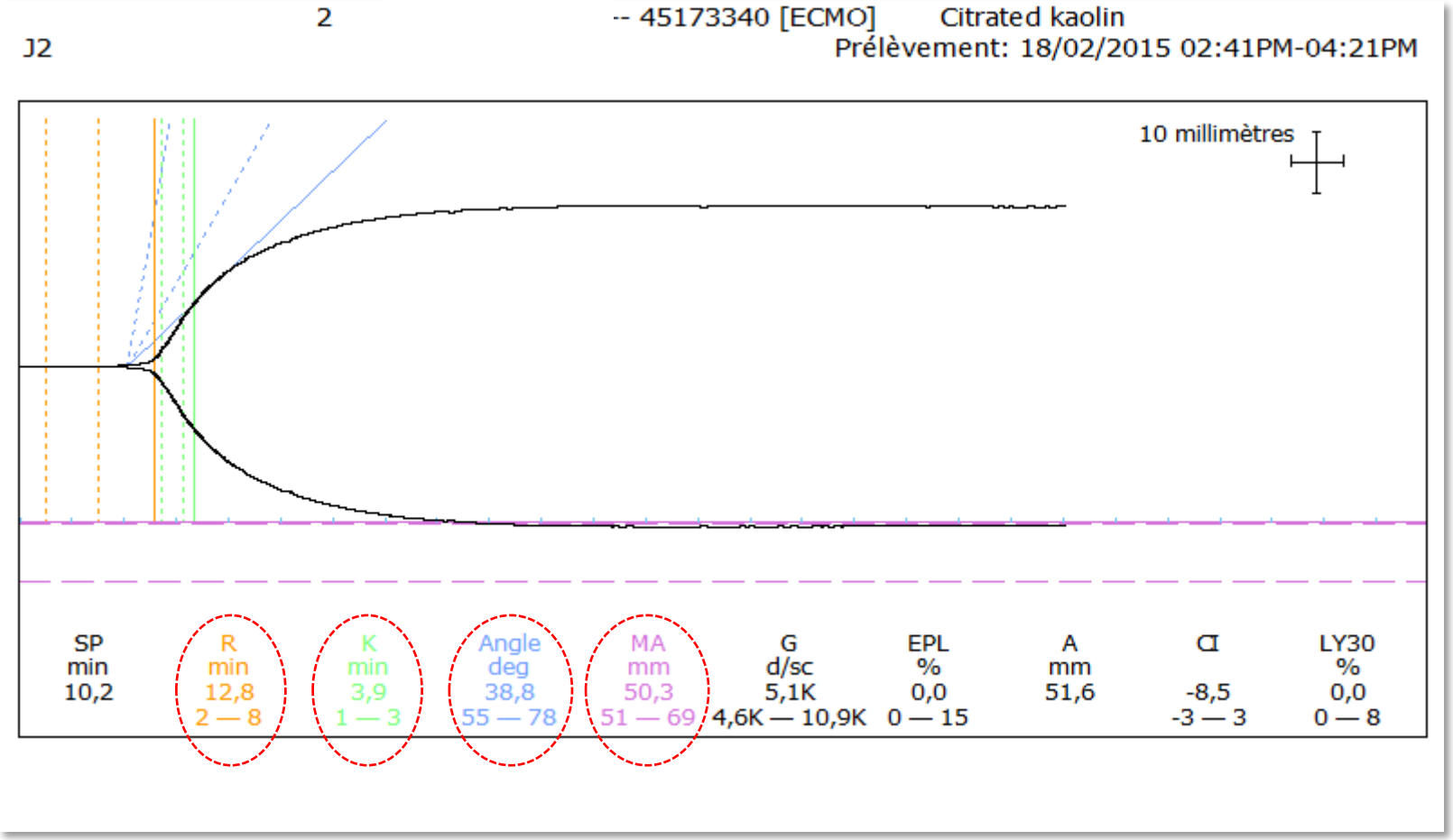
- Myocardite (qui senrévelera être une grippe)
- Dégradation très rapide de la situation
- ECMO ECLS
- Pas de no flow
- Low flow 45 mn en cumulé
- Canulation fémoro-fémorale gauche

Bilan de coagulation de 22h
Hémorragie modérée au site d'insertion des canules
Hémorragie sphère ORL
HNF 550 UI/Kg/j

- APTT > 150
- Activité anti Xa = 0.5
- Plaquettes = 80 000
- TP=37%

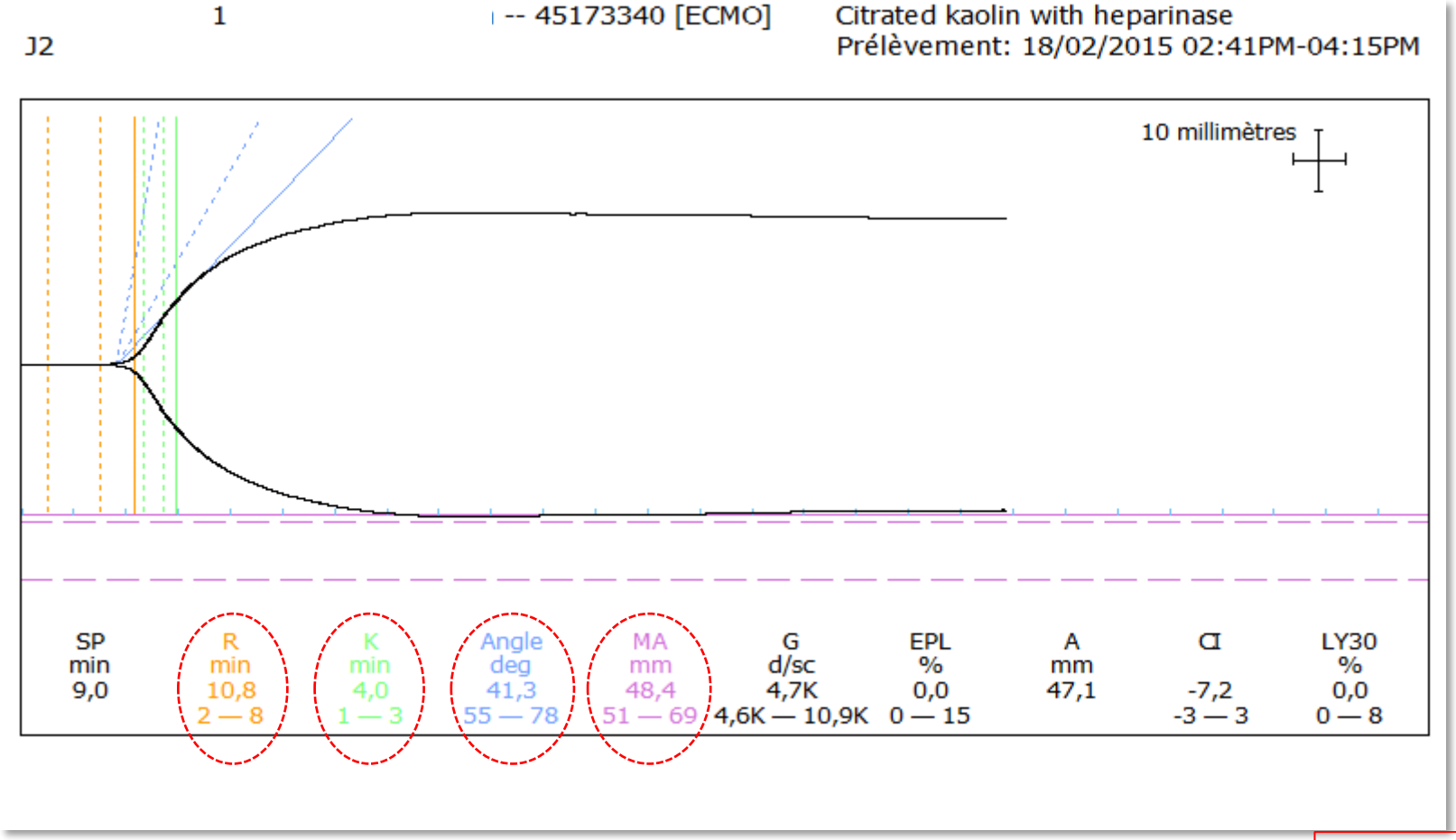
Quel est votre conduite vis-à-vis de l'héparine ?

Prélèvement de 14h du sang total alors que la patiente est sous héparine



On pourrait interpréter toutes ces anomalies de la coag comme un effet de l'héparine…mais

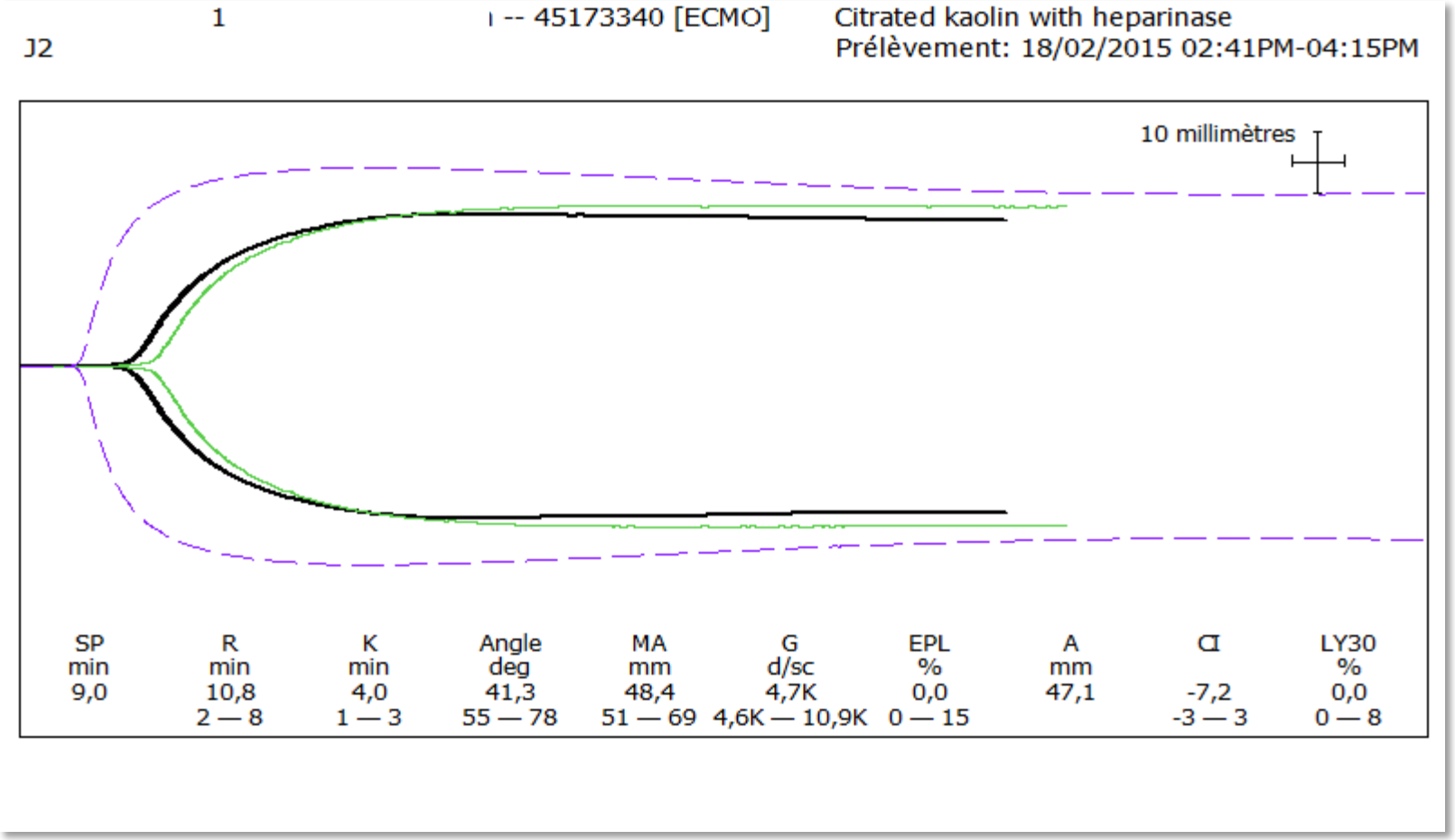
Le même prélèvement avec antagonisation de l'héparine…



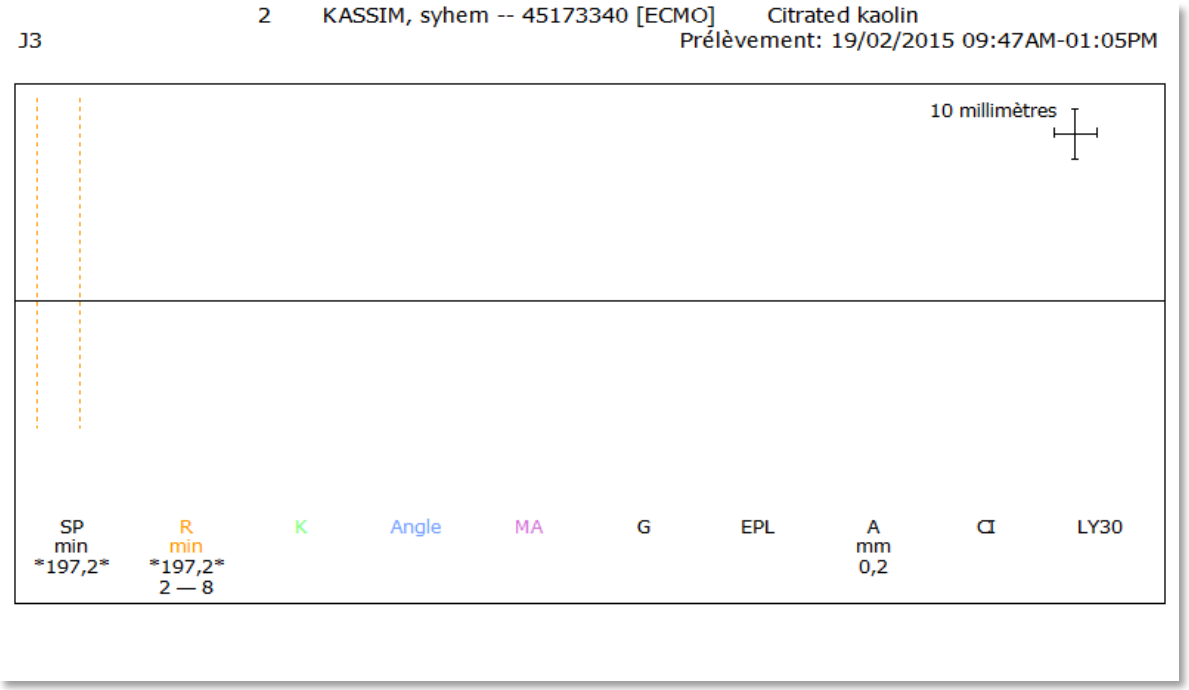
Ça ressemble beaucoup au prélèvement précédent
conclusion le malade n'est absolument pas anti coagulé!!!!

AT3= 15%!!!!!

Une autre façon de le montrer…



- ECMO J3
- Vidange d'un épanchement péricardique + rajout d'une canule cervicale
-Persistance des phénomènes hémorragiques locaux sans critères de gravité



- TCA >150
- Activité anti Xa = 0,7
- Plaquettes = 135 000
- TP=37%
- Anti thrombine: 85%

Association of Bleeding and Thrombosis With Outcome in Extracorporeal Life Support*

Pediatric Critical Care Medicine | February 2015 • Volume 16 • Number 2

- Survie globale 49%(NN 40% ; Ped 57%)
- Evts hémorragiques 23% des cas.
- Survie annuelle stable durant la période de recrutement.
- Evènements hémorragiques significativement corrélés a une diminution de survie de 33% dans la cohortes néonatale et de 32% dans le groupe pédiatrique.
- L'association de plusieurs complications hémorragiques diminue la surviede façon significative.

TABLE 4. Frequency[a] of Complications During Extracorporeal Life Support for Cardiac Support and Relative Risk of Survival[a] (Excludes Cases of Congenital Diaphragmatic Hernia)

	Bleeding				
Variable	*n*	% (*n*)	% Survival	Survival RR[b]	95% CI
Neonatal					
	0	57 (211)	49	1.00	–
	1	28 (103)	35	0.80	0.59–1.07
	2+	16 (58)	19	0.45	0.26–0.77
				$p < 0.001$[a]	
Pediatric					
	0	56 (200)	69	1.00	–
	1	31 (109)	42	0.66	0.52–0.83
	2+	13 (46)	43	0.73	0.52–1.02
				$p = 0.003$[a]	

Association of Bleeding and Thrombosis With Outcome in Extracorporeal Life Support*

Pediatric Critical Care Medicine | February 2015 • Volume 16 • Number 2

- Evts thrombotiques dans 33% des cas.
- Diminution équivalente de la survie ≈ 30% dans les deux groupes de patients.
- L'augmentation du nombre de complication thrombotique chez un même patient diminue la survie.

TABLE 4. Frequency[a] of Complications During Extracorporeal Life Support for Cardiac Support and Relative Risk of Survival[a] (Excludes Cases of Congenital Diaphragmatic Hernia)

Thrombosis				
n	% (*n*)	% Survival	Survival RR[b]	95% CI
0	68 (251)	49	1.00	–
1	20 (75)	21	0.51	0.32–0.81
2	8 (29)	31	0.78	0.45–1.35
3+	5 (17)	12	0.36	0.09–1.35
			$p = 0.014$[a]	
0	67 (239)	67	1.00	–
1	20 (70)	41	0.67	0.50–0.89
2	10 (35)	31	0.57	0.34–0.93
3+	3 (11)	27	0.58	0.23–1.47
			$p = 0.002$[a]	

Factors Associated with Bleeding and Thrombosis in Children Receiving Extracorporeal Membrane Oxygenation

Heidi J. Dalton[1] American Journal of Respiratory and Critical Care Medicine Volume 196 Number 6 2017

- 1ere étude prospective consacrée à l'ECMO.
- Buts de l'étude:
  - Incidence des évènements thrombotiques et hémorragiques.
  - Identifier les facteurs associés à ces évènements.
  - Evaluer leur impact sur le pronostic du patient.
- **514 patients < 19 ans** (centres US majeurs)
  - Survie globale à 54,9%.
  - 27,5 évènements hémorragiques % jours ECMO.
  - 11 évènements thrombotiques % jours ECMO.

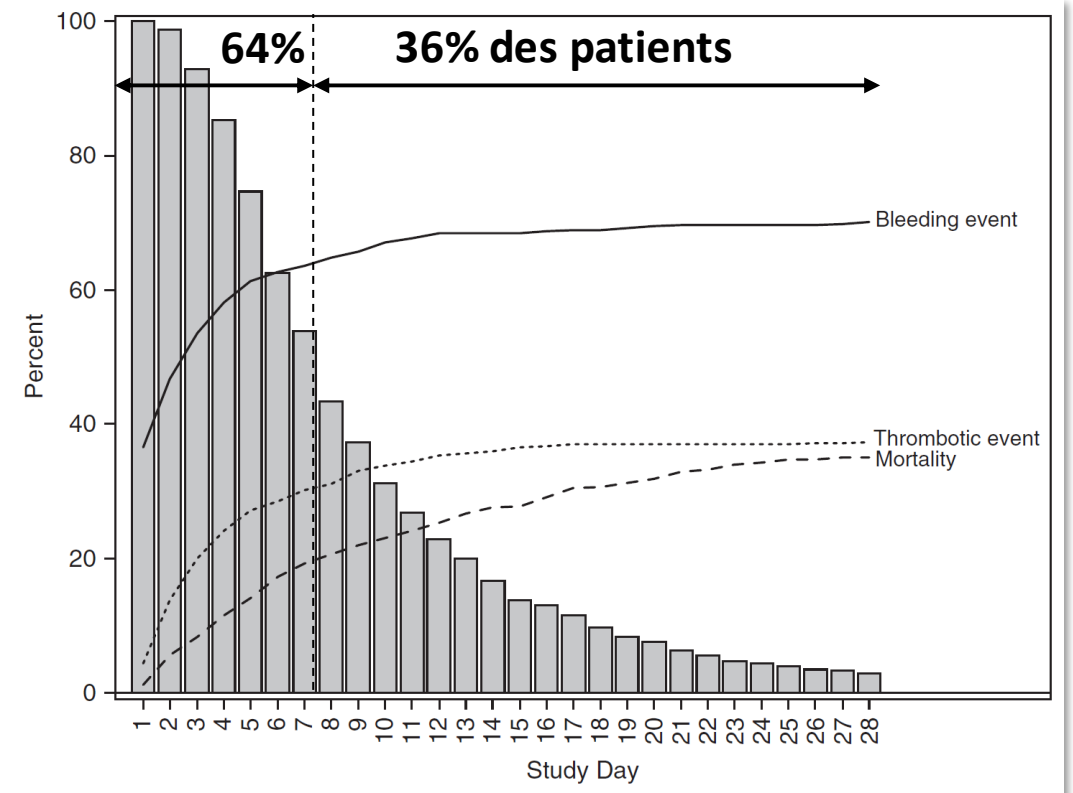


Figure 1. The cumulative percent of patients who have suffered mortality, bleeding events, or thrombotic events by day of extracorporeal membrane oxygenation support. The histogram shows the percent of patients who remain on extracorporeal membrane oxygenation support as the duration of support increases.

