Anesthésie et Réanimation en CCP

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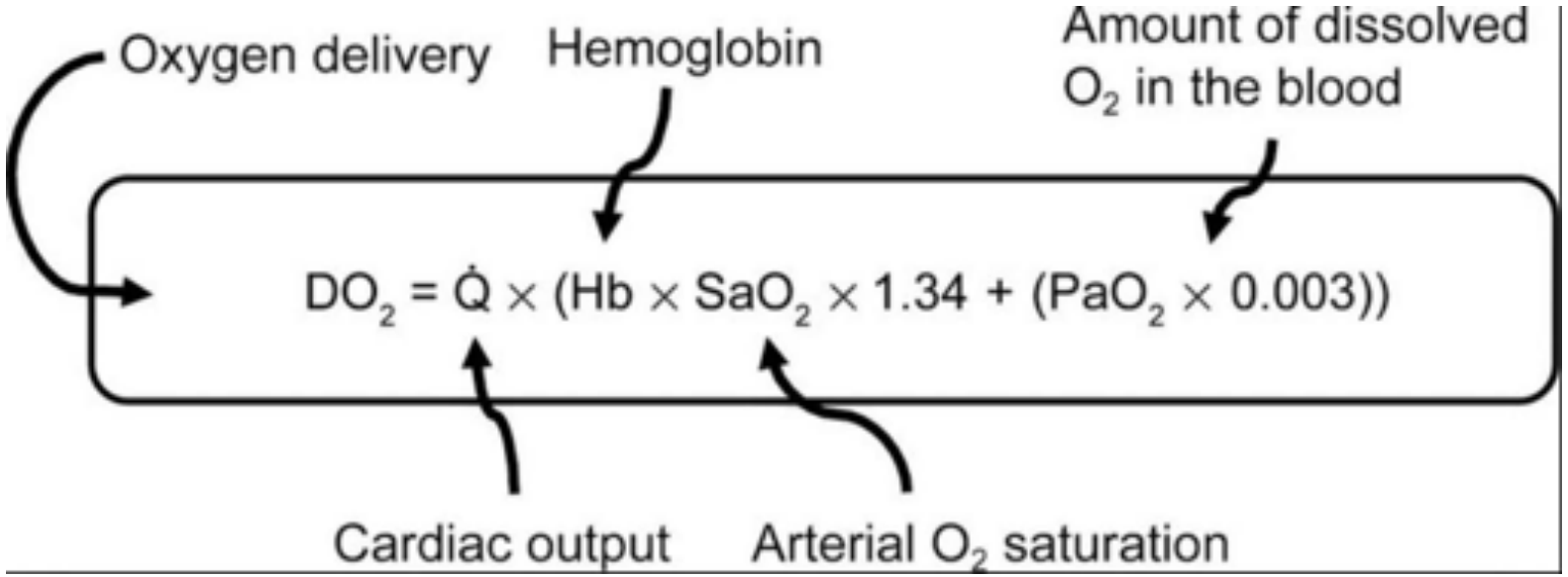
DO2


Oxygen delivery
Hemoglobin
Amount of dissolved O_2 in the blood
$DO_2 = \dot{Q} \times (Hb \times SaO_2 \times 1.34 + (PaO_2 \times 0.003))$
Cardiac output
Arterial O_2 saturation

LCOS

Current Anaesthesia & Critical Care (2005) 16, 347–358

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Current
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CRITICAL CARE

www.elsevier.com/locate/cacc

FOCUS ON: CARDIOVASCULAR

Low cardiac output syndrome in children

Bryn Jones, Mark Hayden*, John F. Fraser, E Janes

- Savoir le reconnaitre
- Comprendre la cause
- Savoir l'anticiper et le prévenir
- Savoir le gérer

Intermacs

Profiles	Brief Description	Details
INTERMACS 1	Critical cardiogenic shock (Crash and burn)	Life-threatening hypotension despite rapidly escalating inotropic support.
INTERMACS 2	Progressive decline (Sliding fast on inotropes)	Declining function despite intravenous inotropic support.
INTERMACS 3	Stable but inotrope dependent (Dependent stability)	Stable on continuous intravenous inotropic support.
INTERMACS 4	Resting symptoms on oral therapy at home	Patient experiences daily symptoms of congestion at rest or during activities of daily living.
INTERMACS 5	Exertion intolerant	Patient is comfortable at rest and with activities of daily living but unable to engage in any other activity.
INTERMACS 6	Exertion limited (Walking wounded)	Patient has fatigue after the first few minutes of any meaningful activity.
INTERMACS 7	Advanced NYHA class III (Placeholder)	Patients living comfortably with meaningful activity limited to mild physical exertion.

INTERMACS: Interagency Registry for Mechanically Assisted Circulatory Support; NYHA = New York Heart Association. Adapted from: Stevenson LW, et al.[25]

Elements diagnostiques LCOS

- **Cliniques:** oligurie, hypoperfusion périphérique, tachycardie
- **Biologiques:**
  - **acidose métabolique:** Approche de Stewart ☞ meilleure prédictibilité
    Durward et AL *The strong ion gap predicts mortality in children following cardiopulmonary bypass surgery.*
    Pediatr Crit Care Med 2005;6(3):281–5.
  - **lactates élevées:** seuil à 6 mmol/l ou ascencion >0.75mmol/l/h
    Charpie JR et Al *Serial blood lactate measurements predict early outcome after neonatal repair or palliation for complex congenital heart disease.*
    J Thorac Cardiovasc Surg 2000;120(1):73–80.
  - **BNP, Troponine.** cinétique de la Troponine et du BNP plus élevée que la norme pour la pathologie concernée
- **Svo2 ou Svco2 :** Norme variable selon la malformation et sa réparation
- **NIRS:**

ETT

Permet d'apprécier:

- la fonction de chaque ventricule
  - *Diastolique:* Profil transmitral
  - *Systolique:* FR, FE, IM dp/dt, TAPSE
- Ces indices n'ont été validé par aucune étude en pédiatrie
- La tachycardie constitue la principale limite
- La cinétique de ces indices peut être intéressante
- La cinétique globale et segmentaire
- L'œdème myocardique
- Les pressions pulmonaires
- La volémie
- Les lésions résiduelles

Traquer la lésion résiduelle

INTERVENTIONAL CARDIOLOGY AND SURGERY

Cardiac ECMO for biventricular hearts after paediatric open heart surgery

R R Chaturvedi, D Macrae, K L Brown, M Schindler, E C Smith, K B Davis, G Cohen, V Tsang, M Elliott, M de Leval, S Gallivan, A P Goldman

Heart 2004;90:545–551. doi: 10.1136/hrt.2002.003509

15% des ECMO post cardiotomies présentaient des lésions résiduelles

- Obstruction à l'éjection ventriculaire
- Shunt residuel
- Fuite d'une VAV

Check list des causes à éliminer

- Vérifier l'airway: position sonde, taille
- Vérifier la ventilation: atélectasie, pneumothorax
- Tamponnade
- Crise d'HTAP
- Troubles du rythme
- Lésions résiduelles (CIV résiduelle, gradient sur les voies d'éjection...), montages vicieux.
- Troubles électrolytes (Hypocalcémie)

LCOS origines

Conditions pre-opératoires

- Défaillance connue : coronaire anormale
- Anatomique : adaptation progressive à la réparation (petit VG)

Conditions per-opératoires

- Longue durée de clampage aortique
- Défaut de protection myocardique
- Sevrage trop précoce de la CEC sans phase d'assistance
- Lésions coronariennes, ventriculaires
- Réparation incomplète

Physiopathologie LCOS

- Incapacité du myocarde à maintenir un débit cardiaque suffisant pour assurer la demande en O2 de la circulation régionale.
- Sans traitement : activation d'un cercle vicieux
    - Morbidité et Décès
    - Insuffisance cardiaque chronique
- Si le bas débit est dorigine ischémique et/ ou stunning et/ou hibernation, réversible par un traitement ad hoc, initié rapidement.

Stunning

Produit par:

- L'afflux de radicaux libres pendant la reperfusion (=> augmentation du Ca intracellulaire)
- La perte de la sensibilité au calcium des filaments contractiles

Survenue : situations dans lesquelles le cœur est exposé à un épisode ischémique

- Angine instable, SCA avec reperfusion précoce, ischémie à leffort
- Clampage aortique en chirurgie cardiaque et en transplantation

Hibernation

- Dysfonction liée à une réduction importante et chronique du débit coronaire (ALCAPA)
- Les cellules myocardiques sont normales
- Après restauration du débit coronaire, à terme, la fonction peut être normale (ALCAPA opérée)
- Hibernation et stunning peuvent associés
  - Ex : ALCAPA post CEC avec protection myocardique insuffisante

Stratégies Thérapeutiques I

Anticiper le LCOS:

- Protection myocardique: respect des délais de réinjection
- Ultrafiltration per CEC
- Autres stratégies anti-inflammatoires
- Phase d'assistance post déclampage

Stratégies Thérapeutiques 2

Traiter le LCOS:

- Optimiser la précharge (KtOG–PVC..)
- Support inotrope
- Optimiser la postcharge:
- VD: NOi, IPDE5
- VG: IPDE3
- Traitement des oedemes interstitiels:
  - Diuretiques à fortes doses
  - Dialyse péritonéale

Fluid overload

Pediatr Crit Care Med. 2014 Feb;15(2):131-8. doi: 10.1097/PCC.0000000000000043.

Early postoperative fluid overload precedes acute kidney injury and is associated with higher morbidity in pediatric cardiac surgery patients.

Hassinger AB[1], Wald EL, Goodman DM.

Author information

Abstract

OBJECTIVE: Fluid overload has been independently associated with increased morbidity and mortality in pediatric patients with renal failure, acute lung injury, and sepsis. Pediatric patients who undergo cardiopulmonary bypass are at risk for poor cardiac, pulmonary, and renal outcomes. They are also at risk of fluid overload from cardiopulmonary bypass, which stimulates inflammation, release of antidiuretic hormone, and capillary leak. This study tested the hypothesis that patients with fluid overload in the early postcardiopulmonary bypass period have worse outcomes than those without fluid overload. We also examined the timing of the association between postcardiopulmonary bypass acute kidney injury and fluid overload.

DESIGN, SETTING, AND PATIENTS: Secondary analysis of a prospective observational study of 98 pediatric patients after cardiopulmonary bypass at a tertiary care, academic, PICU.

INTERVENTIONS: None.

MEASUREMENTS AND MAIN RESULTS: Early postoperative fluid overload, defined as a fluid balance 5% above body weight by the end of postoperative day 1, occurred in 30 patients (31%). Patients with early fluid overload spent 3.5 days longer in the hospital, spent 2 more days on inotropes, and were more likely to require prolonged mechanical ventilation than those without early fluid overload (all $p < 0.001$). Fluid overload was associated with the development of acute kidney injury and more often preceded it than followed it. Conversely, acute kidney injury was not associated with more fluid accumulation. Patients with fluid overload were administered higher fluid volume over the study period, 395.4 ± 150 mL/kg vs. 193.2 ± 109.1 mL/kg ($p < 0.001$), and had poor urinary response to diuretics. Cumulative fluid administered was an excellent predictor of pediatric-modified Risk, Injury, Failure, Loss, and End-stage "Failure" (area under the receiver-operating characteristic curve, 0.963; 95% CI, 0.916-1.000; $p = 0.002$).

CONCLUSIONS: Early postoperative fluid overload is independently associated with worse outcomes in pediatric cardiac surgery patients who are 2 weeks to 18 years old. Patients with fluid overload have higher rates of postcardiopulmonary bypass acute kidney injury, and the occurrence of fluid overload precedes acute kidney injury. However, acute kidney injury is not consistently associated with fluid overload.

Stratégies Thérapeutiques 3

- Corticoïdes: bolus 10 à 50 mg/m2/j, si besoins de remplissage importants à cause des troubles de la microcirculation sur SIRS
- Création de CIA
- Fermeture sternale retardée BEX
- Assistance mécanique
- Optimiser le débit cardiaque et la perfusion tissulaire sans augmenter la consommation en oxygène du myocarde

Inotropes

- Pas de consensus pour traiter le LCOS en chirurgie cardiaque et pédiatrique
- Peu de publications sur les inotropes les + utilisés, encore moins en pédiatrie
- Rares études avec niveau dévidence élevé
- Niveau 1a : au moins 2 études randomisées avec une faible marge derreur
- Catécholamines IPDE Levosimendan

Inotropes

World J Pediatr Congenit Heart Surg. 2018 Jan;9(1):10-21. doi: 10.1177/2150135117731725. Epub 2017 Nov 1.

The Perspective of the Intensivist on Inotropes and Postoperative Care Following Pediatric Heart Surgery: An International Survey and Systematic Review of the Literature.

Roeleveld PP[1], de Klerk JCA[2].

Author information

Abstract

INTRODUCTION: Inotropes are frequently being used in children undergoing heart surgery to prevent or treat low cardiac output syndrome (LCOS). There is only limited evidence that inotropes actually positively influence postoperative outcome. Our aim was to describe the current international practice variation in the use of inotropes following congenital heart surgery.

METHODS: We developed an online survey regarding the postoperative use of inotropes. We sent an invitation to all 197 registered members of the Pediatric Cardiac Intensive Care Society (PCICS) to participate in the survey. We also performed a systematic review of the literature.

RESULTS: Ninety-eight people (50%) responded, representing 62 international centers. Milrinone is routinely used perioperatively by 90 respondents (97%). Adrenaline/epinephrine is routinely used by 43%, dopamine by 36%, dobutamine by 11%, and levosimendan by 6%. Steroids are used routinely by 54% before initiating cardiopulmonary bypass. Vasopressin is used by 44% of respondents. The development of LCOS is monitored with lactate in 99% of respondents, physical examination (98%), intermittent mixed venous saturation (76%), continuous mixed venous saturation (13%), echocardiography (53%), core-peripheral temperature gap (29%), near-infrared spectrometry (25%), and 4% use cardiac output monitors (PiCCO, USCOM). To improve cardiac output, 42% add/increase milrinone, 37% add adrenaline, and 15% add dopamine. Rescue therapy is titrated individually, based on the patients' pathophysiology. A systematic review of the literature failed to show compelling evidence with regard to the benefit of inotropes.

CONCLUSIONS: Despite the lack of sufficient evidence, milrinone is used by the vast majority of caregivers following congenital heart surgery.

Milrinone

Cochrane Database Syst Rev. 2015 Mar 25;(3):CD009515. doi: 10.1002/14651858.CD009515.pub2.

Prophylactic milrinone for the prevention of low cardiac output syndrome and mortality in children undergoing surgery for congenital heart disease.

Burkhardt BE[1], Rücker G, Stiller B.

Author information

Abstract

BACKGROUND: Children with congenital heart disease often undergo heart surgery at a young age. They are at risk for postoperative low cardiac output syndrome (LCOS) or death. Milrinone may be used to provide inotropic and vasodilatory support during the immediate postoperative period.

OBJECTIVES: This review examines the effectiveness of prophylactic postoperative use of milrinone to prevent LCOS or death in children having undergone surgery for congenital heart disease.

SEARCH METHODS: Electronic and manual literature searches were performed to identify randomised controlled trials. We searched CENTRAL, MEDLINE, EMBASE and Web of Science in February 2014 and conducted a top-up search in September 2014 as well as clinical trial registries and reference lists of published studies. We did not apply any language restrictions.

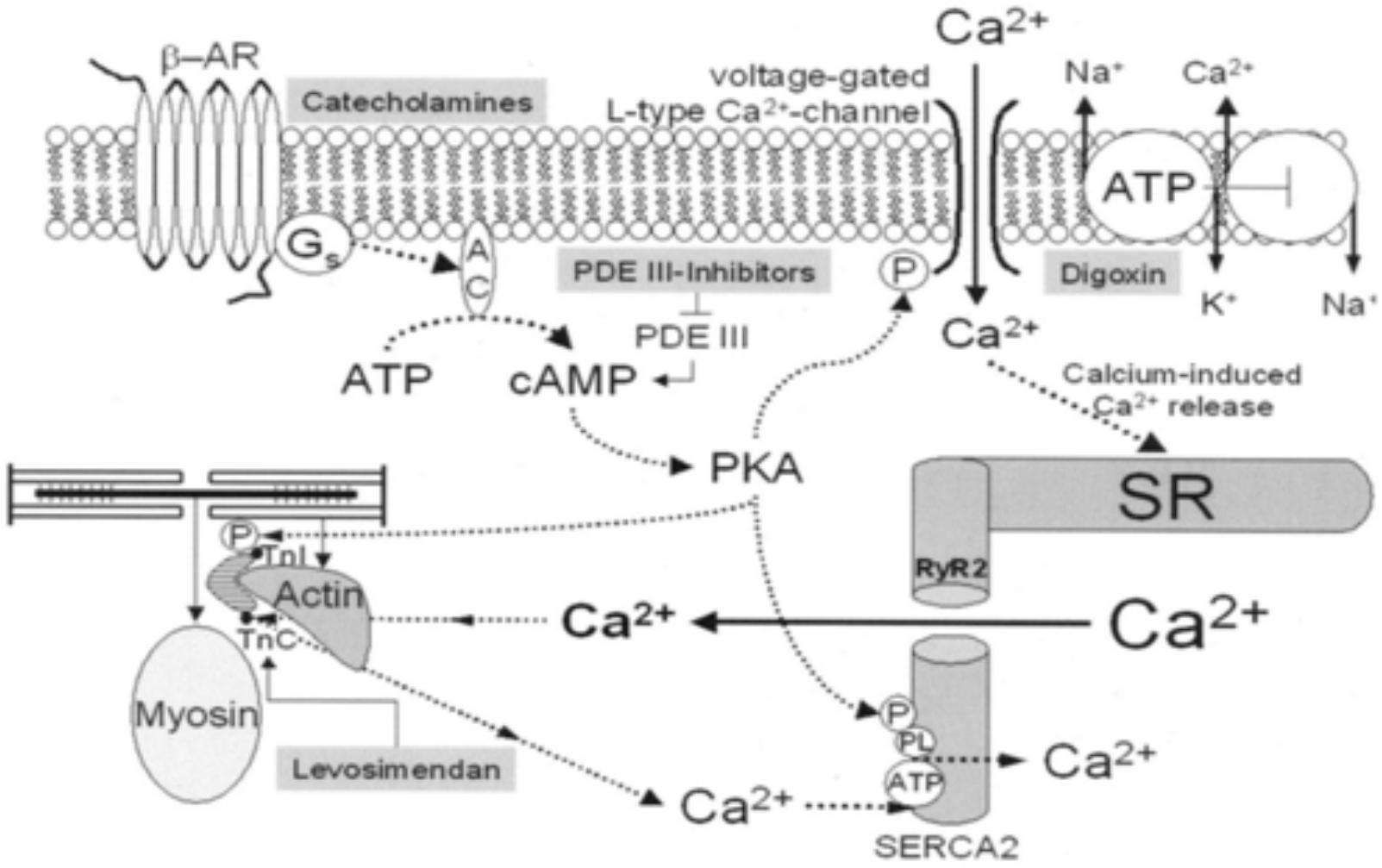
SELECTION CRITERIA: Only randomised controlled trials were selected for analysis. We considered studies with newborn infants, infants, toddlers, and children up to 12 years of age.

DATA COLLECTION AND ANALYSIS: Two review authors independently extracted data according to a pre-defined protocol. We obtained additional information from all study authors.

MAIN RESULTS: Three of the five included studies compared milrinone versus levosimendan, one study compared milrinone with placebo, and one compared milrinone verus dobutamine, with 101, 242, and 50 participants, respectively. Three trials were at low risk of bias while two were at higher risk of bias. The number and definitions of outcomes were non-uniform as well. In one study comparing two doses of milrinone and placebo, there was some evidence in an overall comparison of milrinone versus placebo that milrinone lowered risk for LCOS (risk ratio (RR) 0.52, 95% confidence interval (CI) 0.28 to 0.96; 227 participants). The results from two small studies do not provide enough information to determine whether milrinone increases the risk of LCOS when compared to levosimendan (RR 1.22, 95% CI 0.32 to 4.65; 59 participants). Mortality rates in the studies were low, and there was insufficient evidence to draw conclusions on the effect of milrinone compared to placebo or levosimendan or dobutamine regarding mortality, the duration of intensive care stay, hospital stay, mechanical ventilation, or maximum inotrope score (where available). Numbers of patients requiring mechanical cardiac support were also low and did not allow a comparison between studies, and none of the participants of any study received a heart transplantation up to the end of the respective follow-up period. Time to death within three months was not reported in any of the included studies. A number of adverse events was examined, but differences between the treatment groups could not be proven for hypotension, intraventricular haemorrhage, hypokalaemia, bronchospasm, elevated serum levels of liver enzymes, or a reduced left ventricular ejection fraction < 50% or reduced left ventricular fraction of shortening < 28%. Our analysis did not prove an increased risk of arrhythmias in patients treated prophylactically with milrinone compared with placebo (RR 3.59, 95% CI 0.83 to 15.42; 238 participants), a decreased risk of pleural effusions (RR 1.78, 95% CI 0.92 to 3.42; 231 participants), or a difference in risk of thrombocytopenia on milrinone compared with placebo (RR 0.86, 95% CI 0.39 to 1.88; 238 participants). Comparisons of milrinone with levosimendan or with dobutamine, respectively, did not clarify the risk of arrhythmia and were not possible for pleural effusions or thrombocytopenia.

AUTHORS' CONCLUSIONS: There is insufficient evidence of the effectiveness of prophylactic milrinone in preventing death or low cardiac output syndrome in children undergoing surgery for congenital heart disease, compared to placebo. So far, no differences have been shown between milrinone and other inodilators, such as levosimendan or dobutamine, in the immediate postoperative period, in reducing the risk of LCOS or death. The existing data on the prophylactic use of milrinone has to be viewed cautiously due to the small number of small trials and their risk of bias.

Mécanismes d'action des inotropes



Pourquoi le Levosimendan

Levosimendan: From Basic Science to Clinical Trials

Rognoni et al. Recent Patents on Cardiovascular Drug Discovery, 2011, Vol. 6, No. 1

- Effets vasodilatateurs: Ouverture canaux K+
  - Vasodilatation Coronaire
  - Vasodilatation artères pulmonaires
  - Vasodilatation systémique
- Effets sur la fonction myocardique:
  - Augmente la sensibilité des protéines contractiles à la troponine: Effet inotrope
  - Sans augmenter le flux calcique intracellulaire: Effet lusitrope
  - Pas d'augmentation de consommation d'oxygène
- Combinaison des deux effets:
  - Amélioration du couplage ventriculo-artériel
- Effet antistunning:
  - Evite la surcharge calcique mitochondriale de l'ichémie - reperfusion
  - Stabilise le potentiel membranaire et préserve la fonction des mitochondries
  - Economise les phosphates de haute énergie et limite l'apoptose

J Cardiothorac Vasc Anesth 2018

J Cardiothorac Vasc Anesth. 2018 Feb;32(1):225-235. doi: 10.1053/j.jvca.2017.06.017. Epub 2017 Jun 7.

Nonsurgical Strategies to Reduce Mortality in Patients Undergoing Cardiac Surgery: An Updated Consensus Process.

Landoni G[1], Lomivorotov V[2], Silvetti S[3], Nigro Neto C[4], Pisano A[5], Alvaro G[6], Hajjar LA[7], Paternoster G[8], Riha H[9], Monaco F[3], Szekely A[10], Lembo R[3], Aslan NA[11], Affronti G[3], Likhvantsev V[12], Amarelli C[13], Fominskiy E[2], Balardo Redaelli M[3], Putzu A[14], Baiocchi M[15], Ma J[16], Bono G[6], Camarda V[3], Covello RD[17], Di Tomasso N[3], Labonia M[6], Leggieri C[3], Lobreglio R[18], Monti G[3], Mura P[19], Scandroglio AM[3], Pasero D[18], Turi S[3], Roasio A[20], Votta CD[3], Saporito E[6], Riefolo C[3], Sartini C[3], Brazzi L[21], Bellomo R[22], Zangrillo A[23].

Author information

Abstract

OBJECTIVE: A careful choice of perioperative care strategies is pivotal to improve survival in cardiac surgery. However, there is no general agreement or particular attention to which nonsurgical interventions can reduce mortality in this setting. The authors sought to address this issue with a consensus-based approach.

DESIGN: A systematic review of the literature followed by a consensus-based voting process.

SETTING: A web-based international consensus conference.

PARTICIPANTS: More than 400 physicians from 52 countries participated in this web-based consensus conference.

INTERVENTIONS: The authors identified all studies published in peer-reviewed journals that reported on interventions with a statistically significant effect on mortality in the setting of cardiac surgery through a systematic Medline/PubMed search and contacts with experts. These studies were discussed during a consensus meeting and those considered eligible for inclusion in this study were voted on by clinicians worldwide.

MEASUREMENTS AND MAIN RESULTS: Eleven interventions finally were selected: 10 were shown to reduce mortality (aspirin, glycemic control, high-volume surgeons, prophylactic intra-aortic balloon pump, levosimendan, leuko-depleted red blood cells transfusion, noninvasive ventilation, tranexamic acid, vacuum-assisted closure, and volatile agents), whereas 1 (aprotinin) increased mortality. A significant difference in the percentages of agreement among different countries and a variable gap between agreement and clinical practice were found for most of the interventions.

CONCLUSIONS: This updated consensus process identified 11 nonsurgical interventions with possible survival implications for patients undergoing cardiac surgery. This list of interventions may help cardiac anesthesiologists and intensivists worldwide in their daily clinical practice and can contribute to direct future research in the field.

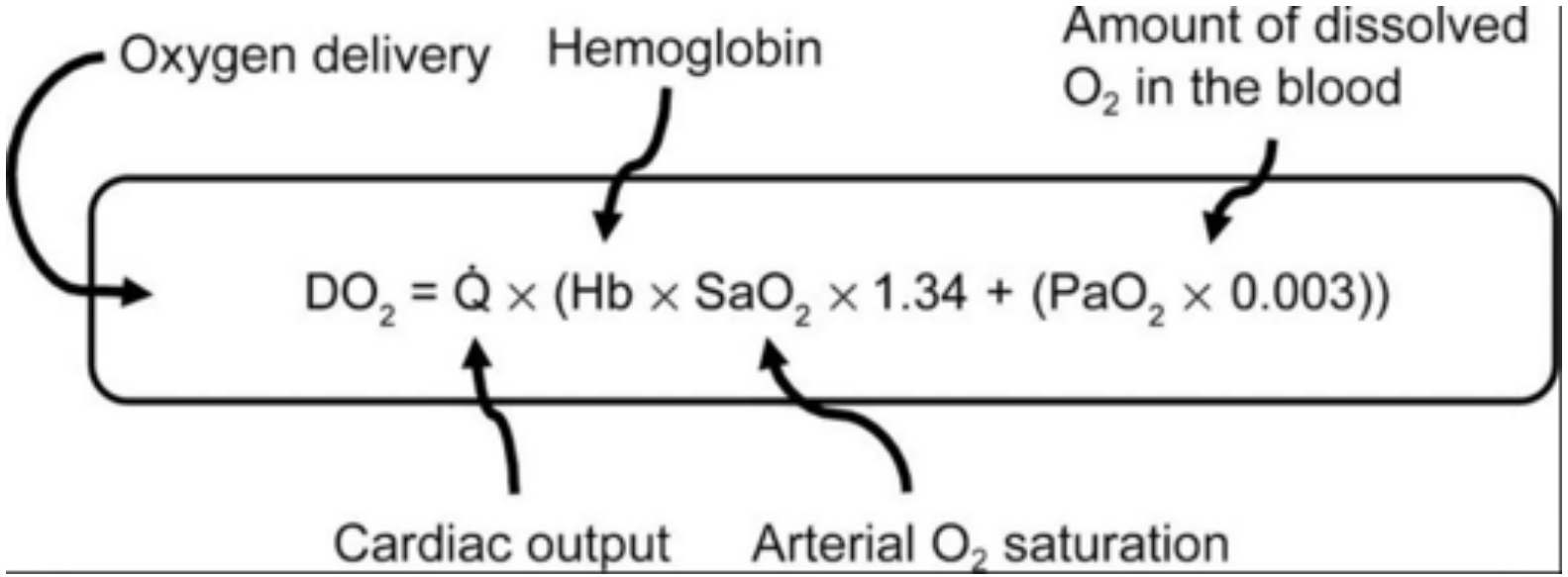
Nonsurgical Strategies to Reduce Mortality in Patients Undergoing Cardiac Surgery: An Updated Consensus Process.

The web survey identified 10 interventions that decreased unadjusted landmark mortality:

- aspirin
- glycemic control
- high-volume surgeon
- leuko-depleted red blood cell transfusion (RBC)
- levosimendan
- non-invasive ventilation (NIV)
- prophylactic intra-aortic balloon pump (IABP)
- vacuum-assisted closure (VAC)
- volatile agents
- tranexamic acid

Aprotinin[49,50] was identified as the only intervention that increased mortality.

DO2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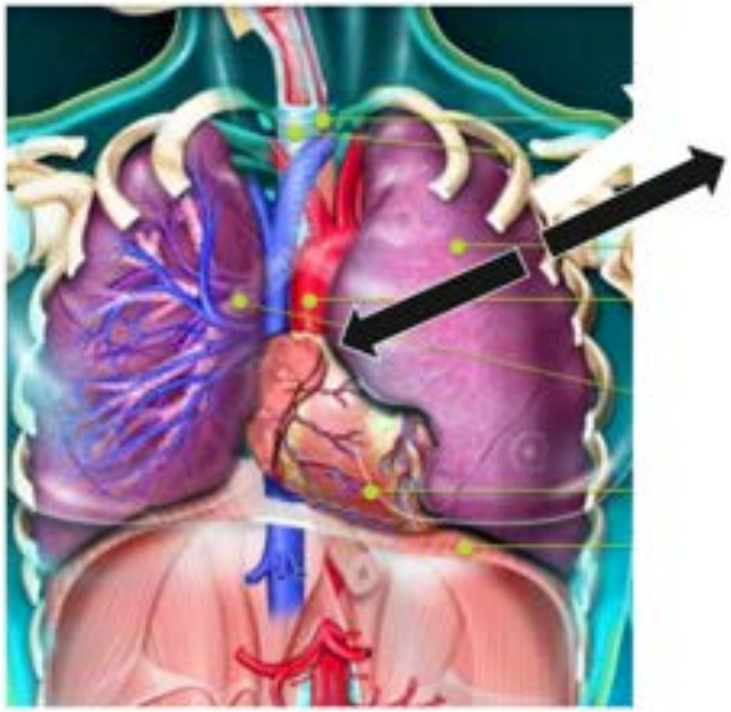
Cardiac output
Arterial O_2 saturation

Effet de VS sur système CV / Repos

En VS, au repos = m respiratoires au repos

- Pression de retour élastique du poumons = Pression de la cage thoracique
- Pression alv = Pression atm
- L'air ne circule pas dans l'arbre bronchique.



Effet de VS sur système CV / Précharge

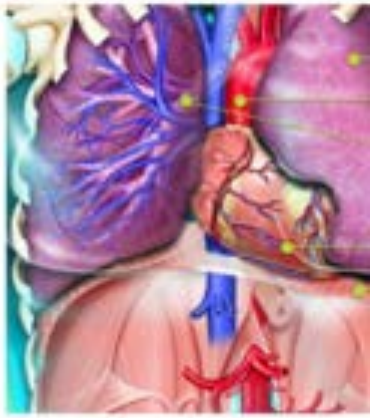
Précharge : tension musculaire au début de la contraction musculaire.