Risque de décès de 1-3% par jour d'ECMO

Factors Associated with Bleeding and Thrombosis in Children Receiving Extracorporeal Membrane Oxygenation

Heidi J. Dalton[1] American Journal of Respiratory and Critical Care Medicine Volume 196 Number 6 2017

Nouveaux évènements hémorragiques pour 100 jours d'assistance par âge et indication d'ECMO

	Respiratory		Cardiac		ECPR		
	Neonatal (1,724 d)	Pediatric (1,123 d)	Neonatal (583 d)	Pediatric (771 d)	Neonatal (153 d)	Pediatric (306 d)	Overall (4,660 d)
Bleeding events, n (%)	282 (16.4)	335 (29.8)	218 (37.4)	297 (38.5)	51 (33.3)	100 (32.7)	1283 (27.5)
Surgical site bleeding, n (%)	84 (4.9)	90 (8.0)	105 (18.0)	116 (15.0)	28 (18.3)	31 (10.1)	454 (9.7)
Chest tube bleeding, n (%)	75 (4.4)	127 (11.3)	139 (23.8)	185 (24.0)	34 (22.2)	62 (20.3)	622 (13.3)
ml/kg, median (IQR)	0.0 (0.0–1.8)	0.0 (0.0–1.3)	17.3 (0.0–48.8)	7.4 (0.0–33.5)	16.7 (3.2–42.4)	0.9 (0.0–15.4)	0.0 (0.0–13.2)
Cannula site bleeding, n (%)	85 (4.9)	124 (11.0)	46 (7.9)	94 (12.2)	13 (8.5)	35 (11.4)	397 (8.5)
Pulmonary hemorrhage, n (%)	33 (1.9)	66 (5.9)	6 (1.0)	26 (3.4)	5 (3.3)	8 (2.6)	144 (3.1)
Gastrointestinal bleeding, n (%)	15 (0.9)	49 (4.4)	1 (0.2)	4 (0.5)	1 (0.7)	11 (3.6)	81 (1.7)
Genitourinary bleeding, n (%)	13 (0.8)	26 (2.3)	2 (0.3)	6 (0.8)	0 (0.0)	3 (1.0)	50 (1.1)
Intracranial bleeding, n (%)	57 (3.3)	16 (1.4)	25 (4.3)	13 (1.7)	6 (3.9)	5 (1.6)	122 (2.6)
Laboratory sample bleeding, n (%)	483 (28.0)	203 (18.1)	145 (24.9)	180 (23.3)	41 (26.8)	73 (23.9)	1125 (24.1)
ml/kg, median (IQR)	9.0 (6.3–11.6)	1.4 (0.6–3.2)	7.1 (4.2–10.3)	2.7 (1.0–5.5)	7.6 (3.7–9.6)	2.4 (1.4–4.5)	6.0 (2.1–9.7)
Only laboratory sample bleeding, n (%)	349 (20.2)	137 (12.2)	63 (10.8)	79 (10.2)	19 (12.4)	32 (10.5)	679 (14.6)

- Evènements hémorragique chez 70,2% des patients…
- …dont 16% d'AVC hémorragique.
- …soit 27,5 evts hémorragiques %j ECMO.
- Rôle joué par les bilans…
- …qui sont la seul cause d'une transfusion dans 42.2% des cas.

Factors Associated with Bleeding and Thrombosis in Children Receiving Extracorporeal Membrane Oxygenation

Heidi J. Dalton[1] American Journal of Respiratory and Critical Care Medicine Volume 196 Number 6 2017

- Forte association entre la ***durée de l'assistance*** et la survenue de complications hémorragiques.
- Les facteurs prédictifs d'hémorragie sont:
  - ***« Cardiac » ECMO.***
  - ***« ECPR » ECMO.***
  - ***ECMO en salle d'opération sur non seuvrabilité de la CEC.***
- Assez grandes variations d'incidence entre les ***centres***!
- Impératif d'homogénéisation des pratiques.

Table 7. Multivariate Model for Daily Bleeding Event

	Adjusted Relative Risk (95% CI)	*P* Value
Age, yr	1.04 (1.02–1.05)	<0.001
Patient placed on ECMO directly from CPB		<0.001
No	Reference	
Yes	1.76 (1.45–2.13)	
Primary ECMO indication		0.002
Cardiac	1.34 (1.11–1.63)	
ECPR	1.52 (1.16–1.98)	
Respiratory	Reference	
Patient has MAS		0.002
No	Reference	
Yes	0.54 (0.34–0.84)	
Organ Failure Index on day of ECMO initiation		0.013
1	1.00 (0.65–1.53)	
2	Reference	
3	1.28 (1.08–1.51)	
4–5	1.47 (1.09–1.97)	
Clinical site		<0.001
A	1.53 (1.24–1.90)	
B	0.58 (0.35–0.95)	
C	0.44 (0.33–0.58)	
D	0.77 (0.59–1.01)	
E	Reference	
F	0.86 (0.64–1.16)	
G	1.21 (0.84–1.73)	
H	0.90 (0.66–1.21)	

Definition of abbreviations: CI = confidence interval; CPB = cardiopulmonary bypass; ECMO = extracorporeal membrane oxygenation; ECPR = extracorporeal cardiopulmonary resuscitation; MAS = meconium aspiration syndrome.

Factors Associated with Bleeding and Thrombosis in Children Receiving Extracorporeal Membrane Oxygenation

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Nouveaux évènements thrombotiques pour 100 jours d'assistance par âge et indication d'ECMO

	Respiratory		Cardiac		ECPR		
	Neonatal (1,724 d)	Pediatric (1,123 d)	Neonatal (583 d)	Pediatric (771 d)	Neonatal (153 d)	Pediatric (306 d)	Overall (4,660 d)
Thrombotic events, n (%)	154 (8.9)	104 (9.3)	66 (11.3)	122 (15.8)	17 (11.1)	48 (15.7)	511 (11.0)
Patient-related thromboses, n (%)	27 (1.6)	39 (3.5)	33 (5.7)	75 (9.7)	7 (4.6)	29 (9.5)	210 (4.5)
Intracranial infarction, n (%)	17 (1.0)	17 (1.5)	5 (0.9)	15 (1.9)	0 (0.0)	17 (5.6)	71 (1.5)
Limb ischemia, n (%)	2 (0.1)	15 (1.3)	21 (3.6)	26 (3.4)	0 (0.0)	10 (3.3)	74 (1.6)
Intracardiac clot, n (%)	0 (0.0)	1 (0.1)	0 (0.0)	25 (3.2)	0 (0.0)	0 (0.0)	26 (0.6)
Aortopulmonary shunt clot, n (%)	1 (0.1)	0 (0.0)	2 (0.3)	0 (0.0)	0 (0.0)	0 (0.0)	3 (0.1)
Pulmonary embolus, n (%)	0 (0.0)	0 (0.0)	0 (0.0)	6 (0.8)	0 (0.0)	0 (0.0)	6 (0.1)
Other, n (%)	7 (0.4)	18 (1.6)	5 (0.9)	10 (1.3)	7 (4.6)	2 (0.7)	49 (1.1)
Circuit-related thromboses (requiring change-out), n (%)	129 (7.5)	70 (6.2)	36 (6.2)	55 (7.1)	12 (7.8)	22 (7.2)	324 (7.0)
Entire circuit, n (%)	51 (3.0)	20 (1.8)	8 (1.4)	12 (1.6)	3 (2.0)	7 (2.3)	101 (2.2)
Oxygenator, n (%)	8 (0.5)	10 (0.9)	9 (1.5)	17 (2.2)	4 (2.6)	4 (1.3)	52 (1.1)
Bladder, n (%)	16 (0.9)	5 (0.4)	3 (0.5)	6 (0.8)	2 (1.3)	0 (0.0)	32 (0.7)
CVVH, n (%)	1 (0.1)	1 (0.1)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.3)	3 (0.1)
Tubing, n (%)	7 (0.4)	14 (1.2)	2 (0.3)	1 (0.1)	1 (0.7)	0 (0.0)	25 (0.5)
Arterial cannula, n (%)	1 (0.1)	3 (0.3)	1 (0.2)	1 (0.1)	0 (0.0)	0 (0.0)	6 (0.1)
Bridge, n (%)	1 (0.1)	0 (0.0)	0 (0.0)	1 (0.1)	1 (0.7)	0 (0.0)	3 (0.1)
Hemofilter, n (%)	19 (1.1)	4 (0.4)	4 (0.7)	0 (0.0)	2 (1.3)	2 (0.7)	31 (0.7)
Pump head, n (%)	0 (0.0)	2 (0.2)	0 (0.0)	2 (0.3)	0 (0.0)	1 (0.3)	5 (0.1)
Venous cannula, n (%)	1 (0.1)	3 (0.3)	1 (0.2)	0 (0.0)	0 (0.0)	0 (0.0)	5 (0.1)
Other, n (%)	32 (1.9)	20 (1.8)	11 (1.9)	22 (2.9)	2 (1.3)	9 (2.9)	96 (2.1)
Hemolysis, n (%)	275 (16.0)	145 (12.9)	108 (18.5)	78 (10.1)	24 (15.7)	35 (11.4)	665 (14.3)

Factors Associated with Bleeding and Thrombosis in Children Receiving Extracorporeal Membrane Oxygenation

Heidi J. Dalton[1] American Journal of Respiratory and Critical Care Medicine Volume 196 Number 6 2017

Outcome…

- Survie globale de la cohorte est de 54,9%, variable bien sur en fonction de l'indication, mais pas fonction de l'âge ni du site ECMO.
- Les évènements hémorragiques et thrombotiques sont associés à une statu clinique altéré à la sortie de réanimation *(Patient Overall Performance Category score; Pediatric Cerebral Performance Category score).*
- Rôle statistique important des mort cérébrales dans cette association.
- La survenue d'une hémolyse ne semble pas avoir d'impact sur l'état clinique à la sortie de réanimation.
- En analyse multivariée, les évènements hémorragiques sont associés à une sur-mortalité *(Hazard Ratio = 1,75).*

	Bleeding Event		
	No (*n* = *153*)	Yes (*n* = *361*)	*P* Value
Total FSS at hospital discharge			0.323*
n	101	181	
Mean (SD)	8.7 (2.95)	9.1 (3.11)	
Minimum, maximum	6.0, 24.0	6.0, 21.0	
Median (IQR)	8.0 (6.0–10.0)	8.0 (7.0–10.0)	
POPC score at hospital discharge, n (%)			<0.001*
1 (good)	21 (13.7)	31 (8.6)	
2 (mild disability)	46 (30.1)	82 (22.7)	
3 (moderate disability)	29 (19.0)	49 (13.6)	
4 (severe disability)	5 (3.3)	19 (5.3)	
5 (Coma/vegetative)	0 (0)	0 (0)	
6 (brain death)	52 (34.0)	180 (49.9)	
PCPC score at hospital discharge, n (%)			<0.001*
1 (normal)	56 (36.6)	89 (24.7)	
2 (mild disability)	33 (21.6)	64 (17.7)	
3 (moderate disability)	10 (6.5)	17 (4.7%)	
4 (severe disability)	2 (1.3)	11 (3.0)	
5 (Coma/vegetative)	0 (0)	0 (0)	
6 (brain death)	52 (34.0)	180 (49.9)	

Definition of abbreviations: FSS = Functional Status Scale; IQR = interquartile range; PCPC = Pediatric Cerebral Performance Category; POPC = Pediatric Overall Performance Category.
FSS is only measured on survivors, whereas POPC and PCPC include death as the worst possible score.
**P* values are based on the Wilcoxon rank-sum test.

Conduite de l'assistance

⚠ **Volémie**

- Risque hémodilution → Priming sanguin (Hte >30%)
- Volume de dilution augmenté → Adapter doses médicaments
- Aggravation hémodynamique transitoire → Démarrage progressif +++
- Syndrome de fuite capillaire

⚠ **Température**

- Déperdition thermique +++ → Réchauffeur sur le circuit
  → Priming réchauffé

⚠ **Anticoagulation**

- Spécificités néonatales: Déficit en AT3, moindre sensibilité à l'héparine, immaturité hépatique…
- → Surveillance ACT, Héparinémie, AT3 +++

Fluid therapy remains an important cornerstone in the prevention of progressive chugging in extracorporeal membrane oxygenation

- Importance d'avoir la bonne volémie
- Attention à l'hypervolémie

Conduite de l'assistance

- **Hémodynamique**
  - Débit: NN 100cc/kg/mn Enfant 80cc/kg/mn Adulte 60cc/kg/mn
    (+20% si assistance VV)
  - PAM > 45 mmHg NN (> 60 mmHg adultes)
  - Hématocrite > 30%
  - PVC 5-10mmHg

→ **Bonne perfusion tissulaire ↔ SvO_2 > 70% +++**

Conduite de l'assistance

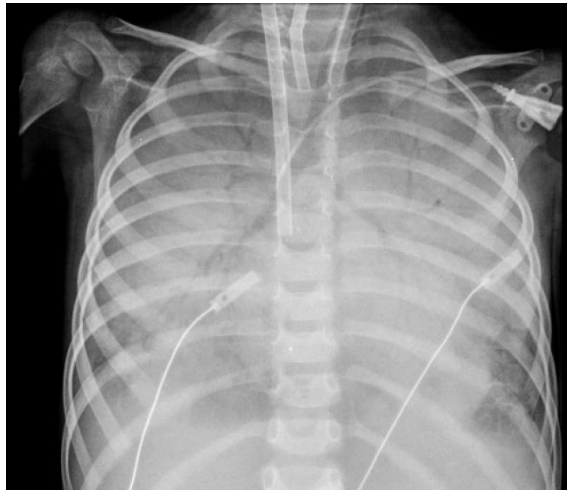
- **Décharge gauche?**

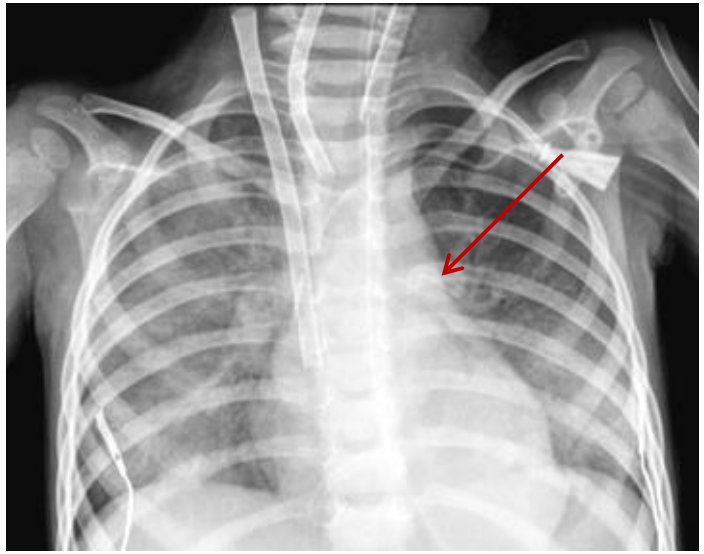
Fonction VG trop altérée pour ouvrir VAo

ETT: Pas d'ouverture VAo
Dilatation des cavités gauche
↗ POG, ↗ PTDVG

RT: Œdème pulmonaire

Atrioseptostomie
Canule de décharge atriale gauche



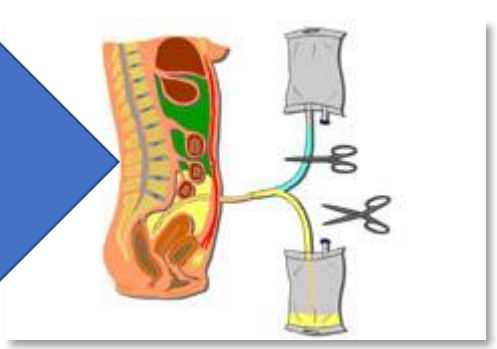


Continue et ECMO Veino-Artérielle

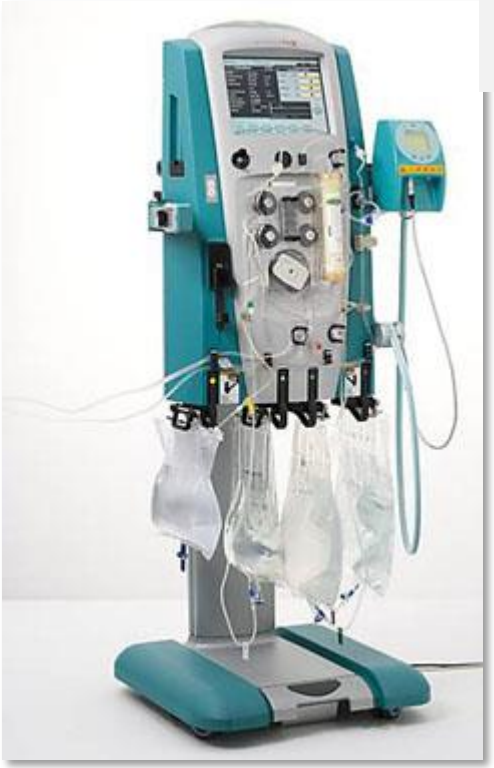
Conséquences de la surcharge hydrique

- **Œdème pulmonaire:**
  - Ventilation prolongée
  - Trouble de l'oxygénation
- **Œdème cardiaque:**
  - Dysfonction ventriculaire
  - Retard de récupération
- **Œdème rénal:**
  - Insuffisance rénale
  - Oligo-Anurie
- **Œdème périphérique:**
  - Hypoxie cellulaire
  - Défaillance multiviscérale

Insuffisant
Inefficace



Diurétiques



Dialyse Péritonéale

HémoDiafiltration Veino-Veineuse Continue et ECMO Veino-Artérielle Pédiatrique

- **Une surcharge hydrique est très fréquente dans ces situations**

- **Surcharge Hydro-Sodée**
  - Congestion (Œdème pulmonaire; œdème périphérique …)
- **Expansion volémique:**
  - Rétablissement d'une volémie efficace
  - Transfusion sanguine liée au priming puis au traitement des conséquences hématologiques de l'ECMO (Concentrés globulaires; Plasma; Plaquettes)
- **Apports hydriques « obligatoires »**
  - Purges
  - Thérapeutiques
  - Nutrition
- **Trouble de la perméabilité capillaire**
  - Syndrome inflammatoire non spécifique / sepsis associé
  - Syndrome post-arret cardiaque
- **Lésion rénale aiguë**
  - Immaturité rénale du nouveau-né
  - Oligo-anurie
  - Insuffisance rénale aiguë

Selewski DT, Askenazi DJ, Bridges BC, Cooper DS, Fleming GM, Paden ML, et al. The impact of fluid overload on outcomes in children treated with extracorporeal membrane oxygenation: a multicenter retrospective cohort study. Pediatr Crit Care Med. 2017;18(12):1126–35.

- Surcharge hydrique > 30% associée à une surmortalité
- 84% de la cohorte ➔ Pic de surcharge hydrique > 10%
- 67% de la cohorte ➔ Pic de surcharge hydrique > 20%
- 29% de la cohorte ➔ Pic de surcharge hydrique > 50%

Hémodiafiltration Veino-veineuse continue et ECMO Veino-Artérielle Pédiatrique

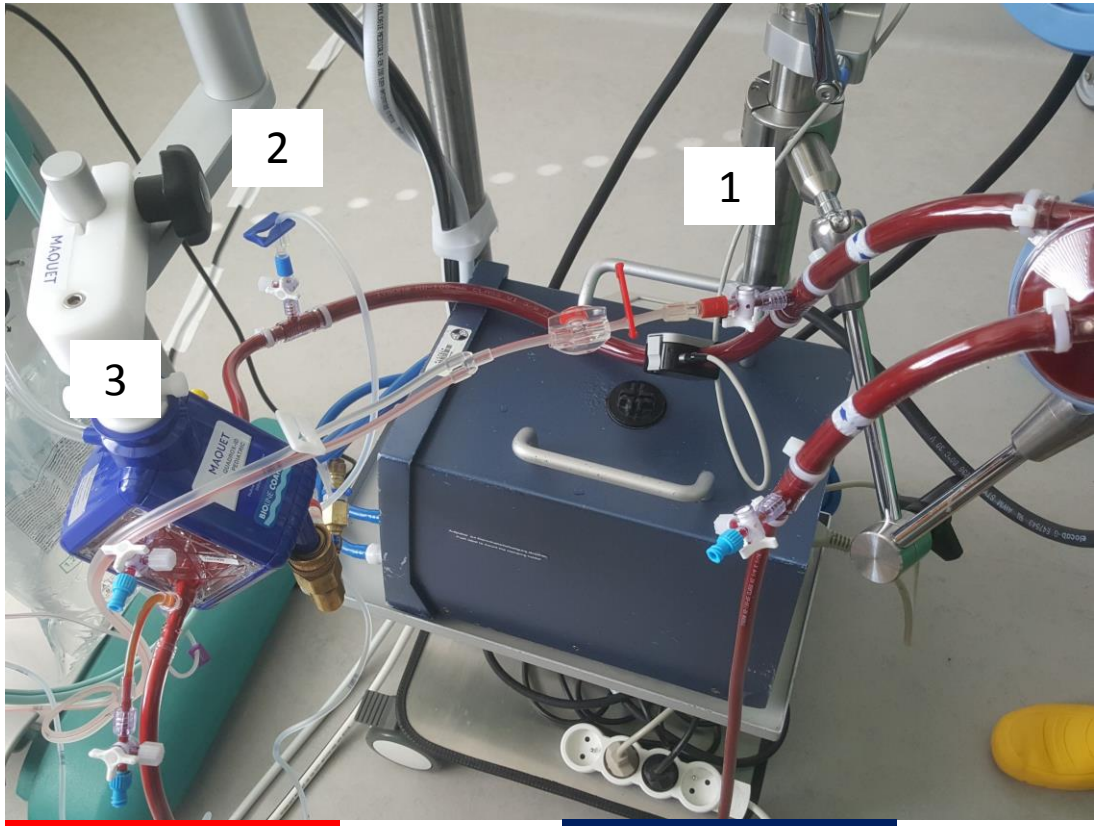
	Réanimation Active	Optimisation	Stabilisation	Désescalade
Principes	Sauvetage	Perfusion d'organe	Récupération d'organe	Rétablissement fonction d'organe
Buts	Correction de l'etat de choc	Optimisation de la perfusion	Maintien d'une volémie	Mobilisation oedème
Durée	**Minutes**	**Heures**	**Jours**	**Jours/Semaines**
Clinique	Chocs (cardiogénique)	Etat instable	Etat stable	Amélioration
Nature apports hydriques	Bolus rapide	Expansion volémique 5-10 ml/kg	Bilan hydrique entrée-sortie équilibré	Bilan hydrique entrée-sortie négatif

Evolution dans le Temps

Diurétiques

HémoDiafiltration Veino-Veineuse Continue

Montage Final



Ligne artériele

Ligne veineuse

- Ligne prélèvement patient (rouge) en amont de l'oxygénateur et du débitmètre.
- Ligne de retour veineuse patient (bleue) en amont de l'oxygénateur et en aval du débitmètre.
- L'oxygénateur sert de filtre de sécurité supplémentaire
- La capacité à arrêter les embols gazeux fait parti des critères de choix de l'oxygénateur par les IAC (100ml d'air).