Retour vx systémique dépend du gradient

- Pression systémique moyenne

des veines extra thoraciq =système veineux capacitif qui dépend

  - débit sanguin (volume contraint)
  - tonus vasculaire + /-
  - réservoir splanchnique (vo non contraint)



- POD

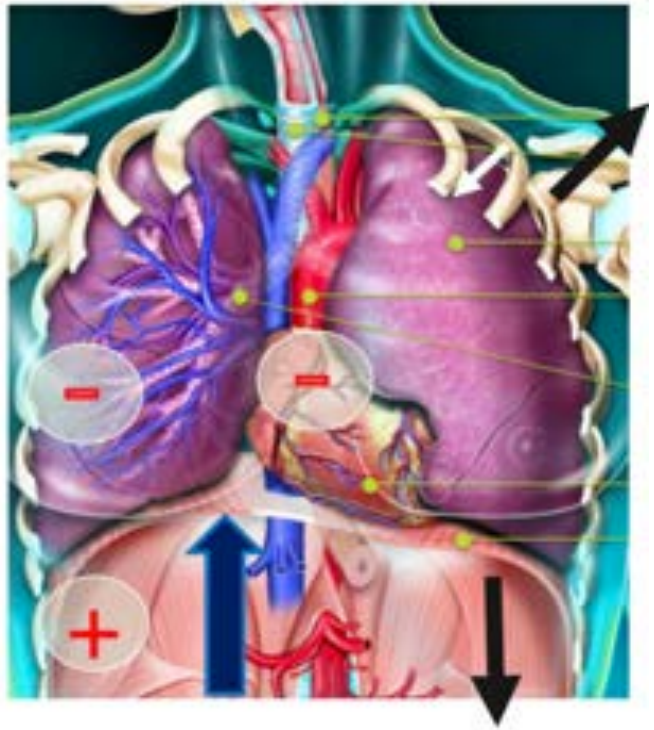
change en parallèle avec la pression qui l'entoure = pression pleurale

Effet de VS sur système CV / Précharge

En VS à l'inspiration

- pr pleurale - => PIT - => ↓ POD
- ↑ Pr intra abdo
- ↑ gradient

= > ↑ retour veineux = ↑ débit



- limitée par la collapsibilité des veines

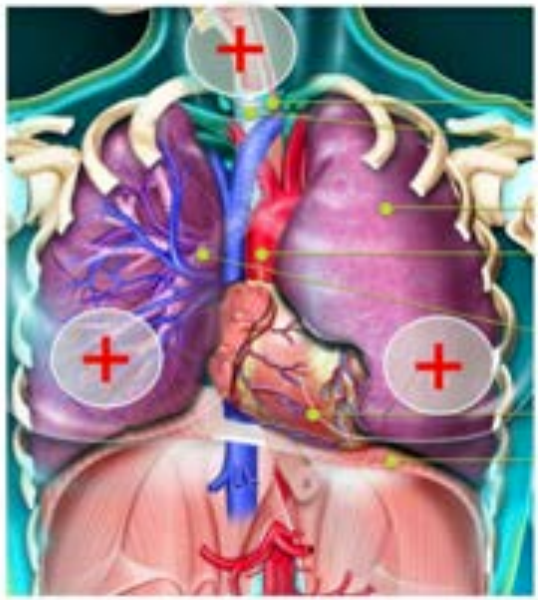
Pr intra abdo tres +

= > collapsus VCI sousdiaphragmatique

Effet VM sur cœur droit

En Ventilation mécanique

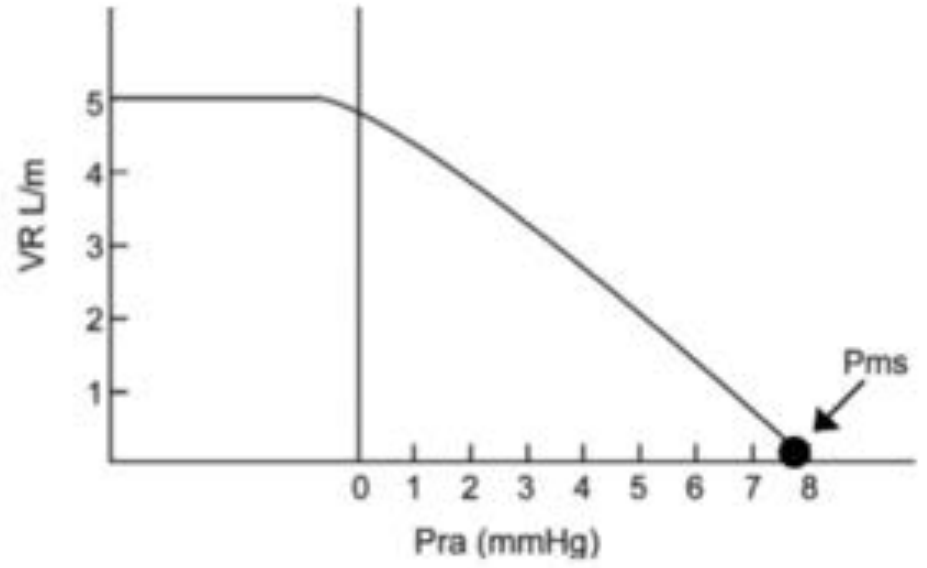
- En inspiration Pr + vs négatif
  - ↑ pression alvéolaire
  - ↑ pression pleurale
- Pression pleurale + tout le cycle respiratoire
- A l'expiration PEEP

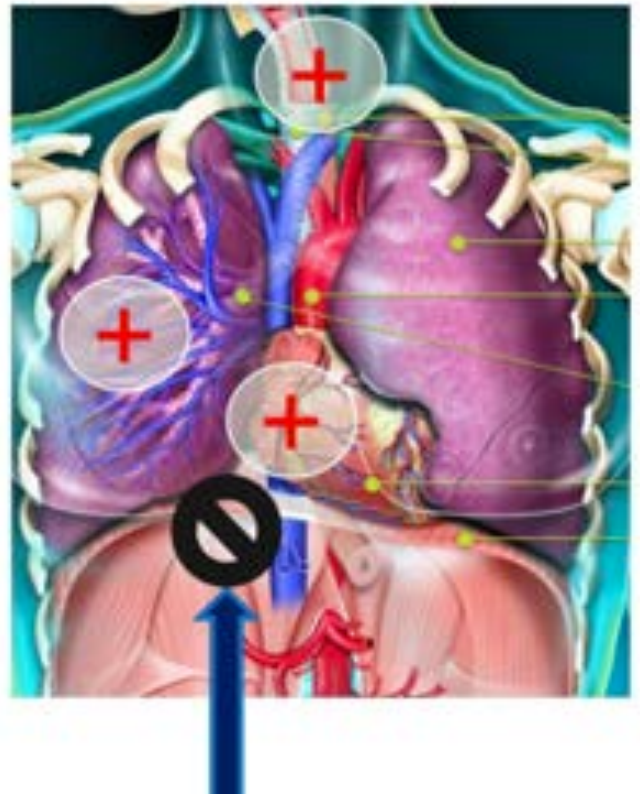


Effet VM sur cœur droit / Précharge

En inspiration, en VM :

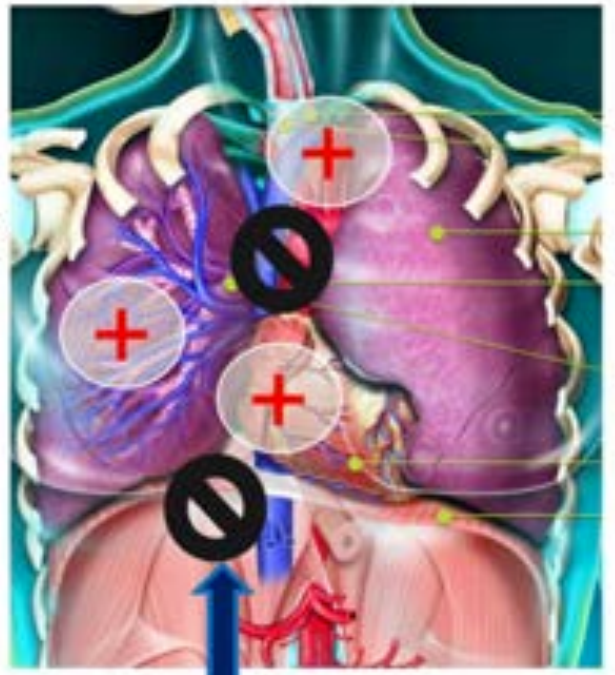
- Pr alvéolaire + => transmise pr pleurale => ↑ POD
  => ↓ retour veineux
  => ↓ précharge VD





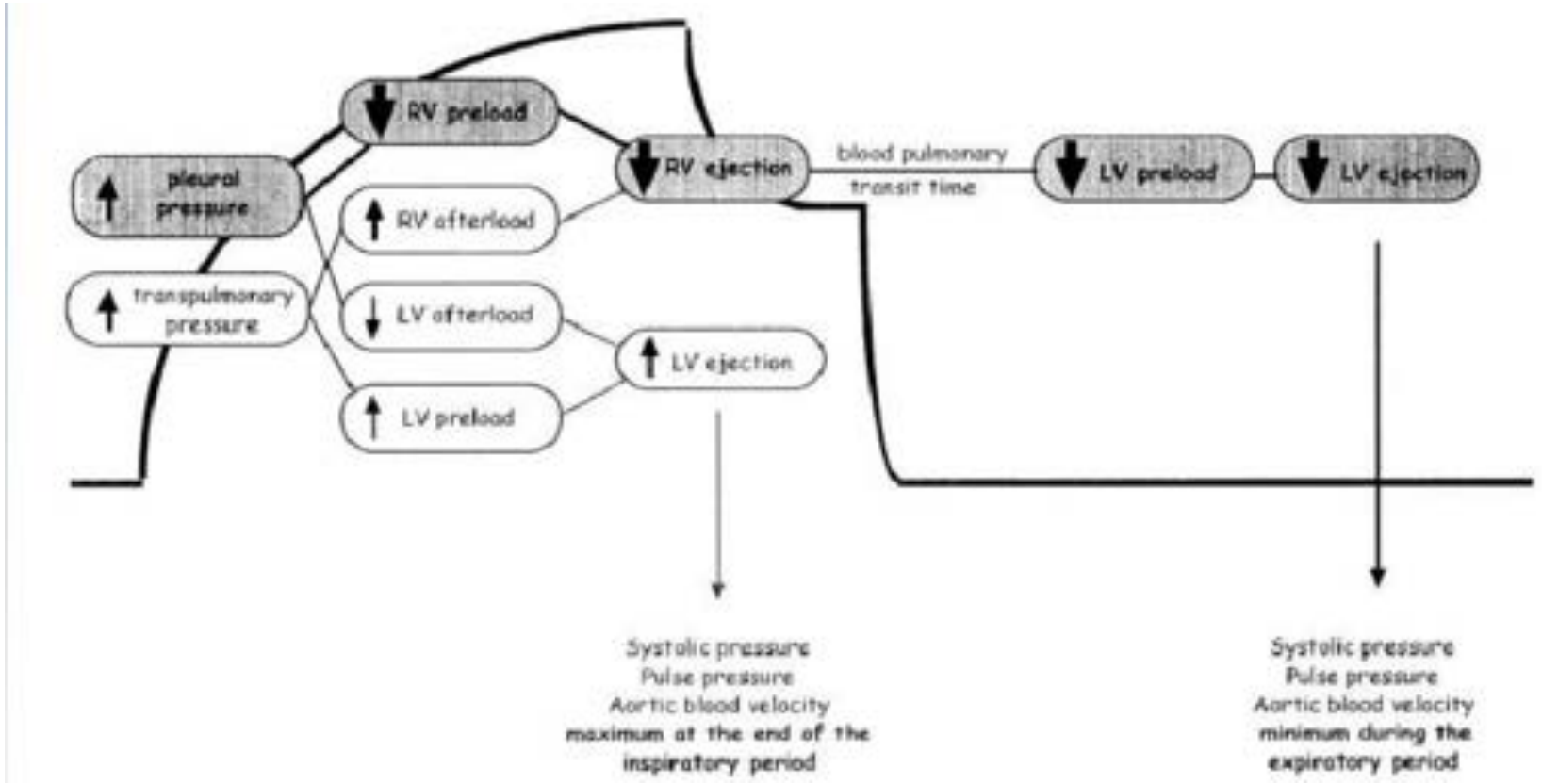
Effet VM sur cœur droit / Synthèse

- ↑ Pr° pleurale
  - ↑ Pr° OD
  - ↓ du retour veineux systémique
  - ↓ **précharge du VD**
- ↑ Pr° alvéolaire
  - ↑ R vasculaire pulmonaire
  - ↑ **postcharge du VD**



=> ↓ débit cardiaque Dr

Interation coeur poumon



Effets de la Ventilation mécanique (pression positive)

- Augmentation de la pression pleurale
- Augmentation du volume pulmonaire
- Correction de l'hypoxémie
- Correction de l'hypercapnie
- Réduction du travail des muscles respiratoires

Correction de l'hypercapnie

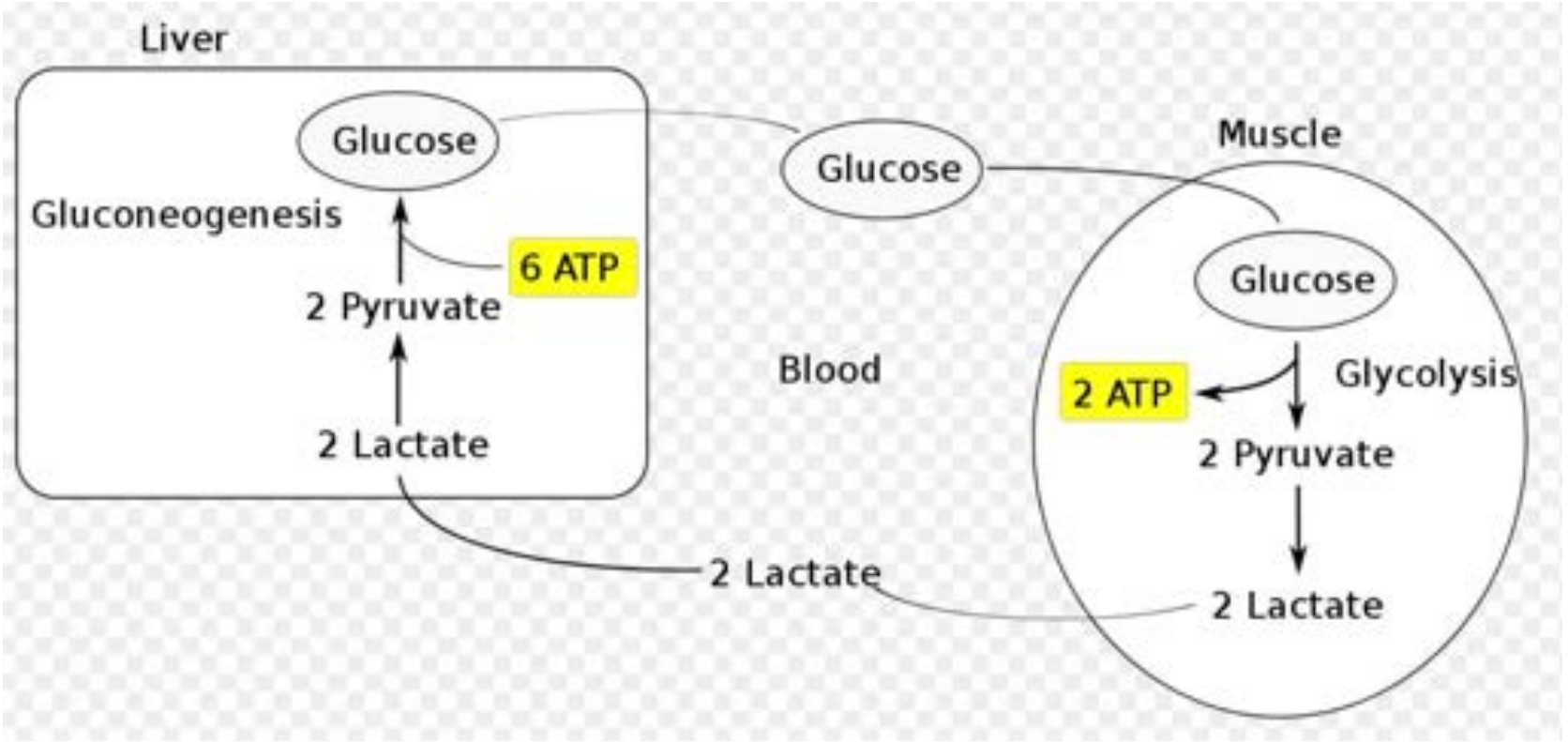
- L'hypercapnie potentialise la vasoconstriction hypoxique.
- Sa correction baisse les RVP
- Les effets hémodynamiques des modifications de la $PaCO_2$ sont d'autant plus marqués que ces modifications sont brutales.
- NIRS

Traitement de l'hyperdébit pulmonaire

Objectifs en urgence :

- Augmenter les RVP et diminuer les RVS
- Ventilation mécanique
  (FiO2 21 % - Hypercapnie - Peep)
- Correction d'une acidose métabolique
- Augmenter la viscosité sanguine ---> CG
- CO2 inhalé en dernière intention
- Vasodilatateur : Régitine ± Corotrope
- Eviter les inotropes
- Tt l'hyperkaliémie : Lasilix
- Si Tt inefficace : reprise chirurgicale : clip

Lactates


Liver
Glucose
Gluconeogenesis
6 ATP
2 Pyruvate
2 Lactate
Glucose
Blood
2 Lactate
Muscle
Glucose
2 ATP
Glycolysis
2 Pyruvate
2 Lactate

Intérêt des lactates

Serum lactates correlate with mortality after operations for complex congenital heart disease. *Ann Thorac Surg. 1997 Sep*

Initial postoperative serum lactate levels predict survival in children after open heart surgery. *Intensive Care Med. 1996 Dec*

Serial blood lactate leves as a predictor of mortality in children after cardiopulmonary bypass surgery. *Pediatr Crit Care Med 2008 May*

- Lactatémie > 2 mmol/L si > 48h = valeur prédictive dcd 60%

Lactates et BE

PLoS One. 2018 Oct 5;13(10):e0205309. doi: 10.1371/journal.pone.0205309. eCollection 2018.

Base excess is superior to lactate-levels in prediction of ICU mortality after cardiac surgery.

Zante B[1,2], Reichenspurner H[2], Kubik M[2,3], Kluge S[3], Schefold JC[1], Pfortmueller CA[1].

Author information

Abstract

INTRODUCTION: Cardiac surgery with the use of cardiopulmonary bypass is known to induce distinct metabolic changes. Respective changes in acid-base status including increased systemic lactate levels were previously related to clinical outcomes, but data remain controversial. Therefore, we aim to investigate the relevance of lactate and base excess (BE) levels on ICU-mortality in patients admitted to the ICU after cardiac surgery.

MATERIALS AND METHODS: Perioperative data of patients treated in a tertiary care academic center admitted to the ICU after on-pump surgery were analyzed in a retrospective fashion. Receiver operation characteristic (ROC) curves were constructed for admission lactate-levels and BE with calculation of optimal cut-off values to predict ICU mortality. Univariate followed by multivariate regression models were constructed to identify potential outcome-relevant indices.

RESULTS: Data from 1,058 patients were included in the analysis. Area under the curves for prediction of ICU mortality were 0.79 for lactate levels at ICU admission (sensitivity 61.9%/ specificity 87.5%; optimal cut-off level 3.9mmol/l), and 0.7 for BE (sensitivity 52.4%/ specificity 93.8%, optimal cut-off level -6.7), respectively. Multivariate regression identified BE < -6.7 as the single metabolic predictor of ICU-mortality (HR 4.78, 95%-CI 1.4-16.33, p = 0.01). Explorative subgroup analyses revealed that the combination of lactate ≤3.9mmol/l and BE ≤ -6.7 has stronger impact on mortality than a combination of lactate of >3.9mmol/l and BE > -6.7 (HR 2.56, 95%-CI 0.18-37.17).

CONCLUSIONS: At ICU-admission, severely reduced BE appears superior to hyperlactatemia with regard to prediction of ICU-mortality in patients after cardiac surgery.

Lactates et BE

- Elevated lactate levels after cardiac surgery may be caused by anaerobic glycolysis due to tissue hypoxia (known as hyperlactatemia "type A") related to insufficient macro- or micro- hemodynamics, by pulmonary diseases or by decreased oxygen carrying capacity related to bleeding.
- Likewise, increased lactate levels from non-hypoxic origins are known as "type b"-hyperlactatemia, may occur in cardiosurgical patients.
- Furthermore, drug therapy, hypothermia and the usage of CPB may lead to elevated lactate levels post cardiac surgery. Similar like lactate levels, an elevated base deficiency (BD) has many causes post-cardiac surgery

SaO2 et DO2

SaO_2 et DO_2

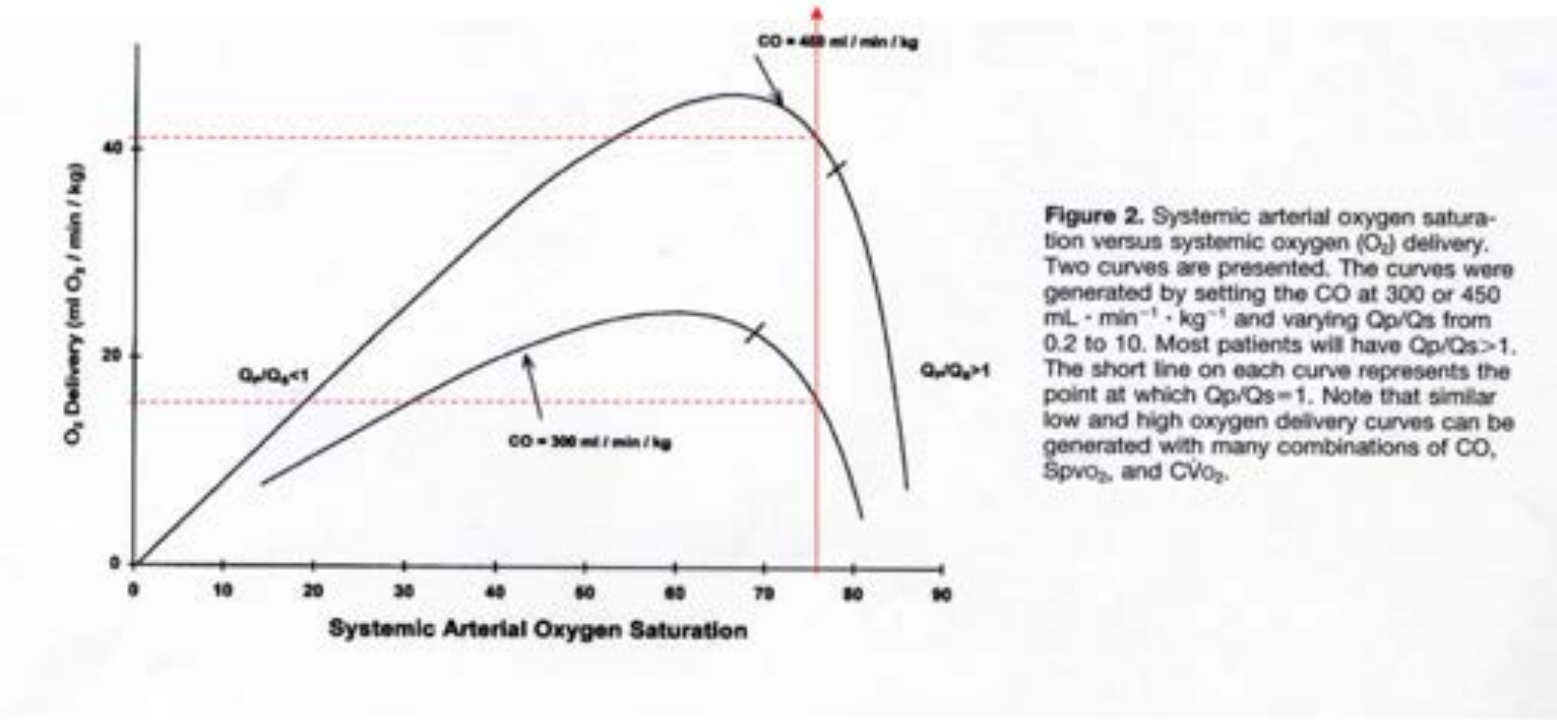


Figure 2. Systemic arterial oxygen saturation versus systemic oxygen (O_2) delivery. Two curves are presented. The curves were generated by setting the CO at 300 or 450 mL · min^{-1} · kg^{-1} and varying Qp/Qs from 0.2 to 10. Most patients will have Qp/Qs>1. The short line on each curve represents the point at which Qp/Qs=1. Note that similar low and high oxygen delivery curves can be generated with many combinations of CO, $Spvo_2$, and CVo_2.

Une SaO_2 correcte peut être associée à une faible $D0_2$, et à des $Sv0_2$ très diverses

SvO2 et DO2

SvO_2 et DO_2

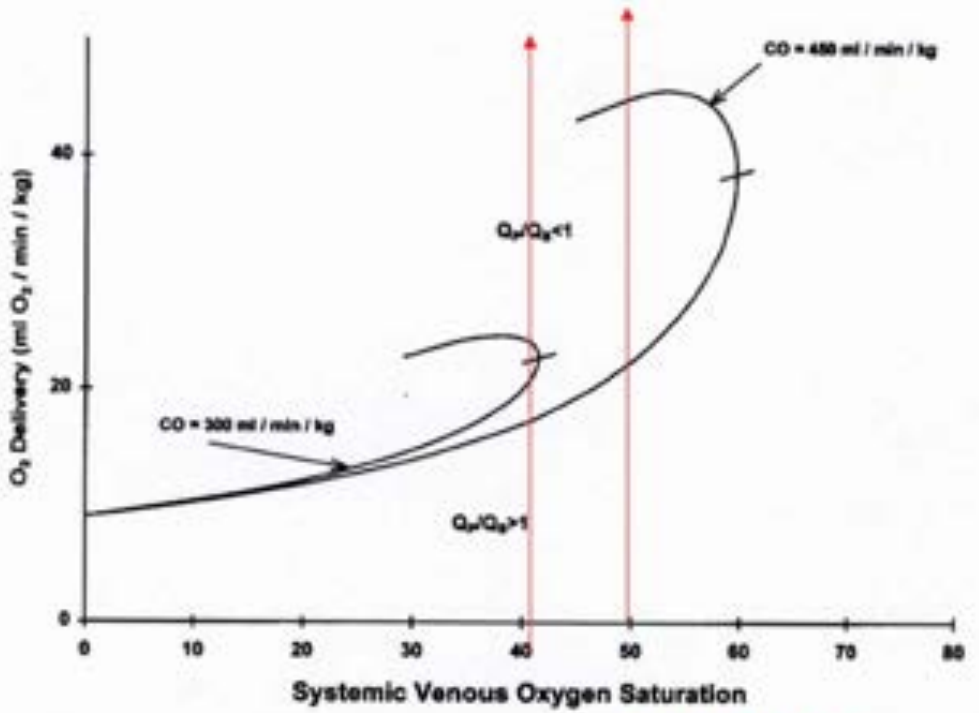


Figure 3. Systemic oxygen (O_2) delivery against Svo_2.

SvO_2 mieux corrélée mais non linéaire avec $D0_2$

Les plus hautes $Sv0_2$ = meilleures $D0_2$

Le pic de $D0_2$ ne correspond pas au pic de $Sv0_2$ sur chaque courbe.

Pour la même SvO_2, la DO_2 dépend du QP/QS

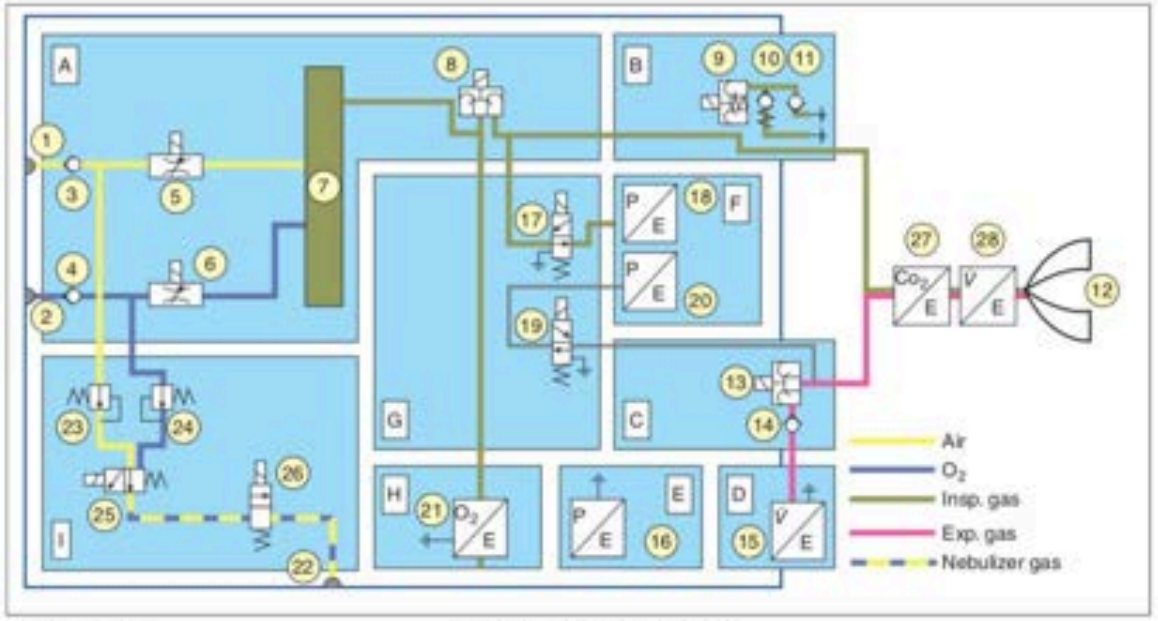
Indication VM

- Apnea
- Clinical Signs Of Increased Work Of Breathing
- Cardiovascular Signs Of Respiratory Distress
- Hypoxemic Respiratory Failure
- Hypercapnic Respiratory Failure
- Shock
- Postoperative Respiratory Failure
- Upper Airway Obstruction
- Inability To Protect The Airway From Aspiration
- Secretions

Respirateur

FIGURE 3-1 Examples of commonly used intensive care ventilators: A. Dräger Infinity V500, B. Hamilton G5, C. Maquet Servo i, D. Covidien PB840. (Image with permission from Nellcor Puritan Bennett LLC, Boulder, Colorado, doing business with Covidien.)

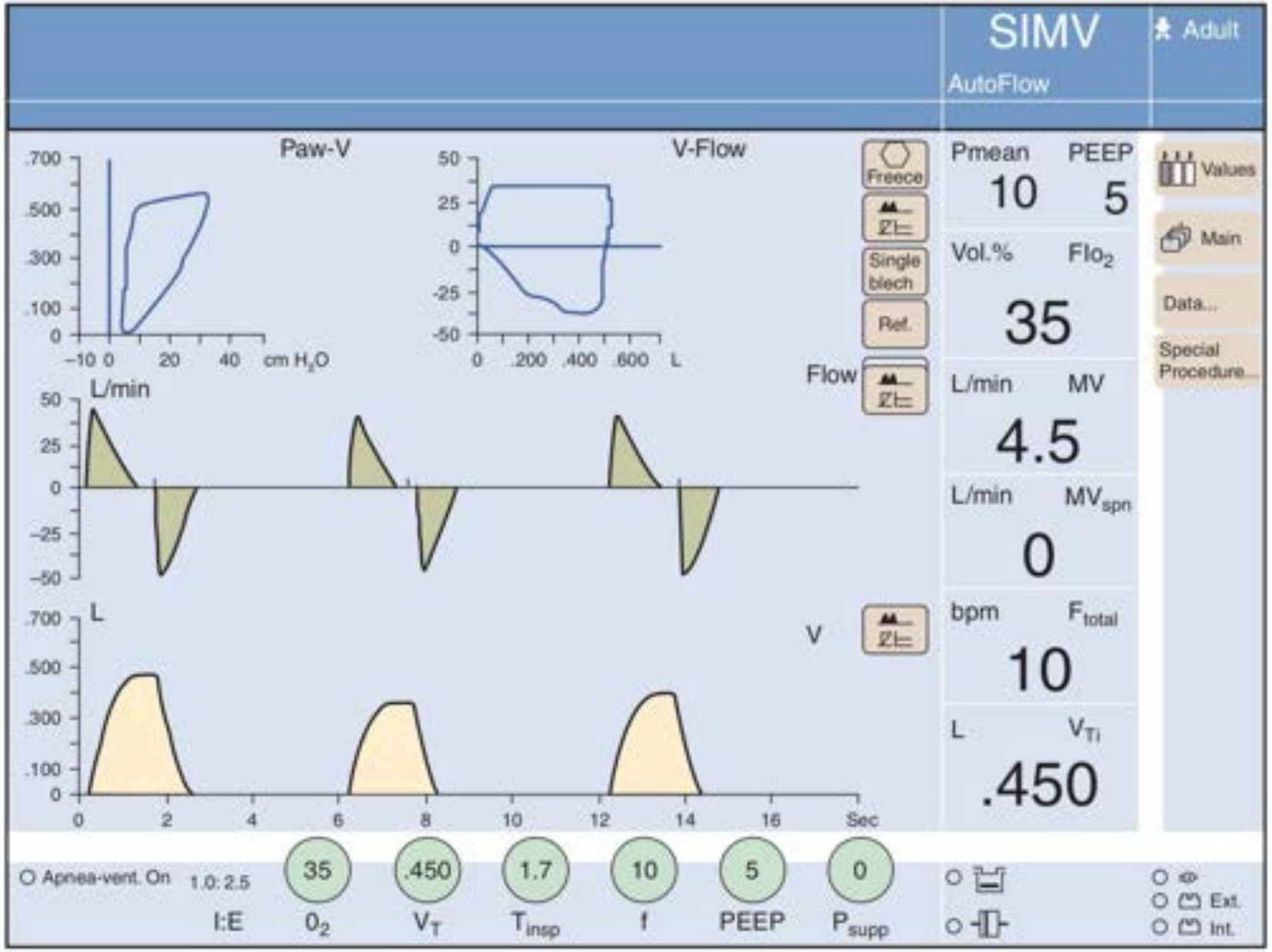
Respirateur



1 Air gas inlet
2 O_2 gas inlet
3 Air nonreturn valve
4 O_2 nonreturn valve
5 Air metering valve
6 O_2 metering valve
7 Tank
8 Mixed gas metering valve
9 Safety valve
10 Emergency expiratory valve
11 Emergency breathing valve
12 Patient's lungs
13 Expiratory valve
14 Nonreturn valve
15 Expiratory flow sensor
16 Barometric pressure sensor
17 Calibration valve for inspiratory pressure sensor
18 Inspiratory pressure sensor
19 Calibration valve for expiratory pressure sensor
20 Expiratory pressure sensor
21 O_2 sensor
22 Nebulizer outlet
23 Air pressure regulator
24 O_2 pressure regulator
25 Nebulizer mixer valve
26 Nebulizer changeover valve
27 CO_2 sensor
28 Neonatal flow sensor (depending on the patient category)

FIGURE 3-2 Pneumatic schematic of the Dräger Infinity V500 intensive care ventilator. **A.** Gas-mixture and gas-metering assembly. Gas from the supply lines enters the ventilator via the gas-inlet connections for oxygen and air (*1,2*). Two nonreturn valves (*3,4*) prevent one gas from returning to the supply line of the other gas. Mixing takes place in the tank (*7*) and is controlled by two valves (*5,6*). Inspiratory flow is controlled by a third valve (*8*). **B.** Inspiratory unit consists of safety valve (*9*) and two nonreturn valves (*10,11*). In normal operation, the safety valve is closed so that inspiratory flow is supplied to the patient's lungs (*12*). During standby, the safety valve is open and enables spontaneous inspiration by the emergency breathing valve (*11*). The emergency expiratory valve (*10*) provides a second channel for expiration when the expiratory valve (*13*) is blocked. **C.** Expiratory unit consists of the expiratory valve (*13*) and a nonreturn valve (*14*). The expiratory valve is a proportional valve and is used to adjust the pressure in the patient circuit. In conjunction with the spring-loaded valve of the emergency air outlet (*10*), the nonreturn valve (*14*) prevents pendulum breathing during spontaneous breathing. **D.** Expiratory flow sensor. **E.** Barometric pressure sensor. Conversion of mass flow to volume, body temperature and pressure saturated (*BTPS*) requires knowledge of ambient pressure. **F.** Pressure measurement assembly. Pressure in the patient circuit is measured with two independent pressure sensors (*18,20*). **G.** Calibration assembly. The pressure sensors are regularly zero calibrated by connection to ambient pressure via the two calibration valves (*17,19*). **H.** Oxygen sensor. **I.** Medication nebulizer assembly. (Reproduced, with permission, from Dräger Medical AG & Co. KG. *V500 Operator's Manual*. Luebeck, Germany.)

Respirateur



VNI

TABLE 4-4: CAUSES OF POSTOPERATIVE RESPIRATORY FAILURE

Intrapulmonary causes

- Atelectasis
- Aspiration
- Pneumonia
- Acute respiratory distress syndrome/acute lung injury
- Volume overload/congestive heart failure
- Pulmonary embolism (thrombus, air, fat)
- Bronchoconstriction (asthma/COPD)
- Pneumothorax

Extrapulmonary causes

- Shock
- Sepsis
- Decreased respiratory motor output
- Phrenic nerve injury
- Diaphragmatic dysfunction
- Upper airway obstruction
- Obstructive sleep apnea

Failure

TABLE 23-3: CRITERIA FOR EXTUBATION READINESS TEST FAILURE

Proposed criteria for failure of extubation readiness during 2 hours on CPAP <5 cm H_2O or T-piece

Clinical Criteria:

- Diaphoresis
- Nasal flaring
- Increasing respiratory effort
- Tachycardia (increase in heart rate >40 bpm [breaths per minute])
- Cardiac arrhythmias
- Hypotension
- Apnea

Laboratory Criteria:

- Increase in end-tidal CO_2 >10 mm Hg
- Decrease of arterial pH <7.32
- Decline in arterial pH >0.07
- Pa_{O_2} <60 mm Hg with an FI_{O_2} >40 (P/F O_2 ratio <150)
- Sp_{O_2} declines to <5%

From Newth, et al. Weaning and extubation readiness in pediatric patients. *Pediatr Crit Care Med.* 2009;10:1–11.

VNI

- NIV exerts its main effects on the pulmonary and on the cardiovascular systems.
- Through the application of a positive end-expiratory pressure (PEEP), with or without a pressure support during inspiration, NIV restores lung volumes by opening atelectatic areas (a common postoperative finding),
- Increases alveolar ventilation and reduces the work of breathing
- By reopening atelectasis, NIV can prevent postoperative pneumonia
- NIV is increasingly being used in the postoperative period of heart surgery with an 85% success rate and is associated with a lesser need for IMV

VNI

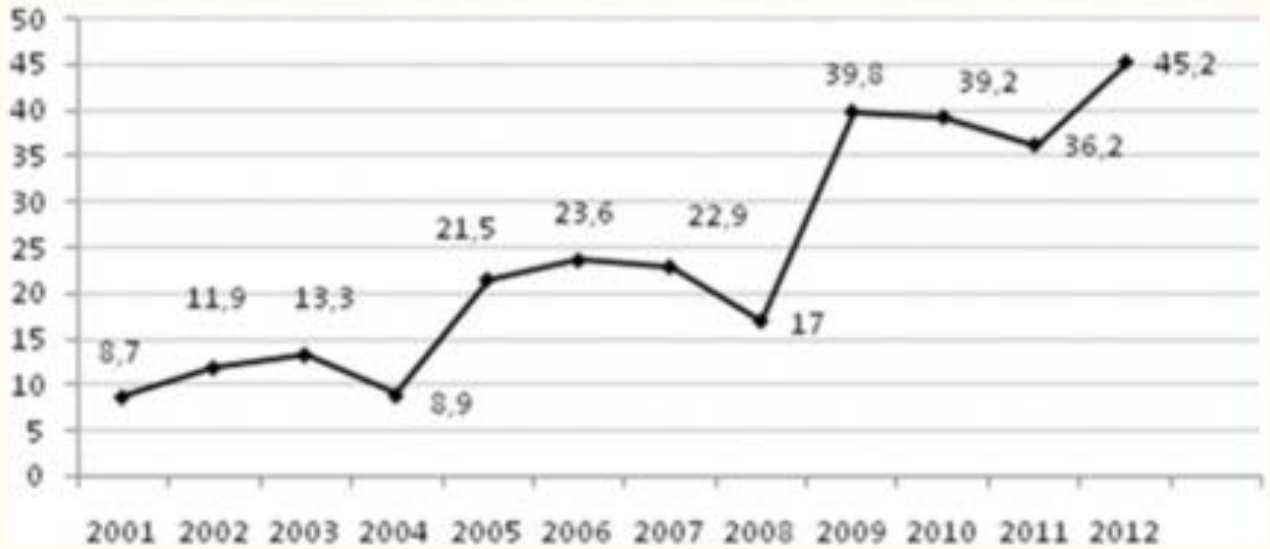


Fig. 1

Evolution in the use of non-invasive ventilation (NIV) (percentage of patients with NIV)

Lunettes Haut Débit

High-flow oxygen therapy, as compared with standard oxygen therapy or noninvasive ventilation, resulted in reduced mortality in the ICU and at 90 days.