HémoDiafiltration Veino-Veineuse Continue et ECMO Veino-Artérielle Pédiatrique

- **La mise en place** d'une hemodiafiltration veino-veineuse représente une situation exceptionnelle et exigeante.
- **Les indications** relèvent:
  - De la surcharge hydrique dans 45% des cas.
  - D'une lésion rénale aiguë dans 35%.
  - Certaines équipes, l'installent de façon préventive dans 16% des cas.
- Le recours a une hémodiafiltration veino-veineuse pourrait être associée à une **diminution de la durée d'assistance** chez l'enfant.
- Elle autorise l'élargissement des apports hydriques **et permet d'atteindre les objectifs nutritionnels** dans des situations ou une restriction hydrique est en principe indispensable.
- L'utilisation de ces techniques ne semblent **pas associées à une aggravation de la fonction rénale.** Il est cependant impératif de ne pas générer d'hypotension, de bas débit ni de basculer sur un versant hypovolémique.
- La surveillance prend ici tout son sens.

Fleming GM, Askenazi DJ, Bridges BC, Cooper DS, Paden ML, Selewski DT, et al. A multicenter international survey of renal supportive therapy during ECMO: the kidney intervention during extracorporeal membrane oxygenation (KIDMO) group. ASAIO J. 2012;58(4):407–14.

Conduite de l'assistance

- **Ventilation**
  - Mettre le poumon au repos / Éviter collapsus alvéolaire

ECMO AV
Volume courant 6-8 ml/kg
Fréquence 5-20/mn
$P_{crête}$ 20-25 cmH_2O
PEEP 5-10 cmH_2O
30% < FiO_2 < 40%

→ PCO_2 35-45mmHg PO_2 > 60-100mmHg
SaO2 > 80% pH 7.35-7.45

Conduite de l’assistance

- **Anticoagulation**
  - Héparine 50-100 UI/kg à la cannulation puis selon bilan de coagulation (antiXa+++).

- **Sédation & Analgésie**
  - La conduite de la sédation est toujours un problème.
  - Stop sédation → Évaluation neurologique.

- **Infection**
  - Pas d’antibioprophylaxie
  - Désinfection du site de cannulation
  - Prélèvements bact/fung multisites systématiques / 3 j
  - Rôle des marqueurs inflammatoires CRP vs procalcitonine.

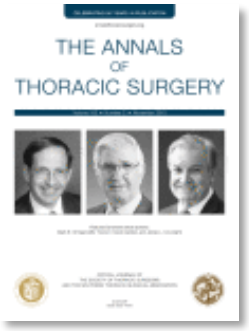
Conduite de l’assistance

- **Normothermie**

- **Nutrition**
  - Apport calorique et protéique suffisant
  - Entérale ou parentérale

- **Manipulation prudente ++++++++**

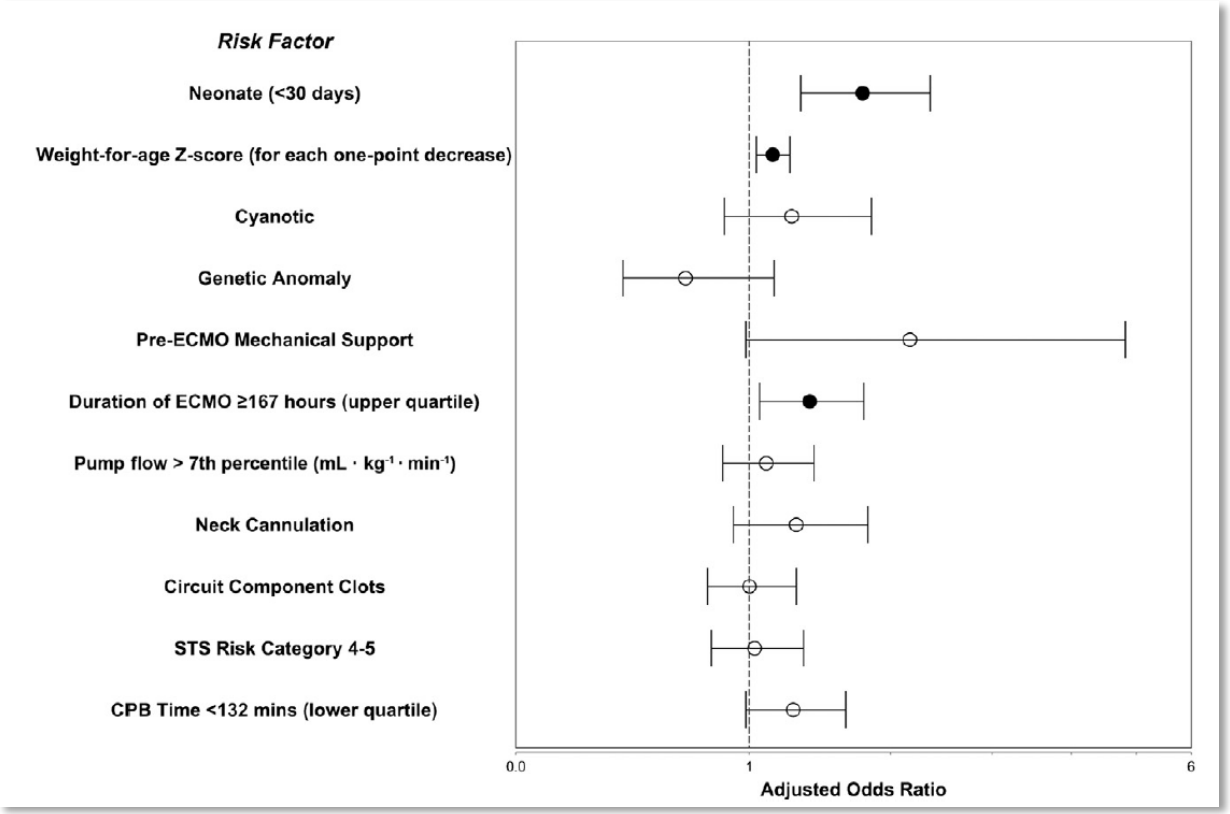
Epidemiology of Stroke in Pediatric Cardiac Surgical Patients Supported With Extracorporeal Membrane Oxygenation



David K. Werho Ann Thorac Surg 2015;100:1751–7

- 3517 patients (registre ELSO)
- 12% d'AVC.
- Surmortalité dans le groupe AVC.

Surgical patients had a 12.3% incidence of stroke with high rates of hemorrhagic stroke (10%), and low rates of ischemic stroke (3.3%). Patients with stroke experienced a greater rate of death at cannula removal (52% versus 25% without stroke; $p < 0.0001$) and in-hospital mortality (72% versus 51% without stroke; $p < 0.0001$; Fig 1); the overall in-hospital mortality rate for cardiac surgical patients requiring ECMO was 53%.



Sevrage de l'ECMO

Sevrage considéré devant l'apparition de signes de récupération cardiaque et/ou pulmonaire

Récupération pulmonaire

Amélioration clinique de la compliance pulmonaire
Meilleure aération pulmonaire sur la RT
Diminution de la dépendance à l'oxygénateur

Récupération cardiaque

Retour d'une pulsatilité sur la courbe de pression artérielle
Meilleure fonction ventriculaire à l'ETT
Maintient d'une perfusion systémique adéquate avec des pressions de remplissage basses et un bas débit d'ECMO

La cause de la défaillance Cardiaque / Respiratoire doit être totalement réversible

Stabilité hémodynamique à ¼ de débit:

Le patient doit avoir récupéré de toute anomalie métabolique majeure (acidose; lactate etc…).

La courbe artérielle doit être pulsée depuis plus de de 24h.

La PA moyenne doit être normale pour l'âge avec soutient inotrope modéré.

La fonction pulmonaire doit être normale à ¼ de débit et FiO2 machine abaissée

Thorax / echo pulmonaire normale.

Absence d'HATP à l'échocardiographie.

Le patient doit tolérer une épreuve de sevrage complète de l'assistance de plus de 15 mn:

- Echocardio compatible.
- Gazométrie normale PaO2/FiO2 > 300; Lactates artériels < 2 mmol/l.
- Absence demodification des NIRS.

ECLS in Pediatric Cardiac Patients

Matteo Di Nardo[1], Graeme MacLaren[2,3], Marco Marano[1], Corrado Cecchetti[1], Paola Bernaschi[4] and Antonio Amodeo[5]*

Cardiac Runs by Diagnosis

Age Group: 0 - 30 days

	Total Runs	*Avg Run Time*	*Longest Run Time*	*Survived*	*% Survived*
Congenital Defect	5,825	143	1524	2,319	40%
Cardiac Arrest	97	135	600	31	32%
Cardiogenic Shock	107	150	669	44	41%
Cardiomyopathy	143	211	867	87	61%
Myocarditis	87	263	868	44	51%
Other	740	169	1871	338	46%

Age Group: 31 days and < 1 year

	Total Runs	*Avg Run Time*	*Longest Run Time*	*Survived*	*% Survived*
Congenital Defect	3,443	146	2736	1,609	47%
Cardiac Arrest	117	130	587	49	42%
Cardiogenic Shock	86	136	1157	40	47%
Cardiomyopathy	203	240	2506	114	56%
Myocarditis	96	212	1246	69	72%
Other	722	173	2880	352	49%

Age Group: 1 year and < 16 years

	Total Runs	*Avg Run Time*	*Longest Run Time*	*Survived*	*% Survived*
Congenital Defect	1,641	140	1282	788	48%
Cardiac Arrest	139	138	2352	57	41%
Cardiogenic Shock	168	140	1347	89	53%
Cardiomyopathy	544	193	3605	337	62%
Myocarditis	314	181	1207	222	71%
Other	1,073	168	3605	593	55%

FIGURE 2 | Cardiac Runs by diagnosis: % of survival on ECMO. Avg, average.

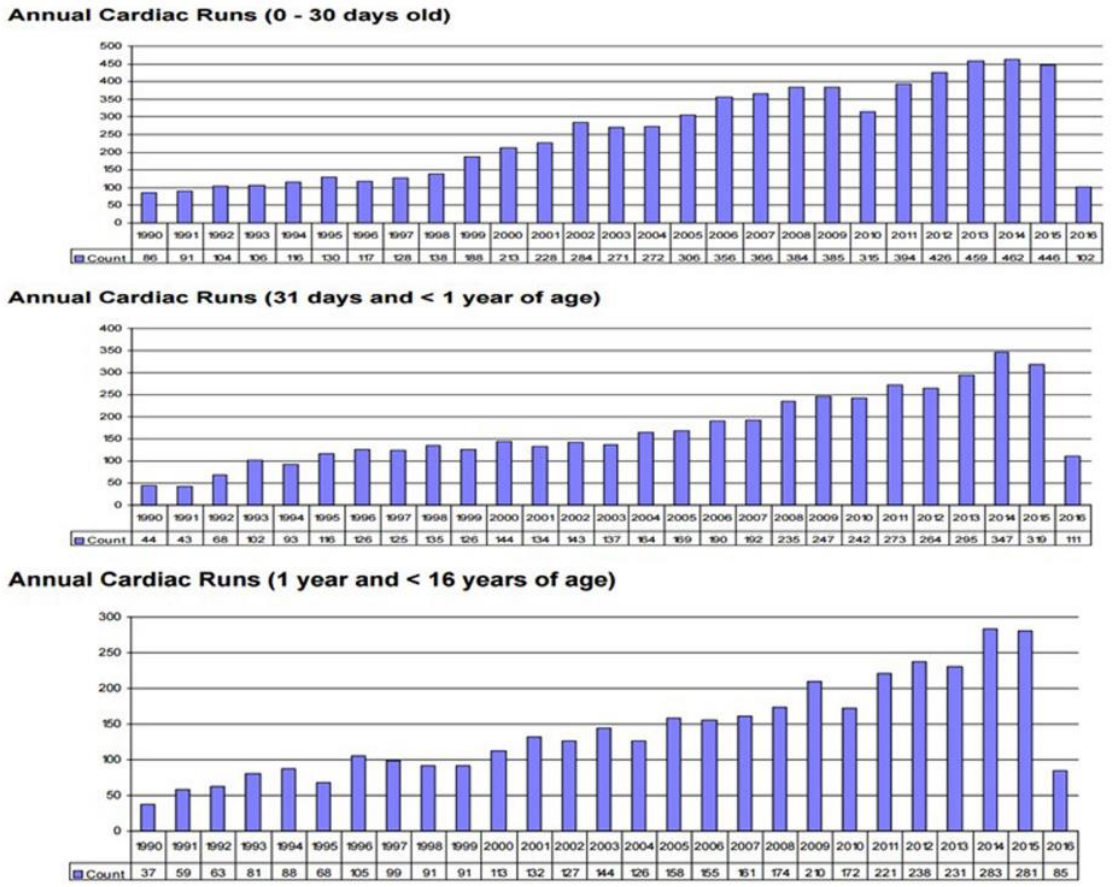


FIGURE 1 | Annual neo/ped ECMO runs. (International Summary 2016. Courtesy of P. Rycus from the ELSO Registry).

Clinical Management of Pediatric Ventricular Assist Devices

David S. Cooper, MD, MPH[1]; René Prêtre, MD[2]

Pediatr Crit Care Med 2013; 14:S27–S36

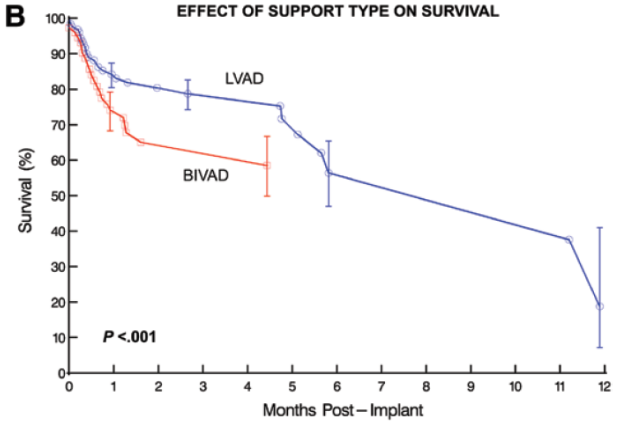
- Cardiopathie bien caractérisée.
- Un projet medico-chirurgical cohérent (anticipation).
- Implantation avant l'apparition de défaillance d'organe irréversible…
- …et avant l'état de choc!
- Information des parents +++
- Importance du bilan anatomique…
  - Valves
  - Parois ventriculaires
  - Aspects des gros vaisseaux.
- …et du bilan fonctionnel, en particulier du ventricule droit.

Issue	Possible Solution/Comments
Aortic insufficiency	Aortic insufficiency of 2+ or greater must be corrected; the aortic valve leaflets can be partially oversewn or the valve can be replaced with a bioprosthetic valve
Mitral regurgitation	Generally does not require repair
Mitral stenosis	Must be corrected surgically or with mitral valve replacement with a bioprosthetic valve
Tricuspid insufficiency	For 3+ to 4+ tricuspid regurgitation consider annuloplasty (ring or modified DeVega annuloplasty)
Mechanical prosthetic valves (rare problem in pediatrics)	Aortic valve: consider replacement with a bioprosthetic valve; mitral valve: generally does not require replacement; consider greater anticoagulation

« initiate support urgently rather than emergently »

Un Dogme
Privilégier l'Assistance Mono-Ventriculaire

- Morbi-mortalité inférieur pour mono-VAD vs bi-VAD.
- Un certain degré de dysfonction VD reste compatible avec le bon fonctionnement d'un mono-VAD gauche.



Berlin Heart EXCOR Pediatric Ventricular Assist Device for Bridge to Heart Transplantation in US Children
Christopher S. Almond *Circulation*. 2013;127:1702-1711 Circulation

Au bloc opératoire

- *Gestion préemptive de la défaillance ventriculaire droite.*
  - *Milrinone-adrénaline*
  - *Vasodilatateurs pulmonaires (iNO+++)*
  - *La « bonne » volémie*
- *Importance du monitorage du ventricule droit*
- *Echographie trans-oesophagienne …avec un bon échographiste!*

Mais c’est pas toujours possible…

- **Défaillance VD précoce:**
  - La plus fréquente.
  - Normalisation du retour veineux suite au L-VAD sur VD limite.
  - RVPulm ↗après une CEC.
  - Evaluation de la fonction VD =exercice difficile. Surestimation fréquente.
  - Transfusion.
- **Défaillance VD tardive:**
  - La plus grave.
  - Relève d’une vrai dysfonction VD.
- Assistance VD nécessaire dans 10-20% des cas.
- Importance de l’optimisation préopératoire du VD.
- Préférer une implantation élective en BiVAD que la séquence L-VAD-dysfonction VD – BiVAD.

Right ventricular failure in patients with the HeartMate II continuous-flow left ventricular assist device: Incidence, risk factors, and effect on outcomes

Kormos et al J Thorac Cardiovasc Surg 2010;139:1316-24

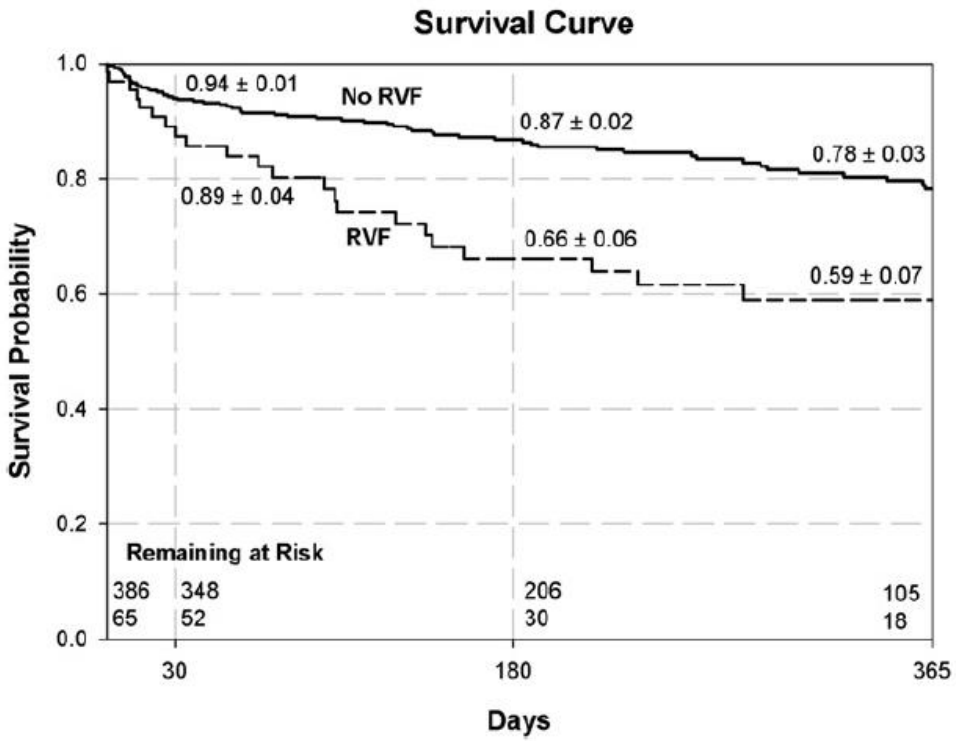
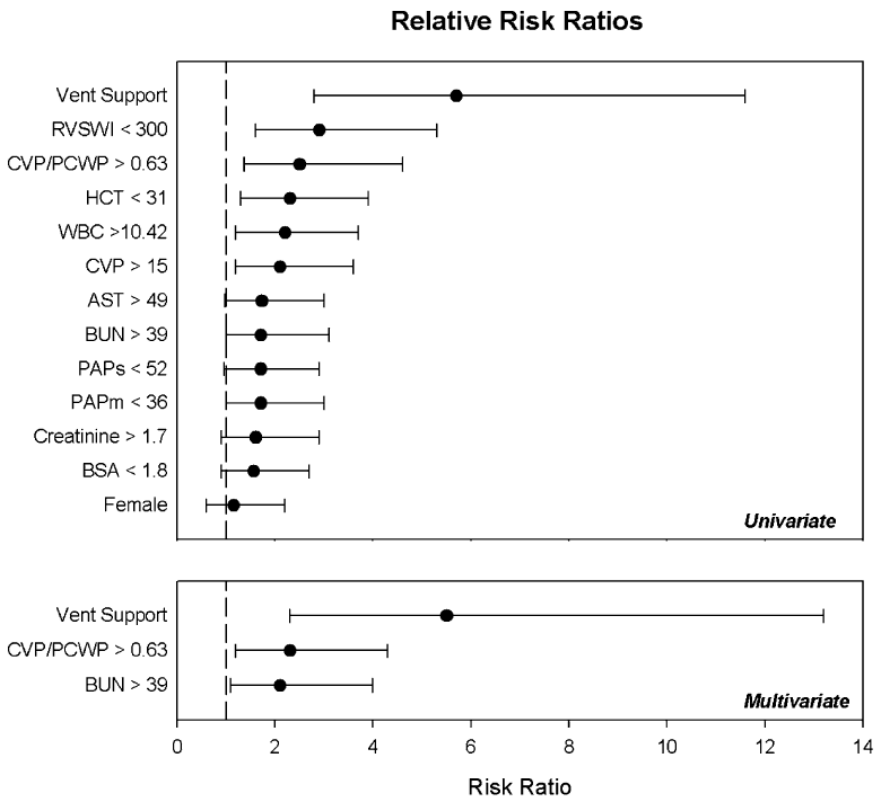


FIGURE 1. Kaplan–Meier survival for patients with and without early RVF receiving the HeartMate II LVAD, which includes the need for RVADs or extended inotropic support for more than 14 days.