Lunettes Haut Débit

Physiological impact of high-flow nasal cannula therapy on postextubation acute respiratory failure after pediatric cardiac surgery: a prospective observational study.

Shioji N[1], Iwasaki T[1], Kanazawa T[1], Shimizu K[1], Suemori T[1], Sugimoto K[1], Kuroe Y[1], Morimatsu H[1].

Author information

Abstract

BACKGROUND: Reintubation after pediatric cardiac surgery is associated with a high rate of mortality. Therefore, adequate respiratory support for postextubation acute respiratory failure (ARF) is important. However, little is known about the physiological impact of high-flow nasal cannula (HFNC) therapy on ARF after pediatric cardiac surgery. Our working hypothesis was that HFNC therapy for postextubation ARF after pediatric cardiac surgery improves hemodynamic and respiratory parameters.

METHODS: This was a prospective observational study conducted at a single university hospital. Children less than 48 months of age who had postextubation ARF after cardiac surgery were included in this study. HFNC therapy was started immediately after diagnosis of postextubation ARF. Data obtained just before starting HFNC therapy were used for pre-HFNC analysis, and data obtained 1 h after starting HFNC therapy were used for post-HFNC analysis. We compared hemodynamic and respiratory parameters between pre-HFNC and post-HFNC periods. The Wilcoxon signed-rank test was used to analyze these indices.

RESULTS: Twenty children were included in this study. The median age and body weight were 4.5 (2.3-14.0) months and 4.3 (3.1-7.1) kg, respectively. Respiratory rate (RR) significantly decreased from 43.5 (32.0-54.8) to 28.5 (21.0-40.5) breaths per minute ($p = 0.0008$) 1 h after the start of HFNC therapy. Systolic blood pressure also decreased from 87.5 (77.8-103.5) to 76.0 (70.3-85.0) mmHg ($p = 0.003$). Oxygen saturation, partial pressure of arterial carbon dioxide, heart rate, and lactate showed no remarkable changes. There was no adverse event caused by HFNC therapy.

CONCLUSIONS: HFNC therapy improves the RR of patients who have postextubation ARF after pediatric cardiac surgery without any adverse events.

Lunettes Haut Débit

Respir Med. 2017 Oct;131:210-214. doi: 10.1016/j.rmed.2017.08.027. Epub 2017 Sep 1.

The use of high-flow nasal cannula (HFNC) as respiratory support in neonatal and pediatric intensive care units in Germany - A nationwide survey.

Schmid F[1], Olbertz DM[2], Ballmann M[3].

Author information

Abstract

BACKGROUND: High-flow nasal cannula (HFNC)[1] is a technique of oxygen supply, initially being used as a potentially less-invasive alternative to nasal continuous positive airway pressure (nCPAP)[2] for premature infants/neonates, which nowadays crosses the border of neonatal care. HFNC builds up a positive end-expiratory pressure (PEEP)[3] but lacks the opportunity for continuous monitoring. Therefore, pressure-depending complications are a risk. Our goal was to evaluate the current use of HFNC in Germany regarding indications, techniques of application and complications experienced.

STUDYDESIGN: We used a questionnaire sent to 226 pediatric clinics.

RESULTS: We received responses from 67 pediatric clinics (29.6%). HFNC was applied in the age group of 8 to 14 years in 42% and between 14 and 18 years in 33% of the clinics. 54% of the clinics have been using HFNC for more than 3 years. Applied flow rates varied strongly among the clinics. 70% of the clinics use HFNC outside of the established indications (alternative to nCPAP for premature infants and neonates, bronchiolitis) for pneumonia, support after extubation and non-adherence to nCPAP. Severe complications such as pneumothorax have been seen by 17,9% of the clinics.

CONCLUSION: We reported for the first time a nationwide overview about the expanded use of HFNC in pediatric clinics. Our results emphasize the fact that, even though HFNC is widely accepted as a non-invasive procedure there is still a potential of severe side effects. Therefore the use of HFNC should be monitored continuously and closely within an intensive or intermediate care unit.

Lunettes Haut Débit 1,5 L/kg/min

In neonates and infants a flow rate of 2 L/kg/min has been proposed, whereas in children flow rates should get closer to 1 L/kg/min

HFNC appears to provide an increased level of respiratory support with a reduced work of breathing than conventional oxygen supply with nasal cannula or face masks, whilst not being considered as invasive as nCPAP.

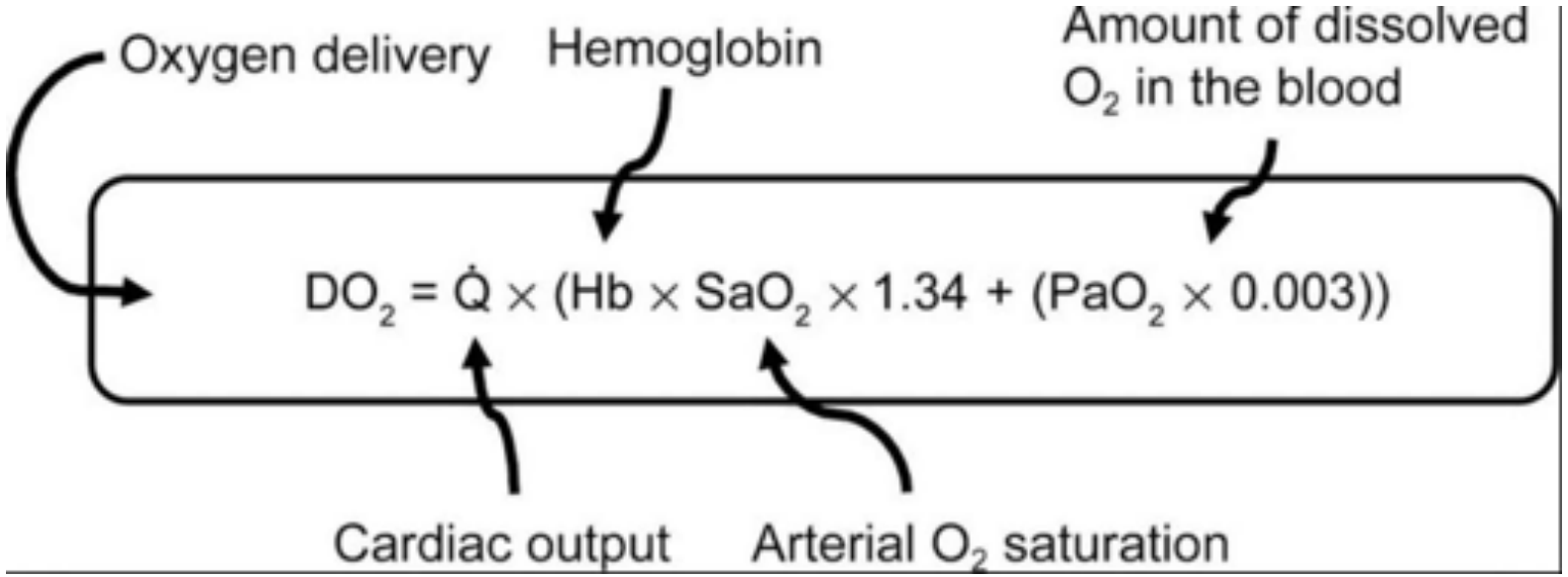
Furthermore, due to the humidified and heated gas-mixture, children tolerate HFNC better than conventional oxygen supply, because of not having the sense of dry nasal or oral mucosa. The humidified and heated air also improves the mucociliary clearance

An important mechanism of action consists of the continuous wash-out of the nasopharyngeal dead space. A consistent high flow rate leads to a reduced alveolar carbon dioxide concentration and thus reduced hypercapnia.

As respiratory support with nCPAP, the HFNC-system provides a positive airway pressure and thus builds up a positive end-expiratory pressure (PEEP), which can be similar, greater or less than those produced by the nCPAP-systems.

But in comparison to nCPAP, there is no monitoring available for the level of extending pressure in HFNC. Furthermore the pressure can vary dangerously because of a fluctuating leak through the mouth and nasal passages

DO2


Oxygen delivery
Hemoglobin
Amount of dissolved O_2 in the blood
$DO_2 = \dot{Q} \times (Hb \times SaO_2 \times 1.34 + (PaO_2 \times 0.003))$
Cardiac output
Arterial O_2 saturation

Épargne transfusionnelle chez l'enfant: Pourquoi ?

- Risques liés à la transfusion homologue
  - Problème de santé publique
  - Encore plus crucial chez l'enfant
  - 0,95% des enfants transfusés développent une complication
- Majorité des techniques utilisées chez l'adulte
  - Applicables à l'enfant
  - ± contraintes spécifiques

European Society of Anaesthesiology.

EJA

Eur J Anaesthesiol 2017; **34**:332–395

GUIDELINES

Management of severe perioperative bleeding: guidelines from the European Society of Anaesthesiology

First update 2016

Sibylle A. Kozek-Langenecker, Aamer B. Ahmed, Arash Afshari, Pierre Albaladejo, Cesar Aldecoa, Guidrius Barauskas, Edoardo De Robertis, David Faraoni, Daniela C. Filipescu, Dietmar Fries, Thorsten Haas, Matthias Jacob, Marcus D. Lancé, Juan V.L. Pitarch, Susan Mallett, Jens Meier, Zsolt L. Molnar, Niels Rahe-Meyer, Charles M. Samama, Jakob Stensballe, Philippe J.F. Van der Linden, Anne J. Wikkelsø, Patrick Wouters, Piet Wyffels and Kai Zacharowski

The management of perioperative bleeding involves multiple assessments and strategies to ensure appropriate patient care. Initially, it is important to identify those patients with an increased risk of perioperative bleeding. Next, strategies should be employed to correct preoperative anaemia and to stabilise macrocirculation and microcirculation to optimise the patient's tolerance to bleeding. Finally, targeted interventions should be used to reduce intraoperative and postoperative bleeding, and so prevent subsequent morbidity and mortality. The objective of these updated guidelines is to provide healthcare professionals with an overview of the most recent evidence to help ensure improved clinical management of patients. For this update, electronic databases were searched without language restrictions from 2011 or 2012 (depending on the search) until 2015. These searches produced 18 334 articles. All articles were assessed and the existing 2013 guidelines were revised to take account of new evidence. This update includes revisions to existing recommendations with respect to the wording, or changes in the grade of recommendation, and also the addition of new recommendations. The final draft guideline was posted on the European Society of Anaesthesiology website for four weeks for review. All comments were collated and the guidelines were amended as appropriate. This publication reflects the output of this work.

Risks of transfusion: outcome focus

Bruce D. Spiess

Transfusion 2004

TABLE 1. Risks of transfusion (the classics)*

Risk	Incidence
1. Hepatitis B	1/5,800-1/150,000 units
2. Hepatitis C	1/872,000 units
3. HIV	1/1.4-2.4 million
4. HTLV	1/1.5 million
5. TTV	52%
6. West Nile virus	1/1.4 million
7. Cytomegalovirus conversion	7%
8. Epstein-Barr virus	0.5%
9. TRALI	1/5,000-10,000
10. ABO-Rh mismatch	
Occurrence	1/6,000-20,000
Mortality	1/100,000-500,000
11. Delayed hemolytic reaction	1/2,500
12. Alloimmunization (PLTs and WBCs)	1/10
13. Alloimmunization (RBCs)	1%
14. Allergic reactions	1%-4%
15. Febrile reaction	0.1%-1%
16. GVHD	1/400-1/10,000
17. Volume overload	10%-40%
18. Depressed erythropoiesis	Universal

* Some of the reported risks of transfusion. Data are reported either as risk per number of units transfused or as percentage.

Transfusion 2008

Transfusion. 2008 Jan;48(1):73-80. Epub 2007 Sep 24.

Blood transfusions in children: a multi-institutional analysis of practices and complications.

Slonim AD[1], Joseph JG, Turenne WM, Sharangpani A, Luban NL.

Author information

Abstract

BACKGROUND: Blood product transfusions are a valuable health-care resource. Guidelines for transfusion exist, but variability in their application, particularly in children, remains. The risk factors that threaten transfusion safety are well established, but because their occurrence in children is rare, single-institution studies have limited utility in determining the rates of occurrence. An epidemiologic approach that investigates blood transfusions in hospitalized children may help improve our understanding of transfused blood products in this vulnerable population.

STUDY DESIGN AND METHODS: This was a nonconcurrent cohort study of pediatric patients not more than 18 years of age hospitalized from 2001 to 2003 at 35 academic children's hospitals that are members of the Pediatric Health Information System (PHIS).

RESULTS: A total of 51,720 (4.8%) pediatric patients received blood product transfusions during the study period. Red blood cells (n = 44,632) and platelets (n = 14,274) were the two most frequently transfused products. The rate of transfusions was highest among children with neutropenia, agranulocytosis, and sickle cell crisis. Asian and American Indian patients had important differences in the rate of blood transfusions and their complications. Resource use in terms of length of stay and costs were higher in patients who received transfusion. Of those patients who received transfusions, 492 (0.95%) experienced a complication from the administered blood product. This accounted for a rate of complications of 10.7 per 1,000 units transfused.

CONCLUSIONS: The administration of blood products to children is a common practice in academic children's hospitals. Complications associated with these transfused products are rare.

Transfusion 2008

- Etude de cohorte de patients <18 ans de 2001 à 2003
- 35 hôpitaux pédiatriques académiques
- 51 720 (4.8%) patients transfusés
- CGR = 44 632 et plaquettes = 14 274
- 492 patients = 0.95% avec complications
- Taux de complications = 10.7/1000 unités transfusées

Critical Care Medicine 2014

Crit Care Med. 2014 Mar;42(3):675-90. doi: 10.1097/CCM.0000000000000176.

Transfusion in critically ill children: indications, risks, and challenges.

Parker RI[1].

Author information

Abstract

OBJECTIVE: To provide a concise review of transfusion-related issues and practices in the pediatric patient population, with a focus on those issues of particular importance to the care of critically ill children.

DATA SOURCE: Electronic search of the PubMed database using the search terms "pediatric transfusion," "transfusion practices," "transfusion risks," "packed red blood cell transfusion," "white blood cell transfusion," "platelet transfusion," "plasma transfusion," and "massive transfusion" either singly or in combination.

STUDY SELECTION AND DATA EXTRACTION: All identified articles published since 2000 were manually reviewed for study design, content, and support for indicated conclusions, and the bibliographies were scrutinized for pertinent references not identified in the PubMed search. Selected studies from this group were then manually reviewed for possible inclusion in this review.

DATA SYNTHESIS: Well-designed studies have demonstrated the benefit of "restrictive" transfusion practices across the entire age spectrum of pediatric patients across a wide spectrum of pediatric illness. However, clinician implementation of the more restrictive transfusion practices supported by these studies is variable. Additionally, the utilization of both platelet and plasma transfusions in either a "prophylactic" or "therapeutic" setting appears to be greater than that supported by published data.

CONCLUSIONS: The preponderance of prospective, randomized trials and retrospective analyses support the use of a restrictive packed RBC transfusion policy in most clinical conditions in children. Neonatal transfusions guidelines rely largely on "expert opinion" rather than experimental data. Current transfusion practices for both platelets and coagulant products (e.g., fresh-frozen plasma and recombinant-activated factor VII) are poorly aligned with recommended transfusion guidelines. As with adults, current transfusion practices in children often do not reflect implementation of our current knowledge on the need for transfusion. Greater efforts to implement current evidence-based transfusion practices are needed.

Critical Care Medicine 2014

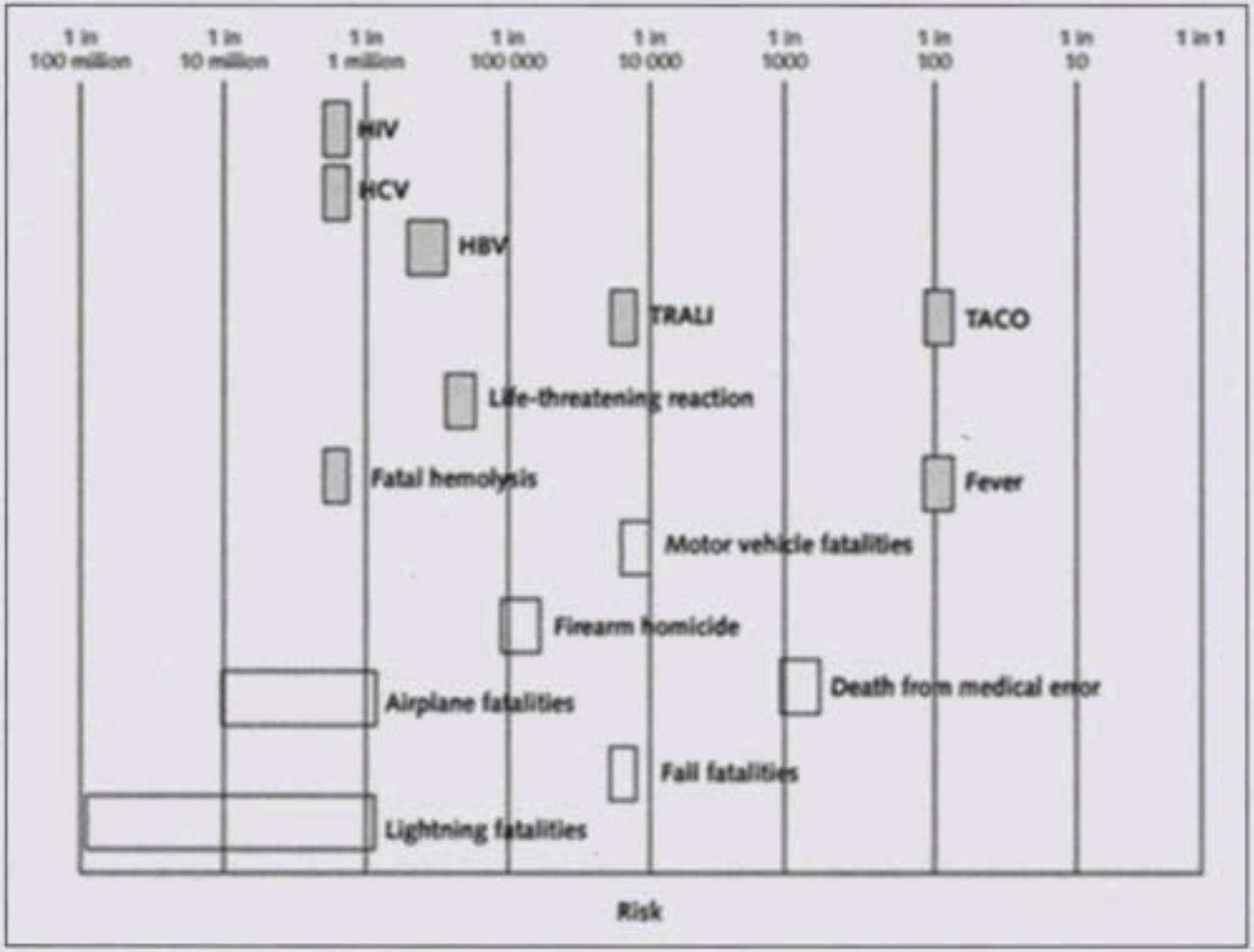


Figure 1. Adverse effects of RBC transfusion contrasted with other risks. HCV = hepatitis C virus, HBV = hepatitis B virus, TRALI = transfusion-related acute lung injury, TACO = transfusion-associated circulatory overload. Reproduced with permission from Carson et al (1).

TRALI in children

Journal of Critical Care 2014

Contents lists available at ScienceDirect

Journal of Critical Care

journal homepage: www.jccjournal.org

Incidence, risk factors, and outcome of transfusion-related acute lung injury in critically ill children: A retrospective study☆

Hilde D. Mulder, MD [a,1], Quinten J.J. Augustijn, MSc [a,1], Job B. van Woensel, MD, PhD [a], Albert P. Bos, MD, PhD [a], Nicole P. Juffermans, MD, PhD [b], Roelie M. Wösten-van Asperen, MD, PhD [a,*]

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ARTICLE INFO

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ABSTRACT

Purpose: Acute lung injury (ALI) that develops within 6 hours after transfusion (TRALI) is the leading cause of transfusion-related morbidity and mortality. Both incidence and patient and transfusion-related risk factors are well studied in the adult critically ill patient population. Clinical data on TRALI in the pediatric population are sparse and are mainly limited to case reports and hemovigilance reporting systems. The objective of this study was to determine incidence, risk factors, and outcome of TRALI in critically ill children.

Materials and Methods: In a retrospective cohort study, all first-time admissions to the pediatric intensive care unit from January 1, 2009, until December 31, 2012, were screened for onset of TRALI using the consensus criteria.

Results: Of 2294 admitted patients, 304 were transfused, of whom 21 (6.9%) developed TRALI. Compared with transfused control subjects, risk factors for TRALI were mechanical ventilation (odds ratio, 18.94 [2.38-2452.56]), sepsis (odds ratio, 7.20 [2.69-19.69]), and high Pediatric Risk of Mortality III score (odds ratio, 1.05 [1.01-1.10]). Patients with TRALI had a higher mortality and a longer duration of mechanical ventilation when compared with transfused control subjects.

Conclusions: Transfusion-related ALI is relatively common in critically ill children. The incidence in the pediatric intensive care unit population is similar to that in adult intensive care unit patients. High PRISM score on admission, mechanical ventilation and sepsis were identified as independent risk factors, which may help to assess the risks and benefits of transfusion in critically ill patients.

TRALI in children

Journal of Critical Care 2014

	TRALI (n = 21)	No TRALI (n = 283)	P
Demographic characteristics			
Age (y), mean (SD)	4.6 (5.2)	5.0 (5.8)	.79
Male sex, n (%)	13 (61.9)	172 (60.8)	.91
Weight (kg), mean (SD)	19.5 (19.7)	20.6 (20.1)	.80
PICU admission category, n (%)			
Medicine	17 (81.0)	106 (37.5)	<.0001
Respiratory	1 (4.8)	41 (14.5)	.33
Cardiovascular	1 (4.8)	11 (3.9)	.58
Neurology	0	16 (5.7)	.99
Surgery	2 (9.5)	83 (29.3)	.07
Neurosurgery	0	20 (7.1)	.38
Cardiac surgery	0	6 (2.1)	.99
PRISM III score, mean (SD)	22.4 (13.2)	12.8 (9.2)	<.0001
Liver failure, n (%)	2 (9.5)	8 (2.8)	.15
Diabetes, n (%)	0	1 (0.4)	.33
Cardiac surgery, n (%)	0	6 (2.1)	.99
Hematologic malignancy, n (%)	3 (14.3)	21 (7.4)	.22
Mechanical ventilation, n (%)	21 (100.0)	179 (63.3)	<.0001
Sepsis, n (%)	11 (52.4)	35 (12.4)	<.0001
Aspiration, n (%)	2 (9.5)	6 (2.1)	.10
Surgery, n (%)	5 (23.8)	120 (42.4)	.10
Trauma, n (%)	3 (14.3)	22 (7.8)	.40
Pneumonia, n (%)	4 (19.0)	31 (11.0)	.28
DIC, n (%)	7 (33.3)	21 (7.4)	<.0001
Immune compromised, n (%)	5 (23.8)	28 (9.9)	.06
Near drowning, n (%)	1 (4.8)	1 (0.4)	.13
Vt/kg BW, mean (SD)	7.7 (2.6)	7.5 (1.5)	.51
Temperature (°C), mean (SD)	37.2 (1.6)	37.2 (1.2)	.94
Platelet count (10^9/L), median (IQR)	78 (44-213)	204 (107-311)	.002
Leuco count (10^9/L), median (IQR)	5.3 (3.3-17.3)	9.9 (6.0-15.5)	.08
Fluid balance, L/24 h, median (IQR)	1.0 (0.4-2.0)	0.4 (0.1-0.8)	.001
Outcomes			
PICU mortality, n (%)	16 (76.2)	32 (11.3)	<.0001
PICU length of stay (h), median (IQR)	227 (88-354)	101 (43-231)	.07
Ventilation time (h), median (IQR)	183 (52-282)	25 (0-139)	.002

TRALI in children

Journal of Critical Care 2014

Contents lists available at ScienceDirect

Journal of Critical Care

journal homepage: www.jccjournal.org

Incidence, risk factors, and outcome of transfusion-related acute lung injury in critically ill children: A retrospective study☆

To the best of our knowledge, this is the first study describing incidence and risk factors of TRALI in critically ill children. The present study demonstrated that TRALI is relatively common in critically ill children, affecting 6.9% of the transfused children in our population. Most of these patients (90%) had a preexistent risk factor for ALI prior to the onset of TRALI and were thus diagnosed as possible TRALI. High PRISM III score, sepsis, and mechanical ventilation were identified as independent risk factors for the development of TRALI.

No association was found to suggest that the volume of transfused blood products (RBCs, FFPs, or platelets) has an effect on the development of TRALI. In accordance with this, patient-related risk factors were also more important than transfusion-related risk factors in the adult population

TRALI

EJA Guidelines 2016

Recommendation

We recommend a male-only donor policy for plasma-containing blood products to prevent the onset of TRALI. 1C

Transfusion 2015

Transfusion. 2015 Jan;55(1):164-75. doi: 10.1111/trf.12816. Epub 2014 Aug 18.

Low-risk transfusion-related acute lung injury donor strategies and the impact on the onset of transfusion-related acute lung injury: a meta-analysis.

Müller MC[1], van Stein D, Binnekade JM, van Rhenen DJ, Vlaar AP.

Author information

Abstract

BACKGROUND: Transfusion-related acute lung injury (TRALI) is the leading cause of transfusion-related mortality. In the past decade blood banks have implemented low-risk TRALI donor strategies, including a male-only donor policy for plasma-containing blood products to prevent onset of TRALI. We performed a meta-analysis to determine whether use of low-risk TRALI donor strategies for plasma indeed reduces onset of TRALI.

STUDY DESIGN AND METHODS: We searched MEDLINE and Cochrane Central Register of Controlled Trials from January 1995 up to January 2013. Two reviewers independently extracted data on study characteristics, methods, and outcomes. Primary endpoint was onset of TRALI. Subgroup analyses were performed for patient populations prone to develop TRALI and general patient populations.

RESULTS: Ten articles were included. Meta-analysis using a random-effects model taking into account all transfused products showed a significant reduction for the risk of TRALI after implementation of low-risk TRALI donor strategies (odds ratio [OR], 0.61; 95% confidence interval [CI], 0.42-0.88). Data from patient populations prone to develop TRALI showed a significant reduction of TRALI risk (OR, 0.51; 95% CI, 0.29-0.90), while data from general patient populations showed a similar nonsignificant trend (OR, 0.66; 95% CI, 0.40-1.09). Results were similar when taking only plasma products into account (OR, 0.62; 95% CI, 0.42-0.92).

CONCLUSION: The introduction of low-risk TRALI donor strategies for plasma-containing products results in a reduction of TRALI.

Épargne transfusionnelle chez l'enfant: Comment ?

- Techniques d'épargne transfusionnelle

1. Préopératoire: augmenter la masse sanguine
2. Per- et post-opératoire
    - Réduire le saignement
    - Optimiser les pratiques transfusionnelles

- Stratégie d'épargne transfusionnelle
    - Stratégie périopératoire: Pré, per- et post-opératoires
    - Pharmacologiques ou non

Augmenter la masse sanguine

- Fer
- Erythropoïétine (EPO)

Supplémentation en fer

Carence martiale max. vers 10 mois => anémie

- Prise orale de fer : suffisante en préop. mais
  - Délai d'effet vs. programmation de chirurgie
  - Difficultés d'observance
- Administration IV : surtout postop.
  - Injection IVL (30-45 min) sous surveillance ECG
  - Dose maximale ≤ 7 mg/kg/j

Venofer® 5 mg/kg/j en 1 h
Surveillance hémodynamique
Aucun incident

Disponible en ligne sur www.sciencedirect.com
SCIENCE DIRECT®
ELSEVIER
Annales Françaises d'Anesthésie et de Réanimation 24 (2005) 1262–1265
annales françaises d'ANESTHÉSIE et de RÉANIMATION
http://france.elsevier.com/direct/ANNFAR/

Article original

Intérêt du fer intraveineux dans les anémies induites par l'hémodilution en chirurgie cardiaque pédiatrique

Post-haemodilution anaemia in paediatric cardiac surgery: benefit of intravenous iron therapy

S. Hulin *, Y. Durandy

Service de réanimation de chirurgie cardiaque pédiatrique, institut cardiologique Paris-Sud, hôpital Jacques-Cartier, avenue du Noyer-Lambert, 91300 Massy, France

Reçu le 15 septembre 2004 ; accepté le 26 mai 2005

Disponible sur internet le 11 juillet 2005

Résumé

Objectif. – La principale complication de l'hémodilution en chirurgie cardiaque pédiatrique est l'anémie. L'inefficacité de l'apport substitutif de fer oral nous a conduit à étudier l'effet de l'injection de complexe hydroxyde ferrique–saccharose : Venofer®.

Type d'étude. – Ouverte, randomisée.

Patients et méthodes. – Quatre-vingt-treize opérés en hémodilution ont été répartis en deux séries de 44 malades exploitables. Le premier groupe ne recevait pas de fer et le second une injection de 5 mg/kg de Venofer® le matin suivant l'intervention. Les paramètres de l'étude étaient l'hémoglobine, la ferritine et le pourcentage de réticulocytes mesurés en postopératoire à j1 et j5. La comparaison des deux séries a été faite par le test statistique *t* de Student.

Résultats. – Les deux séries étaient analogues en âge, poids, hémoglobine, ferritine et réticulocytes à j1 (aucune différence significative). À j5 la ferritine était supérieure dans le groupe traité 215 ± 87 vs 101 ± 55 µg/l dans le groupe non traité ($p < 0{,}001$) et les réticulocytes étaient supérieurs dans le groupe traité 3,25 ± 1,16 vs 2,65 ± 0,97 % dans le groupe non traité ($p < 0{,}005$).

Conclusion. – L'inflammation postopératoire peut expliquer l'échec du fer oral. L'apport intraveineux pourrait traiter une carence en fer fonctionnelle et/ou favoriser la synthèse d'érythropoïétine endogène. La réversibilité plus rapide de l'anémie lors de l'injection de fer améliore la qualité des suites opératoires.

Annales Françaises d'Anesthésie et de Réanimation 2005

	Poids (kg)	Hb (g/dL)		Ferritine (mg/l)		Réticulocytes (%)	
		J1	J5	J1	J5	J1	J5
Témoin	14,4	11,0	10,6	73,9	101,1	1,5	2,65
Venofer	14,1	10,5	10,3	61,0	215,0 *	1,5	3,25*

Erythropoïétine (EPO)

- EPO pré et/ou post-opératoire seule ou associée
  - à la TAP
  - à l'acide tranexamique …
- Posologies en pédiatrie
  - 180 UI/kg/j pendant 10 j préop. et 4 j postop.
  - 100 UI/kg x 3 /semaine pdt 3 semaines SC + J0 en IV
  - 300 UI/kg x 2 ou 600 UI/kg x1/semaine x 3 semaine
- Efficacité postop. limitée par l'inflammation

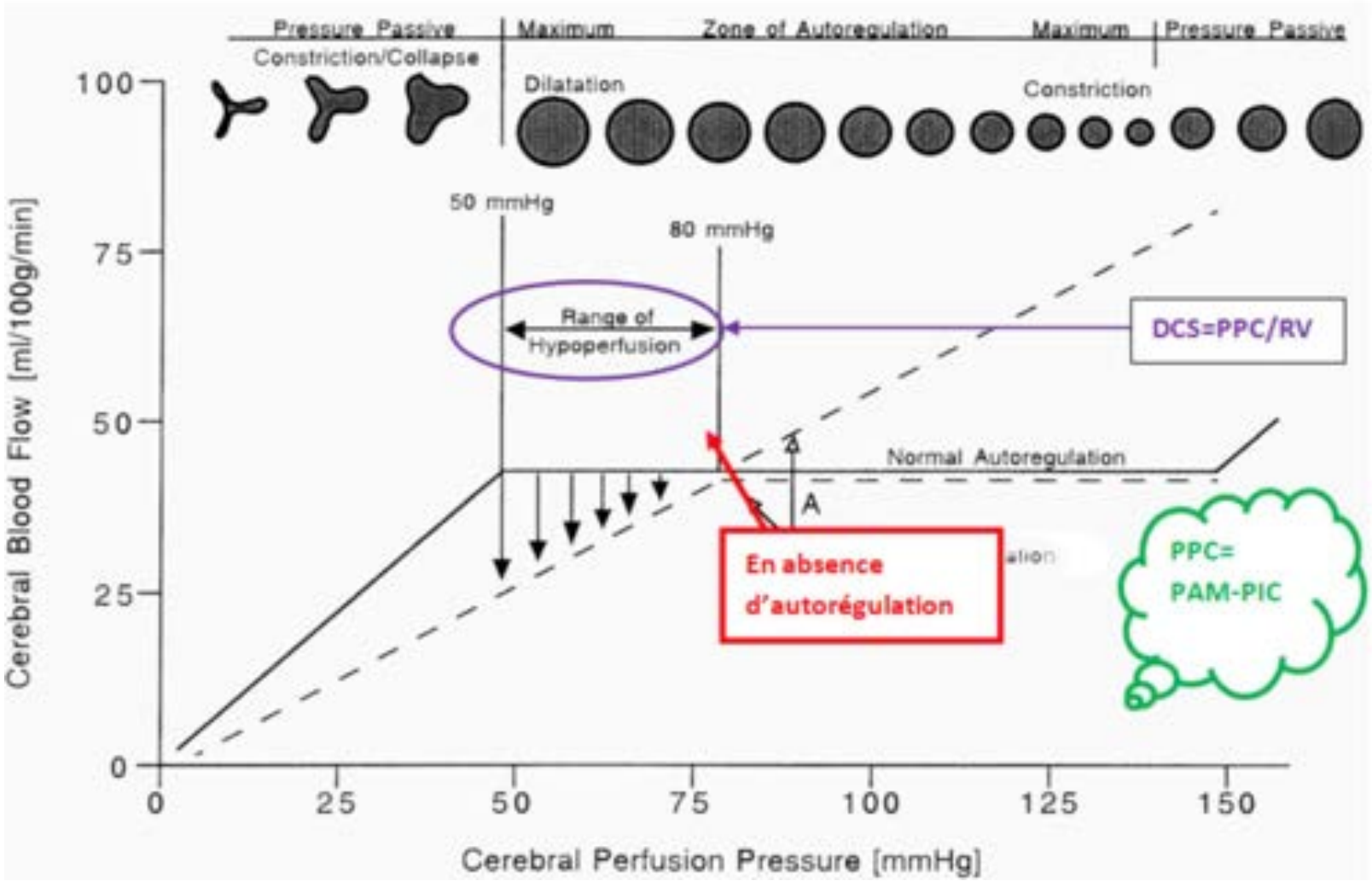
Réduction du saignement

- Limiter les prélèvements sanguins préopératoires
- Hémostase chirurgicale minutieuse —> chirurgien
- Réduire la Pr. hydrostatique intravasculaire
- Dépister/traiter les anomalies de l'hémostase
- Traitements pharmacologiques

Réduire la pression hydrostatique intravasculaire

- Réduire la pression veineuse : position du patient pour favoriser le retour veineux
- Hypotension contrôlée : discutée
  - Seuil acceptable de PAM : inconnu
  - Attention à l'autorégulation surtout cérébrale
  - Danger de l'association hypotension + anémie

L' autorégulation cérébrale



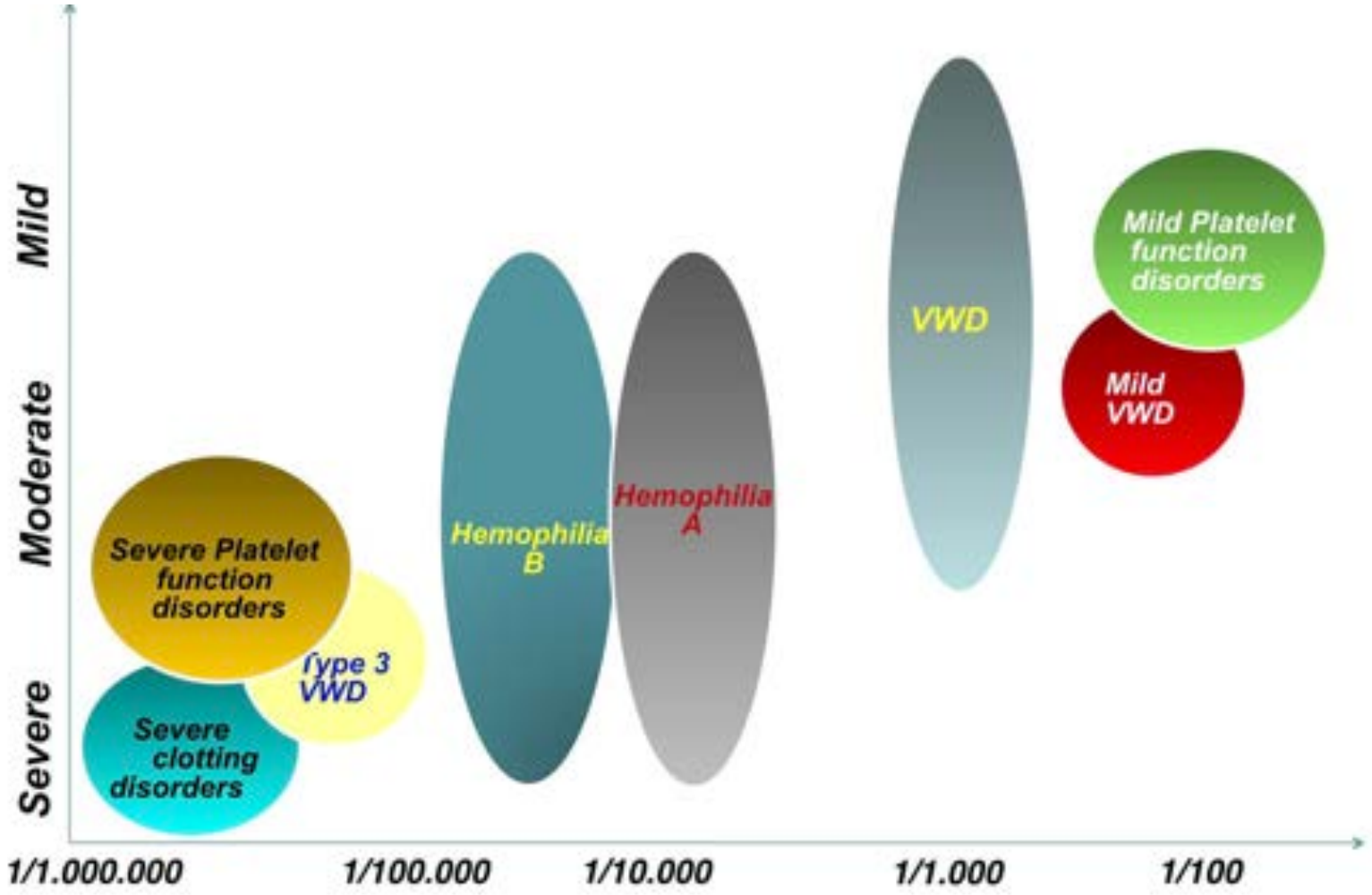
Réduire la pression hydrostatique intravasculaire

- Réduire la pression veineuse : position du patient pour favoriser le retour veineux
- Hypotension contrôlée : discutée
  - Seuil acceptable de PAM : inconnu
  - Attention à l'autorégulation surtout cérébrale
  - Danger de l'association hypotension + anémie

Dépister/traiter les anomalies périopératoires de l'hémostase

- Dépister une anomalie de l'hémostase préop.
- Apport de Vit. K1 chez les nourrissons exclusivement allaités et non substitués
- Substitution préopératoire des hémophiles …
- Prévention de l'hypothermie peropératoire
- Place du thromboélastogramme ?