Prediction of right ventricular failure after ventricular assist device implant: systematic review and meta-analysis of observational studies

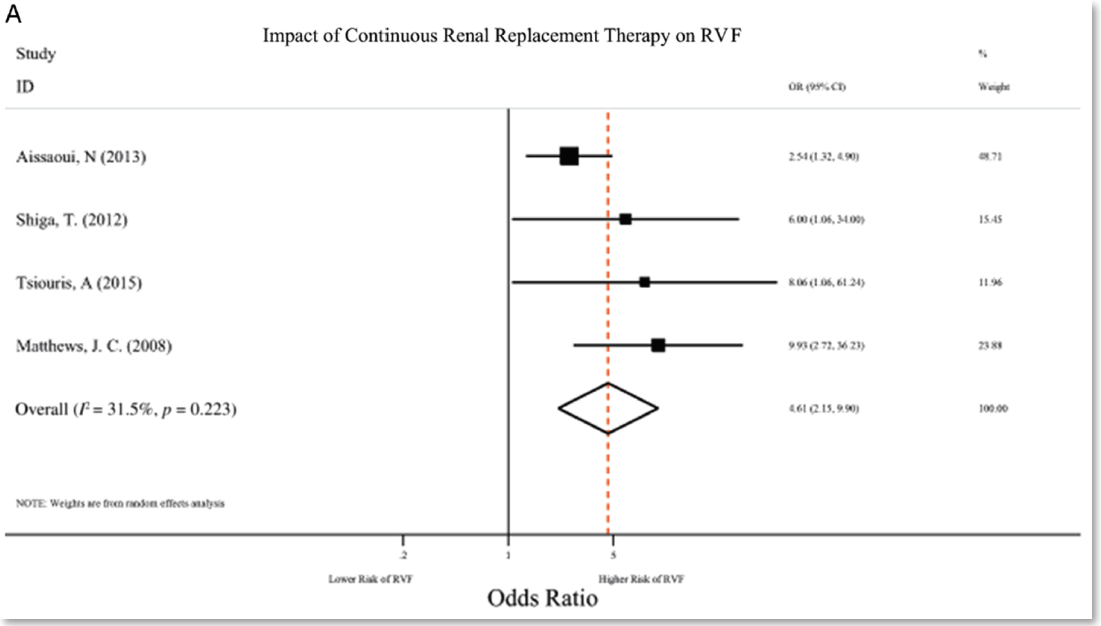
EUROPEAN SOCIETY OF CARDIOLOGY®

Diego Bellavia

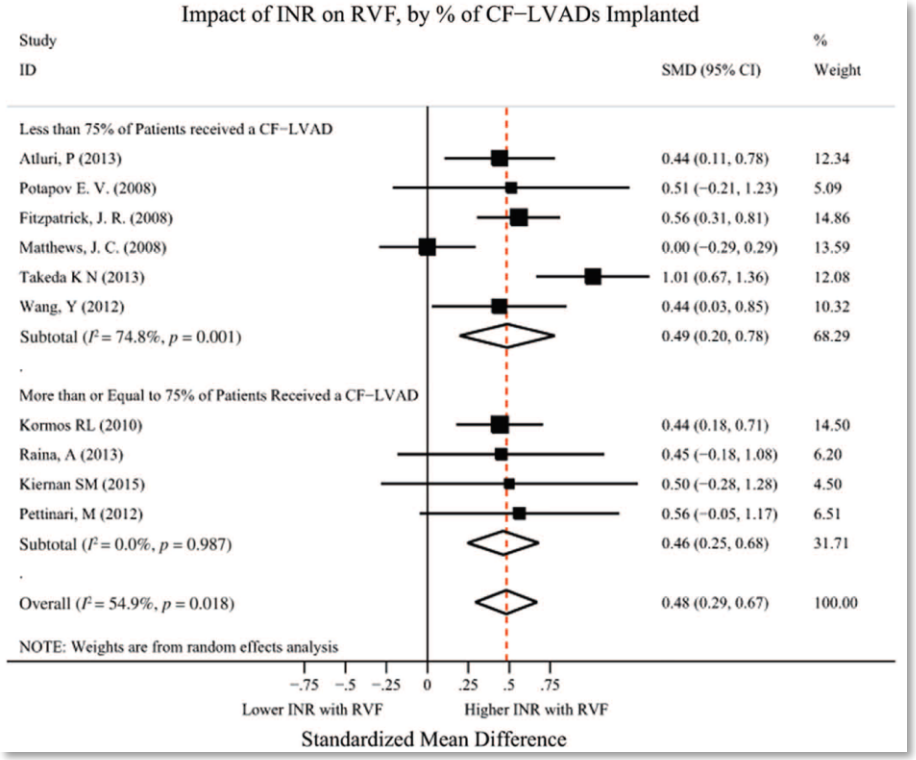
European Journal of Heart Failure (2017) **19**, 926–946

Dialyse

A



La Fonction Hépatique



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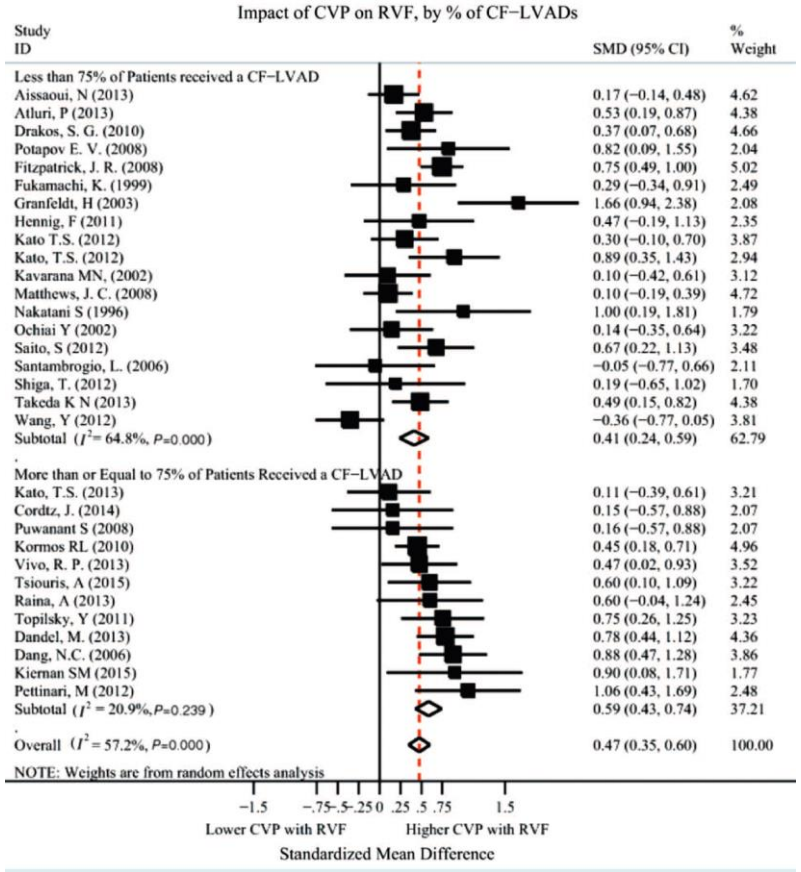
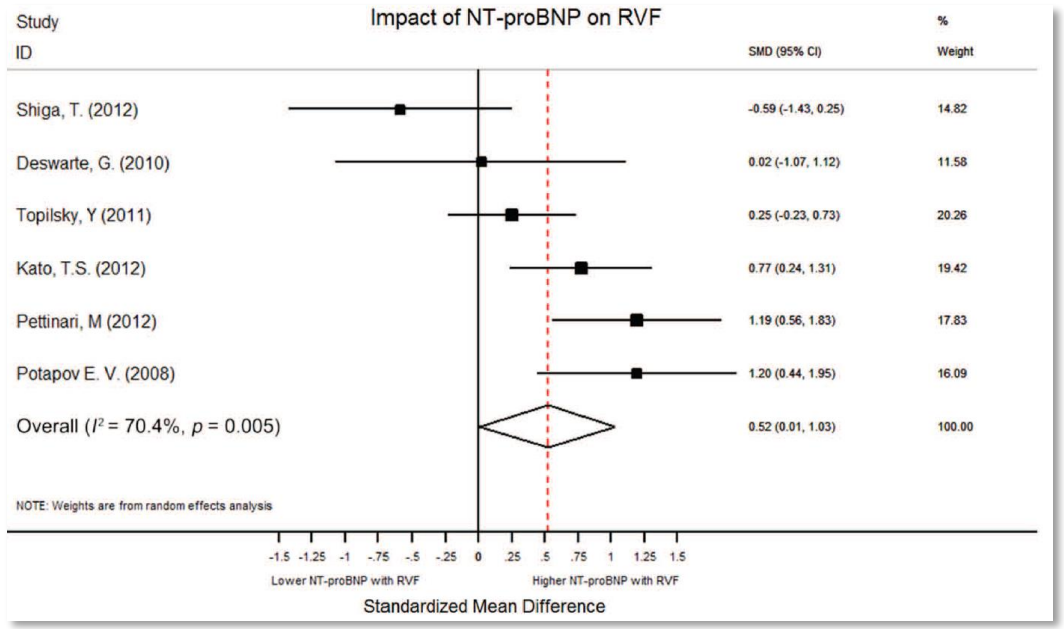
Impact de la PVC



NT-proBNP



Prediction of right ventricular failure after ventricular assist device implant: systematic review and meta-analysis of observational studies

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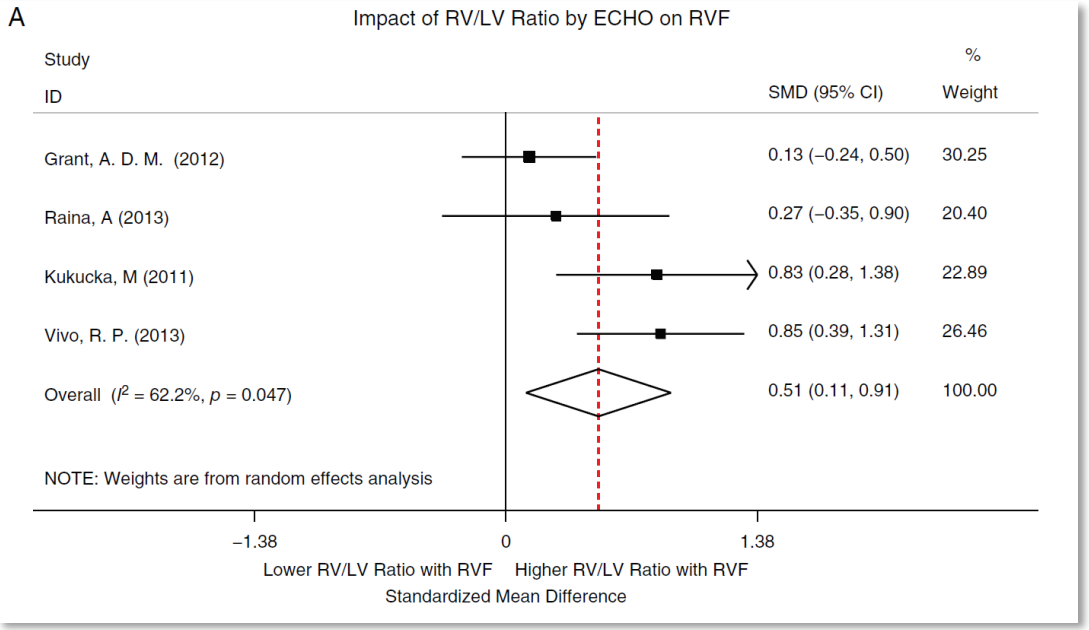
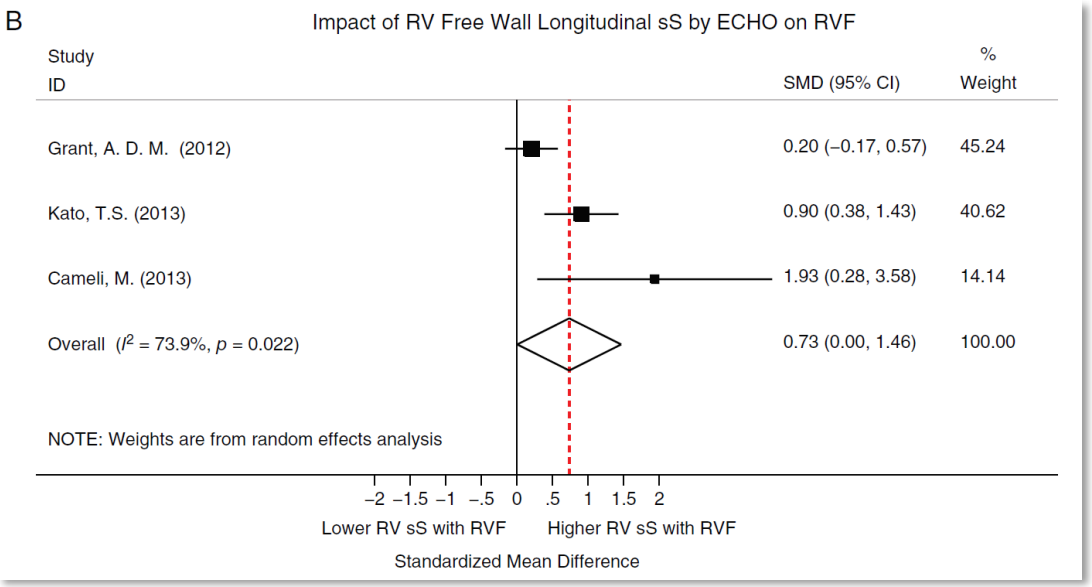
European Journal of Heart Failure (2017) **19**, 926–946

Rapport Ø RV/LV

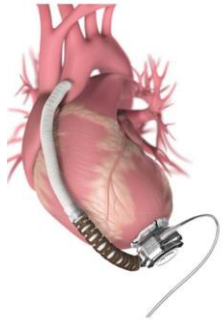
Systolic strain Right free ValF





Clinical Management of Pediatric Ventricular Assist Devices

David S. Cooper, MD, MPH[1]; René Prêtre, MD[2]



Pediatr Crit Care Med 2013; 14:S27–S36

- Assistance ventriculaire à débit continu
- Assistance ventriculaire pulsatile

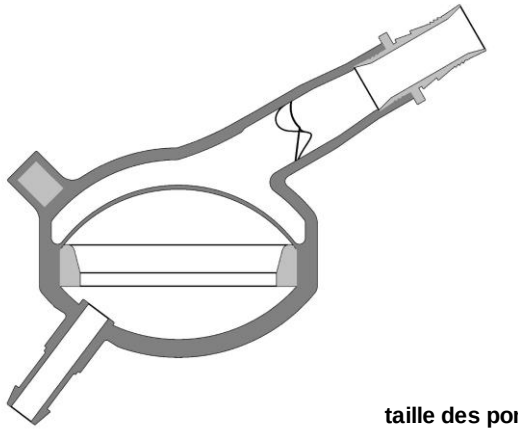
TABLE 2. Main Differences Between Pulsatile and Continuous Flow Devices

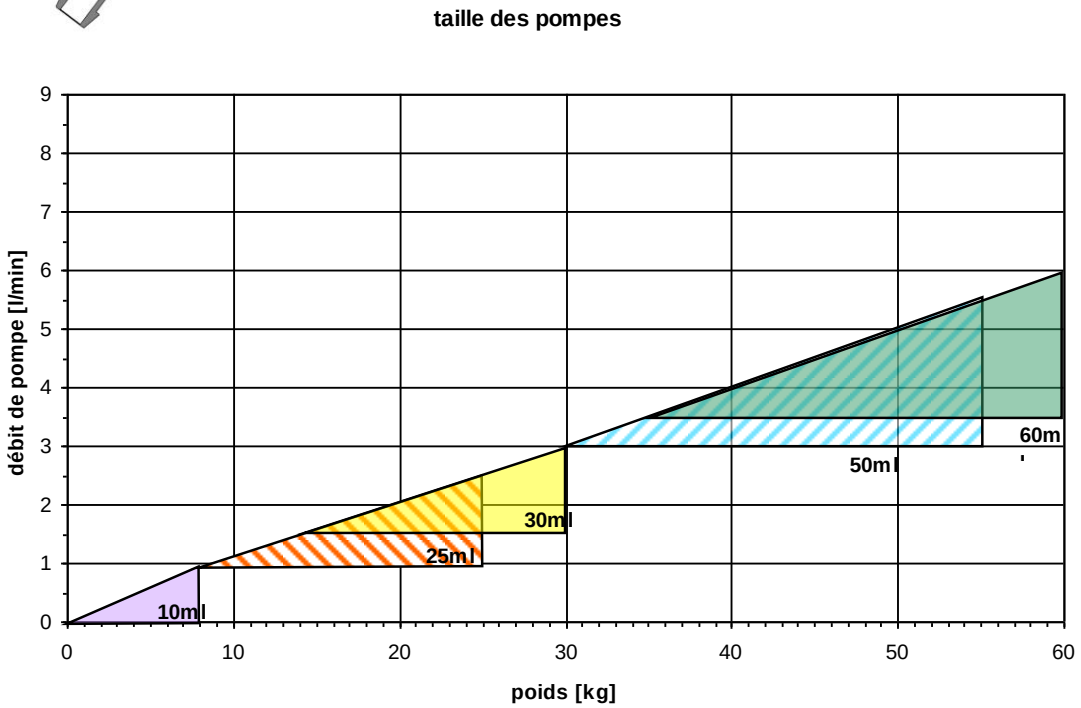
	Pulsatile Device	Continuous Device
Complexity	++	+
Possibility to upgrade to biventricular assist device support[a]	+++	+
Stroke volume (cardiac output)	Fixed	Variable
Recovery of failing peripheral organs	++	+
Risk of infection[b]	++	+
Risk of thrombosis[b]	++	+
Risk of stroke[b]	++	+
Risk of device failure	++	+
Risk of right-sided failure (right ventricle, liver)[b]	++	+
Suitability in heart failure due to dilated cardiomyopathy[c]	++	+++

[a]Upgrade in a continuous flow system requires the implantation of another system (two driving consoles, etc.).
[b]Derived from the adult literature.
[c]Continuous flow systems are available for patients greater than 0.7 m^2. Currently, only pulsatile systems exist for patients less than 0.7 m^2.

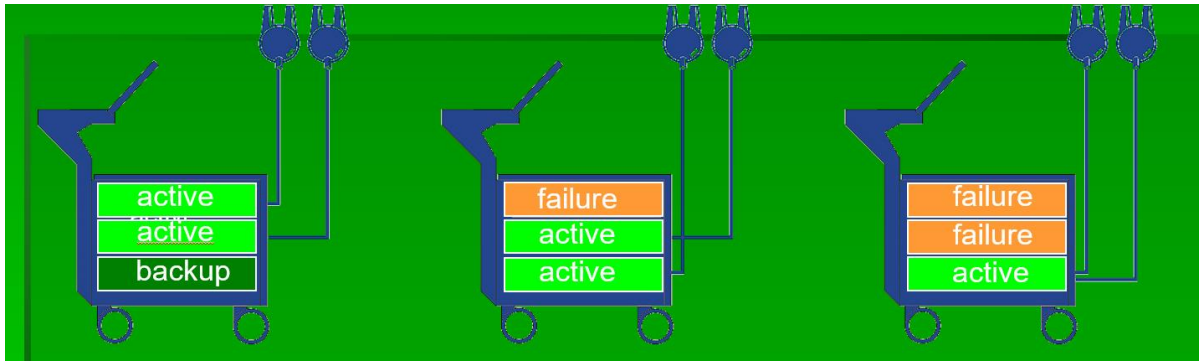
Excor – Berlin Heart

- Paroie en polyurethane transparent.
- 2 chambres…
  - Chambre sanguine..
  - Chambre gazeuse
- …séparées par une membrane triple couche.
- La chambre gazeuse est connectée à l'IKUS.
- La chambre sanguine est connectée au patient.
  - Orifice de drainage.
  - Orifice d'éjection.





Excor – Berlin Heart



Excor – Berlin Heart

- L'assistance gauche consiste habituellement en une canulation apicale VG et Aortique.
- Pour le ventricule droite: canulation oreillette droite et artère pulmonaire.
- Les réglage:
  - La fréquence.
  - La pression d'aspiration (- 40mm Hg)
  - La pression d'éjection (220 mm Hg (80 bts/mn))
  - Le temps relatif systolique (40%).
- Un impératif: obtenir un remplissage et une éjection complète à chaque cycle.

Excor – Berlin Heart

Remplissage insuffisant

- Corriger une hypovolémie.
- Augmenter le temps de diastole.
- Augmenter la pression de drainage.
- Rechercher un problème technique sur la canule apicale. (Echocardio)
- Rechercher une complication
  - Epanchement péricardique.
  - Dysfonction ventriculaire droite.

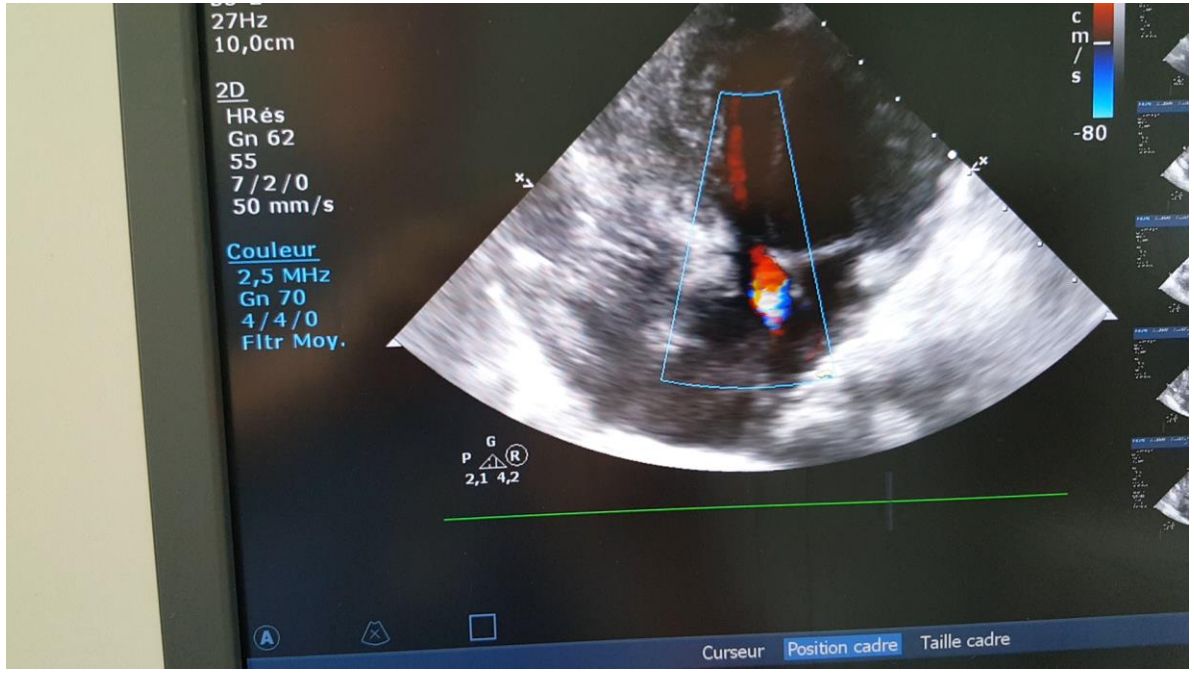
Ejection insuffisante

- Augmenter prudemment la pression d'éjection.
- Augmenter le temps systolique.
- Diminuer les résistance vasculaires systémiques.
- Rechercher un problème technique sur la canule aortique.

Excor – Berlin Heart

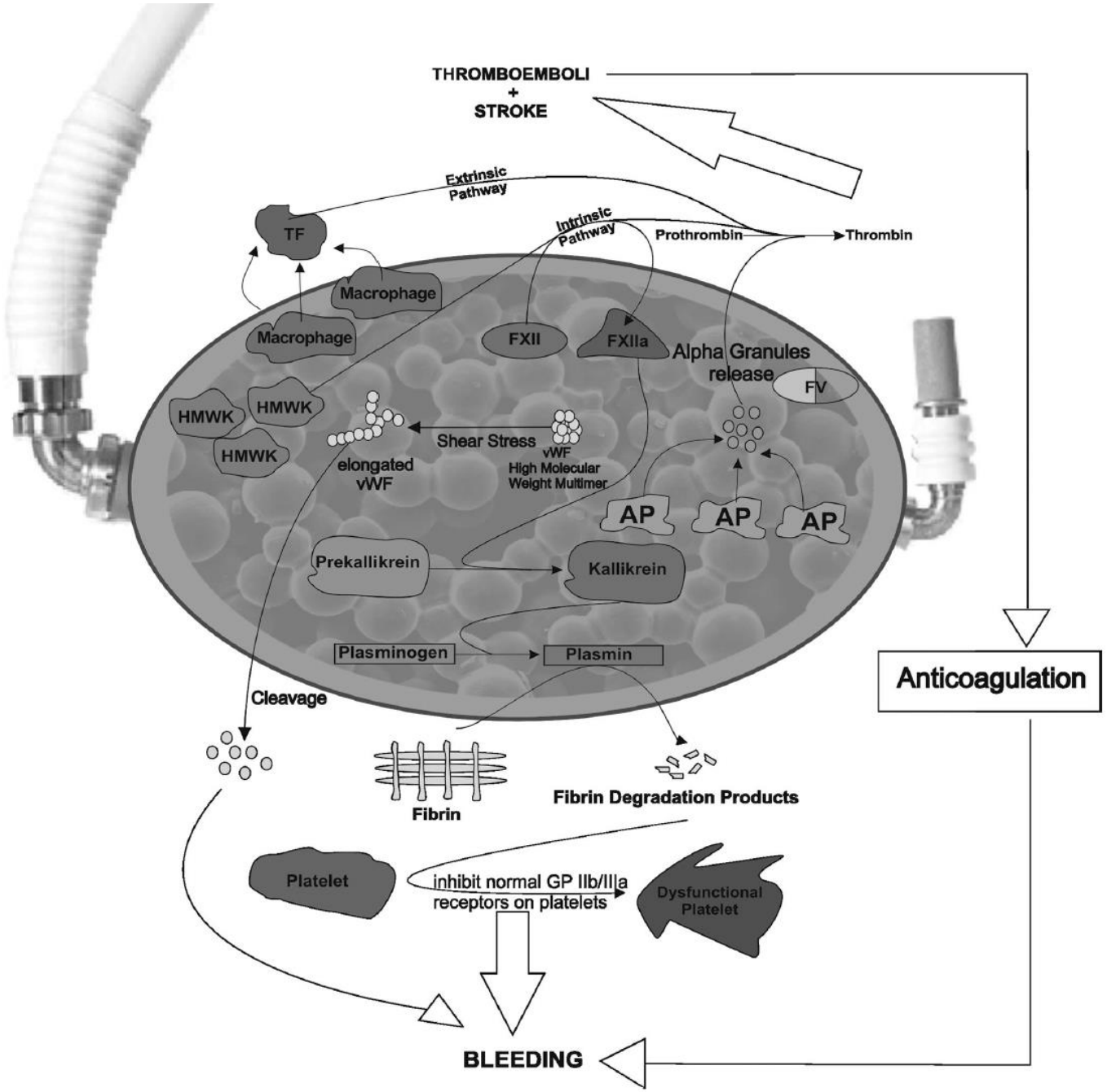
- **Mauvais remplissage de la chambre.**
- **Expansion volémique pendant la nuit.**

- **Retrait des drains la veille.**
- **HNF surdosée le matin.**



Physiologie appliquée au VAD

- Adsorbtion du Kininogène de HPM sur le titanium du VAD ➔ activation de la voie intrinsèque.
- Macrophages et monocytes expriment du facteur tissulaire ➔ activation de la voie extrinsèque.
- Activation plaquettaire avec libérattion de facteurV ➔ amplification des phénomènes thrombotiques.
- Activation de la fibrinolyse par le système Kallikreine.
- Les produits de dégradation de la fibrine ➔ fixation R G2b3a.
- Déficit vWf



Excor – Berlin Heart

TABLE 6. Anticoagulation for Ventricular Assist Devices

Device	Anticoagulation	Anticoagulation Monitoring	Timing of Anticoagulation
Impella 2.5	Heparin	Factor Xa level, 0.3–0.5; aPTT, 45–55 s	Initiate concurrently with percutaneous implantation
Rotaflow VAD	Heparin	Factor Xa level, 0.3–0.5; aPTT, 55–65 s or ACT, 180–200	Initiate and maintain heparin infusion once post-implantation bleeding has ceased
Berlin Heart EXCOR Pediatric	Perioperative: UFH; long-term: LMWH or warfarin + antiplatelet therapy	UFH factor: Xa level, 0.35–0.5 U/mL; LMWH: Xa level, 0.6–1 U/mL; warfarin: INR 2.5–3; antiplatelet: TEG monitoring	0–24 h: no anticoagulation; >24–48 hr: UFH; >48 hr: transition to LMWH or vitamin K antagonist[a] and dipyridomole; >4 d: ASA[b]
HeartMate II	Perioperative: UFH; long-term: warfarin + antiplatelet therapy	UFH: aPTT, 55–65 s or 1.5–1.8× normal; warfarin: INR, 1.5–2; antiplatelet: TEG monitoring	0–24 h: no anticoagulation; >24 h: UFH; >48 h: transition to warfarin and ASA

aPTT = activated partial thromboplastin time, ACT = activated clotting time, INR = international normalized ratio, TEG = thromboelastogram, UFH = unfractionated heparin, LMWH = low–molecular weight heparin, ASA = acetylsalicylic acid.

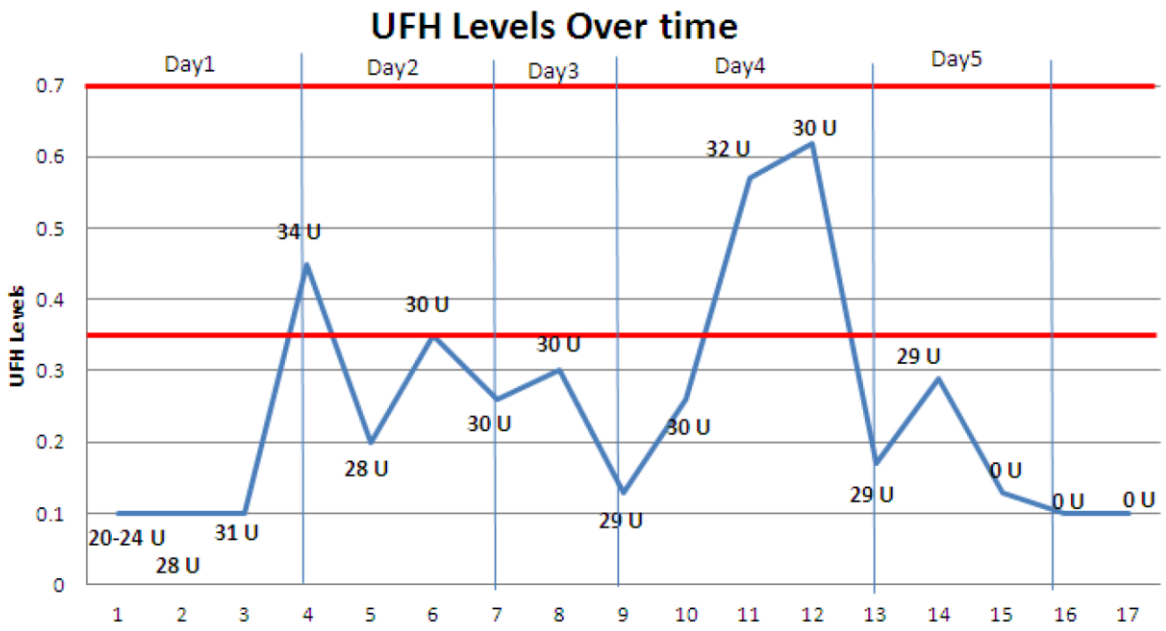
[a]Vitamin K antagonist (warfarin) only used in children younger than 1 yr with stable enteral nutrition.

[b]Dipyridamole started if hemostatically stable, platelet count greater than 40,000/μL.

Pourquoi avons-nous tant de difficulté à maitriser l'hémostase dans ce contexte??

Non respect du protocole d'anticoagulation?

- Atteinte retardée des objectifs d'anticoagulation.
- Patient rarement en fenêtre thérapeutique ou, en tout cas insuffisamment.
- Prélèvements contaminés par de l'héparine, ne reflétant pas le vrai status hémostatique.



Pourquoi avons-nous tant de difficulté à maitriser l'hémostase dans ce contexte??

Le protocole est il adapté?

Center	aPTT or anti-Xa	Target range	Highest range
IDE trial	aPTT	0.35-0.5	--
Boston Children Hospital	Anti-Xa	0.35-0.5	0.5-0.7
Stanford	Anti-Xa	0.35-0.5	--
St Louis	Anti-Xa	0.35-0.5 (<3 mos) 0.35-0.7 (>3 mos)	--
Texas Children's	Anti-Xa	0.35-0.7	0.7-1
Mount Sinai, NY	Anti-Xa and aPTT	0.35-0.5 65-80	--
Edmonton, Stollery	Anti-Xa	0.35-0.5	--
Freeman, Newcastle	Anti-Xa	0.35-0.7	0.7-1
Zurich, University Children	Anti-Xa	0.35-0.7	0.8
German Heart Center	aPTT	60-80	--

Center	Criteria for AP	1st AP Dose range	2nd AP Dose range	3rd AP
IDE trial	Plt>40 000 TEG ADP <70%	Dipyridimol 1mg/kg QID	ASA 0.5mg/kg BID	Based on TEG (Clopidogrel)
Boston Children Hospital	Same IDE	ASA 1 mg/kg BID	Dipyridamol	Based on TEG
Stanford	3-5 days Bleeding	ASA max 30mg/kg/day	Dipyridamol	Clopidogrel
St Louis	Plt >50 000 TEG AA<70	ASA 0.5 mg/kg BID (max 5 mg/kg/d)	Dipyridamol (optional)	--
Texas Children's	~3-5 days	ASA ~4 mg/kg/day	Dipyridamol	--
Mount Sinai, NY	~3-5 days	ASA 0.5 mg/kg BID (max 5 mg/kg/day)	Dipyridamole max 6g/kg/day	Based on PFA-100
Edmonton, Stollery	24-48hrs, TEG	ASA 0.5 mg/kg BID	Dipyridamole	Based on TEG
Freeman, Newcastle	>48 hrs, min bleed	IV Dipyridamol 0.5mg/kg ggt	ASA 1mg/kg BID	Based on TEG (Clopidogrel)
Zurich	Same as IDE	ASA 0.5 mg/kg BID	Dipyridamol	Based on TEG
German Heart Center	1 wk, wires out	ASA 1mg/kg/day (max 5 mg/kg/day)	Clopidogrel	--

Platelet testing to guide aspirin dose adjustment in pediatric patients after cardiac surgery

Sirisha Emani, PhD **The Journal of Thoracic and Cardiovascular Surgery • Volume 154, Number 5**

Results: Suboptimal platelet response to aspirin was detected in 64 of 430 patients (15%) and thrombosis was detected in 11 patients (2.6%). Lack of aspirin responsiveness on initial testing was a significant risk factor for thrombosis ($P < .001$) independent of age, weight, diagnosis, and initial aspirin dose. Dose escalation based on aspirin testing was performed in 40 of 64 patients, and significantly lower rate of thrombosis was observed in patients who underwent dose escalation compared with those without dose escalation (0/40 vs 9/24, $P < .001$). By multivariable analysis, the only significant independent risk factor for thrombosis was failure to increase aspirin dose after initial unresponsiveness ($P < .001$).

The Verify Now device allows automated testing of aspirin responsiveness in pediatric patients.

Excor – Berlin Heart

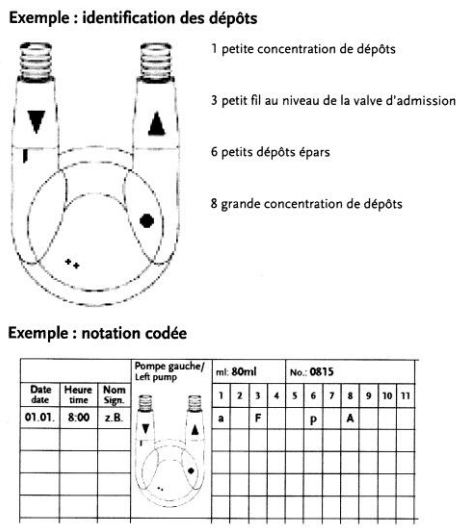
Surveillance de la chambre

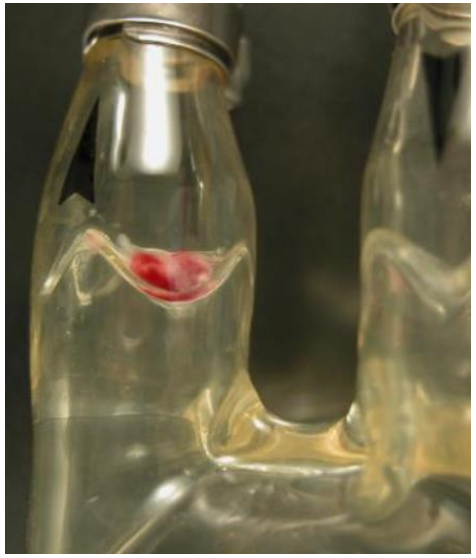
p	petit dépôt ponctuel
P	gros dépôt Ponctuel
a	petit aire de dépôt
A	grande Aire de dépôt
l ou f	petit dépôt linéaire (filamenteux)
L ou F	grand dépôt Linéaire (Filamenteux)
t	petit thrombus
T	gros Thrombus
~	Au dessus des caractères: dépôt flottant

Dépots inquiétants si:

- Ø > 5mm
- Multicolore
- Mobile

} Changement ventricule





Clinical Management of Pediatric Ventricular Assist Devices

David S. Cooper, MD, MPH[1]; René Prêtre, MD[2]

HeartMate II

- Petite taille.
- Implantation dans l'axe de l'orifice de la valve systémique.
- Moins de complications thrombo-emboliques.
- Expérience pédiatrique limitée.
- S^2 cut 1.3 ➔ 1.5 m^2.
- Réglage d'une puissance (lié au nbre de tr/mn), estimation du débit.

A multicenter study of the HeartWare ventricular assist device in small children

The Journal of Heart and Lung Transplantation

Table 1 Baseline Characteristics, HVAD Settings and Outcomes of Study Patients ($n = 13$)

Variable	
Age (years) [median (range)]	8.1 (3.7–10.5)
Gender male [*n* (%)]	7 (54)
Weight (kg) [median (range)]	18.6 (13.5–23.0)
Height (cm) [median (range)]	117 (99–150)
BSA (m^2) [median (range)]	0.8 (0.6–0.9)
Diagnosis	
Cardiomyopathy [*n* (%)]	8 (61.5)
Myocarditis [*n* (%)]	1 (7.7)
Congenital heart disease (biventricular) [*n* (%)]	3 (23.1)
Graft failure post-transplantation [*n* (%)]	1 (7.7)

Table 2 Adverse Events

Variable		Events/patient-year
Bleeding requiring transfusion of RBC[a]	5 (38.5)	0.88
Early	3 (23.1)	0.53
Late	2 (15.4)	0.35
Acute renal dysfunction	4 (30.8)	0.70
Maximum creatinine >3 ULN	3 (23.1)	0.53
Requiring dialysis	1 (7.7)	0.18
Ventilator support >6 days [*n* (%)]	5 (38.5)	0.88
Secondary RV failure [*n* (%)]	4 (30.8)	0.70
Temporary mechanical support of RV[b] [*n* (%)]	2 (15.4)	0.35
RV support (days) [median (range)]	7 (6–8)	
CVP >18 mm Hg	1 (7.7)	0.18
Need for inotropic support >7 days	1 (7.7)	0.18
Chronic PDE-5 inhibitor therapy [*n* (%)]	9 (69.2)	
Drive-line infection [*n* (%)]	2 (15.4)	0.35
Systemic infection [*n* (%)]	2 (15.4)	0.35
Neurologic dysfunction		
Thromboembolic [*n* (%)]	2 (15.4)	0.35
Hemorrhagic [*n* (%)]	0	0.0
Severity		
Transient deficit, no residuum [*n* (%)]	1 (7.7)	0.18
Mild[c] [*n* (%)]	1 (7.7)	0.18
Device thrombosis [*n* (%)]	4 (30.8)	0.70
Medical treatment [*n* (%)]	1 (7.7)	0.18
Device exchange [*n* (%)]	1 (7.7)	0.18
Device decommissioned [*n* (%)]	1 (7.7)	0.18

Second annual Pediatric Interagency Registry for Mechanical Circulatory Support (Pedimacs) report: Pre-implant characteristics and outcomes

Blume E.D. J Heart Lung Transplant 2017

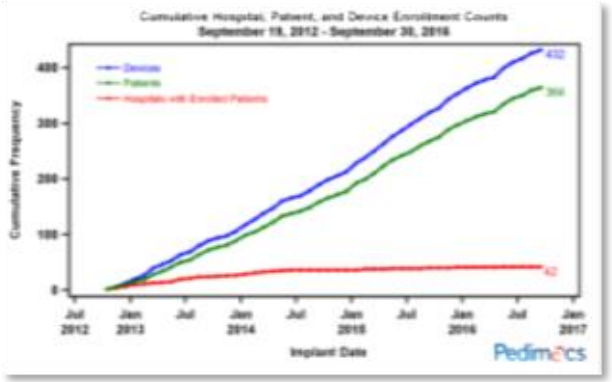


Table 1 Preimplant Characteristics of Pedimacs Patients (n=364)

Characteristic	Mean ± SD or No. (%)
Age, year	9.3 ± 6.5
Age group	
<1 year	69 (19.0)
1–6 years	66 (18.1)
6–10 years	56 (15.4)
11–19 years	173 (47.5)
Diagnosis	
Cardiomyopathy	223 (61.3)
Myocarditis	41 (11.3)
Congenital heart disease	77 (21.2)
Other	23 (6.3)
No previous cardiac operation	209 (57.4)
Heart failure before admission	206 (56.6)
AST > 100 U/liter	79 (22.6)
ALT > 100 U/liter	83 (23.6)
Creatinine > 1.6 mg/dl	17 (4.7)
Intubated	149 (49)
Inotropes	339 (93)
Paralyzed	69 (23)
TPN dependent	106 (35)

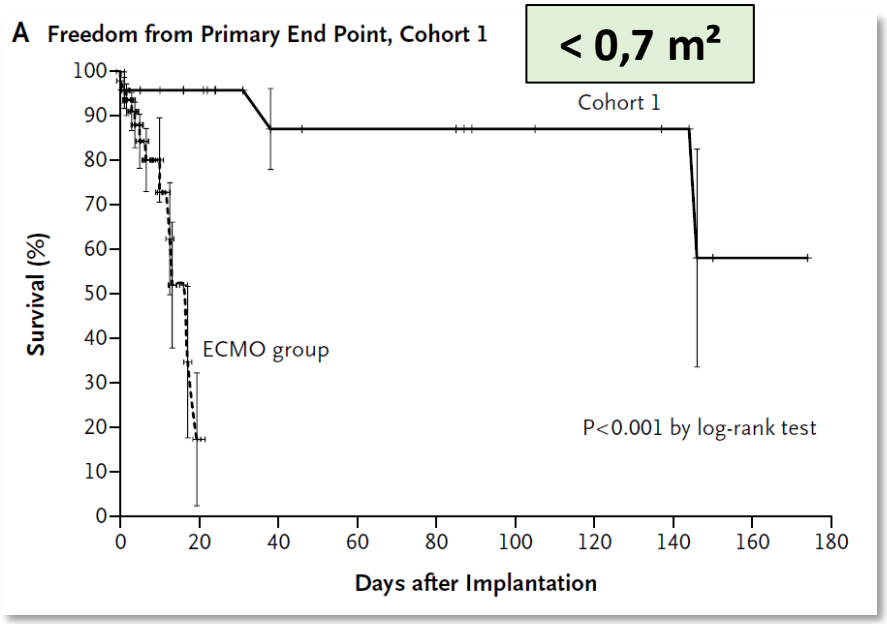
Table 4 Pre-Implant Patient Profile by Device Classification

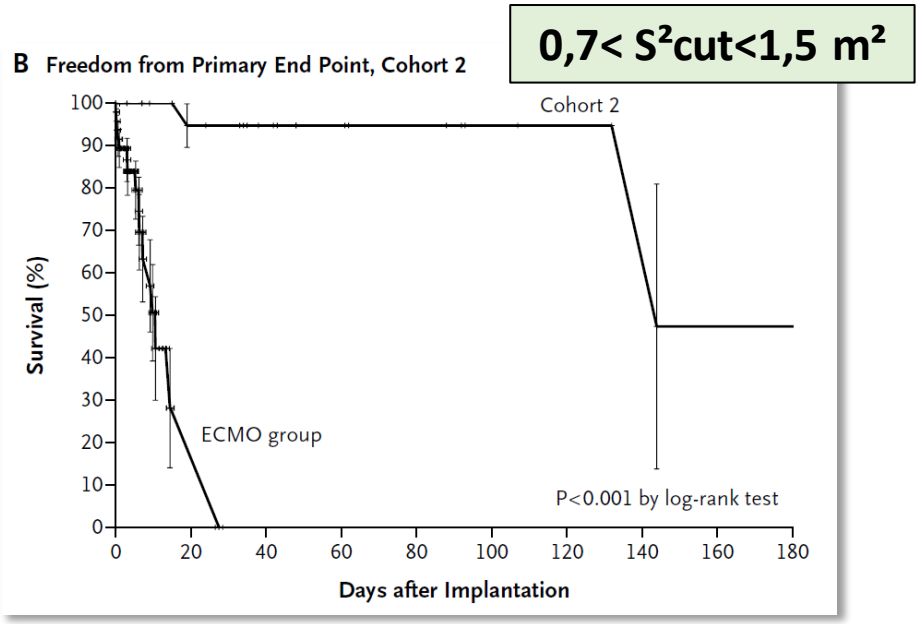
Pre-implant patient profile[a]	Paracorporeal pulsatile No. (%)	Paracorporeal continuous No. (%)	Implantable continuous No. (%)
1: Critical cardiogenic shock	40 (38)	30 (51)	28 (16)
2: Progressive decline	56 (54)	25 (42)	110 (64)
3: Stable but inotrope dependent	6 (6)	4 (7)	26 (15)
4–7: Resting symptoms or less sick	2 (2)	...	8 (5)

[a]The pre-implant patient profile was missing for 6 patients.