Anomalie d'hemostase



Classification of von Willebrand disease

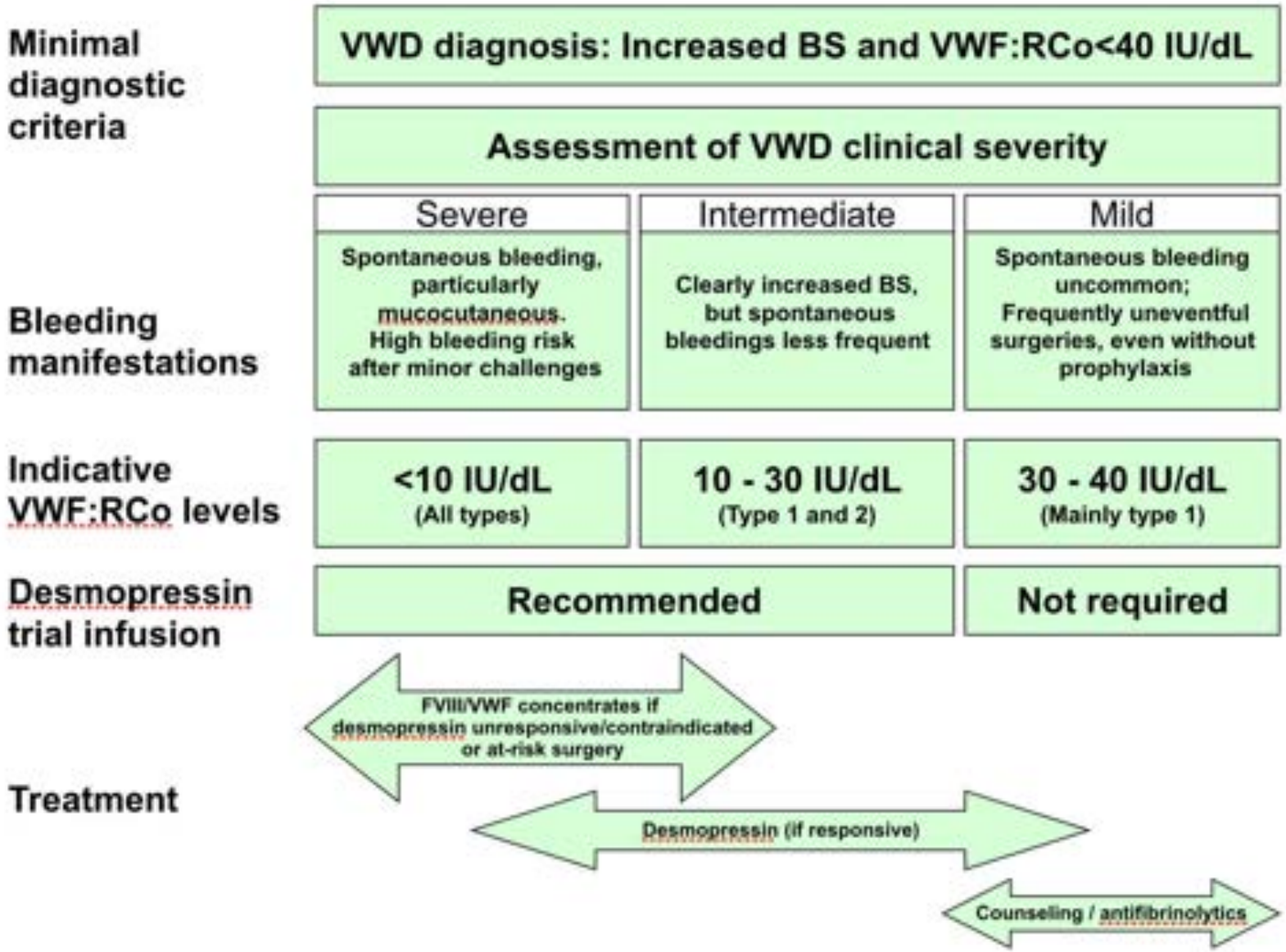
Quantitative deficiency
- Type 1: partial quantitative deficiency (~ 60-70 % of cases)
- Type 3: virtual absence (~ 1-2 % of cases)

Qualitative deficiency
- Type 2: dysfunctional VWF (~ 25-30 % of cases)
    - **A**: loss of high molecular weight multimers
    - **B**: increased affinity for platelet Gp Ib
    - **M**: normal multimers with low activity
    - **N**: reduced VWF-FVIII binding

VWD is a very heterogeneous bleeding disorder

Bleeding severity increases from type 1 to 3 and treatment differs

Clinical spectrum of VWD: implications for management



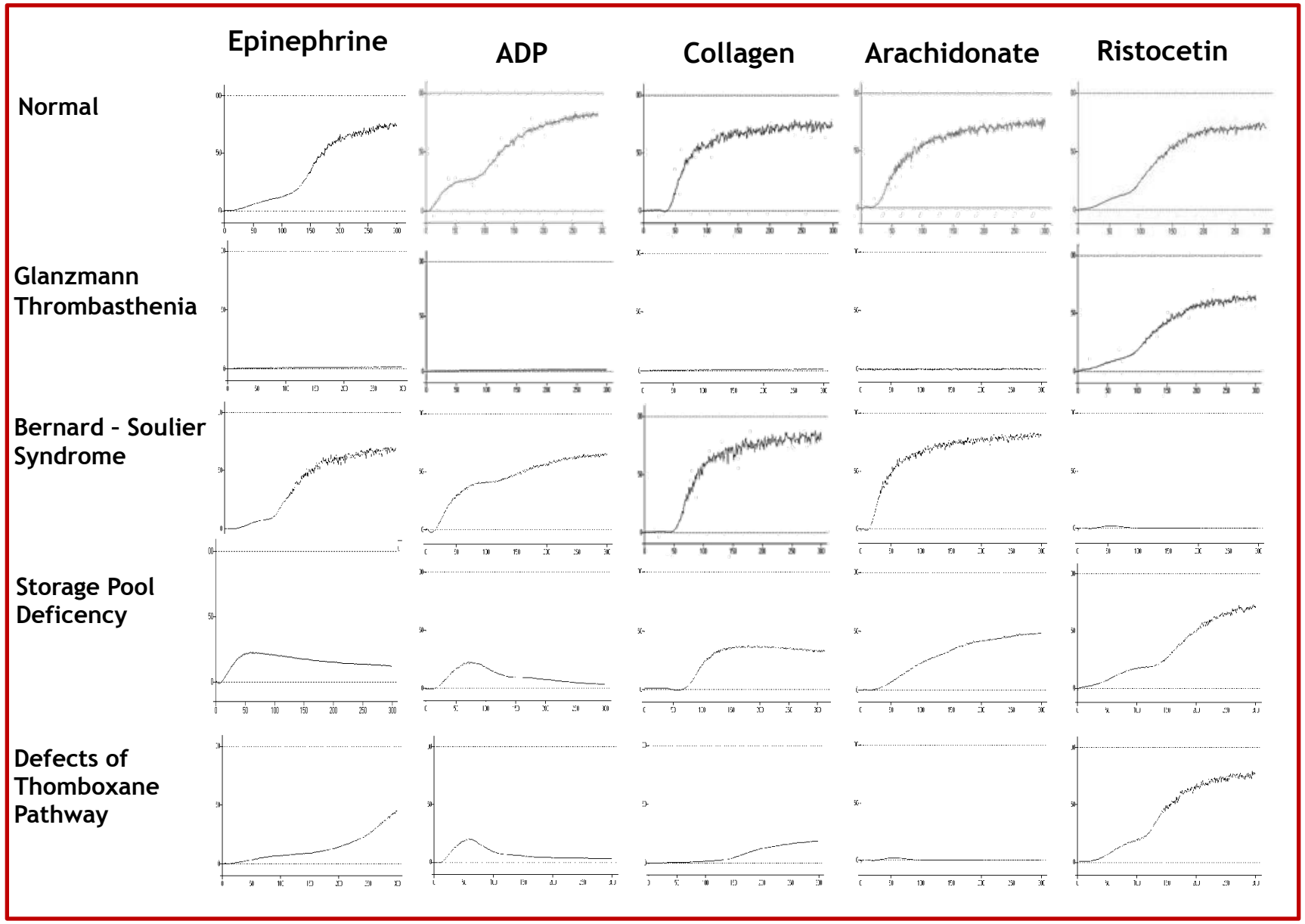
Hémophilie

Carence	Level FVIII/ IX	Clinique
Sévère	< 1 %	Hémorragies spontanées de la petite enfance; hémarthros spontané fréquent; besoin fréquent de thérapie de remplacement
Modérée	1- 5 %	Hémorragies après traumatisme et chirurgie; rarement saignementspontanées
Léger	> 5 % < 40 %	Hémorragies après traumatisme et chirurgie; rarement saignement après un traumatisme

Facteurs

Factor	Hemostatic Level	Plasma t ½ (hours)	Treatment	Dose
Fibrinogen	>50 mg/dl	36-48	pd-Fibrin. FFP	20-40 mg/kg 15-20 mL/kg
II	20-30%	24-36	Prothrombin complex concentrates	30 U/kg
V	15-20%	8-12	FFP	15-20 mL/kg
VII	15-20%	2-3	pd-FVII rFVIIa	40U/kg 15-20 mcg/kg
X	15-20%	10-12	Prothrombin complex concentrates	30 U/kg
XI	15-20%	10-12	FFP pd-FXI DDAVP/FVIIa	15-20 mL/kg
XIII	2-5%	72-96	pd-FXIII r- FXIII	20 U/kg

Diagnosis of inherited platelet function disorders by LTA

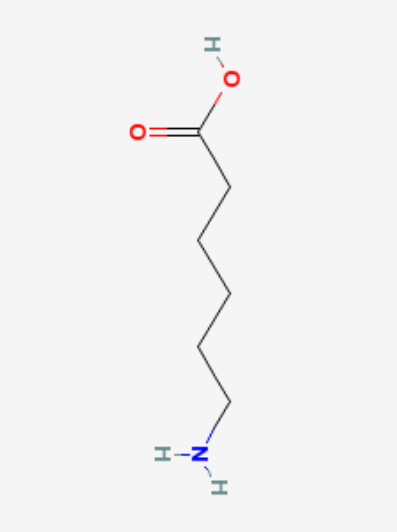


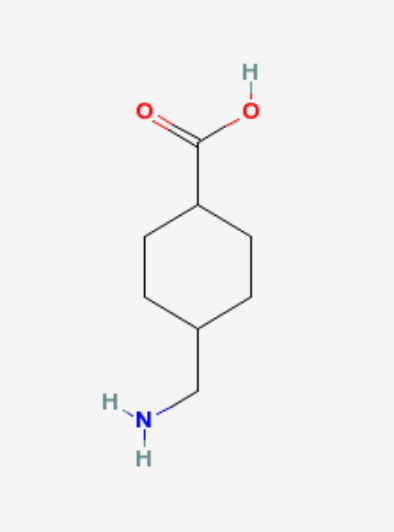
Traitements pharmacologiques

- Antifibrinolytiques
  - Aprotinine : AMM suspendue en 2009
  - Analogues de la lysine
- Facteur VII activé

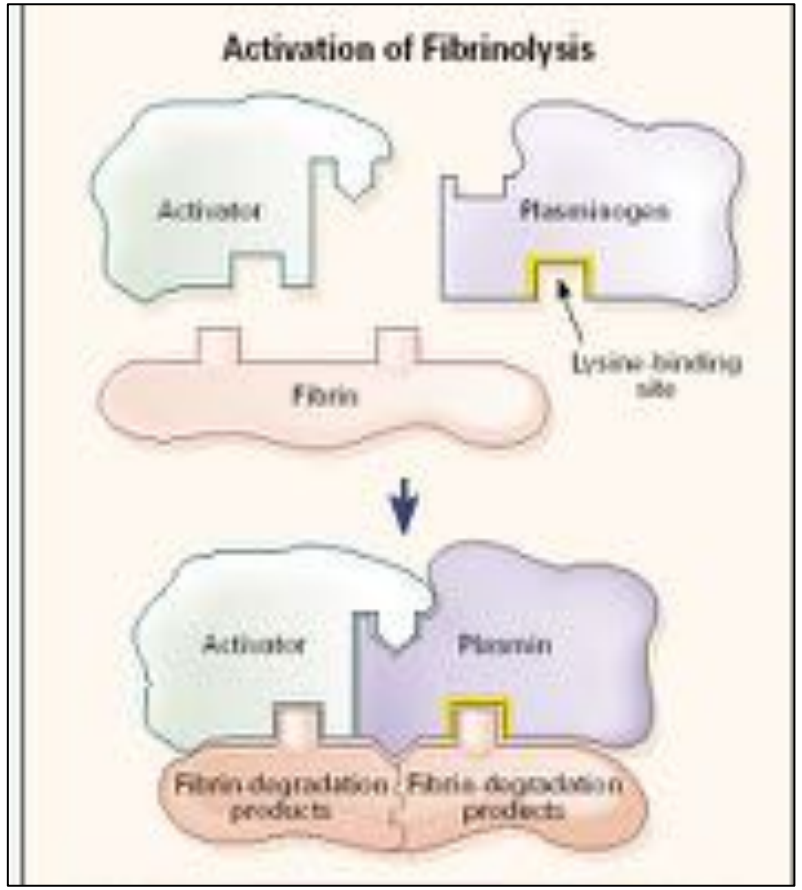
Antifibrinolytiques

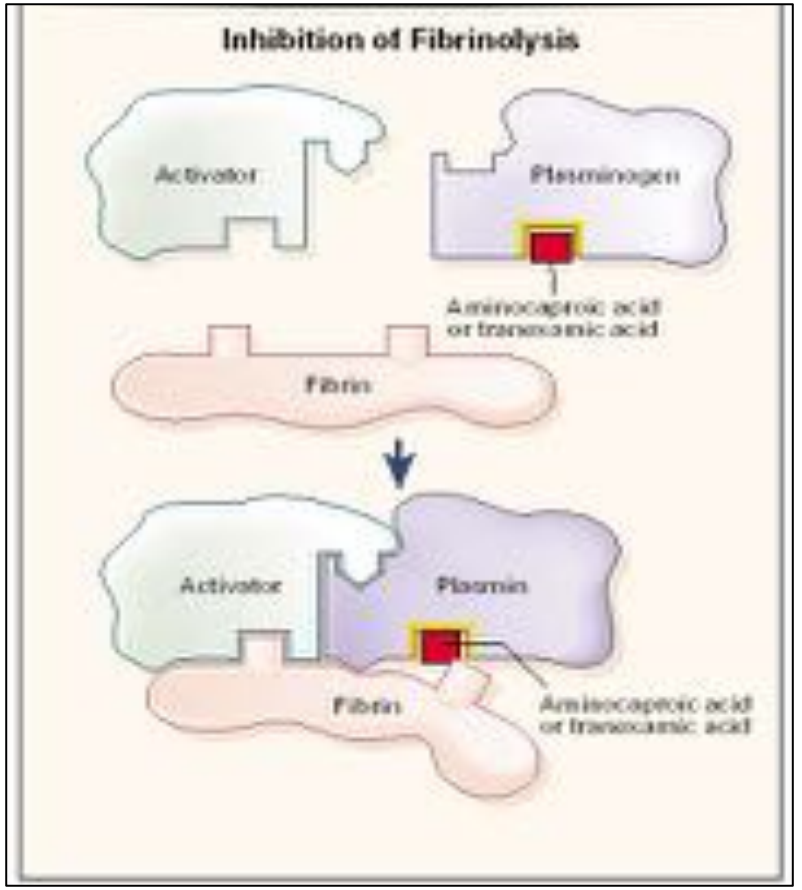
- Acide epsilon-aminocaproïque
  non commercialisé en France
- Acide tranexamique (Exacyl®)
  - Inhibe la formation de plasminogène-fibrine-tPA
  - Chirurgie pédiatrique : cardiaque, hépatique, ortho.





Antifibrinolytic Action of Aminocaproic Acid and Tranexamic Acid





Antifibrinilytiques

BMJ. 2012 Sep 11;345:e5798. doi: 10.1136/bmj.e5798.

Risks of harms using antifibrinolytics in cardiac surgery: systematic review and network meta-analysis of randomised and observational studies.

Hutton B[1], Joseph L, Fergusson D, Mazer CD, Shapiro S, Tinmouth A.

Author information

Abstract

OBJECTIVE: To estimate the relative risks of death, myocardial infarction, stroke, and renal failure or dysfunction between antifibrinolytics and no treatment following the suspension of aprotinin from the market in 2008 for safety reasons and its recent reintroduction in Europe and Canada.

DESIGN: Systematic review and network meta-analysis.

DATA SOURCES: A Cochrane review of antifibrinolytic treatments was chosen as the starting point for this systematic review. Medline, Embase, and the Cochrane register of trials were searched with no date restrictions for observational evidence.

STUDY SELECTION: Propensity matched or adjusted observational studies with two or more of the interventions of interest (aprotinin, tranexamic acid, epsilon-aminocaproic acid, and no treatment) that were carried out in patients undergoing cardiac surgery.

DATA ANALYSIS: Network meta-analysis was used to compare treatments, and odds ratios with 95% credible intervals were estimated. Meta-analyses were carried out for randomised controlled trials alone and for randomised controlled trials with observational studies.

RESULTS: 106 randomised controlled trials and 11 observational studies (43,270 patients) were included. Based on the results from analysis of randomised controlled trials, tranexamic acid was associated on average with a reduced risk of death compared with aprotinin (odds ratio 0.64, 95% credible interval 0.41 to 0.99). When observational data were incorporated, comparisons showed an increased risk of mortality with aprotinin on average relative to tranexamic acid (odds ratio 0.71, 95% credible interval 0.50 to 0.98) and epsilon-aminocaproic acid (0.60, 0.43 to 0.87), and an increased risk of renal failure or dysfunction on average relative to all comparators: odds ratio 0.66 (95% credible interval 0.45 to 0.88) compared with no treatment, 0.66 (0.48 to 0.91) versus tranexamic acid, and 0.65 (0.45 to 0.88) versus epsilon-aminocaproic acid.

CONCLUSION: Although meta-analyses of randomised controlled trials were largely inconclusive, inclusion of observational data suggest concerns remain about the safety of aprotinin. Tranexamic and epsilon-aminocaproic acid are effective alternatives that may be safer for patients.

rFVIIa

EJA Guidelines 2016

We recommend against the prophylactic use of rFVIIa due to increased risk of fatal thrombosis. 1B

We suggest that off-label administration of rFVIIa can be considered for life-threatening bleeding which cannot be stopped by conventional, surgical or interventional radiological means and/or when comprehensive coagulation therapy fails. 2C

Although rFVIIa is efficacious in reducing perioperative bleeding, a limited body of research suggests that rFVIIa might increase morbidity and mortality.

A single-centre, retrospective review (n1/416) of paediatric patients who received rFVIIa intraoperatively or postoperatively found a 56% mortality rate, attributed to neurological, bleeding and septic events.[231]

rFVIIa

EJA Guidelines 2016

Single center experience on dosing and adverse events of recombinant factor seven use for bleeding after congenital heart surgery

Mustafa Kurkluoglu [a], Alyson M. Engle [a], John P. Costello [a,b], Narutoshi Hibino [c], David Zurakowski [d], Richard A. Jonas [a], John T. Berger [e], Dilip S. Nath [a,*]

[a] Division of Cardiovascular Surgery, Children's National Health System, Washington, DC ; [b] The Sheikh Zayed Institute for Pediatric Surgical Innovation, Children's National Health System, Washington, DC ; [c] Department of Cardiothoracic Surgery, Nationwide Children's Hospital, Columbus, OH ; [d] Departments of Anesthesia and Surgery, Boston Children's Hospital, Harvard Medical School, Boston, MA ; [e] Departments of Critical Care Medicine and Cardiology, Children's National Health System, Washington, DC

[a,b,c,d,e] United States

There are limited data on the relationship between the administered dose of recombinant factor seven (rFVIIa) and the development of adverse clinical outcomes after congenital heart surgery. This single institution case series reports on dosing, adverse events, and blood product usage after the administration of rFVIIa in its patient population. A retrospective review identified 16 consecutive pediatric patients at an academic, free-standing, children's hospital who received rFVIIa to curtail bleeding following congenital heart surgery between April 2004 and June 2012. Patients were assessed for survival to hospital discharge versus in-hospital mortality and the presence or absence of a major neurological event during inpatient hospitalization. The median age at surgery was 6.8 months (range: 3 days–42 years). Seven patients (44%) survived to hospital discharge and nine patients (56%) died. The cause of mortality included major neurological events (44%), uncontrolled bleeding (33%), and sepsis (23%). Eight patients (50%) required extracorporeal membrane oxygenation support following congenital heart surgery. The median cumulative rFVIIa dose administered was 97 mcg/kg, and the median cumulative amount of blood products administered was 452 ml/kg. In conclusion, this case series underscores the need to prospectively evaluate the effect that rFVIIa has on patient survival and the incidence of adverse events, including thrombotic and major neurological events, in congenital heart surgery patients. Ideally, a randomized, multicenter study would provide the sufficient numbers of patients and events to test

General coagulation management

EJA Guidelines 2016

8.1. Indications, contraindications, complications and doses

Fibrinogen concentration of less than 1.5 to 2 g l^{-1} is considered as hypofibrinogenaemia in acquired coagulopathy and is associated with increased bleeding risk. C

We recommend treatment of hypofibrinogenaemia in bleeding patients. 1C

We suggest an initial fibrinogen concentrate dose of 25 to 50 mg kg^{-1}. 2C

In cases where fibrinogen concentrate is not available we suggest cryoprecipitate at an initial dose of 4 to 6 ml kg^{-1}. 2C

Plasma transfusion alone is not sufficient to correct hypofibrinogenaemia. C

In cases of bleeding and low factor XIII activity (e.g. <30%) we suggest administration of factor XIII concentrate (30 IU kg^{-1}). 2C

In severe perioperative bleeding we recommend that patients on VKAs should be given PCC and intravenous vitamin K before any other coagulation management steps. 1B

General coagulation management

EJA Guidelines 2016

8.1. Indications, contraindications, complications and doses 2

Prolonged INR/PT or VHA clotting times alone are not an indication for PCC in bleeding patients not on oral anticoagulant therapy. C

We recommend against the prophylactic use of rFVIIa due to increased risk of fatal thrombosis. 1B

We suggest that off-label administration of rFVIIa can be considered for life-threatening bleeding which cannot be stopped by conventional, surgical or interventional radiological means and/or when comprehensive coagulation therapy fails. 2C

We recommend tranexamic acid to prevent bleeding during major surgery and/or treat bleeding due to (or at least suspected) hyperfibrinolysis (e.g. a dose of 20 to 25 mg kg^{-1}). 1B

We suggest the use of DDAVP under specific conditions (acquired VWS). 2C

Based on the current literature, there is no evidence to recommend antithrombin supplementation in elective surgical patients while they are bleeding.

We recommend structured staff education and training. 1C

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Fer en anesthésie-réanimation

B	L'utilisation du fer est recommandée chez les patients en anesthésie uniquement en présence d'une carence martiale.
C	L'utilisation systématique du fer n'est pas recommandée chez les patients en réanimation

EPO en anesthésie-réanimation

B	L'utilisation d'EPO n'est pas recommandée en réanimation.
A	L'utilisation de l''EPO est recommandée en pré-opératoire de la chirurgie orthopédique hémorragique chez les patients modérément anémiques. L'utilisation devra être réservée aux patients ayant une anémie modérée (par exemple Hb : 10 à 13 g/dl) et chez lesquels on s'attend à des pertes de sang modérées (900 à 1800 ml).
B	L'utilisation d'EPO dans le cadre péri-opératoire de la chirurgie colorectale carcinologique n'est pas recommandée, en raison de l'insuffisance de données sur la preuve de son efficacité.

Acide tranexamique en anesthésie-réanimation

B	Il est recommandé d'utiliser l'acide tranexamique dans le cadre péri-opératoire en chirurgie hémorragique chez les patients ne présentant pas de contre-indication à ce produit.
A	Il est recommandé d'utiliser l'acide tranexamique dans les trois premières heures de la prise en charge d'un polytraumatisme, à la dose suivante : 1 gramme en intraveineuse lente de 10 minutes suivi de l'administration de 1 gramme sur 8 heures.

Grade des recommandations

A	Preuve scientifique établie	**C**	Faible niveau de preuve
B	Présomption scientifique	**AE**	Accord d'experts

Quand faut-il débuter la transfusion ?

- En théorie
  - Pour maintenir TaO_2 au-dessus d'un seuil critique
  - TaO_2 critique : inconnu chez l'enfant !
- En pratique ?

Pratiques transfusionnelles en réanimation pédiatrique

Enquête postale auprès des réanimateurs du GFRUP

Group Francophone de Rèanimation et Urgence Pédiatrique

Pediatr Crit Care Med. 2002 Oct;3(4):335-40.

Survey on transfusion practices of pediatric intensivists.

Laverdière C[1], Gauvin F, Hébert PC, Infante-Rivard C, Hume H, Toledano BJ, Guertin MC, Lacroix J; Canadian Critical Care Trials Group.

Author information

Abstract

OBJECTIVE: To describe the red blood cell transfusion practices of pediatric intensivists.

DESIGN: Cross-sectional self-administered survey.

SETTING: Pediatric intensive care units.

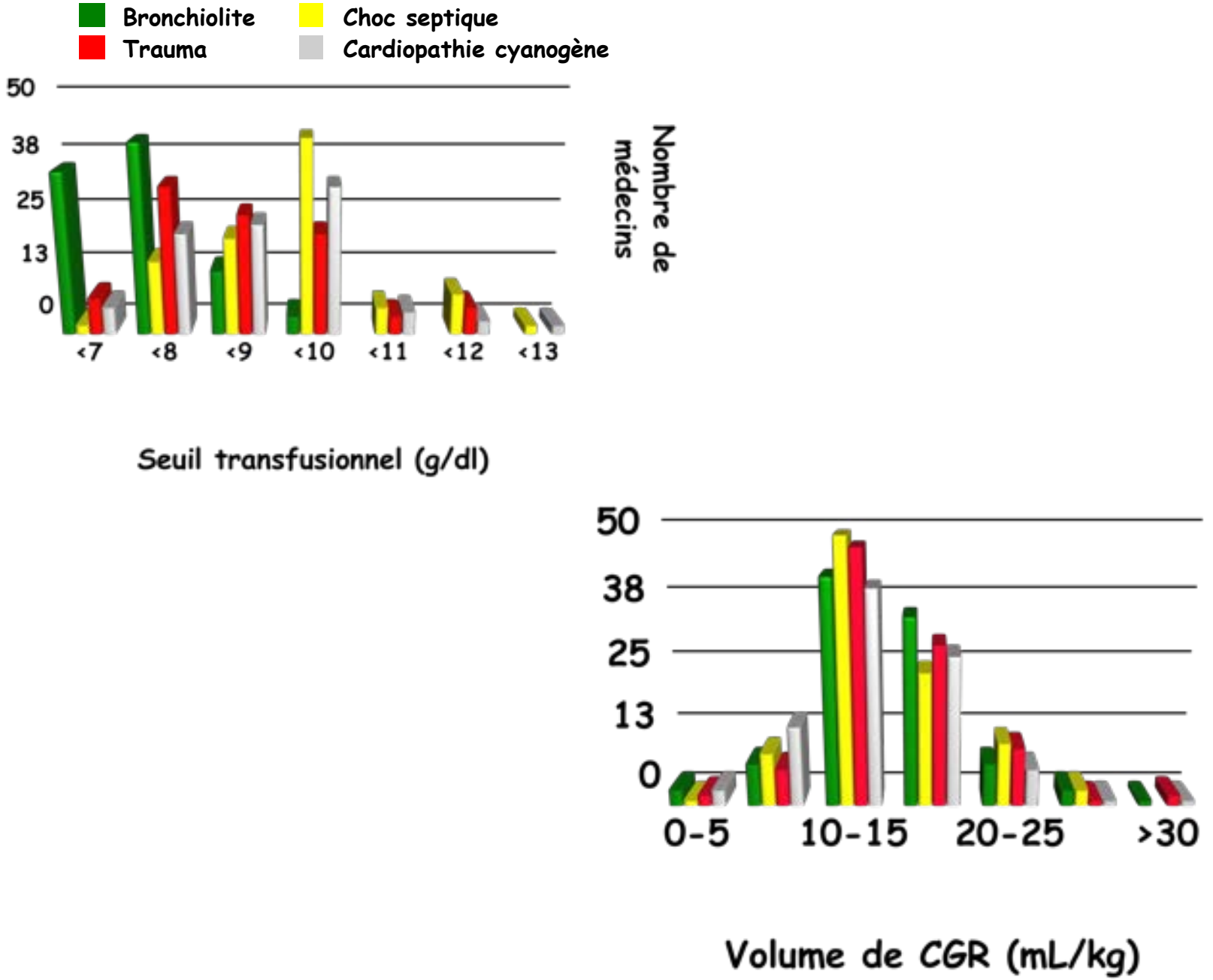
PATIENTS: Academic pediatric intensivists.

INTERVENTIONS: None.

MEASUREMENTS AND RESULTS: Scenario-based survey among English- or French-speaking intensivists from Canada, France, Belgium, or Switzerland, working in tertiary-care pediatric intensive care units. Respondents were asked to report their decisions regarding transfusion practice with respect to four scenarios: cases of bronchiolitis, septic shock, trauma, and the postoperative care of a patient with Fallot's tetrad. The response rate was 71% (163 of 230). The overall baseline hemoglobin transfusion threshold that would have prompted intensivists to transfuse a patient ranged from 7 to 13 g/dL (70-130 g/L) within almost all scenarios. There was a significant difference between scenarios of the average baseline hemoglobin transfusion thresholds ($p < .0001$). A low Pao2, a high blood lactate concentration, a high Pediatric Risk of Mortality score, active gastric bleeding, emergency surgery, and age (2 wks) were important determinants of red blood cell transfusion, whereas none of the respondents' personal characteristics were. The average volume of packed red blood cells transfused in the four scenarios did not differ significantly.

CONCLUSIONS: This survey documented a significant variation in transfusion practice patterns among pediatric critical care practitioners with respect to the threshold hemoglobin concentration for red blood cell transfusion. The volume of packed red blood cells given was not adjusted to the hemoglobin concentration.

Pratiques transfusionnelles en réanimation pédiatrique



Transfusion: Restrictive ou Liberale?

The NEW ENGLAND JOURNAL of MEDICINE

ESTABLISHED IN 1812 APRIL 19, 2007 VOL. 356 NO. 16

Transfusion Strategies for Patients in Pediatric Intensive Care Units

Jacques Lacroix, M.D., Paul C. Hébert, M.D., James S. Hutchison, M.D., Heather A. Hume, M.D., Marisa Tucci, M.D., Thierry Ducruet, M.Sc., France Gauvin, M.D., Jean-Paul Collet, M.D., Ph.D., Baruch J. Toledano, M.D., Pierre Robillard, M.D., Ari Joffe, M.D., Dominique Biarent, M.D., Kathleen Meert, M.D., and Mark J. Peters, M.D., for the TRIPICU Investigators,* the Canadian Critical Care Trials Group, and the Pediatric Acute Lung Injury and Sepsis Investigators Network

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ABSTRACT

BACKGROUND

The optimal hemoglobin threshold for erythrocyte transfusions in critically ill children is unknown. We hypothesized that a restrictive transfusion strategy of using packed red cells that were leukocyte-reduced before storage would be as safe as a liberal transfusion strategy, as judged by the outcome of multiple-organ dysfunction.