Prospective Trial of a Pediatric Ventricular Assist Device

Charles D. Fraser **N Engl J Med 2012;367:532-41.**

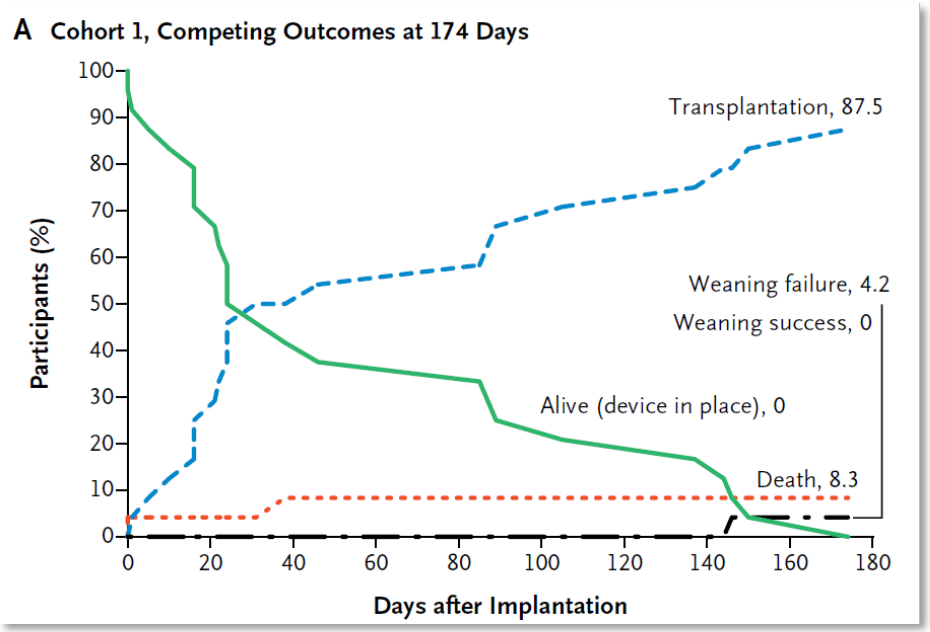


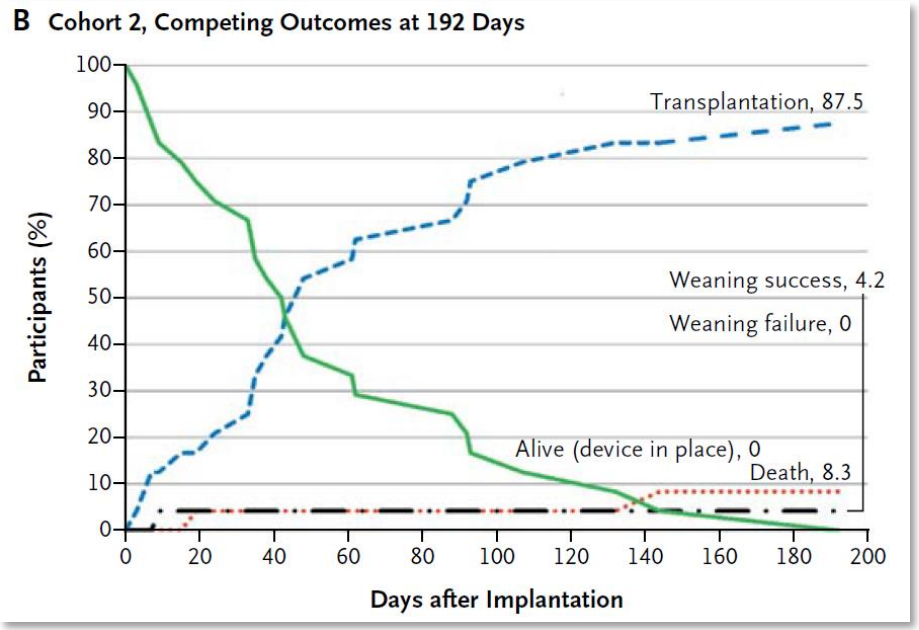


- **2x24 patients réparti en 2 groupes / S² cutané.**
- **VAD = Excor Berlin Heart.**
- **Comparaison à une cohorte historique contemporaine issue ndu registre ELSO.**
- **Analyse avec score de propension.**

Prospective Trial of a Pediatric Ventricular Assist Device

Charles D. Fraser **N Engl J Med 2012;367:532-41.**

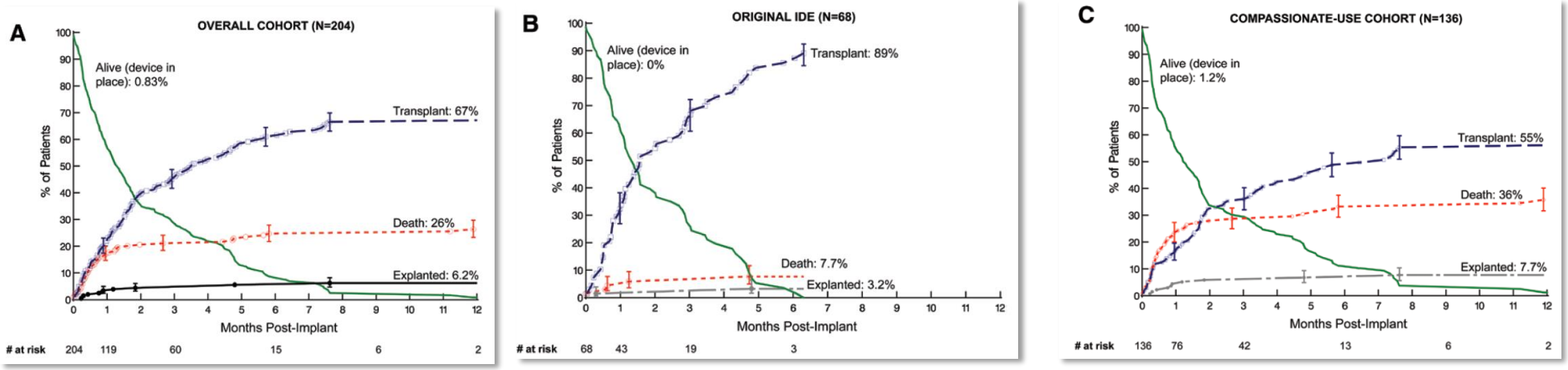




- ***Serious events pour 0,07$_{(c1)}$/ 0,08$_{(c2)}$ patient/jour.***
  1. Major bleeding 42%$_{(c1)}$ / 50$_{(\%c2)}$ des patients.
  2. Infection 63%$_{(c1)}$ / 50%$_{(c2)}$ des patients.
  3. Stroke 29%$_{(c1)}$ / 29%$_{(c2)}$ des patients.

Berlin Heart EXCOR Pediatric Ventricular Assist Device for Bridge to Heart Transplantation in US Children

Christopher S. Almond *Circulation*. 2013;127:1702-1711 Circulation



- 204 patients pédiatriques réunissant l'effectif d'une étude prospective et une cohorte ayant bénéficiée d'une implantation compassionnelle.
- Mortalité corrélée au petit âge, à l'hyperbillirubinémie et au recours à un BiVAD de façon indépendante.
- La 1ère cause de décès = stroke.
- 33% d'AVC: 2/3 ischémiques – 1/3 hémorragiques, dont 13% sont fatals.

INTERMACS Adverse Event Definitions: Adult and Pediatric patients

This document contains the following adverse event definitions:

- Hemolysis
- Right Heart Failure
- Device Malfunction
- Major Bleeding
- Major Infection
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- Cardiac Arrhythmias
- Pericardial Fluid Collection
- Myocardial Infarction
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- Wound Dehiscence
- Arterial Non-CNS Thromboembolism
- Other SAE
- Hepatic Dysfunction
- Hypertension
  - *Adult definition*
  - *Pediatric definition*
- Renal Dysfunction

Adverse events in children implanted with ventricular assist devices in the United States: Data from the Pediatric Interagency Registry for Mechanical Circulatory Support (PediMACS)

J Heart Lung Transplant 2016;35:569–577

- **PEDIMACS** Sept/12 ➔Juin/17
- **Age**: 11 ans (13j – 18 ans)
- **Etiologies:**
  - ➢Cardiomyopathie 73%
  - ➢Myocardite 9%
  - ➢CHD 18%
- **Délai attente transplantation:**
  - ➢Pulsatile flow ➔ 3,8±3,3 mois
  - ➢Continuous flow ➔ 3,4±3,8 mois
- **81% de survie à 6 mois.**

Table 2 Baseline Characteristics of Study Population

	Pulsatile flow (n = 91)	Continuous flow (n = 109)	p-value
Age (years)	4.6 ± 5.0	14.4 ± 3.7	<0.0001
Female	42 (46.2)	36 (33.0)	0.0581
Cardiac diagnosis			0.0083
Cardiomyopathy	56 (61.5)	90 (82.6)	
Myocarditis	10 (11.0)	7 (6.4)	
Congenital heart disease	24 (26.4)	11 (10.1)	
Other	1 (1.1)	1 (0.9)	
Prior cardiac surgery	50 (54.9)	26 (23.9)	<0.0001
Prior ECMO	22 (24.2)	8 (7.3)	0.0009
INTERMACS level			0.0139
I (critical cardiogenic shock)	32 (36.8)	20 (19.0)	
II (progressive decline on inotropes)	43 (49.4)	64 (61.0)	
III (stable, but inotrope-dependent)	7 (8.0)	18 (17.1)	
IV (resting symptoms)	5 (5.7)	3 (2.9)	
Pre-implant device strategy			0.0068
Bridge to transplant—listed	69 (75.8)	59 (54.1)	
Bridge to candidacy	19 (20.9)	44 (40.4)	
Destination therapy	2 (2.2)	6 (5.5)	
Bridge to recovery	1 (1.1)	0 (0.0)	
Implant device type			0.0068
LVAD	59 (64.8)	102 (93.6)	
RVAD	3 (3.3)	1 (0.9)	
BiVAD	23 (25.3)	6 (5.5)	
TAH	6 (6.6)	0 (0.0)	

Data expressed as mean ± standard deviation or as number (%). BiVAD, biventricular assist device; ECMO, extracorporeal membrane oxygenation; INR, international normalized ratio; INTERMACS, Interagency Registry for Mechanically Assisted Circulatory Support; LVAD, left ventricular assist device; RVAD, right ventricular assist device; TAH, total artificial heart.

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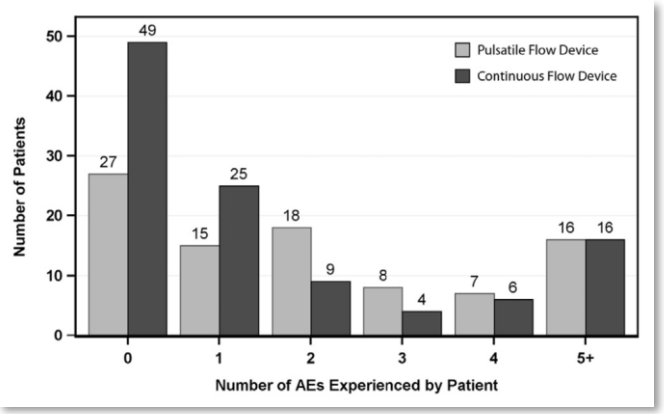
Table 3 Adverse Event Incidence

Event type	Number of events: Pulsatile-flow VAD	Continuous-flow VAD	Total
Arterial non-CNS thromboembolism	0	2	2
Bleeding	31	37	68
Cardiac arrhythmia	9	17	26
Device malfunction	63	16	79
Hepatic dysfunction	3	4	7
Infection	38	40	78
Pump-related, including drive-line	(8)	(6)	(14)
Bloodstream/sepsis	(13)	(10)	(23)
Pulmonary	(7)	(9)	(16)
Other	(10)	(15)	(25)
Neurologic dysfunction	41	11	52
Ischemic stroke	(10)	(1)	(11)
Hemorrhagic stroke	(8)	(1)	(9)
Other	(23)	(9)	(32)
Other SAE	22	18	40
Pericardial drainage	4	9	13
Psychiatric episode	1	9	10
Renal dysfunction	8	7	15
Respiratory failure	12	14	26
Venous thromboembolism	0	1	1
Wound dehiscence	0	1	1
Total	232	186	418

CNS, central nervous system; SAE, serious adverse event; VAD, ventricular assist device; ( ) signify number of events in a subcategory.

Ces quatre complications réunissent 66% de toutes les complications



- **28 décès**
  - ➢11 de défaillance multi-organe.
  - ➢7 de défaillance circulatoire.
  - ➢1 de défaillance respiratoire.
  - ➢1 sevrage dans le cadre d'une L.A.T.A.
- **53,4 complications%patient/jour**
- Au moins 1 complication chez:
  - ➢70% de patients-pulsatile flow.
  - ➢55% des patients – continuous flow.

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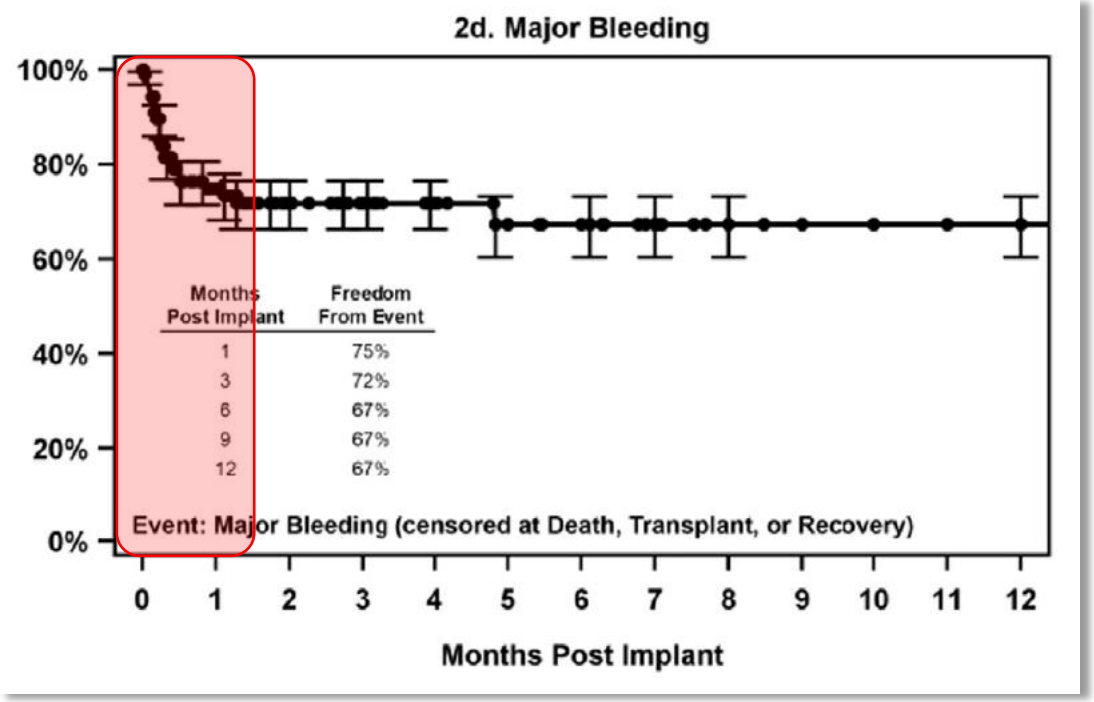
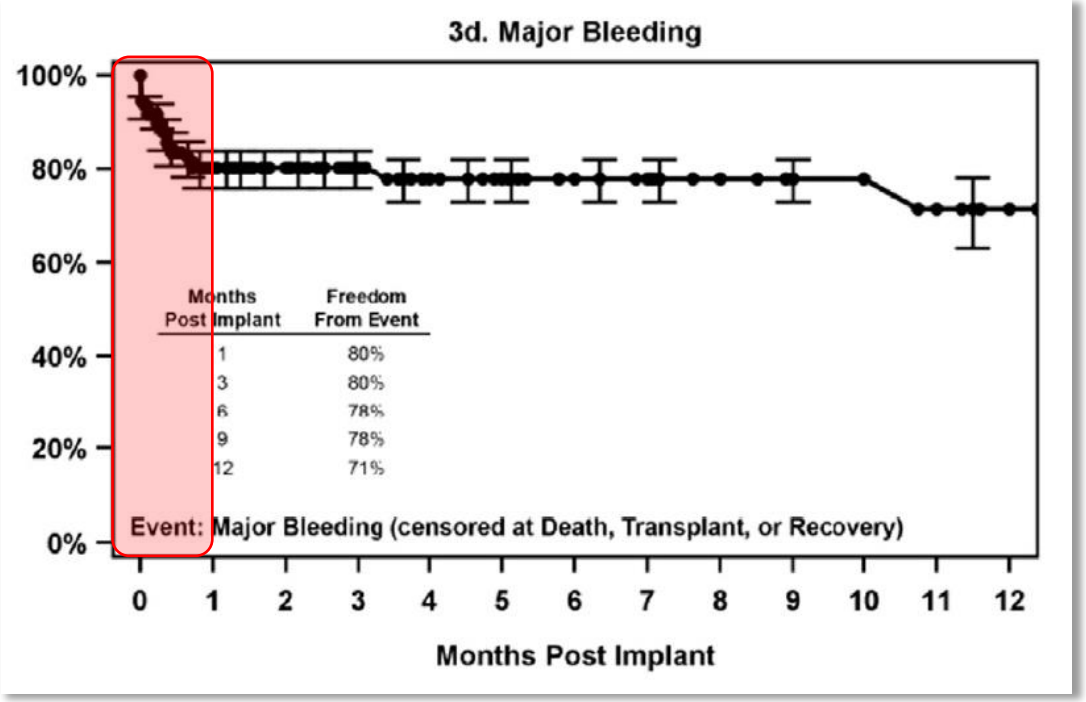
Major Bleeding et Pulsatile Flow VAD