METHODS

In this noninferiority trial, we enrolled 637 stable, critically ill children who had hemoglobin concentrations below 9.5 g per deciliter within 7 days after admission to an intensive care unit. We randomly assigned 320 patients to a hemoglobin threshold of 7 g per deciliter for red-cell transfusion (restrictive-strategy group) and 317 patients to a threshold of 9.5 g per deciliter (liberal-strategy group).

RESULTS

Hemoglobin concentrations were maintained at a mean (±SD) level that was 2.1±0.2 g per deciliter lower in the restrictive-strategy group than in the liberal-strategy group (lowest average levels, 8.7±0.4 and 10.8±0.5 g per deciliter, respectively; P<0.001). Patients in the restrictive-strategy group received 44% fewer transfusions; 174 patients (54%) in that group did not receive any transfusions, as compared with 7 patients (2%) in the liberal-strategy group (P<0.001). New or progressive multiple-organ dysfunction syndrome (the primary outcome) developed in 38 patients in the restrictive-strategy group, as compared with 39 in the liberal-strategy group (12% in both groups) (absolute risk reduction with the restrictive strategy, 0.4%; 95% confidence interval, −4.6 to 5.4). There were 14 deaths in each group within 28 days after randomization. No significant differences were found in other outcomes, including adverse events.

CONCLUSIONS

In stable, critically ill children a hemoglobin threshold of 7 g per deciliter for red-cell transfusion can decrease transfusion requirements without increasing adverse outcomes. (Controlled-trials.com number, ISRCTN37246456.)

From Université de Montréal (J.L., H.A.H., M.T., T.D., F.G., B.J.T.) and McGill University (P.R.) — both in Montreal; University of Ottawa, Ottawa (P.C.H.); University of Toronto, Toronto (J.S.H.); University of British Columbia, Vancouver (J.-P.C.); and University of Alberta, Edmonton (A.J.) — all in Canada; Université Libre de Bruxelles, Brussels (D.B.); Wayne State University, Detroit (K.M.); and the Institute of Child Health, London (M.J.P.). Address reprint requests to Dr. Lacroix at the Sainte-Justine Hospital, Rm. 3431, 3175 Côte Sainte-Catherine, Montreal, QC H3T 1C5, Canada, or at jacques_lacroix@ssss.gouv.qc.ca.

*Investigators and site investigators of the Transfusion Requirements in the Pediatric Intensive Care Unit (TRIPICU) Study are listed in the Appendix.

N Engl J Med 2007;356:1609-19.

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Transfusion Strategies for Patients in Pediatric Intensive Care Units

Jacques Lacroix, M.D., Paul C. Hébert, M.D., James S. Hutchison, M.D., Heather A. Hume, M.D., Marisa Tucci, M.D., Thierry Ducruet, M.Sc., France Gauvin, M.D., Jean-Paul Collet, M.D., Ph.D., Baruch J. Toledano, M.D., Pierre Robillard, M.D., Ari Joffe, M.D., Dominique Biarent, M.D., Kathleen Meert, M.D., and Mark J. Peters, M.D., for the TRIPICU Investigators,* the Canadian Critical Care Trials Group, and the Pediatric Acute Lung Injury and Sepsis Investigators Network

Table 3. Primary and Secondary Outcomes of the Patients.*

Variable	Restrictive-Strategy Group	Liberal-Strategy Group	Absolute Risk Reduction, Odds Ratio, or Difference in Means (95% CI)	P Value
Primary outcome				
New or progressive MODS — no./total no. (%)†	38/320 (12)	39/317 (12)	0.4 (−4.6 to 5.5)	NI‡
Secondary outcomes				
Measures of severity of organ dysfunction§				
No. of dysfunctional organs	1.6±1.4	1.5±1.2	−0.1 (−0.26 to 0.13)	0.87
PELOD score**				
After randomization	9.8±11.9	8.4±10.9	−1.4 (−3.1 to 0.4)	0.16
On day 1	6.3±6.8	5.2±6.2	−1.1 (−2.1 to −0.1)	0.09
Highest daily score after day 1	10.2±13.3	8.9±11.9	−1.2 (−3.2 to 0.8)	0.34
Change in score	3.8±10.9	3.8±9.9	−0.1 (−1.7 to 1.5)	0.97
Average daily score	5.0±6.1	4.2±5.1	−0.8 (−1.7 to 0.1)	0.13
Clinical outcomes — no./total no. (%)†				
Death				
In ICU	11/320 (3)	8/317 (3)	−0.9 (−3.6 to 1.7)	0.50
From any cause during 28-day study	14/320 (4)	14/317 (4)	0 (−3.2 to 3.2)	0.98
Nosocomial infections	65/320 (20)	79/317 (25)	4.6 (−1.9 to 11.1)	0.16
At least 1 adverse event	97/320 (30)	90/317 (28)	−1.92 (−9.0 to 5.2)	0.59
Reactions to red-cell transfusion	3/320 (1)	6/317 (2)	1.0 (−0.9 to 2.8)	0.34
Duration of care — days§				
Mechanical ventilation	6.2±5.9	6.0±5.4	−0.14 (−1.1 to 0.8)	0.76
ICU stay after randomization	9.5±7.9	9.9±7.4	0.46 (−0.7 to 1.7)	0.39

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SYNTHÈSE DE LA RECOMMANDATION DE BONNE PRATIQUE

Transfusion de globules rouges homologues : produits indications, alternatives

Seuils transfusionnels chez le nouveau-né à terme et le nourrisson

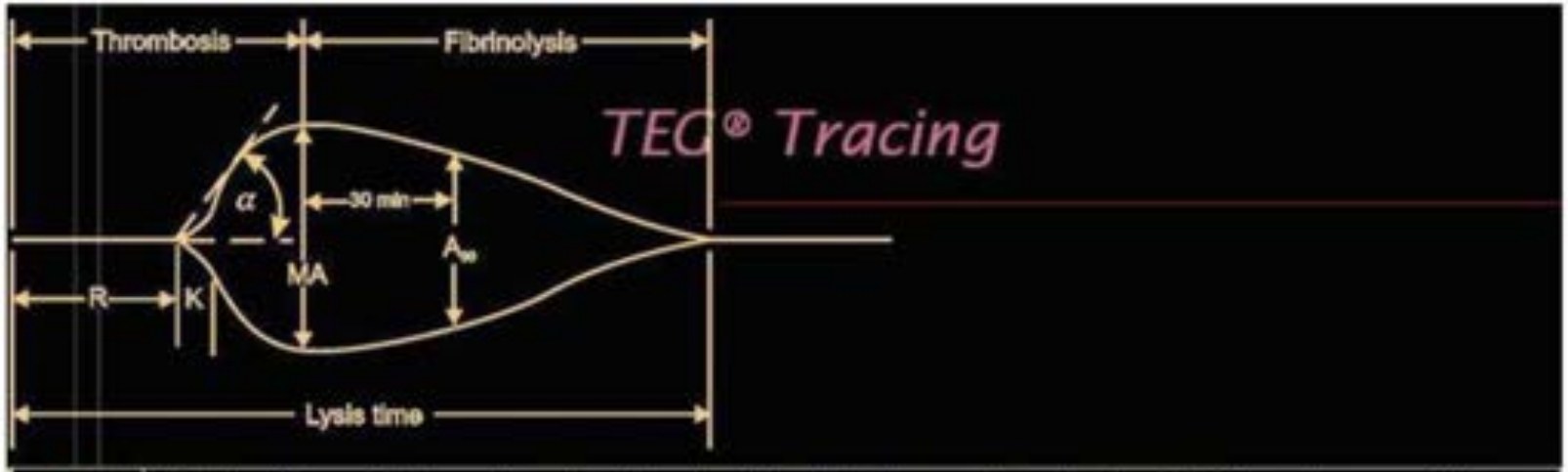
Les indications transfusionnelles ne reposent pas que sur la seule notion de seuil.
Cependant, les seuils transfusionnels suivants, obtenus à partir d'un prélèvement veineux ou artériel, sont généralement recommandés chez le nouveau-né né d'âge gestationnel ≥ 32 semaines d'aménorrhée ou pesant plus de 1500g à la naissance et chez le nourrisson:

AE	• Chez les enfants présentant une cardiopathie congénitale cyanogène : 12 g/dl. • Chez les enfants non stabilisés en réanimation, sous ECMO ou en post-opératoire aigu de chirurgie cardiaque : 10 g/dl. • Chez les enfants ayant une anémie sans signe clinique associé à un taux de réticulocytes <100G/l : 7g/dl.
B	• Chez les enfants stabilisés en réanimation ne souffrant pas de cardiopathie ou stabilisés en post-op d'une correction chirurgicale d'une cardiopathie non cyanogène : 8 g/dl.

Grade des recommandations

A	Preuve scientifique établie	**C**	Faible niveau de preuve
B	Présomption scientifique	**AE**	Accord d'experts

TEG



R	R is the time of latency from the time that the blood was placed in the TEG® analyzer until the initial fibrin formation.
α	The α value measures the rapidity (kinetics) of fibrin build-up and cross-linking, that is, the speed of clot strengthening.
K	K time is a measure of the rapidity to reach a certain level of clot strength.
MA	MA, or Maximum Amplitude, is a direct function of the maximum dynamic properties of fibrin and platelet bonding and represents the ultimate strength of the fibrin clot.
LY30 (EPL)	LY30 measures the rate of amplitude reduction 30 minutes after MA. This measurement gives an indication of the stability of the clot.

HAEMOSCOPE™

TEG

Figure 2. TEG pattern recognition. Reprinted with permission from Haemoscope Corp, USA. Copyright Haemoscope. All rights reserved.

Normal
R;K;MA;Angle = Normal

Anticoagulants/hemophilia
Factor Deficiency
R;K = Prolonged;
MA;Angle = Decreased

Platelet Blockers
Thrombocytopenia/
Thrombocytopathy
R ~ Normal; K = Prolonged;
MA = Decreased

TEG

Fibrinolysis (UK, SK, or t-PA)

Presence of t-PA

R ~ Normal;

MA = Continuous decrease

LY30 > 7.5%; WBCLI30 < 97.5%;

Ly60 > 15.0%; WBCLI60 < 85%

Hypercoagulation

R;K = Decreased;

MA;Angle = Increased

D.I.C

Stage 1

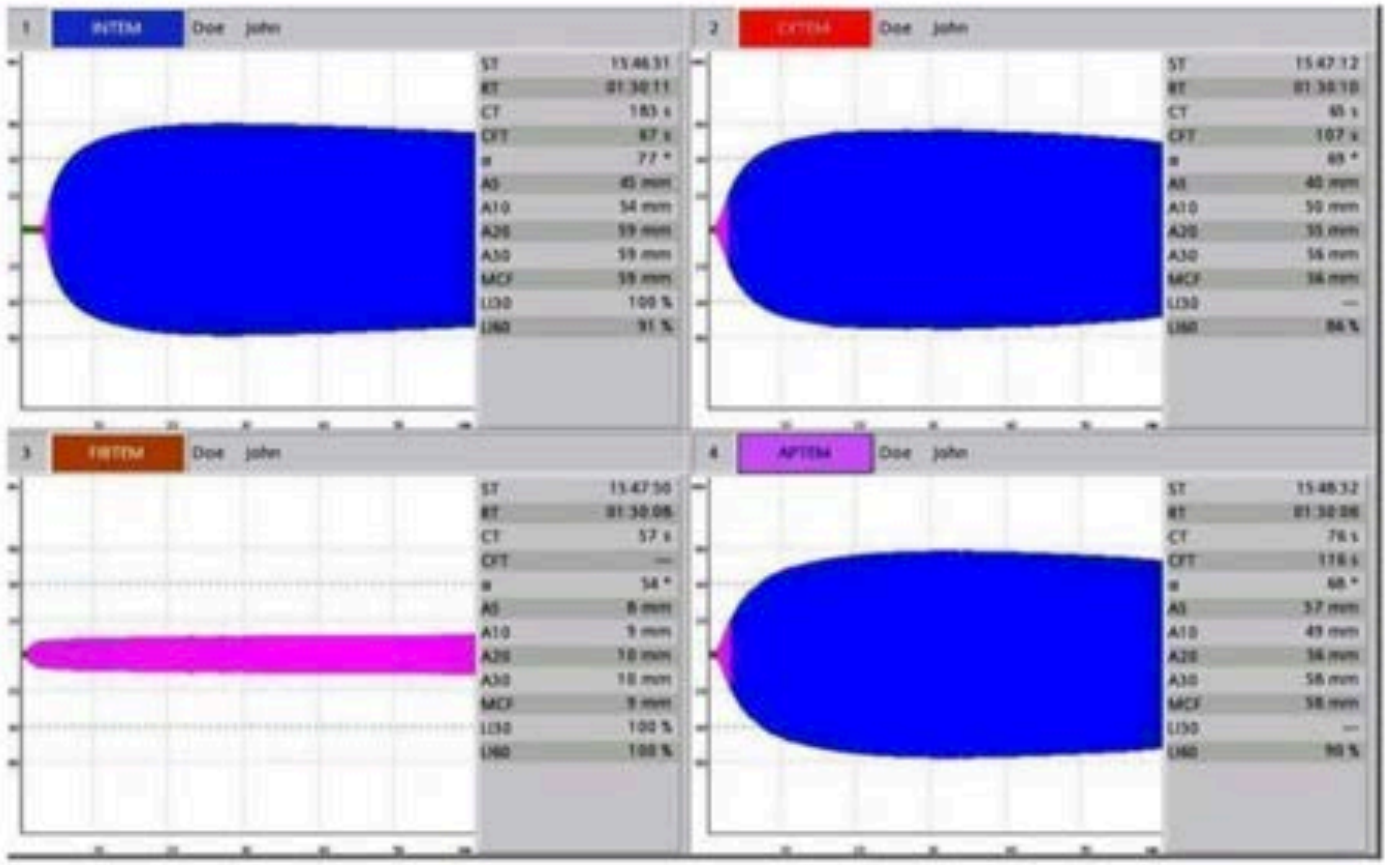
Hypercoagulable state with secondary fibrinolysis

Stage 2

Hypocoagulable state

ROTEM

Figure 3. The main parameters of ROTEM are: clotting time (CT) being equal to "r" time in TEG; clot formation time (CFT) being equal to "K" time in TEG; ALP; maximum clot firmness (MCF) being equal to MA in TEG and finally clot lysis index at 30-60 minutes (CLI30-CLI60) being equal to LY30 and A60 in TEG (Lang 2005). This is ROTEM illustration of a normal patient. INTEM and EXTEM are two different activated baseline analyses. They are both global tests for plasmatic coagulation factors, fibrin polymerization, platelet function and hyperfibrinolysis. INTEM uses ellagic acid and is heparin sensitive while EXTEM applies tissue factor from rabbit brain and has low heparin sensitivity. FIBTEM provides information on fibrin polymerization difficulties and fibrinogen or platelet deficiency. APTEM uses Aprotinin to provide information on hyperfibrinolysis.Reprinted with permission from PENTAPHARM Gmbh, Germany. Copyright PENTAPHARM Gmbh. All rights reserved.



Autotransfusion peropératoire

- "Cell saver" classique : lavage/concentration séquentiel
  - Bols pédiatriques : 70 et 55 ml (BT 55, Dideco)
- OrthoPAT® (Haemomatics) : nouveau séquentiel à disque
  - Traite des volumes assez faibles de sang
  - Intérêt probable en pédiatrie mais pas d'étude
- Systèmes en continu : CATS®

CELL SALVAGE

EJA Guidelines 2016

Recommendation

We recommend the use of red cell salvage, which is helpful for blood conservation in major cardiac and orthopaedic surgery. 1B

We recommend against the routine use of intraoperative platelet-rich plasmapheresis for blood conservation during cardiac operations using CPB. 1B

We recommend that cell salvage is not contraindicated in bowel surgery, provided that the initial evacuation of soiled abdominal contents is undertaken, additional cell washing is performed and that broad-spectrum antibiotics are used. 1C

We suggest that cell salvage is not contraindicated in cancer surgery, provided that blood aspiration close to the tumour site is avoided and leukodepletion filters are used. 2C

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rFVIIa en anesthésie-réanimation

Utilisation du facteur VII recombinant activé (rFVIIa) en anesthésie

A	L'administration systématique du Facteur VIIa recombinant n'est pas recommandée.

rFVIIa en réanimation

B	L'administration systématique du Facteur VIIa recombinant n'est pas recommandée en traumatologie

Retransfusion périopératoire des épanchements sanguins

Récupération de sang per-opératoire

AE	La récupération de sang per-opératoire trouve ses meilleures indications en chirurgie cardiaque et vasculaire. Il n'est pas recommandé d'utiliser la technique de récupération de sang péri-opératoire en cas de champ opératoire infecté et en cas d'utilisation de colles biologiques. Il est recommandé que les volumes de produit sanguin non lavés administrés par voie intraveineuse ne dépassent pas 1 000 ml par patient adulte. La retransfusion de volumes supérieurs nécessite un lavage.

Récupération de sang post-opératoire

AE	La récupération de sang post-opératoire trouve ses meilleures indications en arthroplastie prothétique de genou et en récupération des hémothorax. Il est recommandé que la période de recueil de sang soit limitée aux 6 premières heures post-opératoires. La technique de récupération de sang post-opératoire n'est pas recommandée en cas d'infection, locale ou générale, et en cas d'insuffisance rénale

Transfusion autologue programmée (TAP)

AE	Il n'est pas recommandé de proposer au patient une transfusion autologue programmée en dehors des cas particuliers suivants : groupe sanguin rare, patient polyimmunisé.

Arificial Organs 2015

Artificial Organs

Review Article

Use of Blood Products in Pediatric Cardiac Surgery

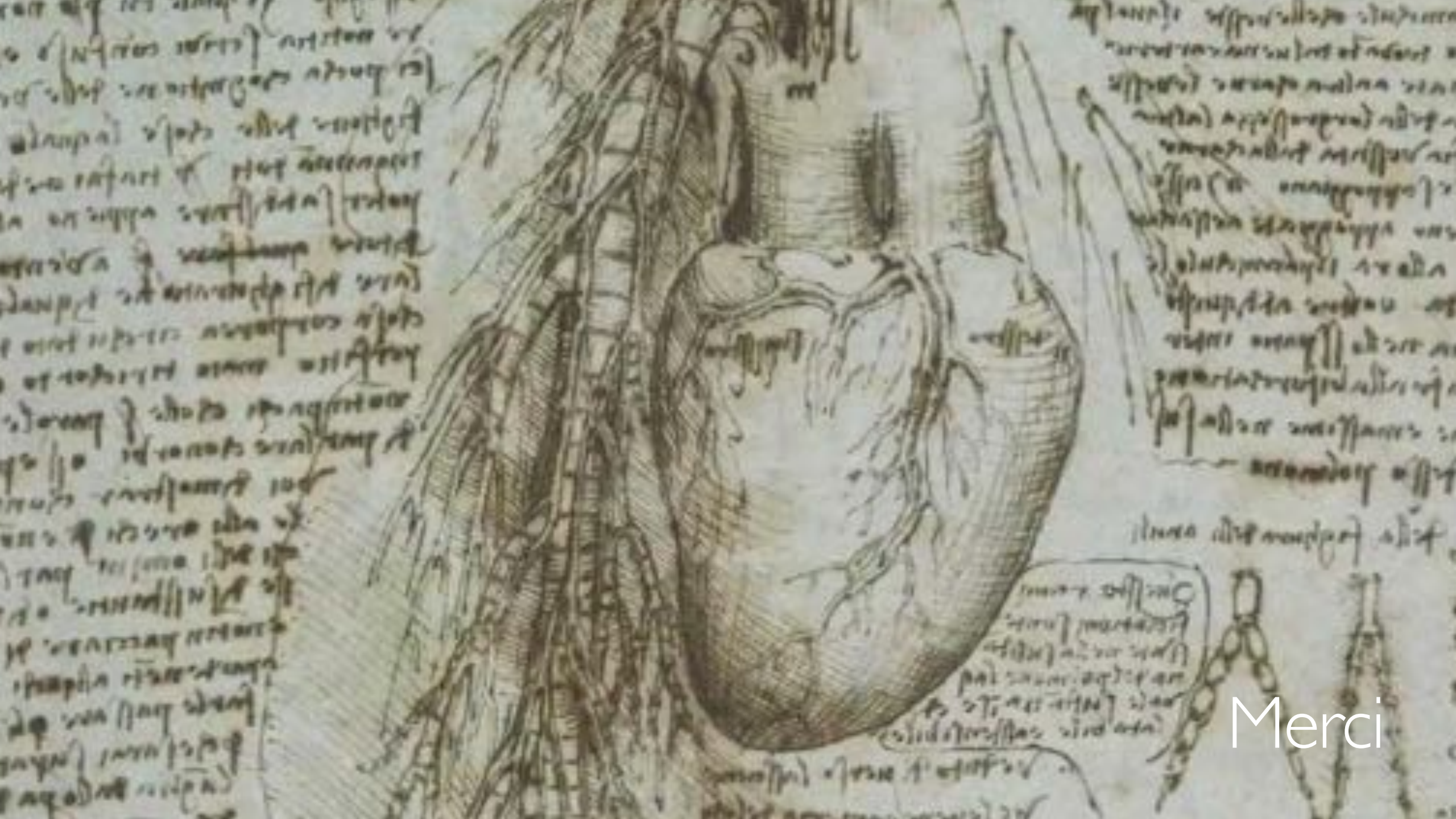
*†Yves Durandy

*Intensive Care and †Perfusion Departments, Pediatric Cardiac Surgery, CCML, Le Plessis-Robinson, France

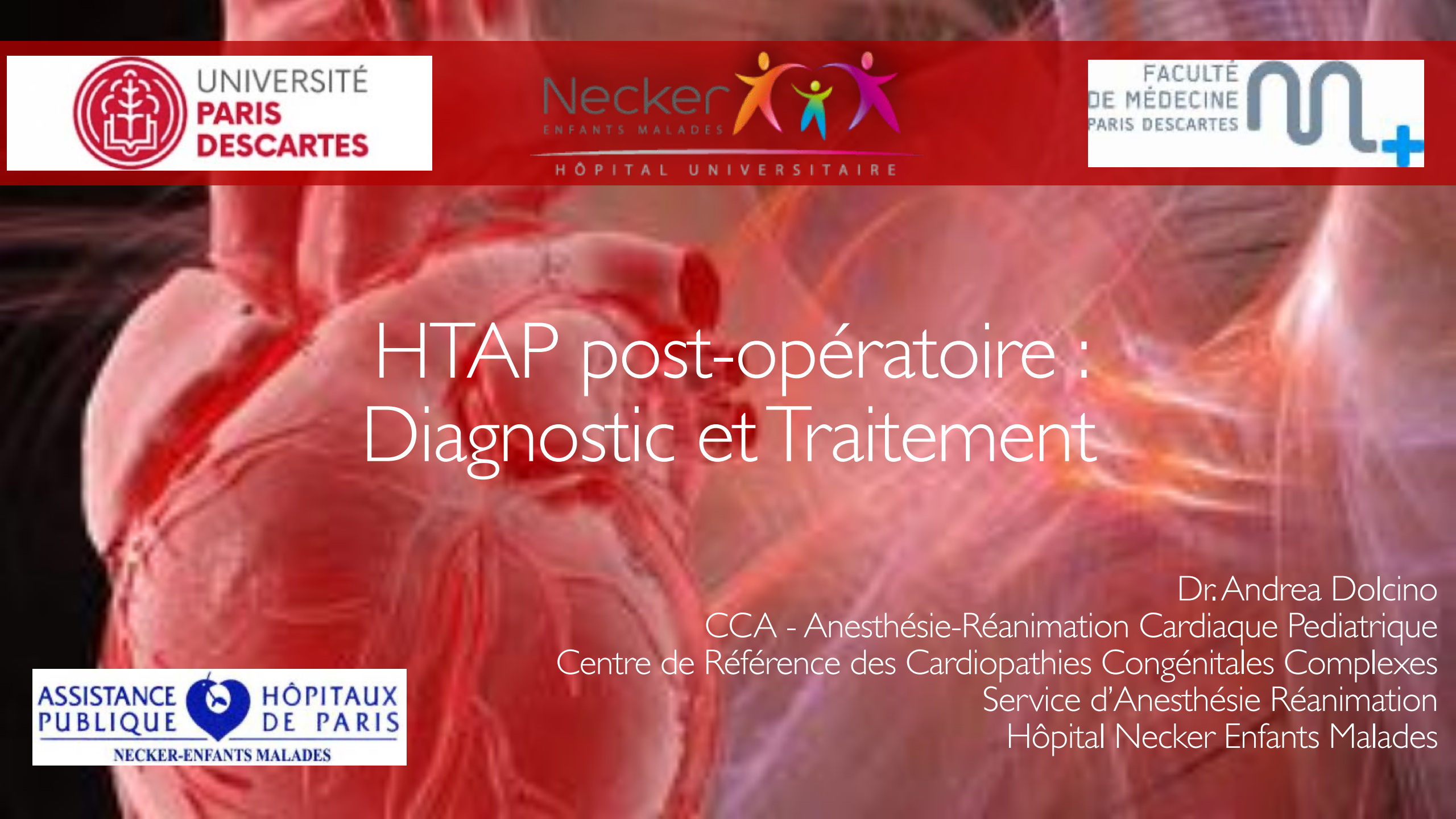
Abstract: In pediatric cardiac surgery, there is a substantial gap between published recommendations or guidelines for blood product use and clinical practice. The drawbacks of blood transfusion are well acknowledged though. The aim of this paper is to present the rationale for packed red blood cells, fresh frozen plasma (FFP), and platelets used in pediatric patients. Blood hemoglobin level is the current trigger used for packed red blood cells transfusion, though commonly admitted to be suboptimal. An increase in hemoglobin level is likely to be associated with an increase in blood oxygen content and blood oxygen delivery. However, above a critical level of hemoglobin, normovolemic anemia is well tolerated, and any increase in hemoglobin will fail to increase oxygen consumption and therefore to improve end-organ oxygen supply. FFP is one way to address the coagulation factors deficiency induced by hemodilution, consumption, or hepatic insufficiency. The volume needed to increase these factors is not negligible. To avoid dilution and/or fluid overload, the use of clotting factor concentrate is recommended. The same remark can be made regarding the treatment of antithrombin III deficiency. Platelets infusion should be restricted to bleeding patients with thrombocytopenia and without surgical bleeding. In clinical studies, the prevention of bleeding through prophylactic infusion of platelets proved to be useless. Optimizing the use of blood products (avoiding overuse, underuse, and inappropriate use) is a challenging task in pediatric cardiac surgery. Data or guidelines cannot replace clinical judgment and the decision to transfuse is left to individual discretion, but the medical community needs to optimize its transfusion practice, otherwise policy-makers without similar expertise may step in to regulate the use of blood products. **Key Words:** Pediatric—Cardiac surgery—Blood products—Usage—Red blood cells—Fresh frozen plasma—Platelets.

Transfusion et épargne transfusionnelle chez l'enfant

1. Recourir à une approche multimodale
    - Préopératoire: augmenter la masse sanguine
    - Per- et post-opératoire
        - Réduire le saignement
        - Optimiser les pratiques transfusionnelles
2. Utiliser des méthodes pharmacologiques ou non
3. Définir une stratégie périopératoire pour chaque patient



Merci



HTAP post-opératoire : Diagnostic et Traitement

Dr. Andrea Dolcino
CCA - Anesthésie-Réanimation Cardiaque Pediatrique
Centre de Référence des Cardiopathies Congénitales Complexes
Service d'Anesthésie Réanimation
Hôpital Necker Enfants Malades

Classification HTAP/HTP Nice 2013

Groupe 1: **HTAP**
1-1 HTAP idiopathique 1-2 HTAP héritable

1-2-1 **BMPR2**
1-2-2 ALK1, ENG, SMAD-9, CAV1, KCNK3 1-2-3 Inconnue

1-3 **Induite par une drogue ou une toxine** 1-4 Associée à autres conditions

1-4-1 des maladies du tissu conjonctif 1-4-2 Infection HIV
1-4-3 Hypertension portale
1-4-4 **Cardiopathie congénitale (±10%)**

1-4-5 Schistosomiase

Groupe 1': **Maladie veino-occlusive** / **Hémangiomatose capillaire (HCP)**
Groupe 1": **Hypertension pulmonaire persistante du nouveau-né**

Groupe 2: **HTP liée aux cardiopathies gauches**

2-1 Dysfonction systolique VG
2-2 Dysfonction diastolique VG

2-3 Valvulopathies

2-4 Obstructions congénitales ou acquises VG et cardiomyopathies congénitales

Groupe 3: HTP liée aux maladies pulmonaires et/ou Hypoxie

3-1 BPCO
3-2 **Maladie interstitielle (MPI)** 3-3 Pathologie mixte
3-4 Pathologie du sommeil
3-5 **Hypoventilation alvéolaire** 3-6 Altitude
3-7 **Anomalie du développement**

Groupe 4: HTP thromboembolique chronique

Groupe 5: HTP de mécanismes multifactoriels incertains

5-1 Troubles hématologiques
5-2 Troubles systémiques : sarcoïdose...

5-3 Maladie métabolique (glycogène, Gaucher, dysthyroïdie)

5-4 Divers : obstruction tumorale, fibrose médiastin, Insuffisance rénale chronique dialysée

Classifing pulmonary hypertension

Type de shunt : HTAP

Shunt pre-tricuspide :

- CIA (ostium secundum ou sinus venosus)
- RVPA partiel ou total

Shunt post-tricuspide

- CIV
- Canal artériel
- Fenêtre aorto-pulmonaire

Shunts combinés

Cardiopathies congénitales complexes

- CAV (partiel ou complet)
- TAC
- VU sans sténose pulmonaire
- TGV avec CIV sans sténose pulmonaire et/ou CA
- Autre

Etat de la réparation

Non opérée

Opérée : palliative ou réparation

Dérivation cavo-pulmonaire

Pas de VD, pas d' HTAP

Augmentation des RVP

HTAP post capillaire

Pathologie valvulaire VG

Obstacle intra coeur gauche

Transplantation cardiaque

RVP élevées -> limite de TCP

Rareté des blocs coeur-poumon

Indication extrême

Défaillance VD post-transplanation

HTAP post opératoire

- Augmentation de la PAP en post-opératoire de cardiopathie congénitale avec shunt gauche-droit = HTAP
- Principalement : augmentation des résistances vasculaires pulmonaires
  - Cardiopathies + CEC, ventilation, PCO2, infection…
- La PAP augmente si la fonction VD est performante
- Progrès des moyens diagnostic : tests pre-op
- Arsenal thérapeutique efficace et nouvelle voies

Différente des atteintes primitives chroniquee ± idiopathiques

Hopkins RA. Eur J Cardiothorac Surg. 1991

Avant le NO

Pulmonary hypertensive crises following surgery for congenital heart defects in young children.