Major Bleeding et Continuous flow VAD



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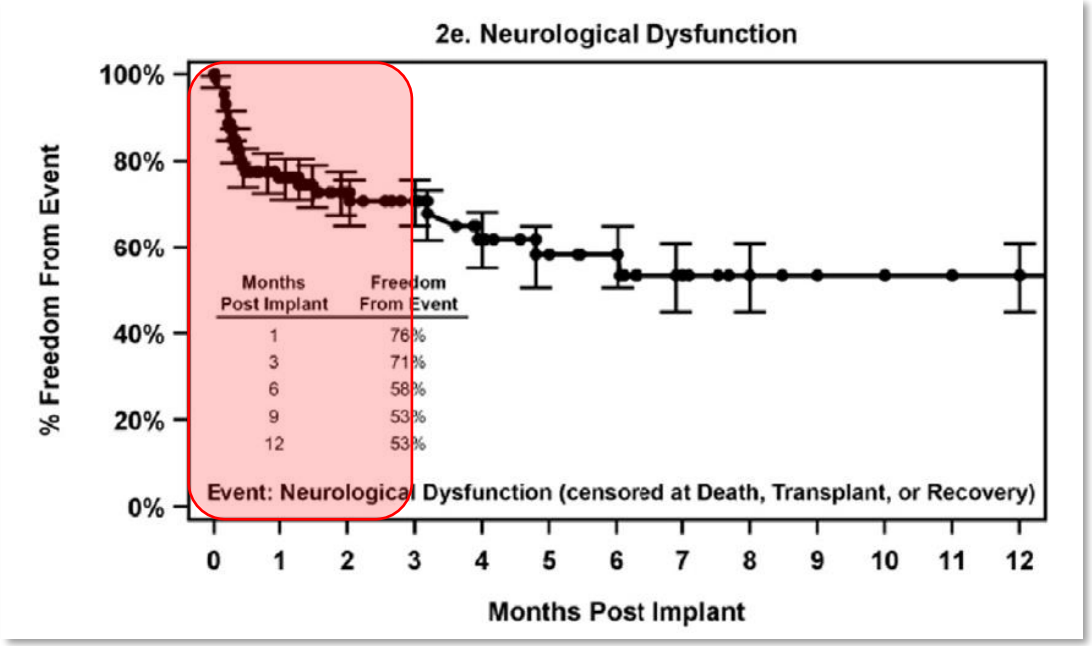
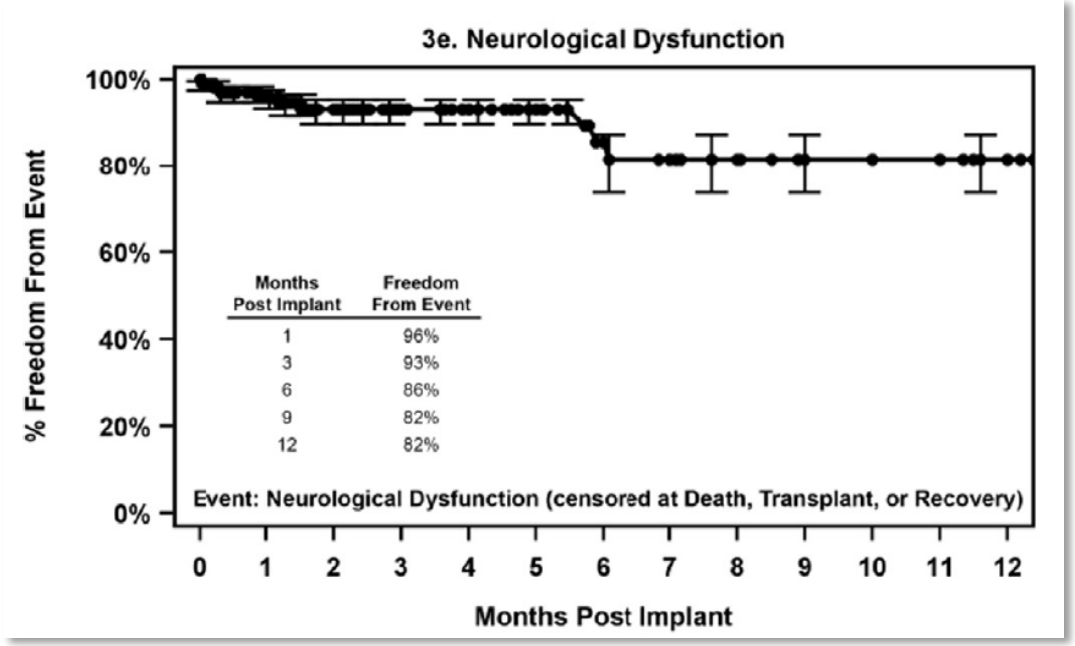
Evènements Neurologiques et Pulsatile-Flow VAD



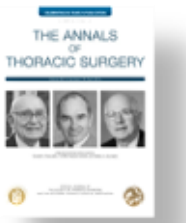
Evènements Neurologiques et Continuous-Flow VAD



Excor- Complications Neurologiques

Center	Time	N	Number of Cerebrovascular Events (CVE)	Types of CVE	Timing of CVE
NA IDE trial (47 centers in US/Canada)	2007-2010	204	73 events in 59 pts **(29%)**	**89% ischemic** 9% hemorrhagic	50% within first 14 days, 25% in next 14 days (75% early)
Newcastle/Great Ormond Street	2004-2011	102	26 pts **(25%)**	**88% ischemic** 12% hemorrhagic	All early stokes (<6 wks) were fatal
Italy, Bambino Gesu	2002-2012	25	9 pts **(36%)**	55% hemorrhagic 44% ischemic	Throughout support
Turkey	2002-2012	9	2 pts **(22%)**	**100% ischemic**	Late (>400 days of support)
Little Rock, Arkansa	2005-2012	39	16 events in 12 pts **(31%)**	**75% ischemic** 13% hemorrhagic 13% conversions	Highest risk early (prior to establishment of therapeutic AC
Dallas	2006-2010	14	4 pts **(28%)**	n/a	n/a

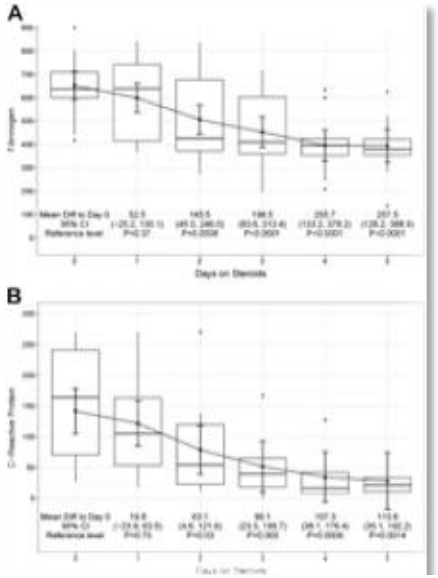
Steroid Therapy Attenuates Acute Phase Reactant Response Among Children on Ventricular Assist Device Support



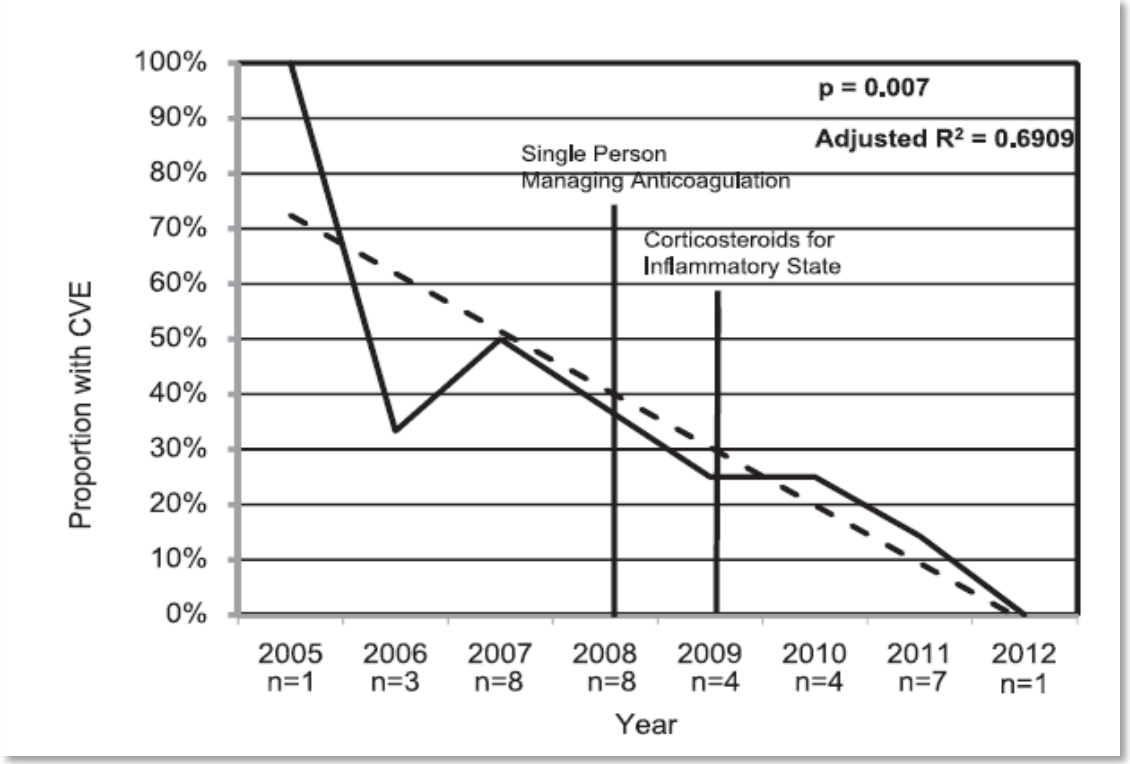
Jonathan W. Byrnes, **Ann Thorac Surg 2015;99:1392–8**

Incremental Reduction in the Incidence of Stroke in Children Supported With the Berlin EXCOR Ventricular Assist Device

Jonathan W. Byrnes, **Ann Thorac Surg 2013;96:1727–33**



- Importance d'une équipe référente qui manage la conduite du traitement anticoagulant et antiaggrégant.
- Idéalement en lien avec le laboratoire d'hémostase.



Incremental Reduction in the Incidence of Stroke in Children Supported With the Berlin EXCOR Ventricular Assist Device

Jonathan W. Byrnes

Ann Thorac Surg 2013;96:1727–33

Table 3. Nature of Stroke, Timing, and Radiographic Evidence

Pt	Stroke Nature	VAD Day	Radiographic Findings	Neurologic Outcome
1	Hemorrhagic	16	CT: Right intraparenchymal hemorrhage. Herniation of midline structures and effacement of right cerebral sulci.	Withdrawal of support secondary to neurologic devastation.
3	Embolic	2	CT: Edema left greater than right suggesting acute infarct. Edema in right frontal and left frontal, temporal, and parietal lobes.	Withdrawal of support secondary to neurologic devastation.
3	Hemorrhagic	42	CT: Encephalomalacia in frontal lobes and left temporal lobe. Right temporal lobe hemorrhage with subfalcine herniation and midline shift.	
8	Embolic	4	CT: Focal edema in left frontal lobe, insular cortex, and putamen.	No PSOM performed. At 6 weeks postexplant, severe right hemiplegia, moderate expressive and receptive speech deficit, and moderate cognitive defect at time of discharge. At 1 year, she was beginning to ambulate; residual right-sided hemiparesis. No speech or cognitive testing available.
9	Embolic	13	CT: Low attenuation in the right hemisphere, right basal ganglia, and mixed low and high attenuation change in the left thalamus	No PSOM performed. Patient had moderate left hemiplegia, moderate expressive and receptive speech deficit, and moderate cognitive defect at time of discharge 6 weeks postexplant. Patient monitored at referring center, no midterm follow-up.
9	Embolic	16	CT: New infarct in right putamen.	
13	Embolic	1	CT: Acute stroke of left posterior frontoparietal cortex.	6-week postexplant PSOM of 0. No physical disability at 1 year; WISC-IV of 87.

Incremental Reduction in the Incidence of Stroke in Children Supported With the Berlin EXCOR Ventricular Assist Device

Jonathan W. Byrnes

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Table 3. Nature of Stroke, Timing, and Radiographic Evidence

Pt	Stroke Nature	VAD Day	Radiographic Findings	Neurologic Outcome
14	Embolic	Explant	CT: Multiple low areas of attenuation compatible with infarction in the left parieto-occipital cortex, right putamen, right caudate nucleus, and in the right frontal lobe.	6-week postexplant PSOM of 1.5. At 1 year, mild right-sided hemiplegia, mild receptive and expressive language deficit; BSID-III of 90.
17	Subdural & Embolic	6	CT: 6- × 33-mm intrahemispheric subdural hematoma, right parietal edema.	6-week postexplant PSOM of 0. No physical disability at 1 year. WISC-IV of 108.
18	Embolic	27	CT: Right frontal and left cerebellar areas of attenuation.	6-week PSOM of 4. Follow-up at 1 year not possible secondary to patient death 6 months postexplant.
20	Embolic	20	CT: Initially normal, 48 hours later repeat CT demonstrated low attenuation in right thalamus.	6-week PSOM of 0. At 1 year, no physical disability; WISC-IV of 87.
27	Embolic	11	CT: Multifocal bilateral areas of hypodensity.	6-week PSOM of 10. At 1 year, wheelchair-bound, severe right and moderate left hemiplegia; severe expressive and receptive speech delay. No cognitive testing.
29	Embolic	95	CTA: Acute right carotid occlusion and right putaminal stroke. Near occlusion of the cavernous and supraclinoid RICA with extension into M1 segment. Collateral filling of right MCA via ACA.	6-week PSOM of 1. At 1 year, 4/5 left hand intrinsic muscle strength, otherwise no physical disability. No cognitive testing available.
29	Embolic	110	CTA: Evolution to encephalomalacia in areas of previous stroke. Now poor flow in proximal basilar artery with reconstitution of flow in the posterior cerebral arteries bilaterally by way of the PCA.	
33	Embolic	0	CT: Hypodensities in right parietal, right frontal, right occipital lobes consistent with infarct.	6-week postexplant PSOM of 2.5. Died of sudden death 8 months after transplant.

ACA = anterior cerebral artery; BSID-III = Bayley Scales of Infant Development—Third Edition; CT = computed tomography; CTA = computed tomography angiography; MCA = middle cerebral artery; PCA = posterior cerebral artery; PSOM = Pediatric Stroke Outcome Measure; RICA = right internal carotid artery; WISC-IV = Wechsler Intelligence Scale for Children—Fourth Edition; VAD = ventricular assist device.

Temporary Circulatory Support in U.S. Children Awaiting Heart Transplantation

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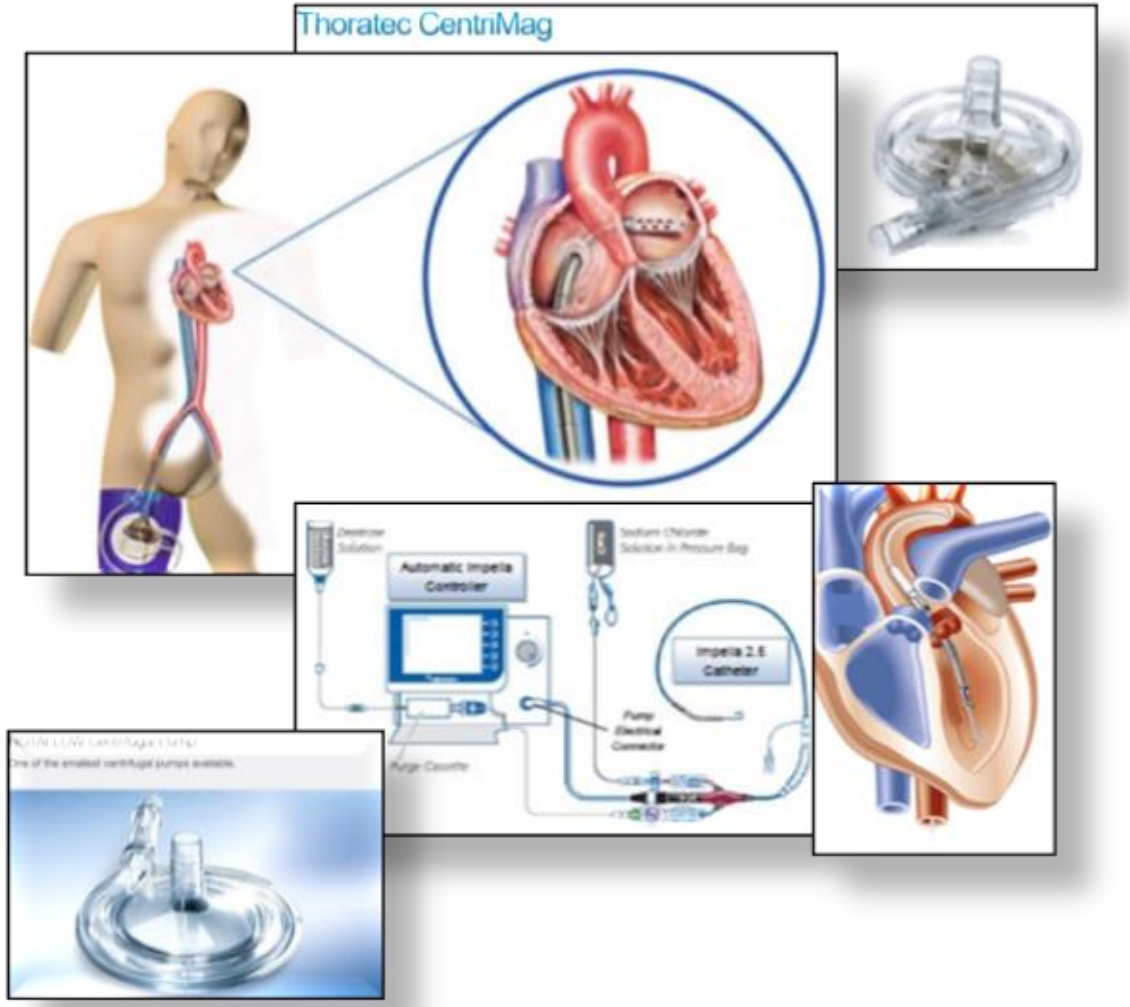

VS

ECMO

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- Pendant la période de l'étude 3316 « enfants » sur liste de transplantation cardiaque.
- 371 (11%) bénéficient d'une assistance mécanique de courte durée.
  - 278 (75%) ➔ ECMO.
  - 93 (25%) ➔ TCS
- Significativement plus d'enfant sous assistance au moment de l'inscription en liste dans le groupe ECMO (57% vs 34%).
- Les patients sous TCS sont ***plus vieux*** *(médiane 10 ans vs 1 an)*, ***plus lourds*** *(médiane 30 kg vs 7 kg)* et significativement ***moins porteur de CC*** *(30% vs 58%) p<0,001*.
- Les patients sous TCS ont une ***mortalité en liste inférieure*** une ***survie après transplantation*** et une ***survie globale supérieure***.

Analyse par score de propension

TABLE 2 Baseline Characteristics of Propensity Score-Matched Study Cohort

	Matched Patients (N = 164)	ECMO Cohort (n = 82)	TCS Cohort (n = 82)	p Value
Age at listing, yrs	9 (1-16)	10 (1-16)	6 (1-16)	0.956
Age categories at listing, yrs				
1-5	71 (43)	35 (43)	36 (44)	1.000
6-12	29 (18)	15 (18)	14 (17)	
13-17	34 (21)	17 (21)	17 (21)	
≥18	30 (18)	15 (18)	15 (18)	
Weight at listing, kg	25 (10-61)	37 (10-62)	23 (10-60)	0.970
Weight categories at listing, kg				
<5	23 (14)	13 (16)	10 (12)	0.544
5-10	29 (18)	13 (16)	16 (20)	
11-25	30 (18)	12 (15)	18 (22)	
26-50	21 (13)	13 (16)	8 (10)	
>50	61 (37)	31 (38)	30 (37)	
Cardiac diagnosis at listing				
Congenital heart disease	57 (35)	29 (35)	28 (34)	1.000
Cardiomyopathy	96 (59)	48 (59)	48 (59)	
Renal function at listing				
Preserved	120 (73)	61 (74)	59 (72)	0.872
Moderate dysfunction	27 (16)	12 (15)	15 (18)	
Severe dysfunction	17 (10)	9 (11)	8 (10)	
Dialysis at listing	12 (7)	6 (7)	6 (7)	1.000

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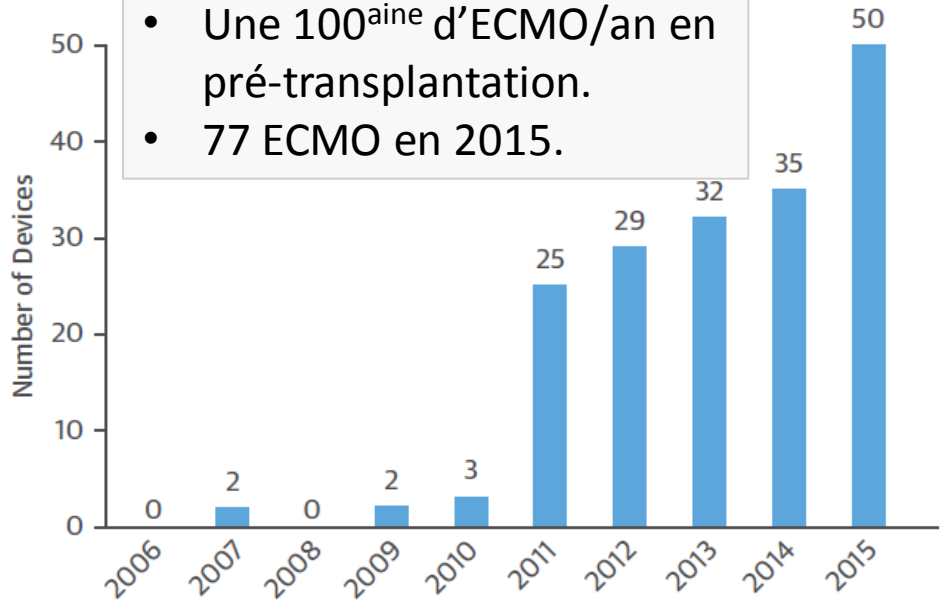
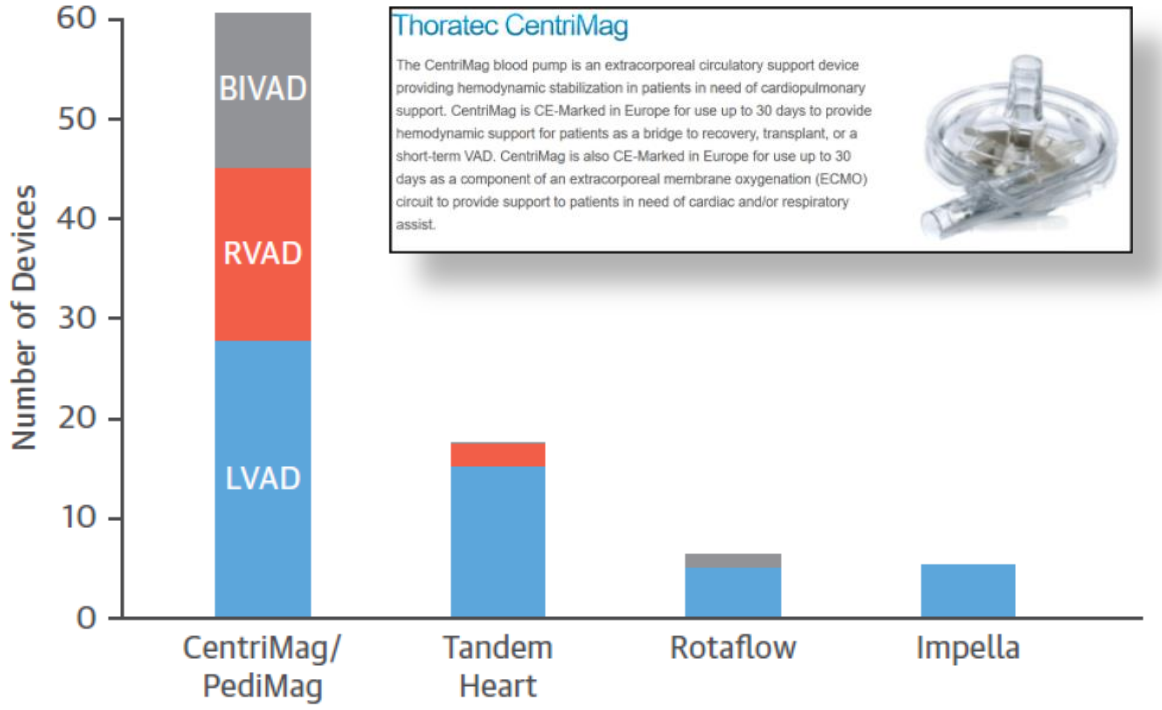
FIGURE 1 U.S. Growth of Temporary Circulatory Support Device Utilization as a Bridge to Transplant Over the Last 10 Years

- Une 100aine d'ECMO/an en pré-transplantation.
- 77 ECMO en 2015.