22 patients à risques avec cathéter AP
50% de décès si HTAP systémique

Traitement :
Fentanyl, Tolazoline, O2, Isuprel et dérivés nitrés

Mécanisme de l'HTAP

- 1. Augmentation des résistances vasculaires pulmonaires aiguë post-CEC
- 2. Augmentation du débit pulmonaire avec RVP basses Qp >> Qs sur shunt G-D (CIV résiduelle) Amplifiée par inotropes et VD pulmonaire
- 3. Augmentation des RVP sans HTAP Baisse du Qp avec baisse de SvO2, dysfonction du VD

Responsabilité de la CEC

- Réaction inflammatoire
  - Circuit extracorporel
  - Transfusion
- Stress oxydatif
- CEC ≥ 2h
  - RVP > 30 à 50%
  - Fonction VD < 30%
  - Dysfonction endothéliale plus importante si HTAP
  - Diminution de l'activité de la NO syntase et de la production de NO
  - Atteinte endothélial

Mesurer la PAP

<u>Invasive : Cathéter AP</u>

Chirurgical

Transinfundibulaire

Peu de complication

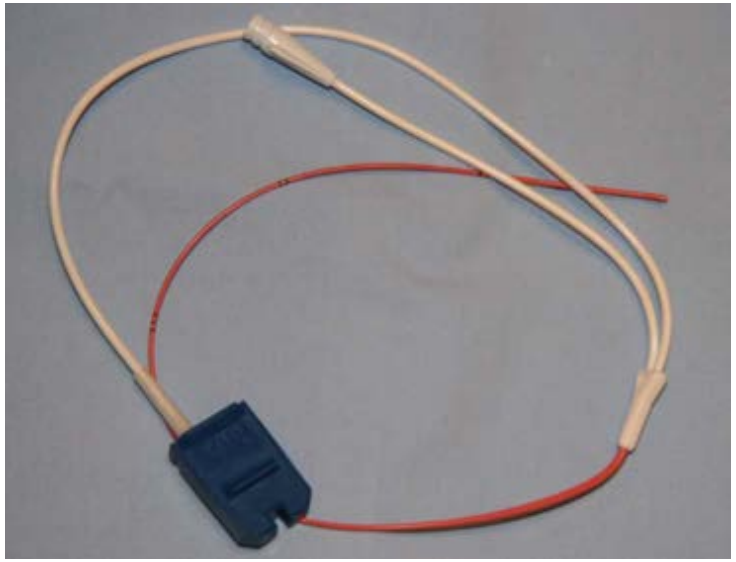
Mesure continue

<u>Non invasive : Echo</u>

Fuite tricuspide

Fuite pulmonaire

Mesure discontinue



Diagnostic de la crise d'HTAP

- PAP augmente +/- fortement
- Ratio PAP/PA > 0,5 > 1
- SaO2 et SvO2 diminuent
- Survenue de bradycardie ± troubles du rythme
- Augmentation de la PVD
- Dysfonction du VD
- Baisse du Qc
- Hyoperfusion coronaire Dt : ischémie – tr du rythme
- Hypoxie, Acidose = aggrave HTAP

Survenue

Rarement en fin de CEC (rechercher un shunt G-D)

Dès les premières heures jusqu'à plusieurs jours post-op

Appréciation de la gravité initiale :

- PAP/PA ≥ 50% et SvO2 > 60% stable
- PAP/PA ≥ 50% et SvO2 ≥ 60% instable
- PAP/PA ≥ 80% et SvO2 < 60% instable

Starter: Stimulation sympathique

- Aspiration trachéale
- Réveil
- Douleurs
- Troubles de ventilation
- Encombrement trachéo-bronchique
- Acidose ventilatoire

Traitement

- FiO2 100%
- Ventilation efficace
- Aspiration trachéale avec circuit clos
- Sédation adaptée
- Produits vasoactifs
- iNO inhalé
- Prostacycline en aérosol ou en intraveineux
- Inhibiteur des phosphodiestérases type V : sildénafil
- Anti endothéline : bosentan

Ventilation

Bas volume courant

- Atélectasies
- Hypercapnie

Augmente RVP

Haut volume courant

- Hyperinflation
- Pression intra-thoracique
- Compression vasculaire

Augmente RVP

Intérêt du décubitus ventral

Recrutement dorsal

Baisse RVP

O2

- Augmentation PaO2 et PAO2 entraîne une réduction modérée des RVP
- Surtout éviter l'hypoxie qui augmente fortement les RVP
- En présence de shunt : la FiO2 élévée augmente peu la PaO2 mais diminue les RVP
- Effet plus important chez le nouveau-né que l'adulte

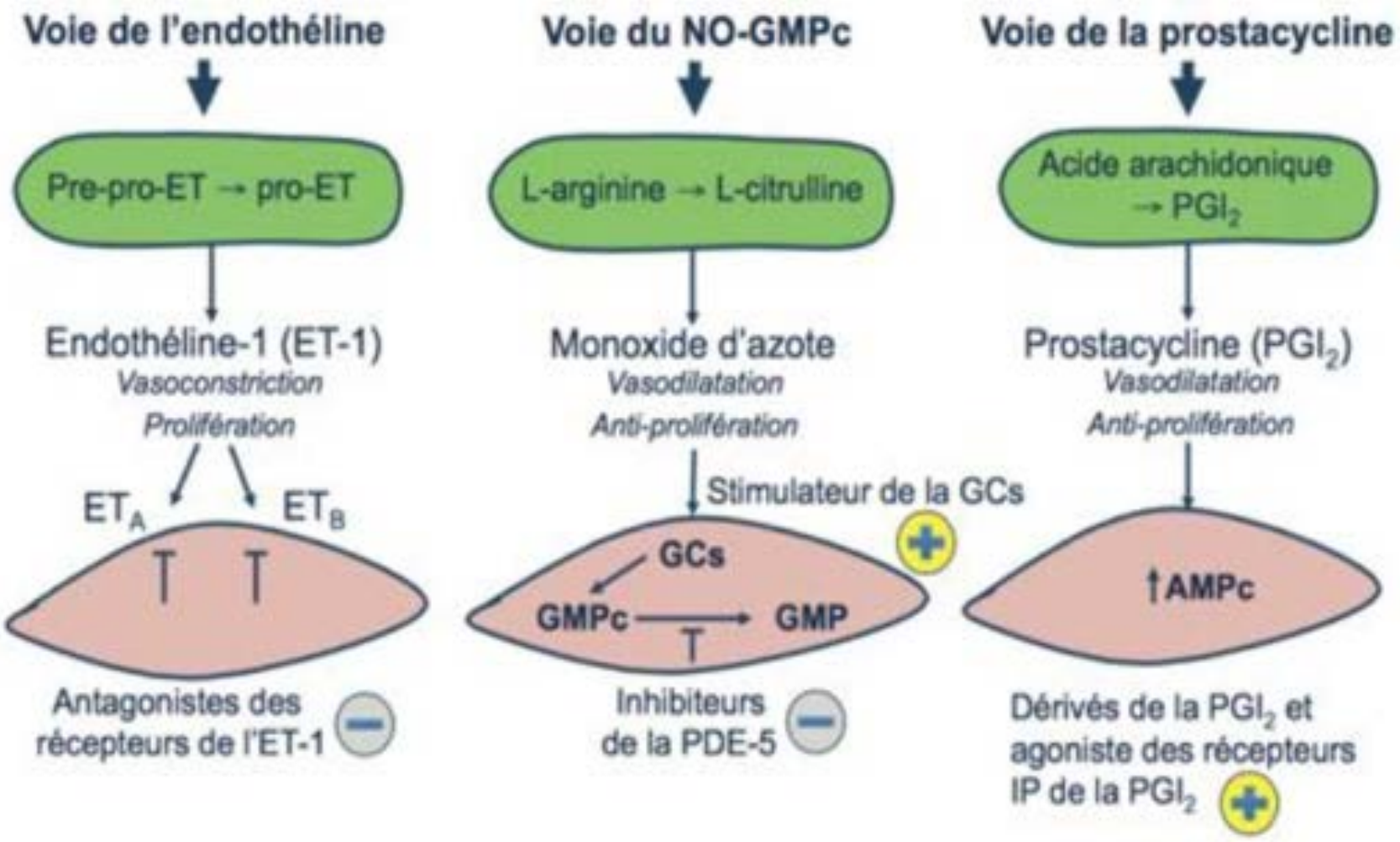
Objectif de la ventilation artificielle

- Augmenter le pH
- Normaliser la PCO2
- Augmenter le PaO2 et PAO2
- Diminuer les pressions intrathoraciques

Sedation

- Pour diminuer la réactivité vasculaire pulmonaire
- Par baisse le relarguage des cathécholamines endogènes
- Morphine – Sufentanyl – Dexmétomidine Midazolam
- Curarisation ± nécessaire

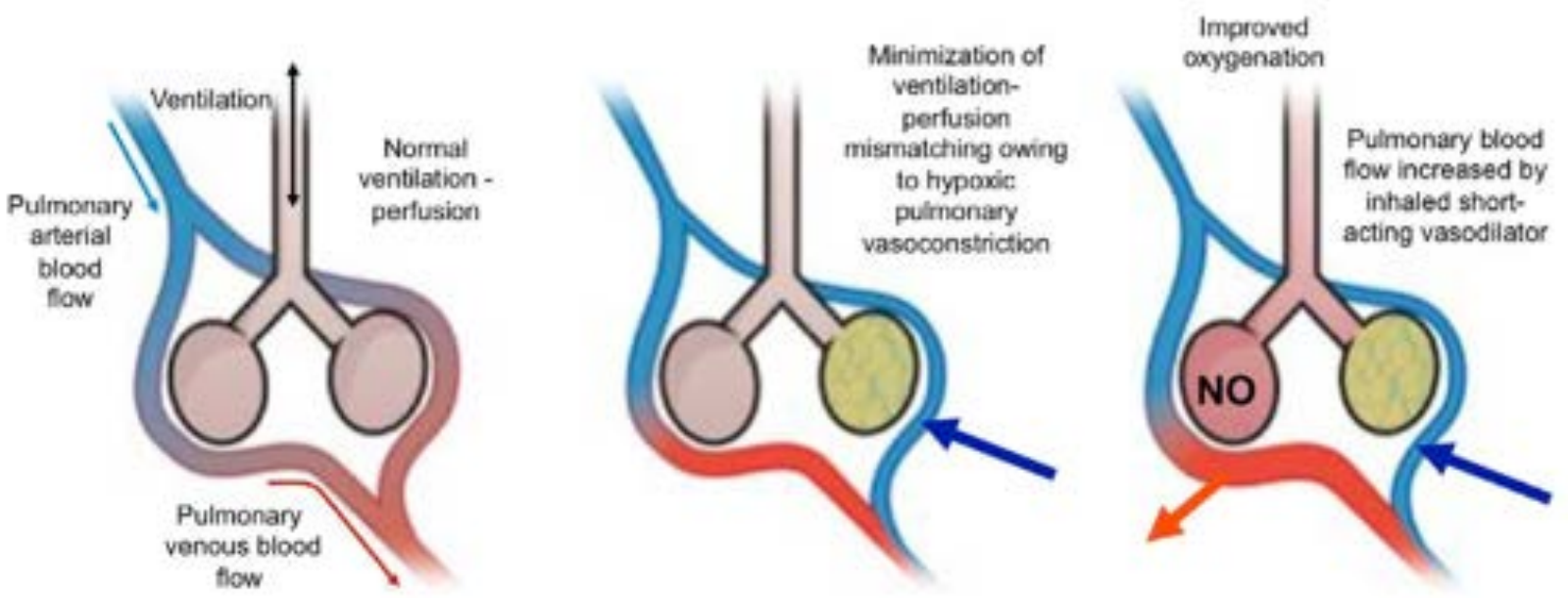
Medicaments



iNO

- Efficacité entre 2 et 80 ppm
- Cible thérapeutique : 20 à 40 ppm
- Fixation sur l'hémoglobine en qq sec
- Formation de méthémoglobine et nitrates
- NO + O2 = NO2 polluant atmosphérique
- Toxicité pulmonaire si NO2 > 2 ppm (NO > 100 ppm)
- Arginine et Citrulline : précurseurs du NO Effet pulmonaire mais faible efficacité

Effet du iNO


Ventilation
Normal ventilation - perfusion
Pulmonary arterial blood flow
Pulmonary venous blood flow
Minimization of ventilation-perfusion mismatching owing to hypoxic pulmonary vasoconstriction
Improved oxygenation
Pulmonary blood flow increased by inhaled short-acting vasodilator
NO

Inibiteurs des phosphodiestérases

Inhibiteurs des PDE 3

Dipyridamole

Milrinone

Inhibiteurs des PDE 5

Sildénafil (Revatio)

Taladafil (Adcirca)

Sildenafil

- PermetlesevrageduNOi,évitel'effetrebond
- Dose per os de 0,5 à 2 mg/kg/6 h (pic à 1h, 1/2 vie 3 à 6h)
- IV nondisponible
- Efficace, effets systémiques faibles
- Sildénafil > NO 20 ppm : sur RVP et améliore Qc
- Sommation des effets avec sildénafil après NO
- Inconvénient: hypoxémie par effet shunt si troubles de ventilation

Prostacyclines

Flolan© IV : traitement essentiel avant le iNO

- Efficace mais effets systémiques importants
- Parfois vasoconstricteurs nécessaires
- Dose 5 à 20 ng/kg/min - 1/2 vie très courte

Iloprost© en aérosol

- 1 à 2,5 n/kg: durée 20 à 25 min de 4 à 9/j
- Effet spécifique sur PAP, pas de shunt
- Pas d'effet sur les plaquettes et le saignement
- Réactions ± fréquentes de broncho-constriction

Treprostinil (Remodulin©) : sous-cutané ou aérosol

- Sous-cut : douleurs locales 1,25 ng/kg/min, max 40
- Aérosol : 4 à 6 fois/j

Sélexipag per os

- agoniste des récepteurs IP de la prostacycline endognène

Agonistes de l'endotheline

Bosentan (Tracleer)

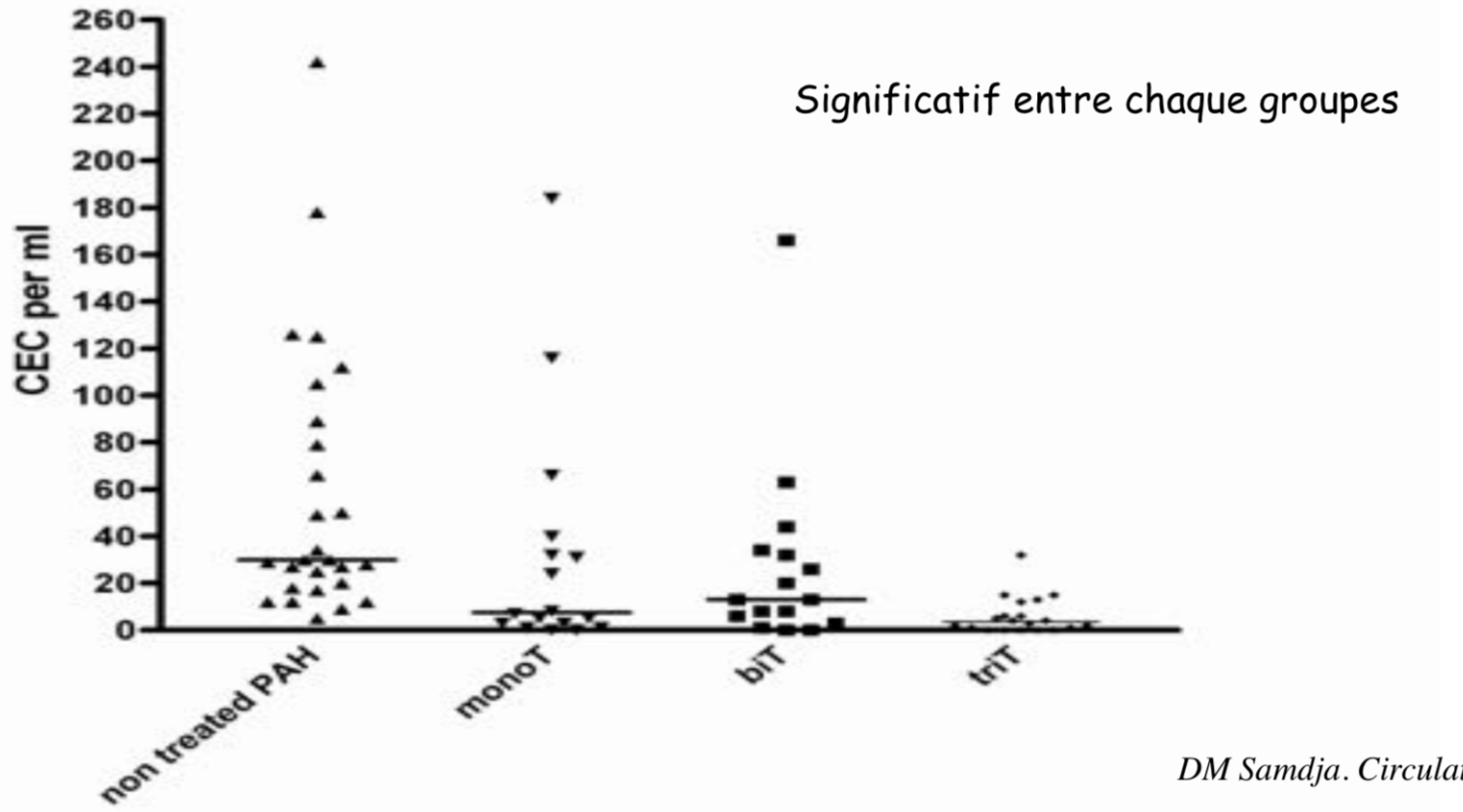
- antagoniste des récepteurs E-1A
- Per os : 2 mg/kg x 2/j (Etude FUTURE 1)
- Action synergique du NO ou du Sildénafil
- Baisse la PAP de 19±14,6% à 50% post CEC, sans variation systémique
- Meilleure tolérance chez l'enfant

Ambrisentan (Volibris)

Macitentan (Opsumit)

Traitements combinés

iNO, puis sildénafil, prostanoïde, bosentan
Evaluation mono, bi et trithérapie
Evaluation de l'effet sur les Cellules Endothéliales Circulantes



DM Samdja. Circulation 2009

Utilisation de Vasodilatateurs Pulmonaires

- Attention aux shunts résiduels : hyperdébit pulmonaire
- Si dysfonction VD, il faut associer :
  - Inotrope : adrénaline, milrinone, levosimendan
  - Vasodilatateurs pulmonaires pour diminuer la postcharge du VD
- Si dysfonction VG (Attention !!!)
  - Vasodilatateurs pulmonaires augmentent la précharge gauche
  - Augmente la dysfonction VG
  - Appréciation écho (retour VP) et POG
  - Inotropes

Extrème prudence si obstacle valvulaire mitral (ex : RVPAt bloqué)

Conclusion

- Déterminisme génétique de l'HTAP-HTP
- Aggravée par la CEC, l'inflammation, l'infection
- Diagnostic : Echo, PAP, SvO2, NIRS
- Utiliser le ratio PAP/PA
- Eliminer les triggers
  - Traitement

    - Action I : Sédation, O2, ventilation (pH, PCO2)

    - Action II : NO, Sildénafil, Prostacycline, Bosentan,

    Complication contrôlable, maintenant rarement fatale

Assistances Circulatoires et Cardiopathies de l'Enfant

Dr. Andrea Dolcino
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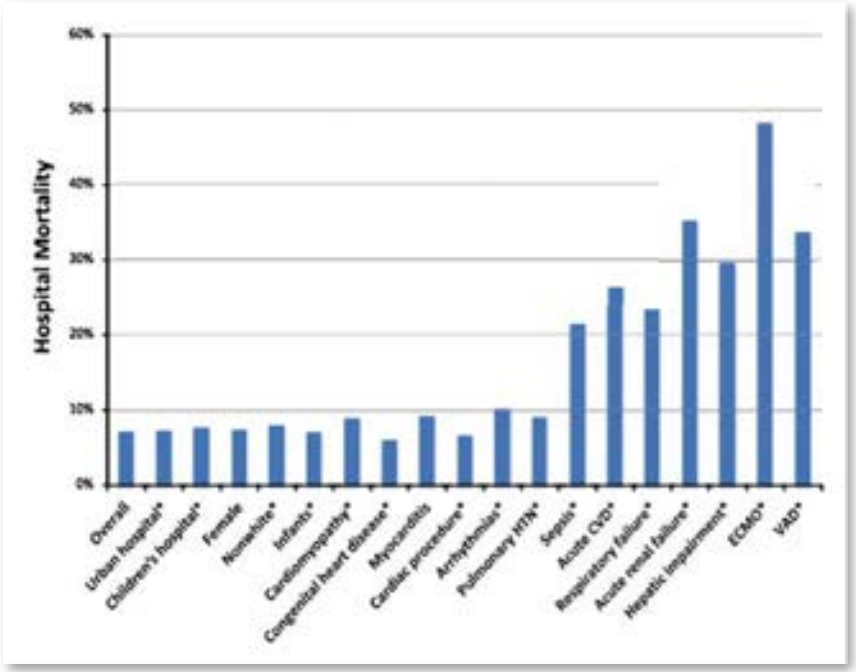
Pourquoi parle-t-on d'assistance aujourd'hui?

Epidemiology and cost of heart failure in children*

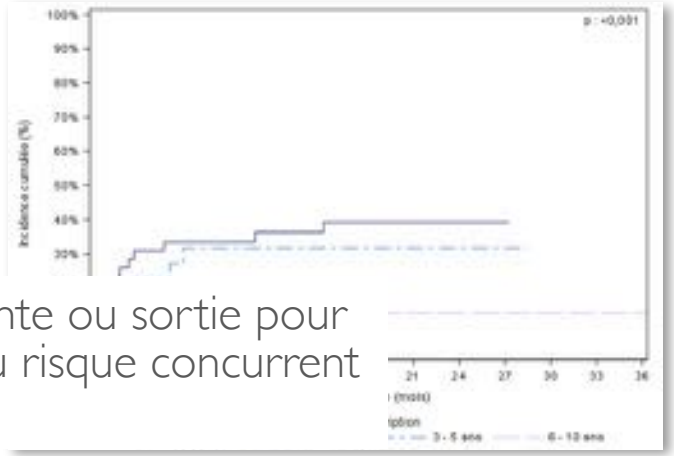
Deipanjan Nandi, Joseph W. Rossano

- Aux USA, 14-18 hospitalisations-IC pour 100 000 *(année 2008)*.
- Durée moyenne de séjour= 19,4 j.
- Mortalité hospitalière de 6-7% globalement *(Mortalité hospitalière en pédiatrie pour une population non IC = 0,4%)*
- Mortalité plus importante pour les enfants de moins de 1 an hospitalisés pour IC (11%).
- Diminution de la mortalité.
- Augmentation de la morbidité.



Le rapport médical et scientifique de l'Agence de Biomedicine 2016

- Durée médiane d'attente d'un greffon = 3mois
- (âge<18 ans - 2011-2012)
- Incidence cumulée de greffe à 6 mois = 64%.
  - ➢ 75% des nouveaux inscrits sont en Réanimation-USC.
  - ➢50% sont ventilés.
  - ➢25% sont sous ECMO.
  - ➢17% ont une assistance ventriculaire.
  - ➢71% Ont un soutient inotrope.



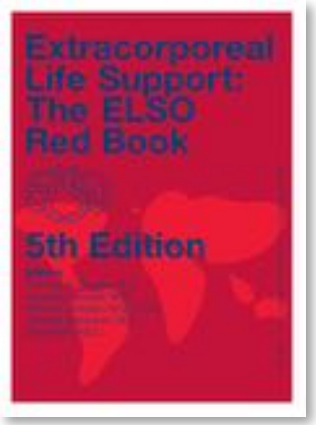
Incidence cumulée de décès en attente ou sortie pour aggravation avec prise en compte du risque concurrent de greffe cardiaque

Historie

- 1970: 1ère ECMO Veino-Artérielle pour choc cardiogénique.
- 1976: ECMO Veino-Artérielle avec pompe centrifuge.
- 1980: Assistance Mono-Biventriculaire avec pompe centrifuge.
- 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

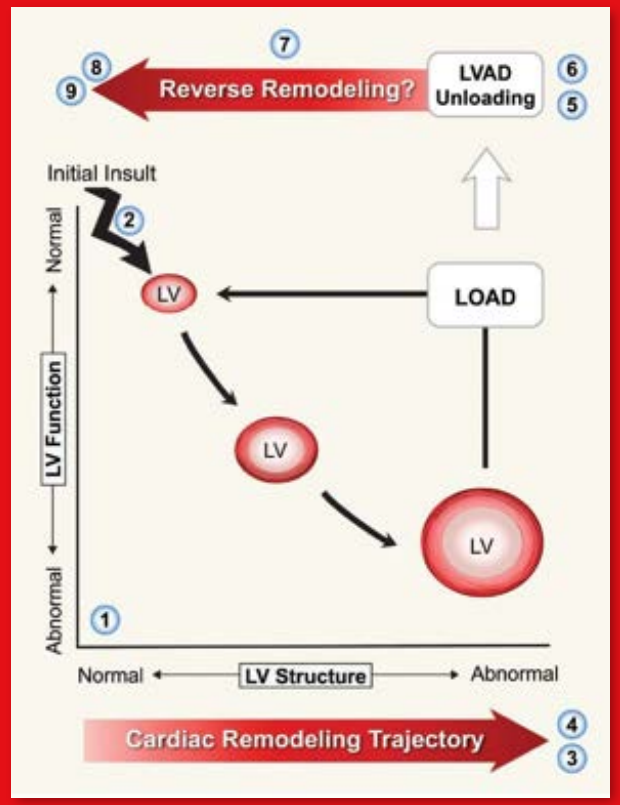
Pedimacs
SUPPORTING HEARTS THROUGH KNOWLEDGE

ELSO



« 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 ???***



Advances in Mechanical Circulatory Support

Bridge to Recovery

Understanding the Disconnect Between Clinical and Biological Outcomes

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-ß-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?

DU des Cardiopathies Congénitales

- 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. Echec de sevrage de la CEC.
  - ➢Centres particulièrement expérimentés.
  - ➢Situations très spécifiques.

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

- 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*.

Congenital Defect/ Myocarditis

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.

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

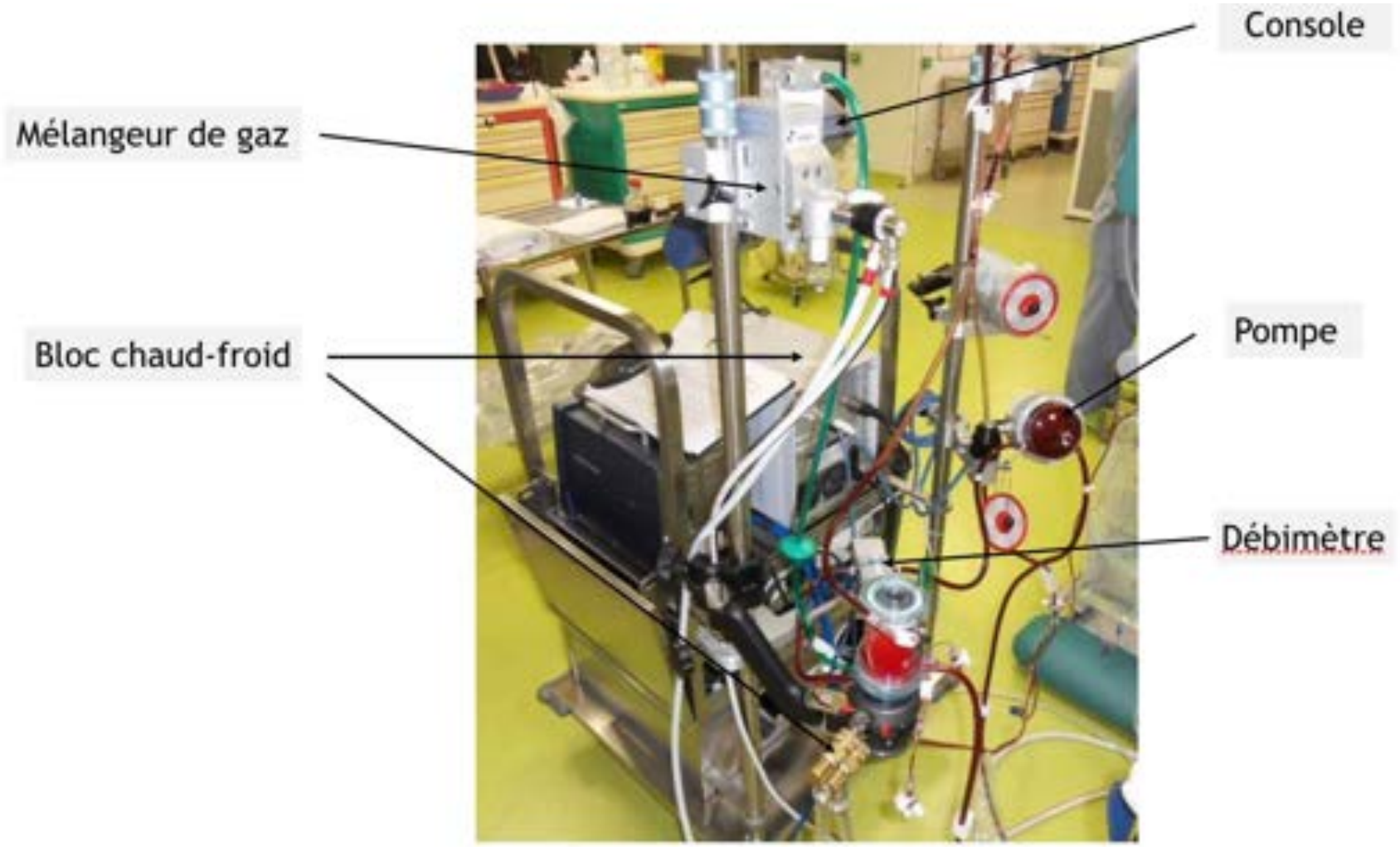
1. ***Rétablissement d'un transport d'oxygène*** normal chez un patient incapable de l'assurer par insuffisance cardiaque aigue.

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.

La machine d'ECMO



Le drainage veineux

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

- 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.

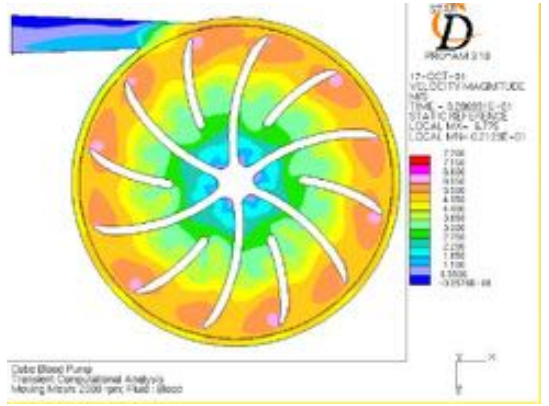
Débit théorique (ml/mn)	Canule Artérielle	Canule Veineuse
400	6	8
450		
500	8	10
550		
600		
650		
700		
750	10	12
800		
850		
900		
950		
1000	12	14
1100		
1200		
1300		
1400	14	15
1500		
1600		
1700		
1800	15	17
1900		
2000		
2100		
2200		
2300		

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		

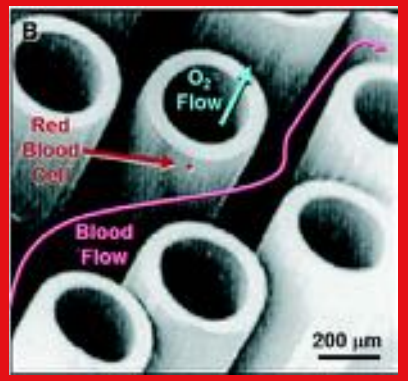
La pompe

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

- 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).

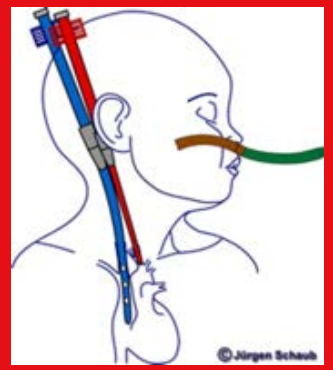


L'oxygénateur

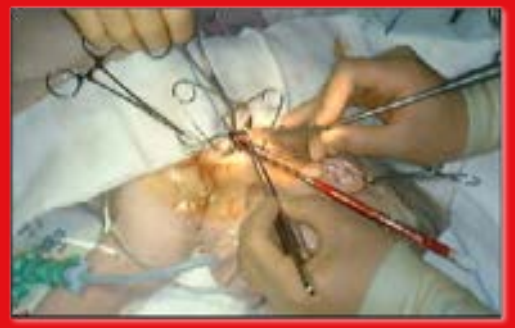


- Oxygénateurs à membranes +++.
- Traitement de surface.
- Moins d'activation de la coagulation.
- Meilleurs échanges gazeux / unité de S^2.
- Moindre résistance à l 'écoulement…
- …donc moins d'hémolyse.

- 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.



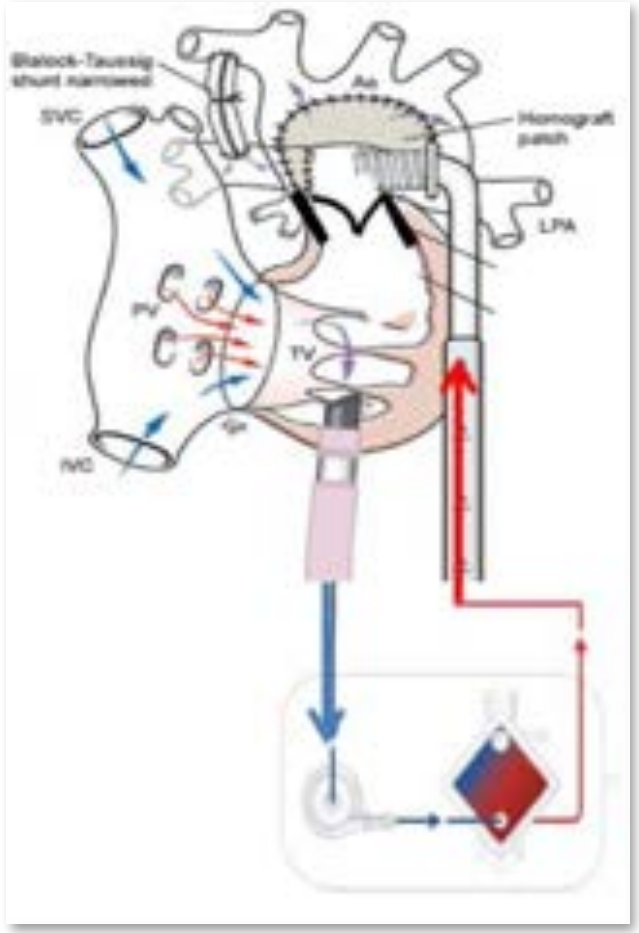
Le site de canulation



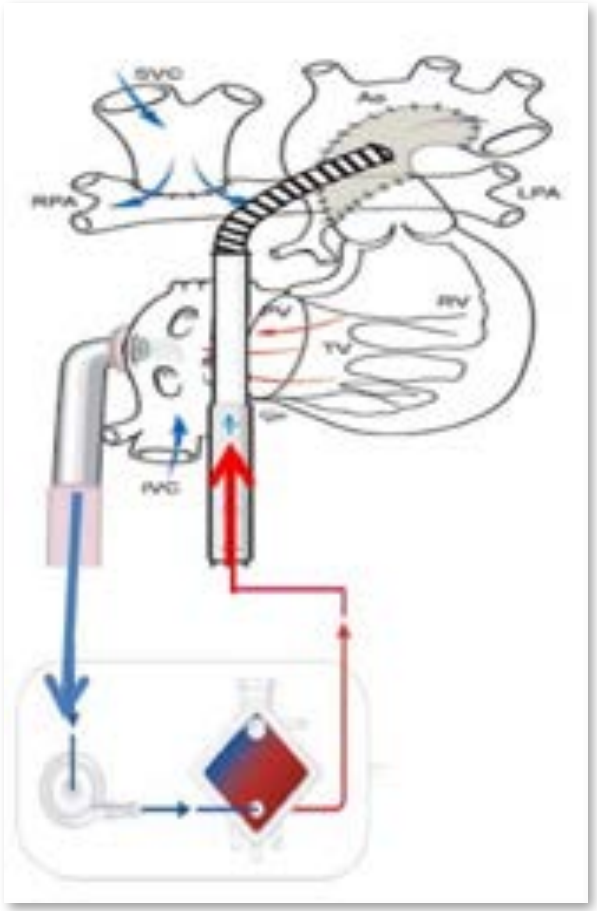
- Périphériques:
  - Percutané vs Chirurgicale
  - Deux sites privilégiés
  1. Jugulo-carotidienne
     - ➢obstruction carotidienne.
     - ➢Complications neurologiques.
  2. Fémoro-fémoral.
     - ➢Taille des canules.
     - ➢Ischémie de membre inférieur.
- Centrale:
  - ➢Sternotomie.
  - ➢Drainage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

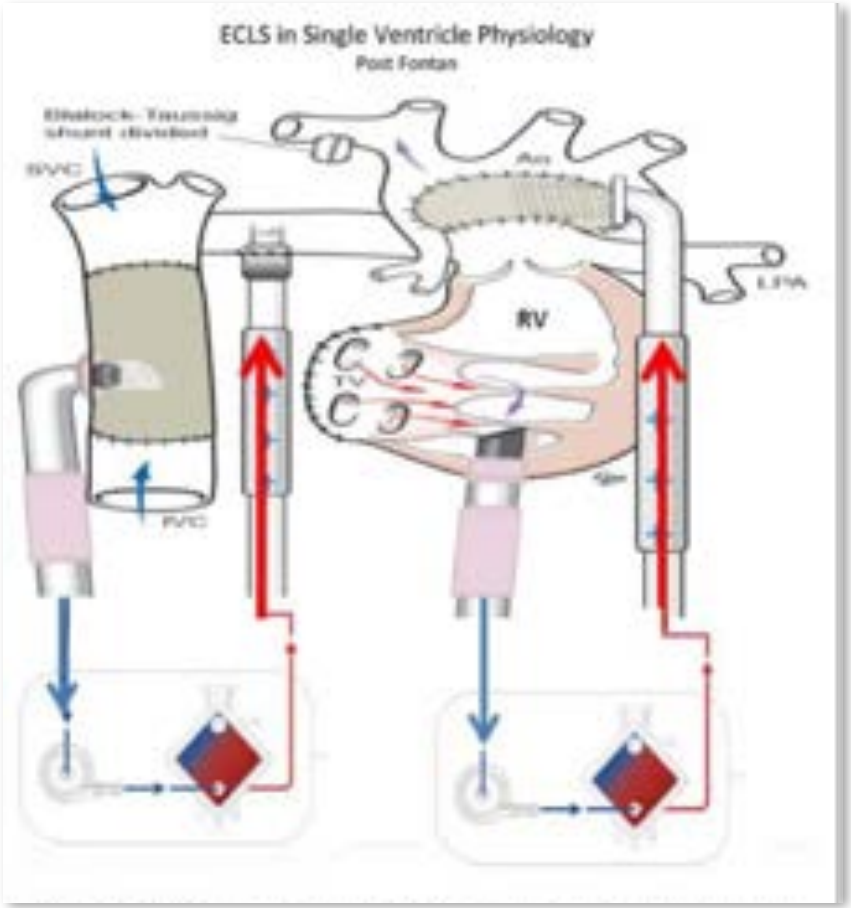
ECMO et Norwood

- Si shunt de Blalock, privilégier l'augmentation du débit à 150-200 ml/kg/mn pour compenser la le perfusion pulmonaire.
- Surmortalité, si on reduit le calibre du shunt.
- 31% de survie.
- Surmortalité en inter-stage.



ECMO et Univentricule



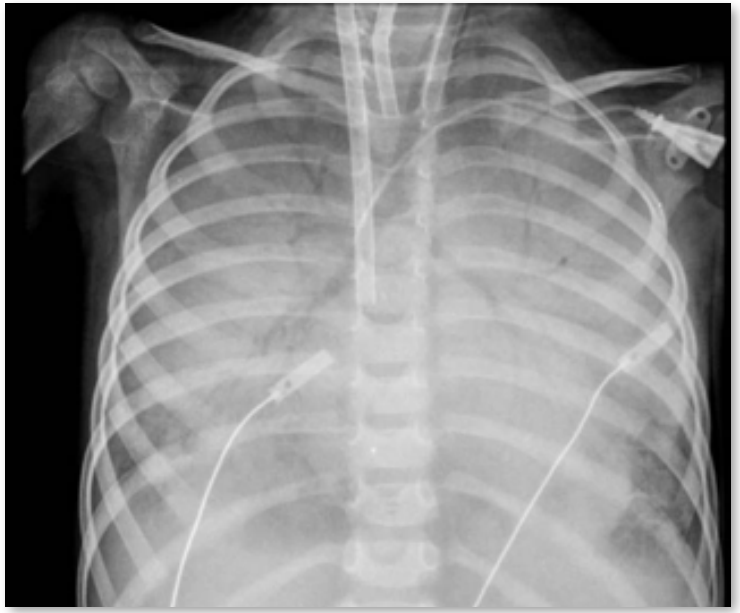


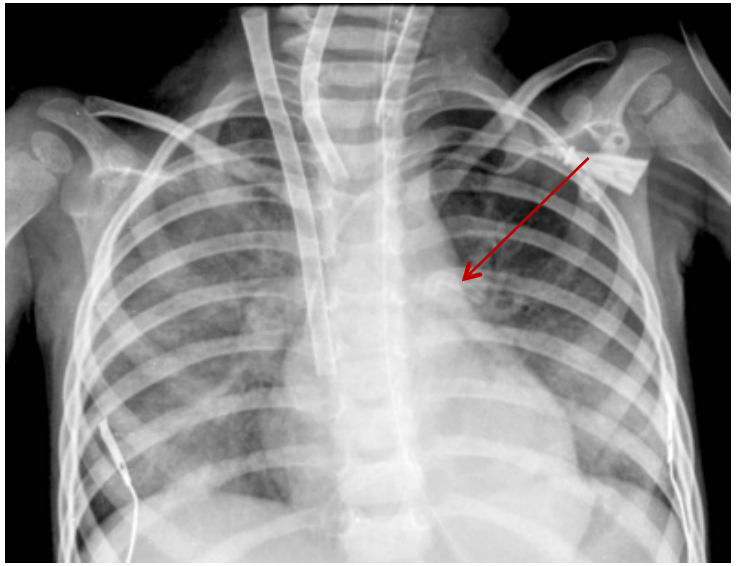
La décharge gauche

- 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 peutêtre insuffisnate.
- Une tentation est d’augmenter le débit d’ECMO.
  - ➢Diminution du retour veineux pulmonaire…
  - ➢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.
- Basculer sur une canulation centrale





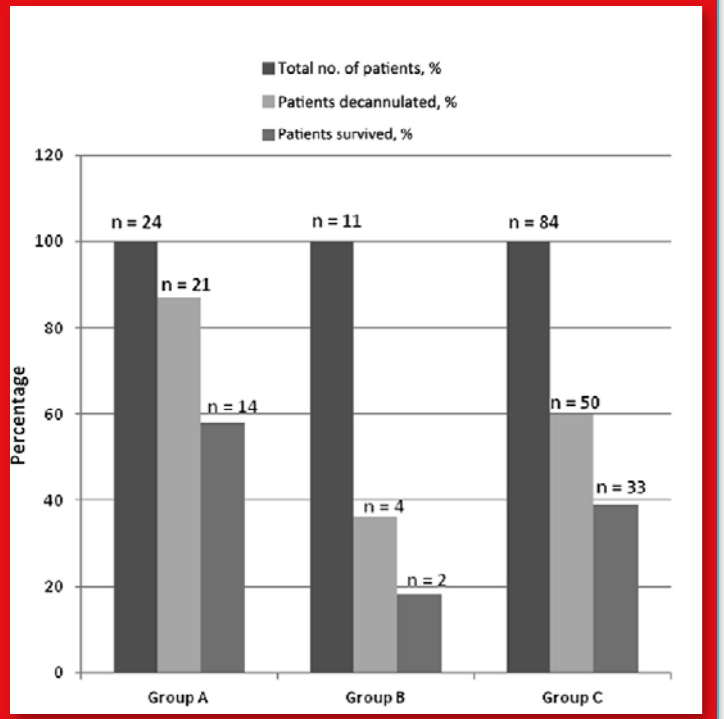
ECMO
post-cardiotomie

- 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.
- SDRA postopératoire avec hypoxémie réfractaire.
- …et lorsque que la situation échape 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



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.

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.

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

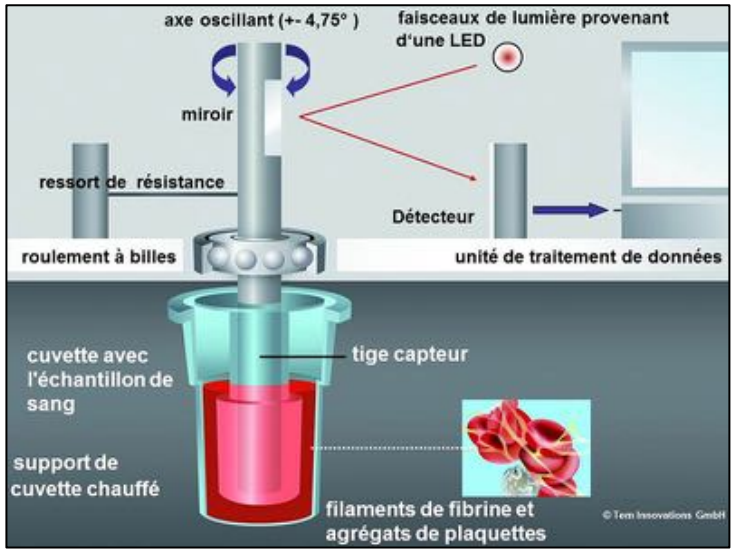
Anesth Analg 2014

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. 2015



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.

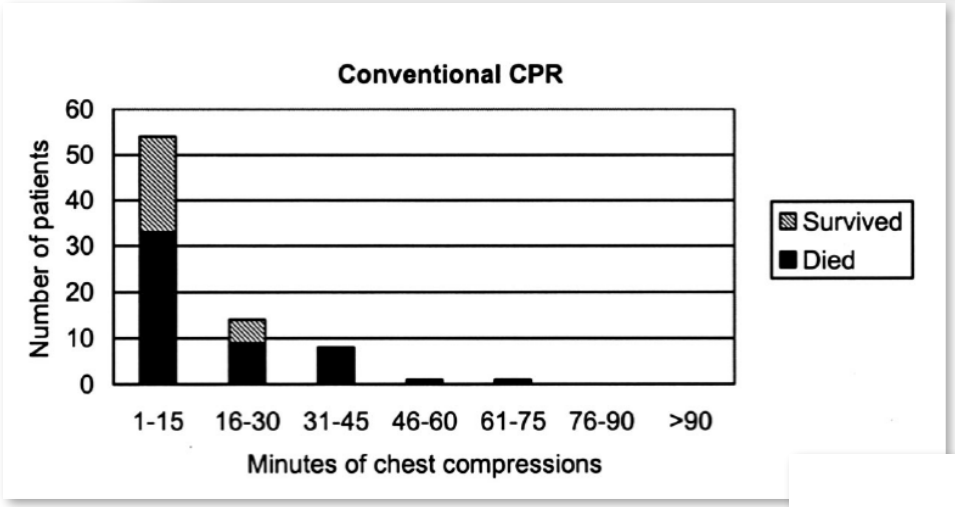
- Pressions télédiastolique intraventriculaire normale-basse.
  - ➢Décharge gauche.
  - ➢FOP.
  - ➢Inotropes à doses raisonnables.
- Promouvoir la perfusion coronaire et l'oxygénation coronaire
  - ➢Pression diastolique.
  - ➢FiO2 sur le ventilateur.
- Essayer de maintenir / de rétablir une pulsatilité.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

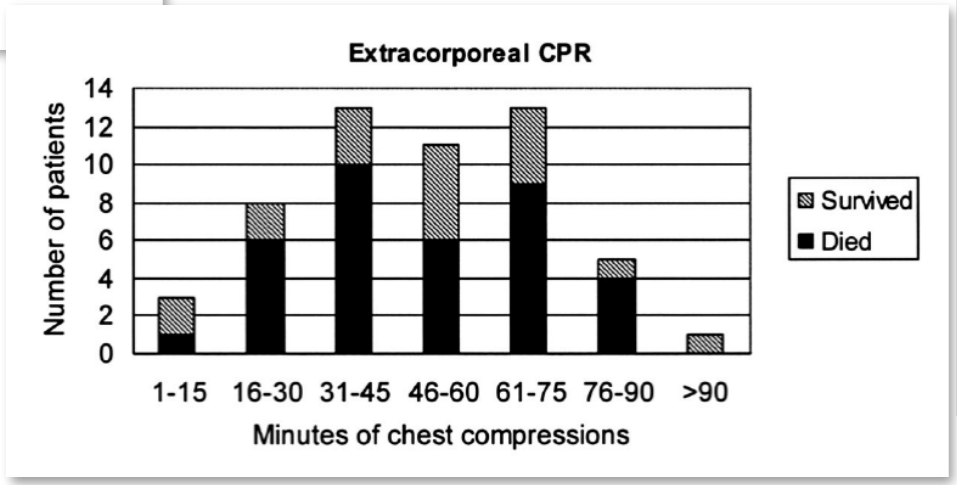
ECMO

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

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





Circulation

JOURNAL OF THE AMERICAN HEART ASSOCIATION

Javier J Lasa 2016

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

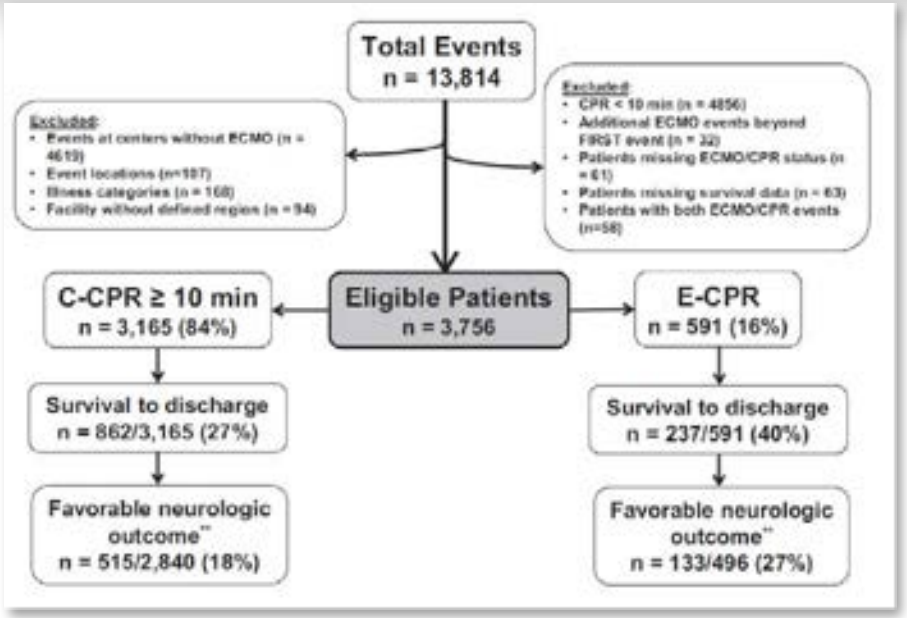
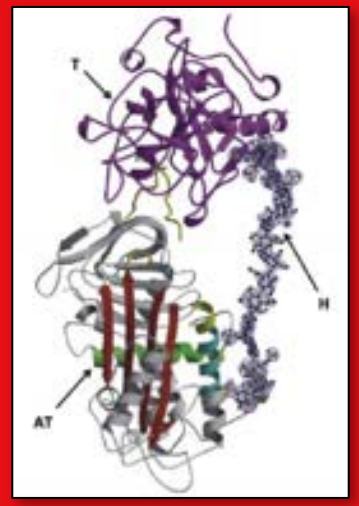


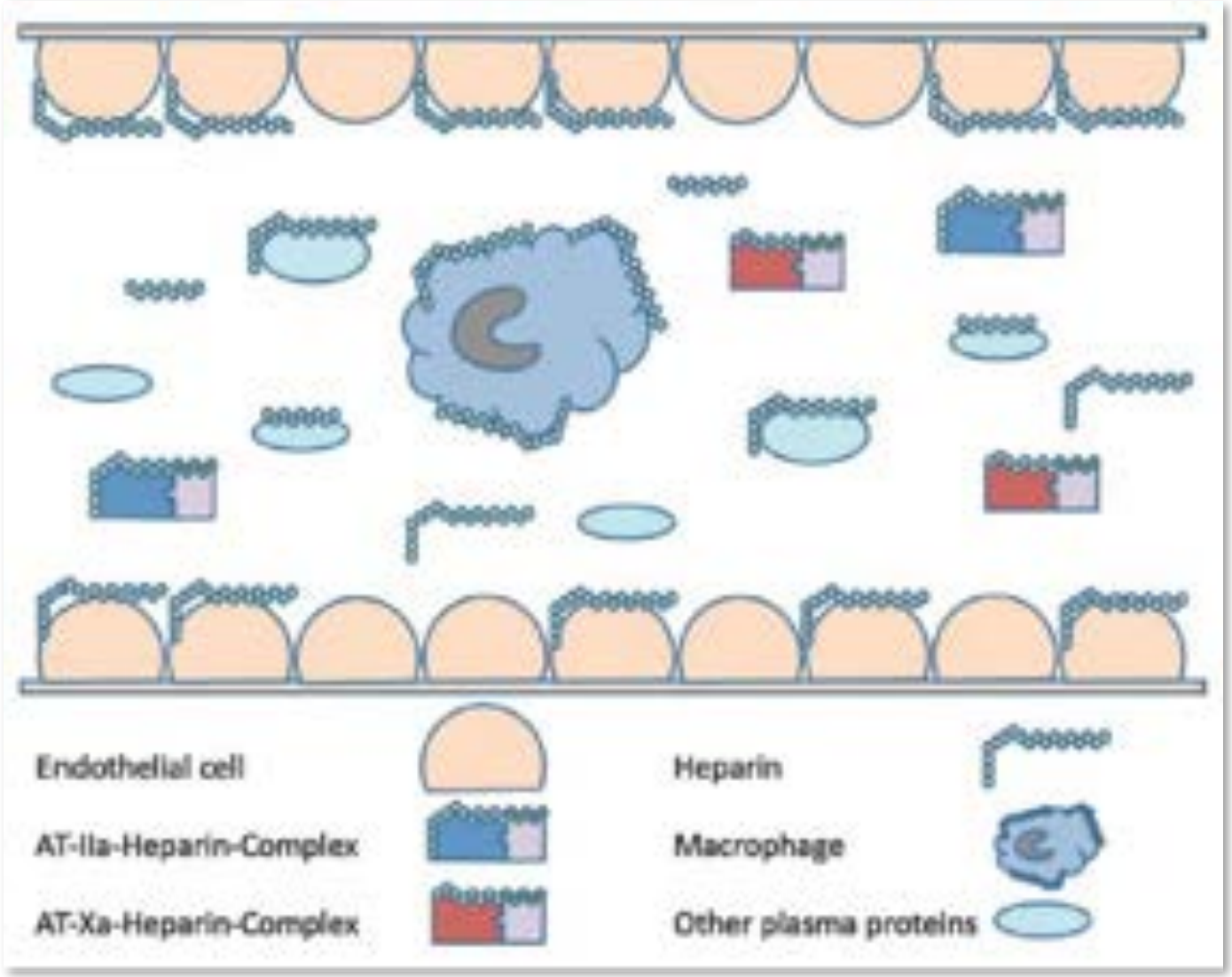
Table 4. Mode of CPR and Survival to Discharge and Favorable Neurological Outcome: Results From Subclassification on the Propensity Score

	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.

Héparine


T
H
AT


Endothelial cell
AT-IIa-Heparin-Complex
AT-Xa-Heparin-Complex
Heparin
Macrophage
Other plasma proteins

Double imperatif

Anticoaguler

- TCK=2-2,5x Témoin
- 0,25 <Anti Xa< 0,4
- 180 < ACT< 250
- Antithrombine > 80%

Prévenir les hémorragies graves

- Plqttes > 80-150 000 g/l
- TP > 50%
- Fibrinogène > 2g/l
- Hb > 12 g/dl

Parler d'anticoagulation dans le contexte d'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

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

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

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

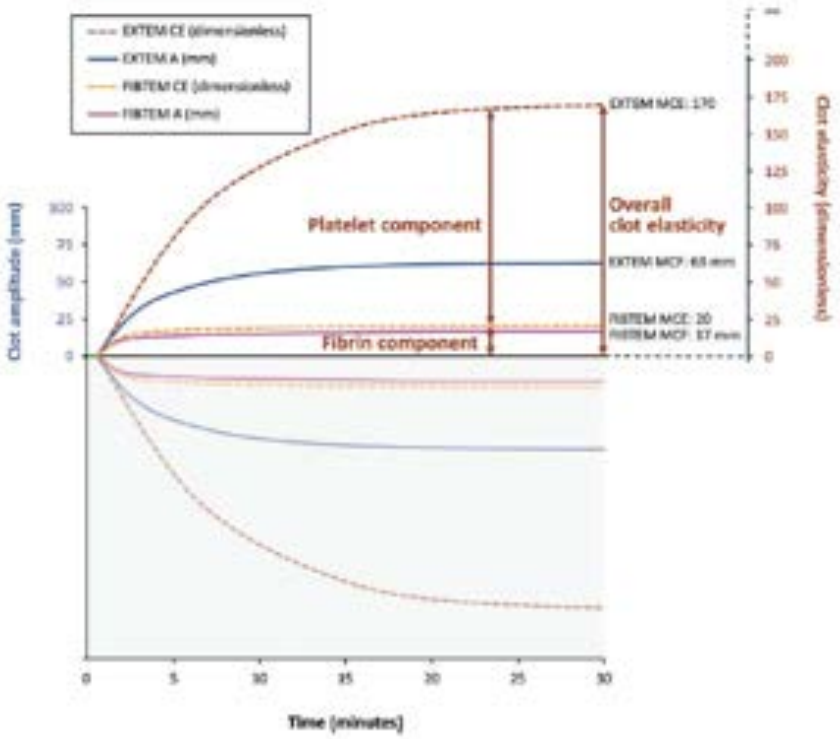
Méthode viscoélastométrique de formation du caillot.

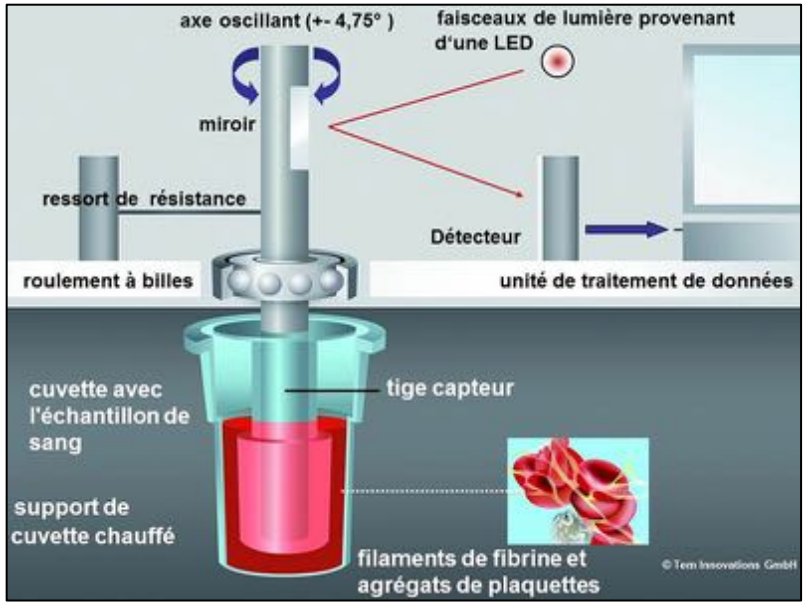
Sur sang total.

En situation de « no flow » (donc la plus thrombogène).

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

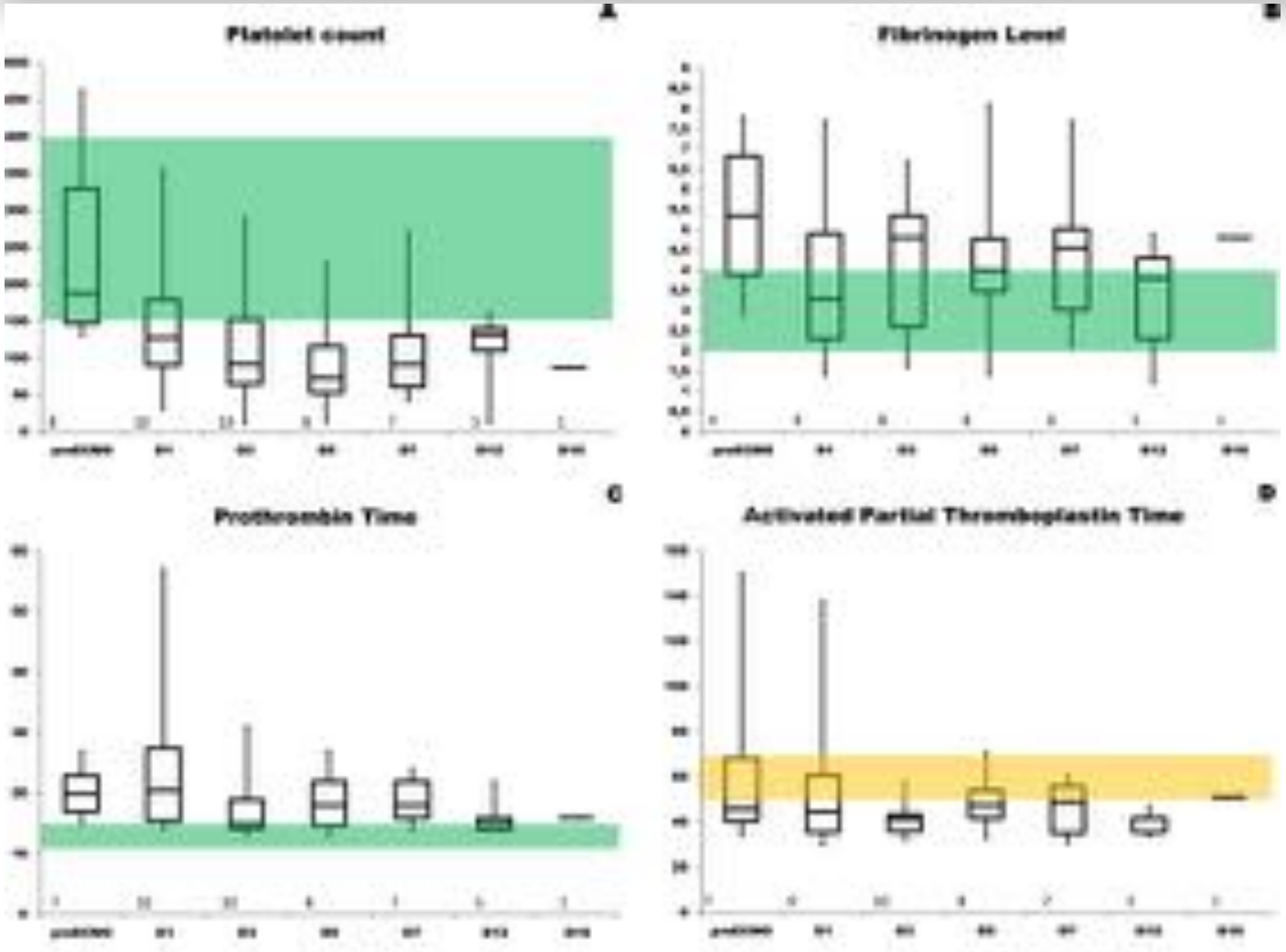
TEG measurements (n=116 respondents)	Routinely	21 (18%)
	Occasionally	29 (25%)
	Never	66 (57%)





- 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



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

- 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.

64% **36% des patients**

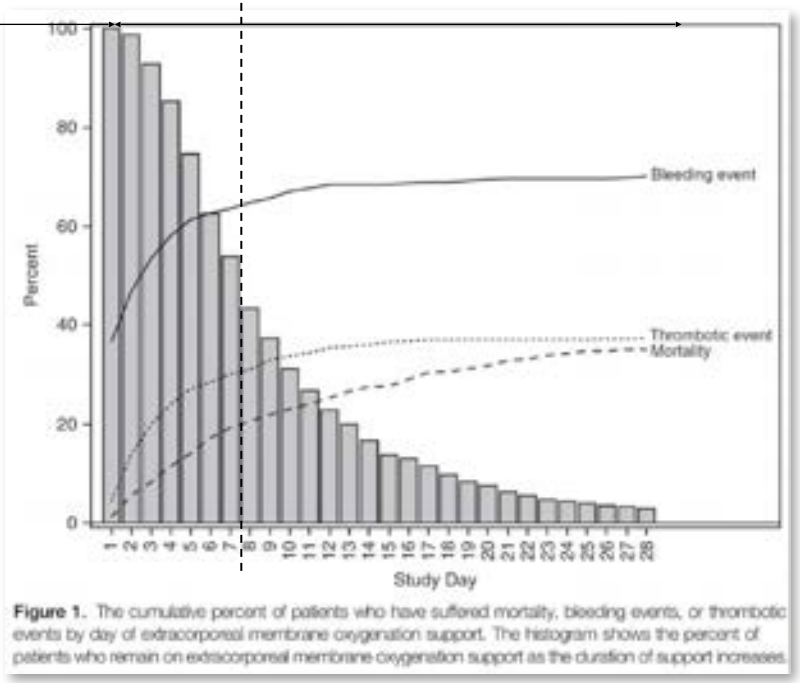


Figure 1. The cumulative percent of patients who have suffered mortality, bleeding events, or thrombotic events by day of extracorporeal membrane oxygenation support. The histogram shows the percent of patients who remain on extracorporeal membrane oxygenation support as the duration of support increases.

- 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.

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 (5.3–11.6)	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)

- 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.

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

- 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 statut 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 +++

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.

Sevrage de l'ECMO

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

Sevrage de l'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.

Initiate support **urgently** rather than **emergently**

Clinical Management of Pediatric Ventricular Assist Devices

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

- 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.

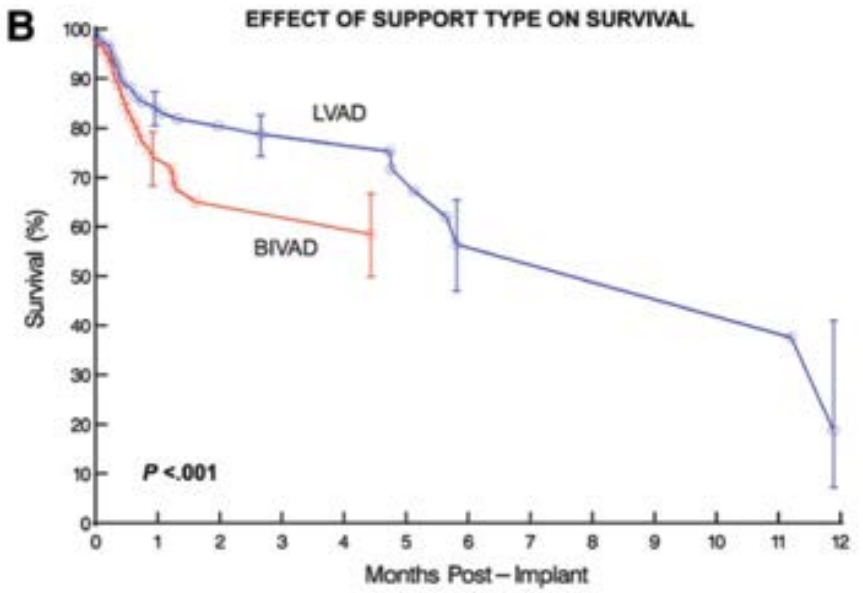
Issue	Possible Solution/Comments
Aortic insufficiency	Aortic insufficiency of 2+ or greater must be corrected; the aortic valve leaflets can be partially oversewn or the valve can be replaced with a bioprosthetic valve
Mitral regurgitation	Generally does not require repair
Mitral stenosis	Must be corrected 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

Un Dogme: Privilégier l'Assistance Mono-Ventriculaire…

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

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

- 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.



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 ce n'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 éllective en BiVAD que la séquence L-VAD-dysfonction VD – BiVAD.

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

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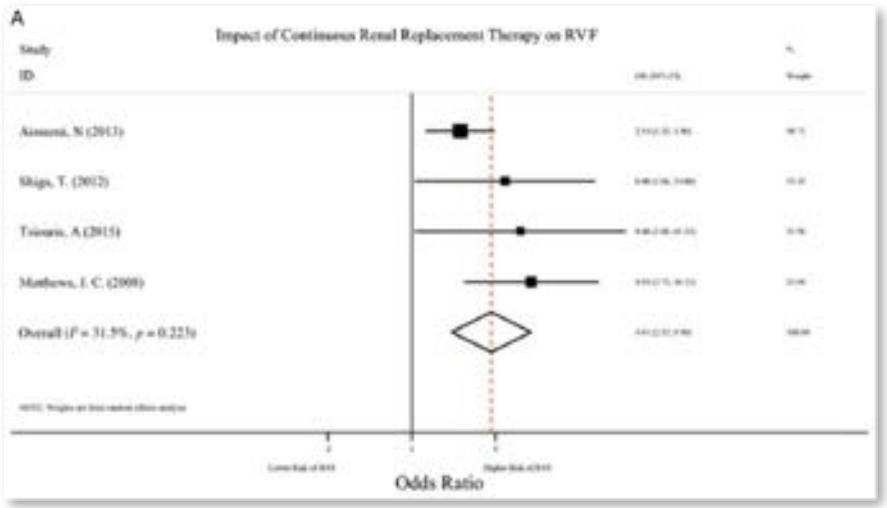
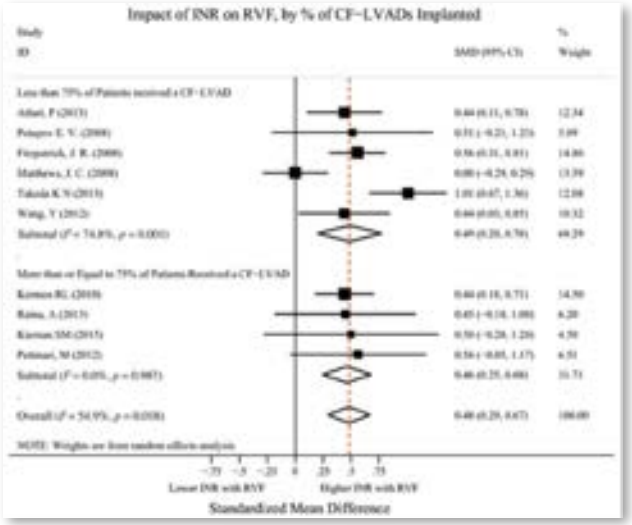
Diego Bellavia

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

Dialyse

La Fonction Hépatique





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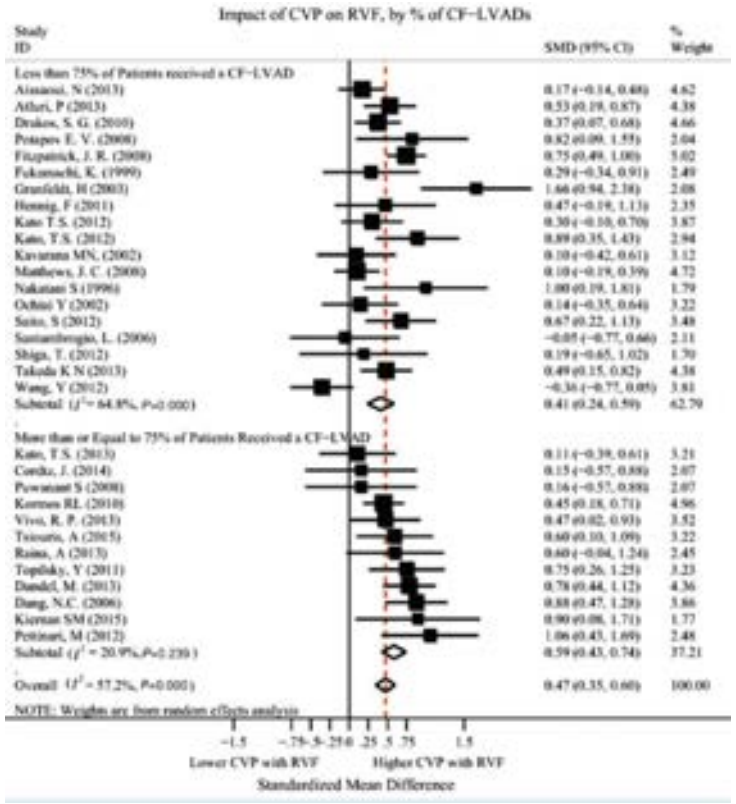
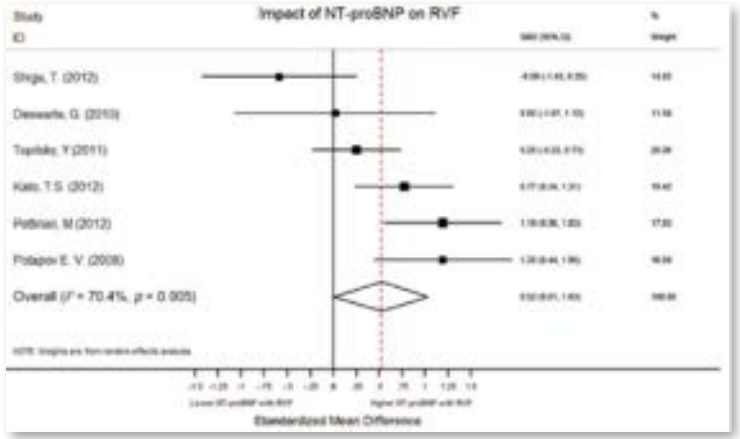
European Journal of Heart Failure (2017) **19**, 926–946

Impact de la PVC



NT-proBNP



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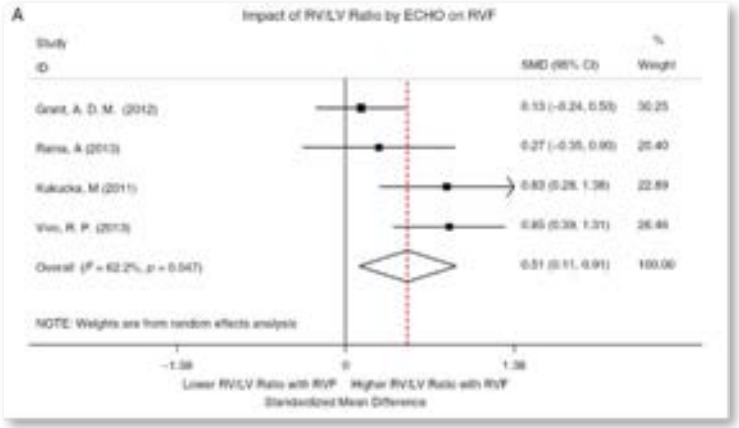
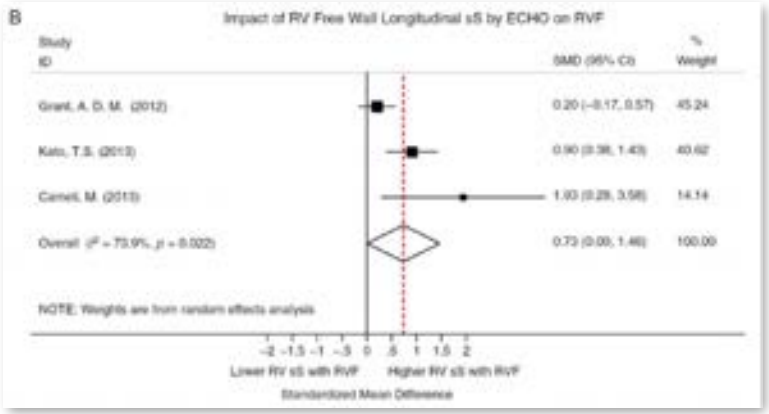
European Journal of Heart Failure (2017) **19**, 926–946

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

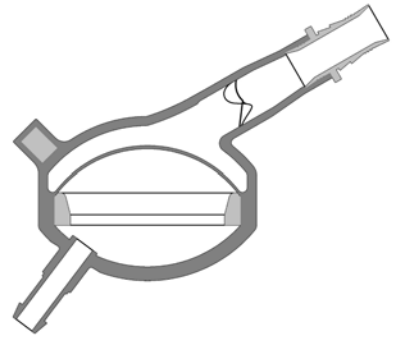
TABLE 2. Main Differences Between Pulsatile and Continuous Flow Devices

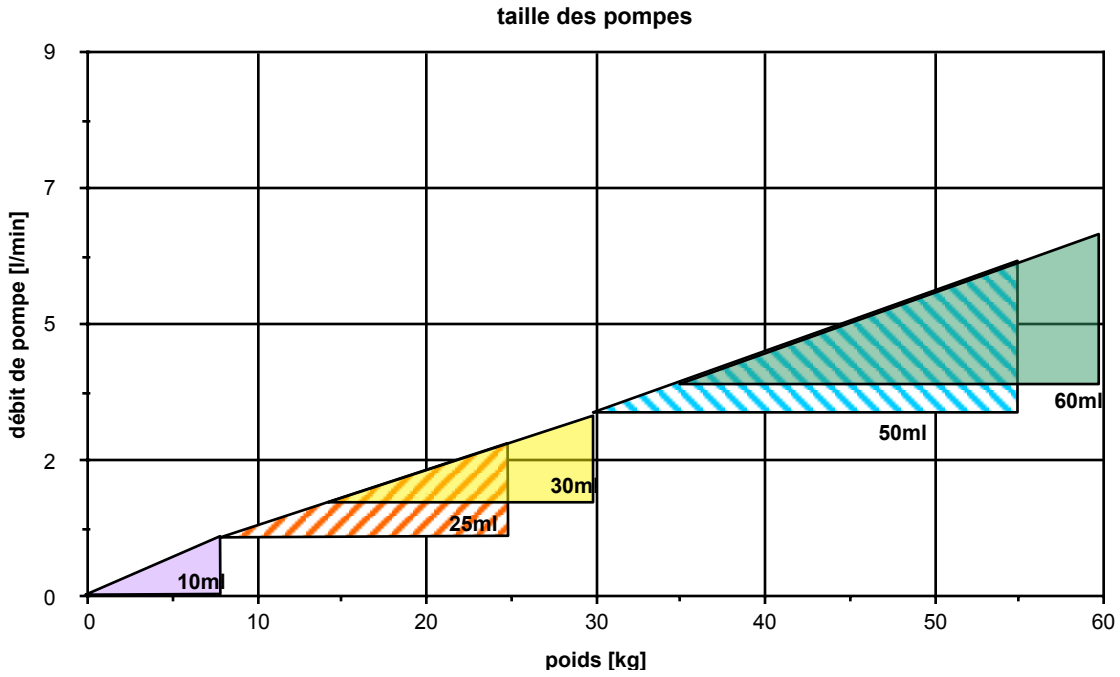
	Pulsatile Device	Continuous Device
Complexity	++	+
Possibility to upgrade to biventricular assist device support[a]	+++	+
Stroke volume (cardiac output)	Fixed	Variable
Recovery of failing peripheral organs	++	+
Risk of infection[b]	++	+
Risk of thrombosis[b]	++	+
Risk of stroke[b]	++	+
Risk of device 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 m². Currently, only pulsatile systems exist for patients less than 0.7 m².