The use of temporary circulatory support devices has grown substantially over the past decade based on Organ Procurement and Transplant Network Registry data.

FIGURE 2 Type and Frequency of Temporary Circulatory Support Device Brands Used in Children as a Bridge to Transplant



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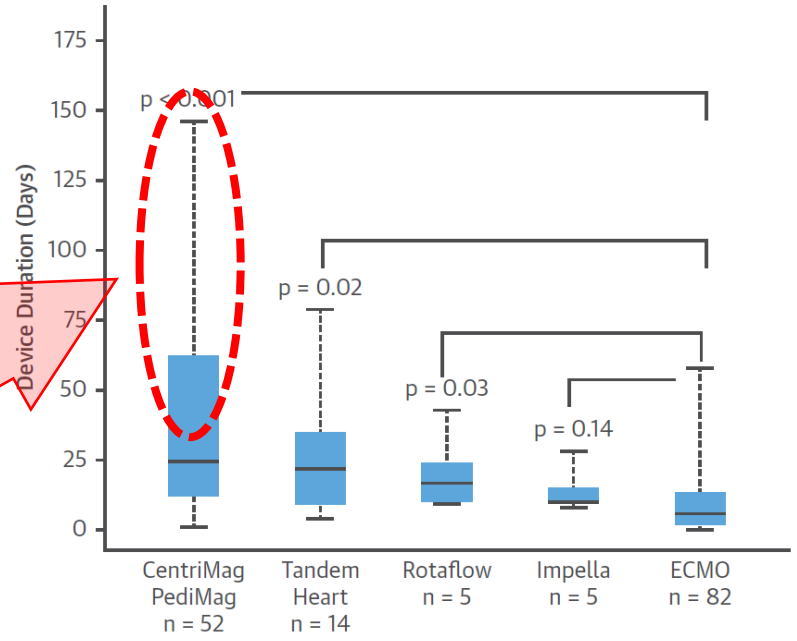
Durée d'assistance plus importante pour les TCS vs ECMO…

…et ce pour toutes les techniques sauf l'impella.

- Les patients sous TCS ont une durée d'assistance 3 fois supérieur vs ECMO (médiane 19j vs 6jours ; p< 0,001).

Last, our findings suggest that select TCS devices—most notably the CentriMag-PediMag system—have made significant inroads not just as short-term circulatory support devices but also as long-term circulatory support devices in clinical situations where existing (Food and Drug Administration-approved) long-term devices have mixed results

FIGURE 3 Comparison of Support Duration for Each Temporary Circulatory Support Device Relative to Conventional ECMO Among Propensity Score-Matched Patients



Temporary Circulatory Support in U.S. Children Awaiting Heart Transplantation

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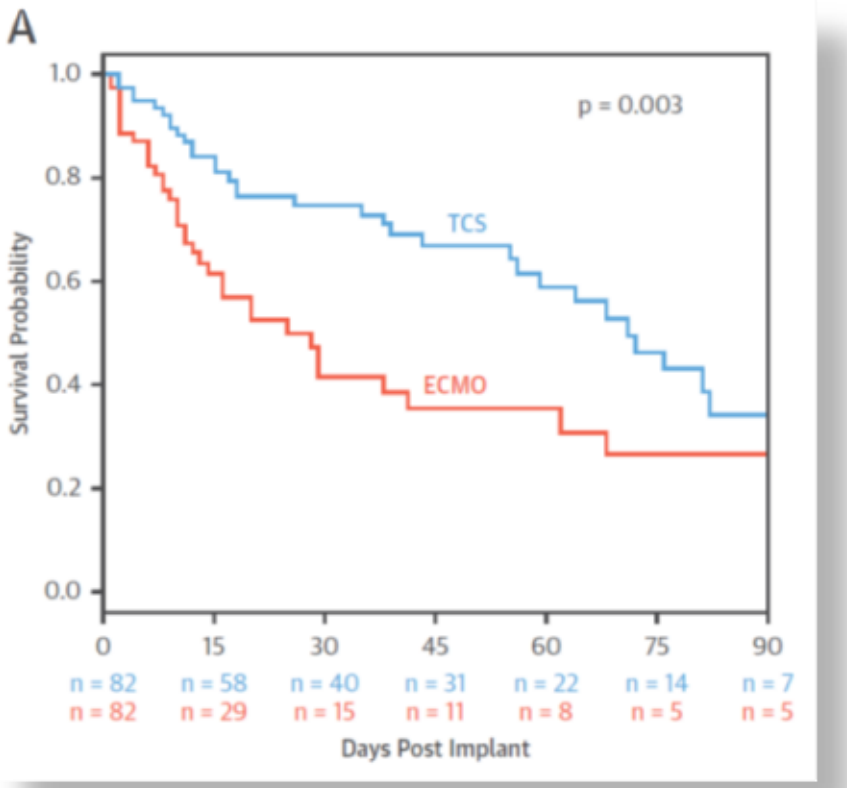
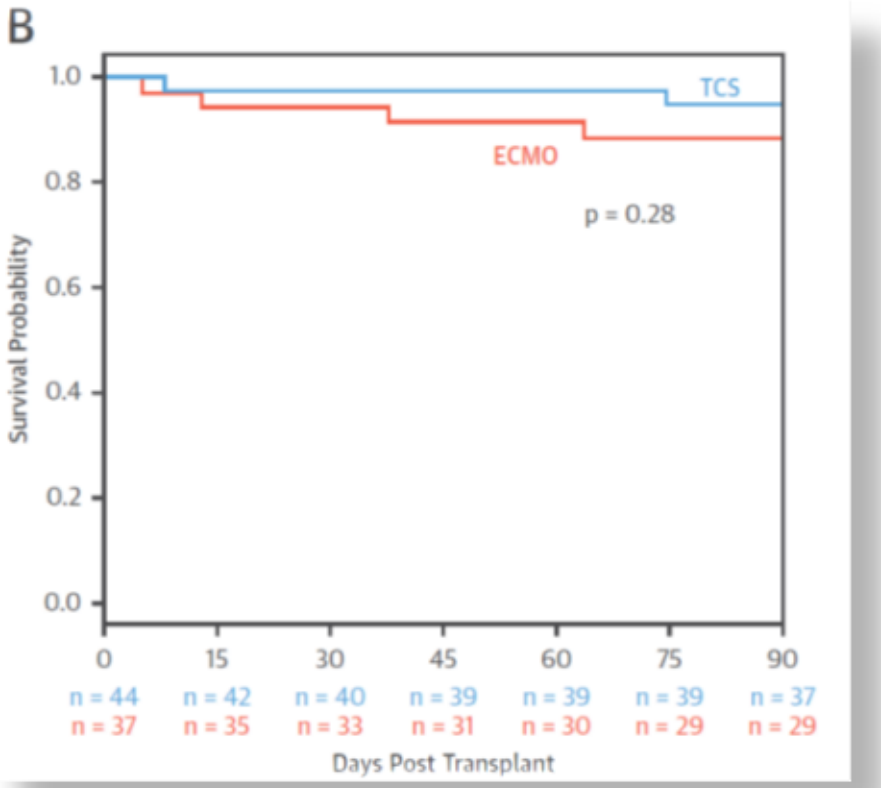
Survie supérieur avec les TCS vs ECMO…

…sans modification significative de la survie post-transplantation.





Ventricular Assist Device Support as a Bridge to Transplantation in Pediatric Patients

Anne I. Dipchand, MD,[a] Richard Kirk, MD,[b] David C. Naftel, PhD,[c] Elizabeth Pruitt, MSPH,[c] Elizabeth D. Blume, MD,[d] Robert Morrow, MD,[e] David Rosenthal, MD,[f] Scott Auerbach, MD,[g] Marc E. Richmond, MD, MS,[h] James K. Kirklin, MD,[i] for the Pediatric Heart Transplant Study Investigators

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- **Pediatric HeartTransplant Study**
- 7135 patients « listés », 5145 transplantés sur 22 années consécutives.
- 995 (19,3%) patients assistés par VAD.
- Le recours à un VAD n'impact pas le pronostic post-transplantation.
- Pronostic post-transplantation meilleurs avec VAD longue durée vs VAD temporaire.
- Pronostic post-transplantation meilleurs avec VAD débit continu vs pulsatil.

TABLE 2 Patients' Demographics and Clinical Characteristics by First Mechanical Circulatory Support Device During Listing and Mechanical Circulatory Support Device Closest to Transplantation

	Listing (n = 7,135)				Transplant (n = 5,145)			
	VAD (n = 821)	ECMO (n = 752)	Neither (n = 5,562)	p Value	VAD (n = 749)	ECMO (n = 287)	Neither (n = 4,109)	p Value
Demographics								
Male	473 (58)	414 (55)	3,113 (56)	0.60	428 (57)	159 (55)	2,259 (55)	0.60
White	530 (65)	537 (71)	4,029 (72)	<0.0001	483 (64)	218 (76)	2,971 (72)	<0.0001
Age, yrs	7.99 ± 6	3.05 ± 5	5.42 ± 6	<0.0001	8.36 ± 6	3.27 ± 5	6.16 ± 6	<0.0001
BSA, m^2	1.04 ± 0.62	0.56 ± 0.45	0.74 ± 0.54	<0.0001	1.07 ± 0.59	0.56 ± 0.43	0.79 ± 0.53	<0.0001
Etiology								
Congenital	162 (20)	387 (51)	3,198 (58)	<0.0001	109 (15)	160 (56)	2259 (55)	<0.0001
Cardiomyopathy	584 (71)	276 (37)	2,158 (39)	<0.0001	569 (76)	100 (35)	1,718 (42)	<0.0001
Other	75 (9)	89 (12)	206 (3)		71 (9)	27 (95)	132 (3)	
Waitlist time, months	3.40 ± 6.77	1.64 ± 2.88	3.24 ± 6.41	<0.0001	3.38 ± 6.46	1.02 ± 1.69	3.24 ± 6.41	<0.0001
Status								
Status 1	740 (90)	718 (96)	4,149 (75)	<0.0001	726 (97)	282 (98)	3,447 (84)	<0.0001
Ventilator	258 (31)	567 (76)	1,047 (19)	<0.0001	133 (18)	208 (72)	626 (15)	<0.0001
Inotropes	567 (69)	594 (79)	2,877 (52)	<0.0001	250 (33)	283 (81)	2,449 (60)	<0.0001
Clinical condition at listing								
Failure to thrive	135 (17)	93 (12)	1,102 (20)	<0.0001	126 (17)	37 (13)	781 (19)	0.02
Renal insufficiency	61 (7)	61 (8)	154 (3)	<0.0001	51 (7)	23 (8%)	105 (3)	<0.0001
Arrhythmias	228 (28)	230 (31)	1,215 (22)	<0.0001	219 (29)	82 (29)	918 (22)	<0.0001

Values are n (%) or mean ± SD.
BSA = body surface area; ECMO = extracorporeal membrane oxygenation; VAD = ventricular assist device.

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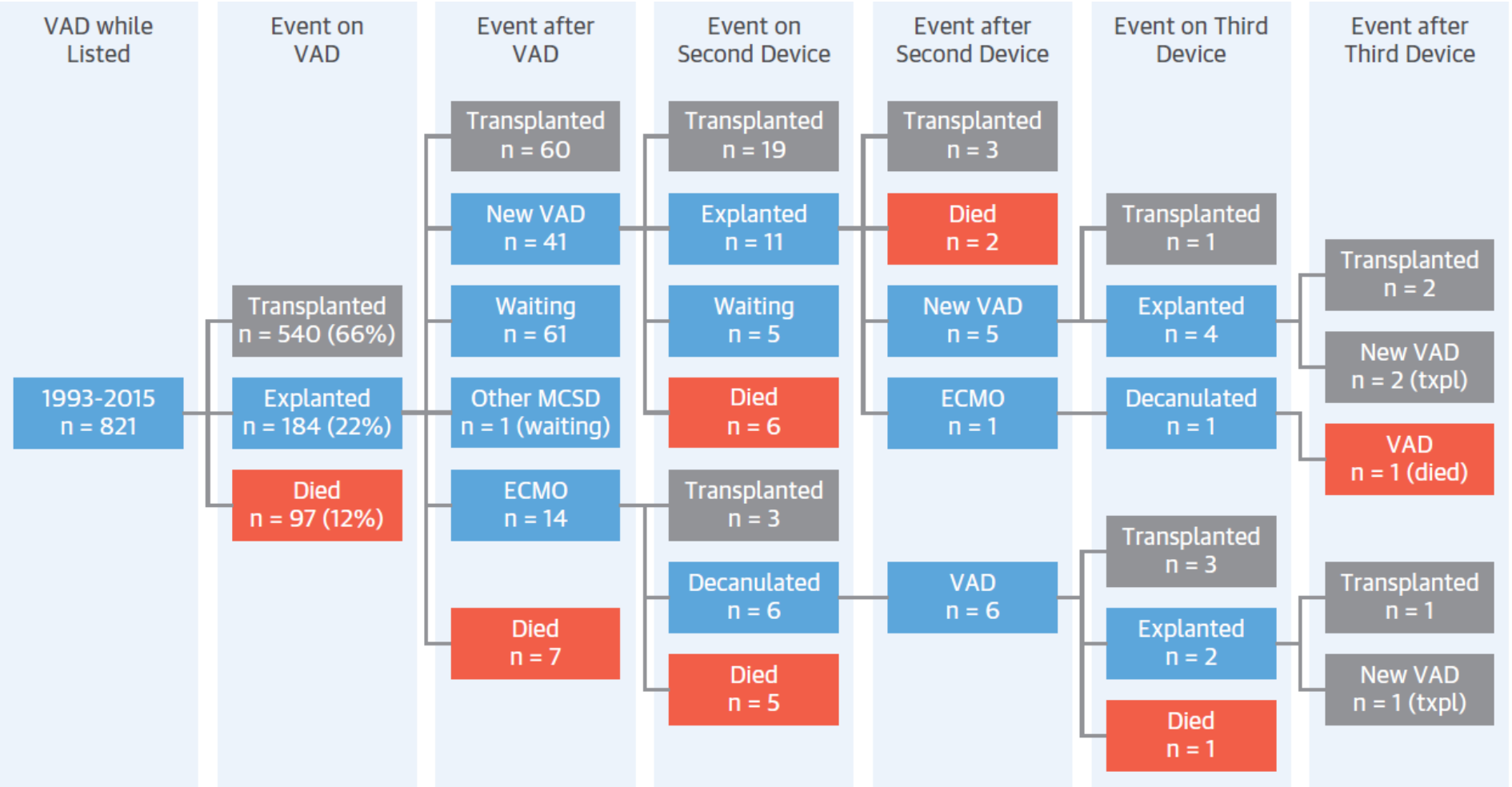

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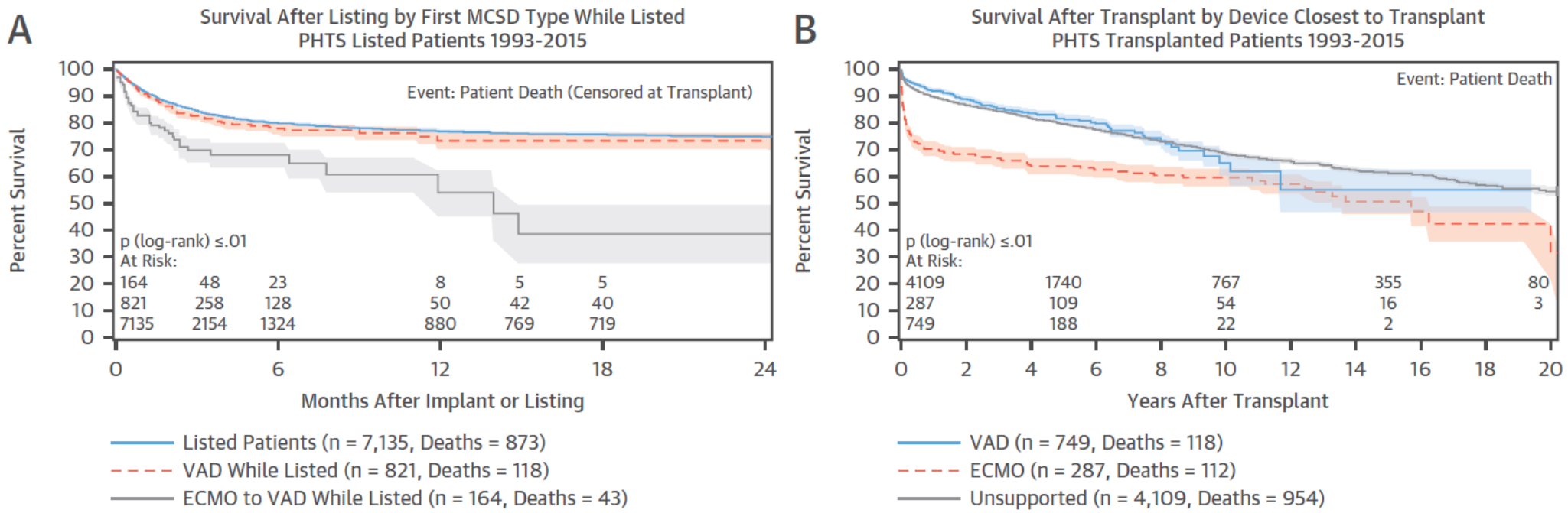
FIGURE 5 **Overall Survival by MCSD Type**



(A) Post-listing survival by first mechanical circulatory support device (MCSD) type while listed. **(B)** Post-transplantation survival by mechanical circulatory support device type closest to transplantation. Abbreviations as in Figures 1 and 4.

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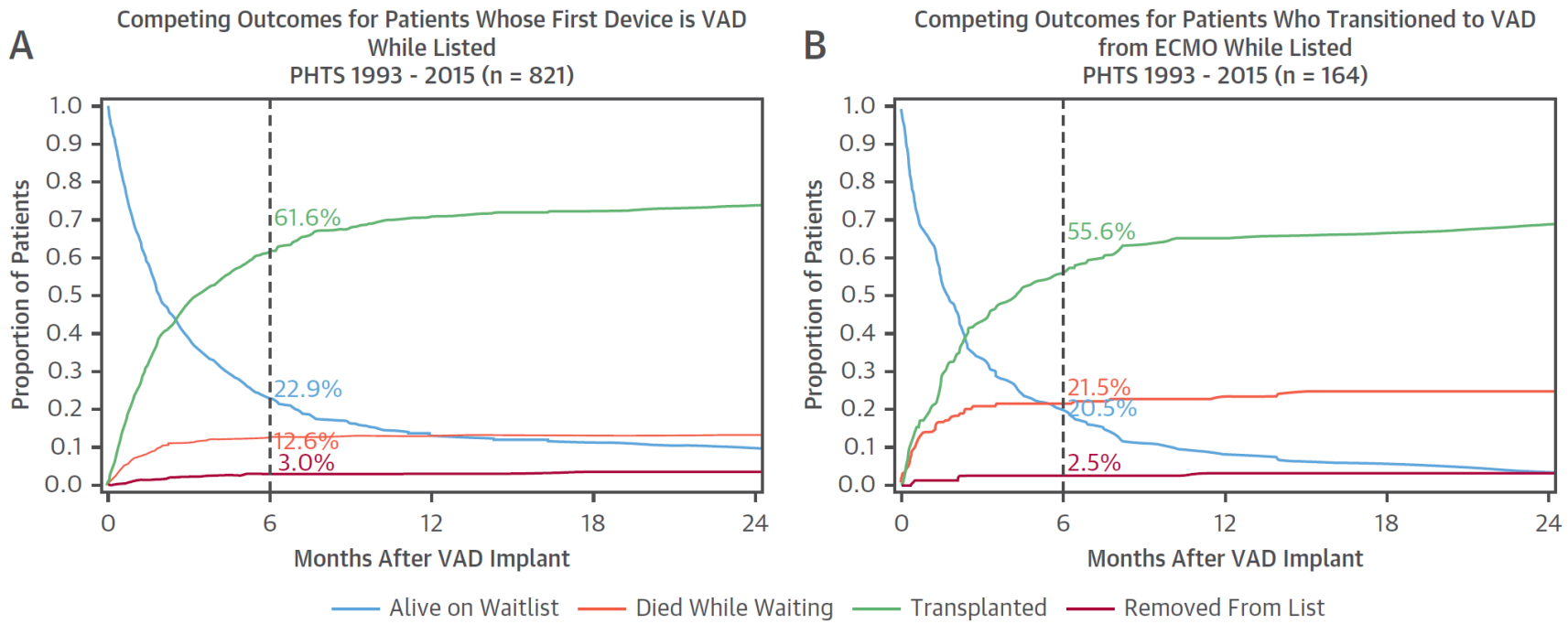
FIGURE 4 **Competing Outcomes for VAD Versus Transition to VAD From ECMO**



Competing outcomes are shown for **(A)** ventricular assist device (VAD) as first device while listed versus **(B)** transition to ventricular assist device from extracorporeal membrane oxygenation (ECMO) ($p = 0.03$). PHTS = Pediatric Heart Transplant Study.