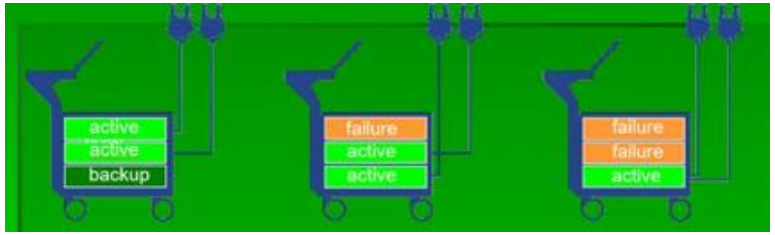
Excor
Berlin Heart

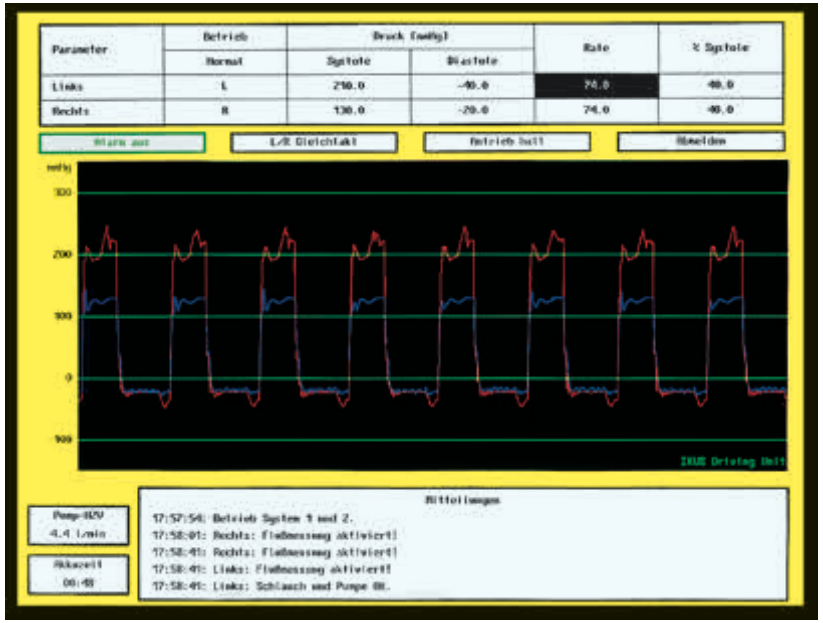
- Paroie en polyurethane transparent.
- 2 chambres…
  - ➢Chambre sanguine..
  - ➢Chambre gazeuse
- …séparées par une membrane triple couche.
- La chambre gazeuse est connectée à l'IKUS.
- La chambre sanguine est connectée au patient.
  - ➢Orifice de drainage.
  - ➢Orifice d'éjection.





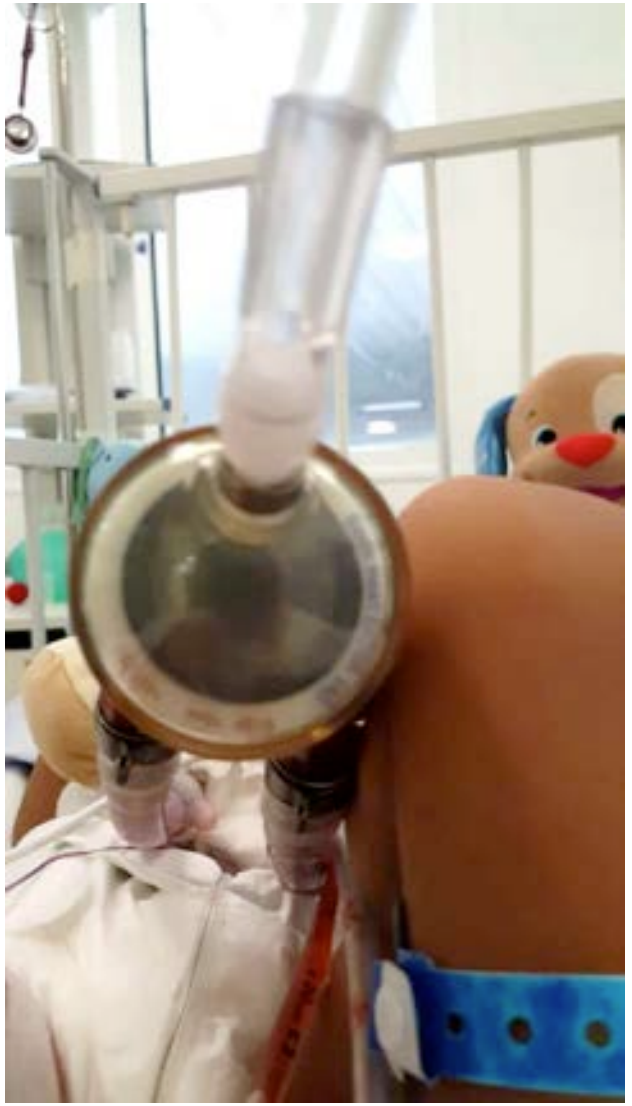
Excor
Berlin Heart





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.



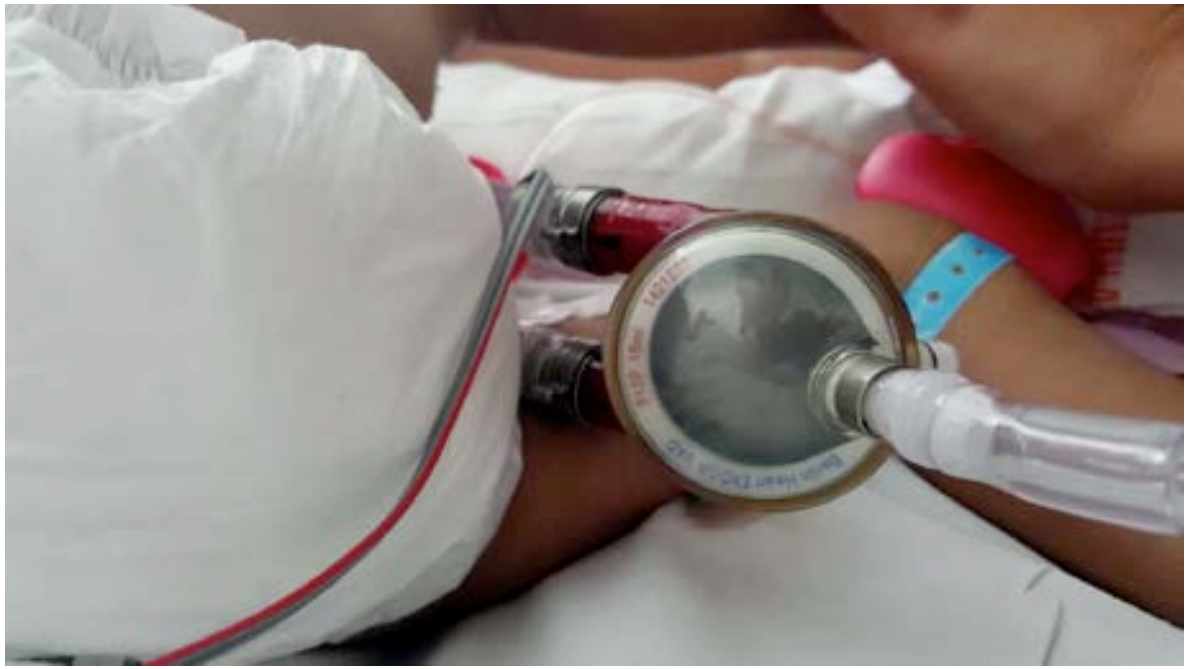
Excor
Berlin Heart

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.

Excor
Berlin Heart

- **Mauvais remplissage de la chambre**



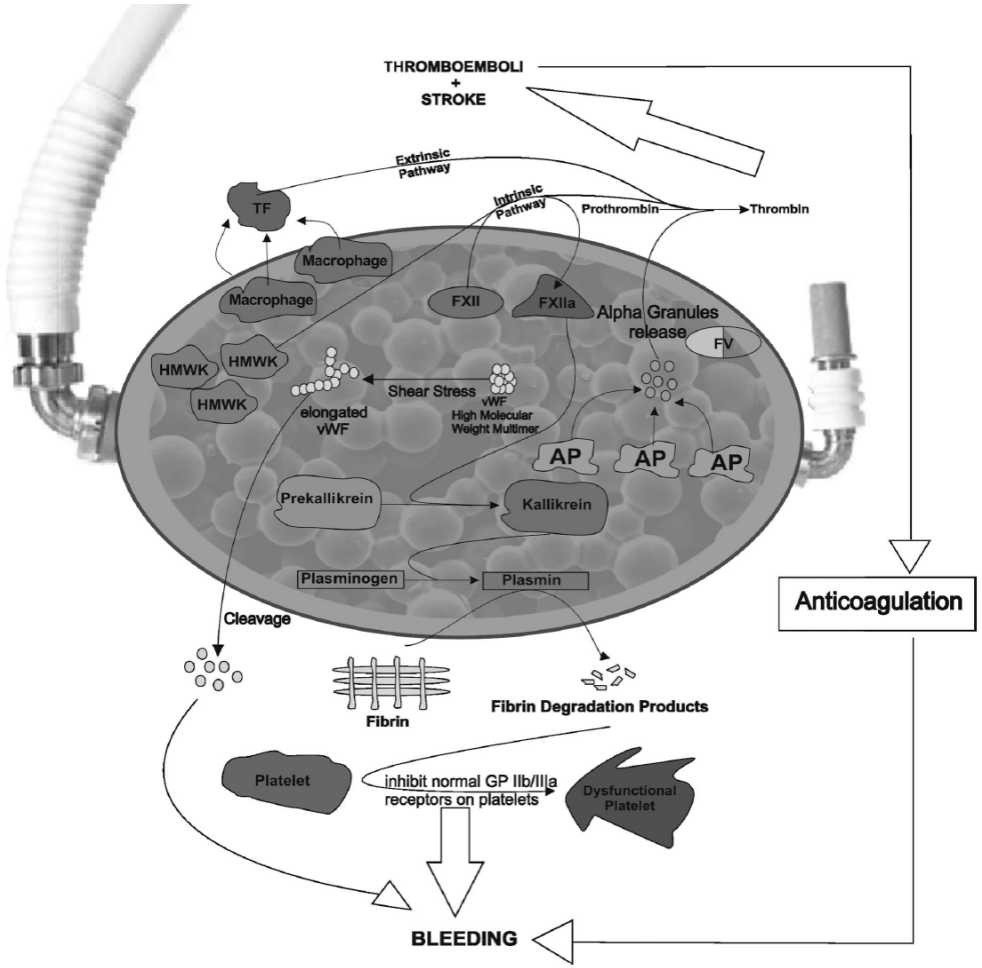
Excor
Berlin Heart

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.

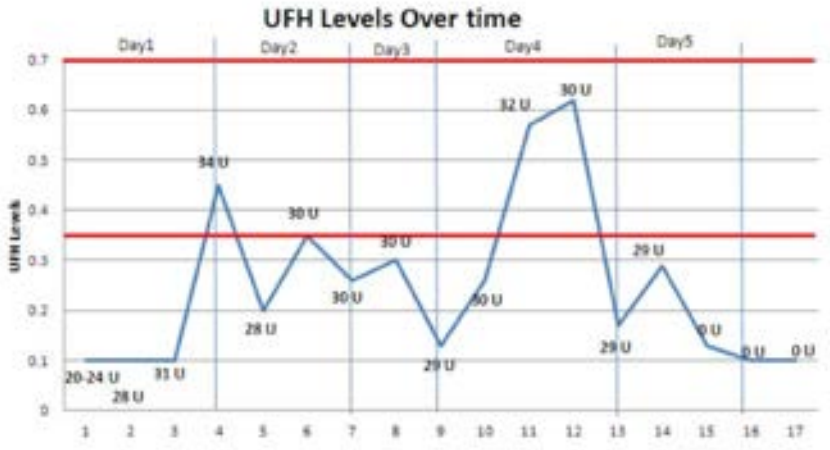
Physiologie appliquée au VAD

- 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



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

- 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?

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	--

The journal of Heart and Lung transplantation 2017

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ORIGINAL CLINICAL SCIENCE

Impact of a modified anti-thrombotic guideline on stroke in children supported with a pediatric ventricular assist device

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The journal of Heart and Lung transplantation 2017

BACKGROUND: Stroke is the most feared complication associated with the Berlin Heart EXCOR pediatric ventricular assist device (VAD), the most commonly used VAD in children, and affects 1 in 3 children. We sought to determine whether a modified anti-thrombotic guideline, involving more intense platelet inhibition and less reliance on platelet function testing, is associated with a lower incidence of stroke.

METHODS: All children supported with the EXCOR at Stanford from 2009 to 2014 were divided into 2 cohorts based on the primary anti-thrombotic guideline used to prevent pump thrombosis: (1) the Edmonton Anti-thrombotic Guideline (EG) cohort, which included children implanted before September 2012 when dual anti-platelet therapy was used with doses titrated to Thromboelastrography/PlateletMapping (TEG/PM); and (2) the Stanford Modified Anti-thrombotic Guideline (SG) cohort, which included children implanted on or after September 2012 when triple anti-platelet therapy was used routinely and where doses were uptitrated to high, weight-based dosing targets, with low-dose steroids administered as needed for inflammation.

RESULTS: At baseline, the EG ($N = 16$) and SG ($N = 11$) cohorts were similar. The incidence rate of stroke in the SG cohort was 84% lower than in the EG cohort (0.8 vs 4.9 events per 1,000 days of support, $p = 0.031$), and 86% lower than in the previous Investigational Device Exemption trial ($p = 0.006$). The bleeding rate was also lower in the SG cohort ($p = 0.015$). Target doses of aspirin, clopidogrel and dipyridamole were higher (all $p < 0.003$), with less dosing variability in the SG cohort than in the EG cohort. There was no difference in adenosine diphosphate inhibition by TEG/PM, but arachidonic acid inhibition was higher in the SG cohort (median 75% vs 39%, $p = 0.008$).

CONCLUSIONS: Stroke was significantly less common in pediatric patients supported with the Berlin Heart EXCOR VAD using a triple anti-platelet regimen uptitrated to high, weight-based dosing targets

Edmonton Protocol vs Stanford Protocol

Table 1 Comparison of Anti-thrombotic Therapy Targets in the Edmonton and Stanford Anti-thrombotic Guidelines for the Berlin Heart EXCOR Pediatric VAD

	Edmonton Guideline	Stanford Guideline
Anti-coagulant	Enoxaparin (anti-Xa 0.6 to 1.0)	Same
Aspirin	Titrated to AA inhibition of >70% by TEG/PM	Titrated to a weight-based dose of 30 mg/kg/day (maximal dose 2,000 mg/day)
Dipyridamole (Persan-tine)	Titrated to an ADP Net G[a] 4 to 8 or ADP inhibition >70% by TEG/PM	Titrated to a weight-based dose of 15 mg/kg/day
Clopidogrel (Plavix)	No recommendation	0.2 mg/kg/day (starting) titrated to a fixed dose of 1 mg/kg/dose once daily
Prednisone	No recommendation	As needed for fibrinogen >600 mg/dl or other signs of inflammation (fever, rise in CRP)[b]

AA, arachidonic acid; ADP, adenosine diphosphate; C-reactive protein; IDE, Investigational Device Exemption (study); INR, international normalized ratio; PM, PlateletMapping; TEG, Thromboelastography; VAD, ventricular assist device.

[a]Net G is calculated by subtracting the percent inhibition of ADP from 100%, dividing by 100, and multiplying the value by the baseline G from the citrated specimen activated with kaolin in the presence of heparinase.

[b]Anti-platelet therapy and steroids titrated primarily to achieve an M_A value of between 55 and 65 mm using a citrated specimen activated with kaolin in the presence of heparinase.

Serious Adverse Event Rates

	Edmonton Guideline n=16	Stanford Guideline N=11
Ischemic Stroke	6 (4.9 per 1000 pt days)	1 (0.8 per 1000 pt days)
Hemorrhagic Stroke	0	0
Systemic Thrombus	1 (0.8 per 1000 pt days)	0
Bleeding	23 (18.8 per 1000 pt days)	11 (8.6 per 1000 pt days)
Pump exchanges	41 (33.6 per 1000 pt days)	21 (16.4 per 1000 pt days)
All serious AEs	71 (58.1 per 1000 pt days	34 (30.5 per 1000 pt days)

Scope of the problem

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

Admiral Grace Hopper

The most dangerous phrase in any language is

“We’ve always done it this way.”

Direct Thrombin Inhibitor Working Group

- Created a collaboration of 10 centers who had utilized DTI for anticoagulation in paracorporeal VAD support
- Shared institutional protocols and practices
- This group evolved into one of the aspects of the Advanced Cardiac Therapies Improving Outcomes Network (ACTION)

Evolving Strategies to Mitigate Bleeding and Stroke

- Use of Steroids
- Dedicated Antithrombosis team
- Stanford AT Guide
- Use of DTI

Direct Thrombin Inhibitors

- Class of intravenous medications that directly inhibit thrombin (FIIa)
- Most commonly used in clinical practice
  - Bivalirudin
  - Argatroban
- Has extensive history of use for adult anticoagulation in the setting of heparin induced thrombocytopenia (HIT)

Mechanism of Action

- Directly inhibits thrombin by binding to the catalytic and anion binding exosite of **circulating** and **clot bound** thrombin
- Thrombin cleaves fibrinogen to fibrin, activated FXIII to FXIIIa which covalently crosslinks fibrin and stabilizes the thrombus
- Thrombin also activates platelets, stimulating aggregations and granule release

Key Differences between UFH and DTI

	Heparin	DTIs
Thrombin inhibition	Binds only circulating thrombin	Binds clot bound and circulating thrombin
Dosing (PK/PD)	Non-linear (logarithmic especially in neonates)	Linear dose response (aPTT may plateau at high concentrations)
AT III dependence	Requires AT III to potentiate thrombin inhibition 1000X	No dependence upon AT III
Reversal	Protamine reversal	No reversal agent
Half life	~ 2 hours	Bivalirudin ~ 19 min Argatroban ~50 min
Associated problems	HIT, osteopenia	?

Bivalirudine

- Bival started in >90% of patients after 12 hours
- Median starting dose of Bival was 0.3 mg/kg/hr (range of 0.1-1.4)
- Dose escalation for bival over time to max median dose of 1mg/kg/hr (range 0.1-3.9)
- All centers utilized aPTT for monitoring, with graduated target ranges
  - Starting aPTT 50-70 and later 80-100

Antiplatelet

- 88% of patients were on antiplatelet agent
  - **Aspirin** median dose of 8 mg/kg/day (range 0.8-33 mg/kg/day)
  - Additional **clopidogrel** use in 16% at median dose of 1 mg/kg/day (range 0.6-1 mg/kg/day)
  - Additional **dipyridamole** in 35% at median dose of 13.5 mg/kg/day (range 0.5-40 mg/kg/day)

Results

	Edmonton Protocol	Stanford Protocol	Boston/DTI protocol
Stroke	4.9*	0.8	1.2
Major bleeding	18.8	8.6	1.7
Pump thrombosis /exchange	33.6	16.4	3.7

Plaquettes

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

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

Sirisha Emani, PhD

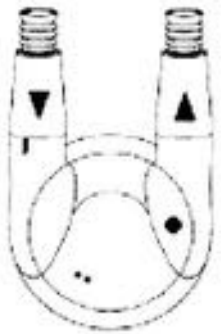
The Journal of Thoracic and Cardiovascular Surgery • Volume 154, Number 5

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 ($P < .001$).

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

Exemple : identification des dépôts



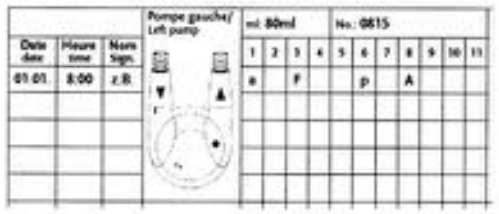
1 petite concentration de dépôts

3 petit fil au niveau de la valve d'admission

6 petits dépôts épars

8 grande concentration de dépôts

Exemple : notation codée



Dépots inquiétants si:

- ➢ Ø > 5mm
- ➢ Multicolore
- ➢ Mobile

HeartWare

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

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.**
- **783 patient-mois.**

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

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.

Pedimacs

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.

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.

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

Ces quatre complications réunissent 66% de toutes les complications

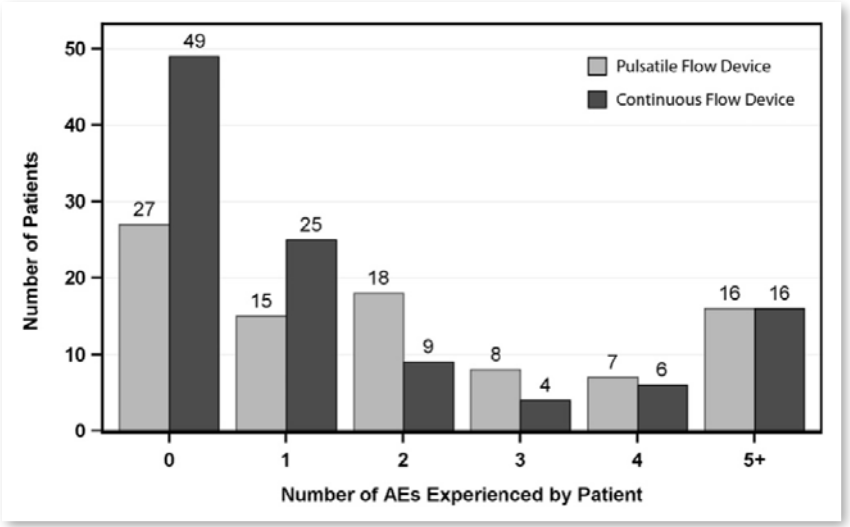


Table 3 Adverse Event Incidence

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.

Saignement

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

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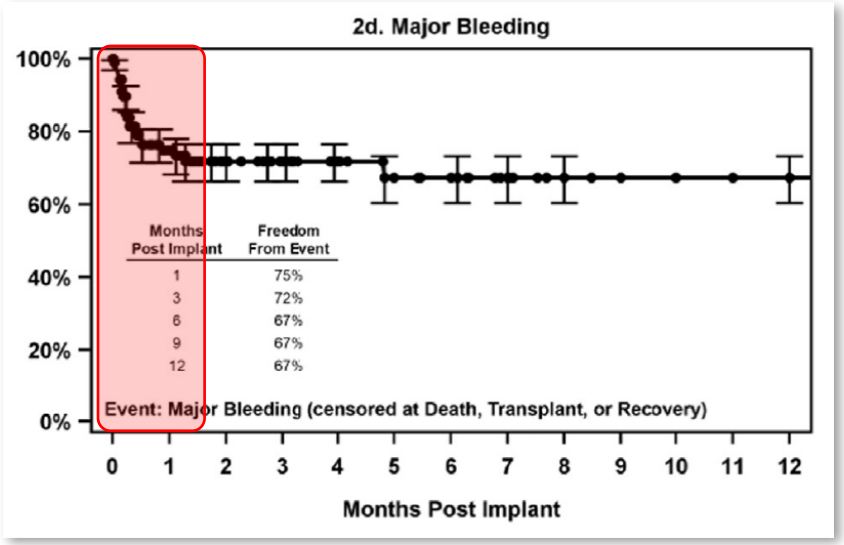
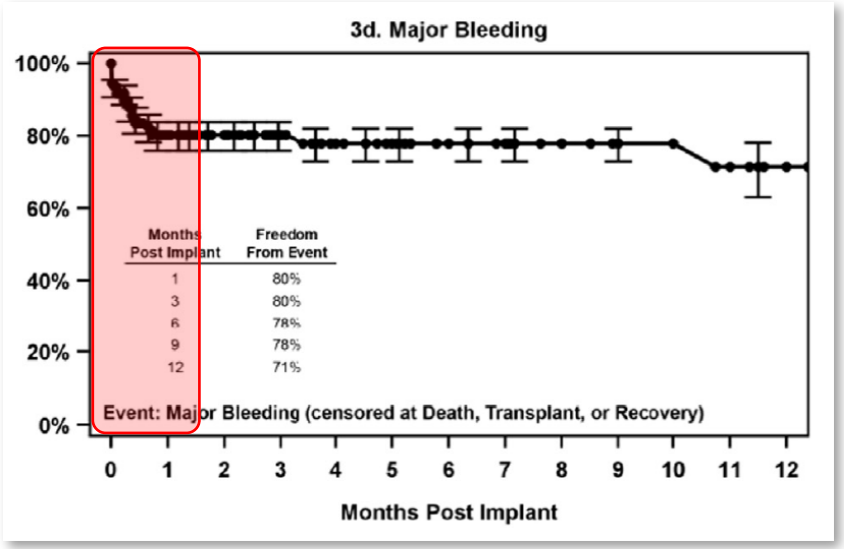
Major Bleeding et Pulsatile Flow VAD



Major Bleeding et Continuous flow VAD



AVC

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

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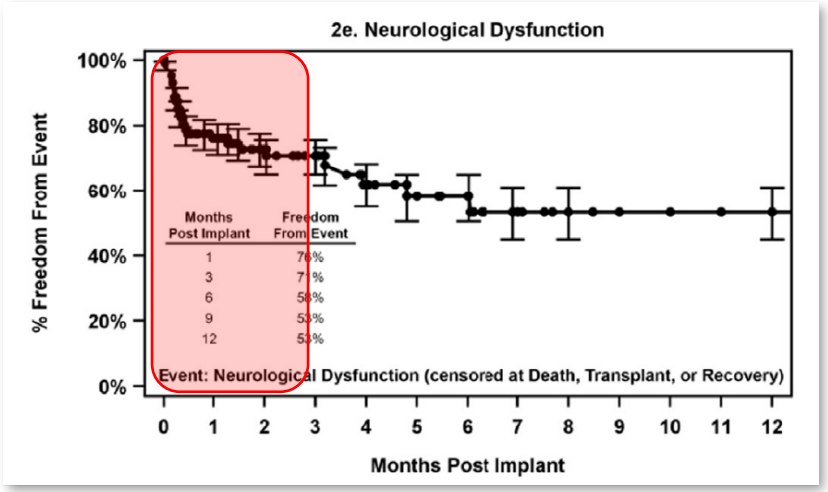
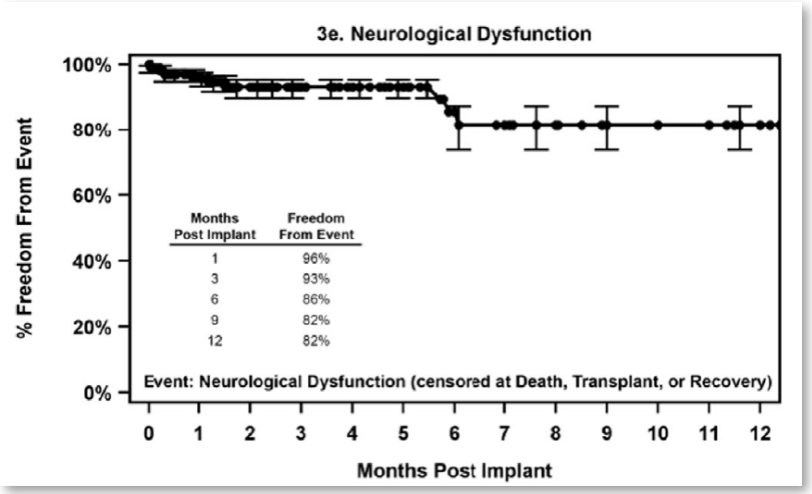
Evènements Neurologiques et Pulsatile-Flow VAD



Evènements Neurologiques et Continuous-Flow VAD



TCS vs ECMO

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

Vamsi V. Yarlagadda, MD,[a,c] Katsuhide Maeda, MD,[b,c] Yulin Zhang, PhD,[c] Sharon Chen, MD,[a,c] John C. Dykes, MD,[a,c] Mary Alice Gowen, RN,[c] Paul Shuttleworth, BSN,[c] Jenna M. Murray, NP,[c] Andrew Y. Shin, MD,[a,c] Olaf Reinhartz, MD,[b,c] David N. Rosenthal, MD,[a,c] Doff B. McElhinney, MD, MS,[a,c] Christopher S. Almond, MD, MPH[a,c]

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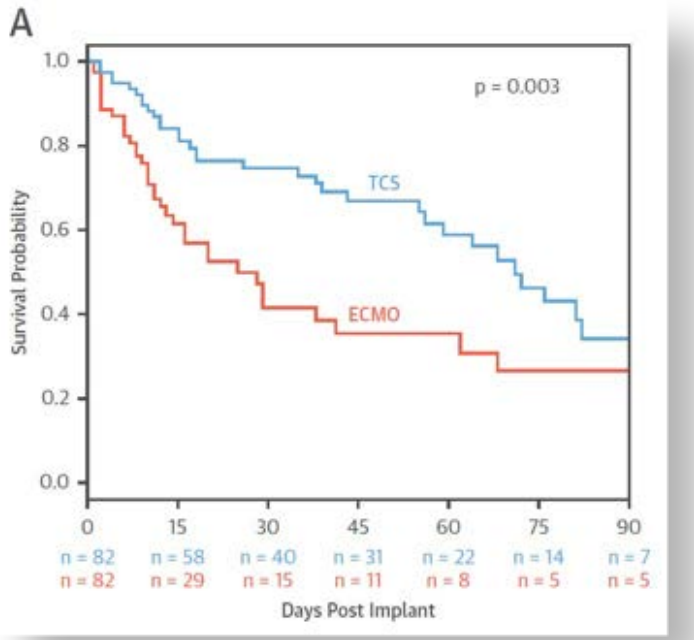
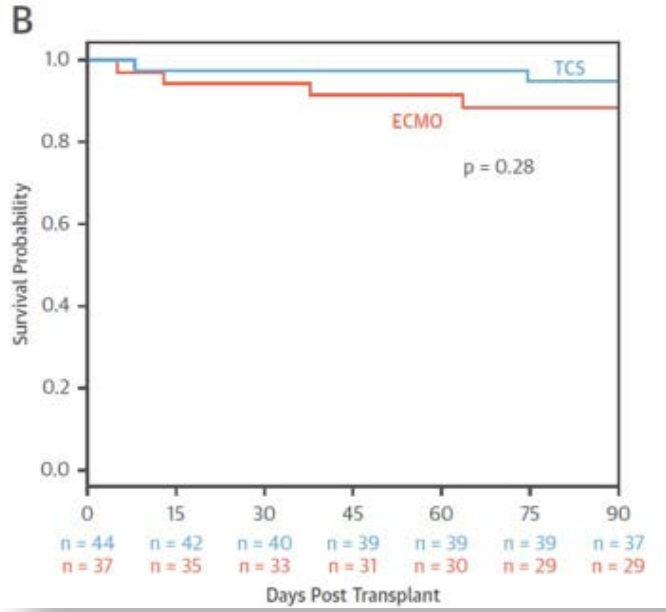
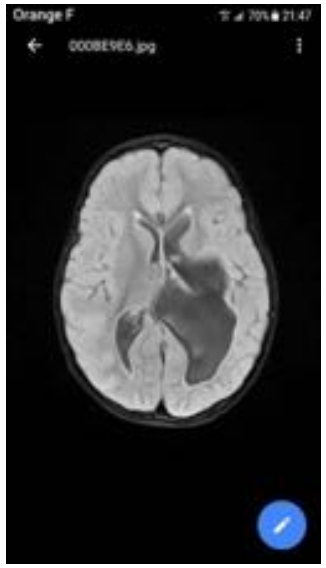
Survie supérieur avec les TCS vs ECMO…

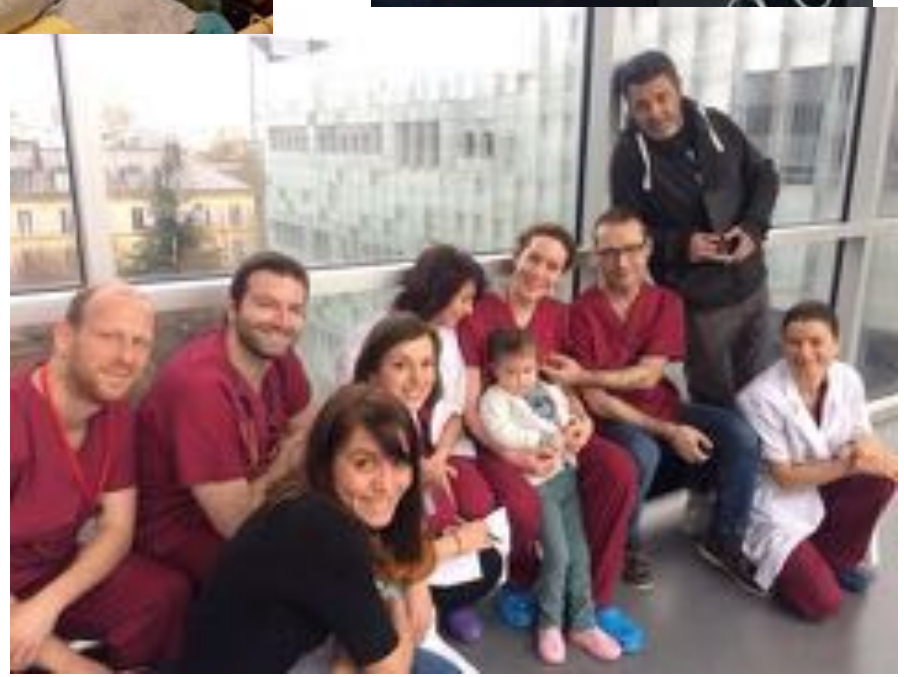
…sans modification significative de la survie post-transplantation.

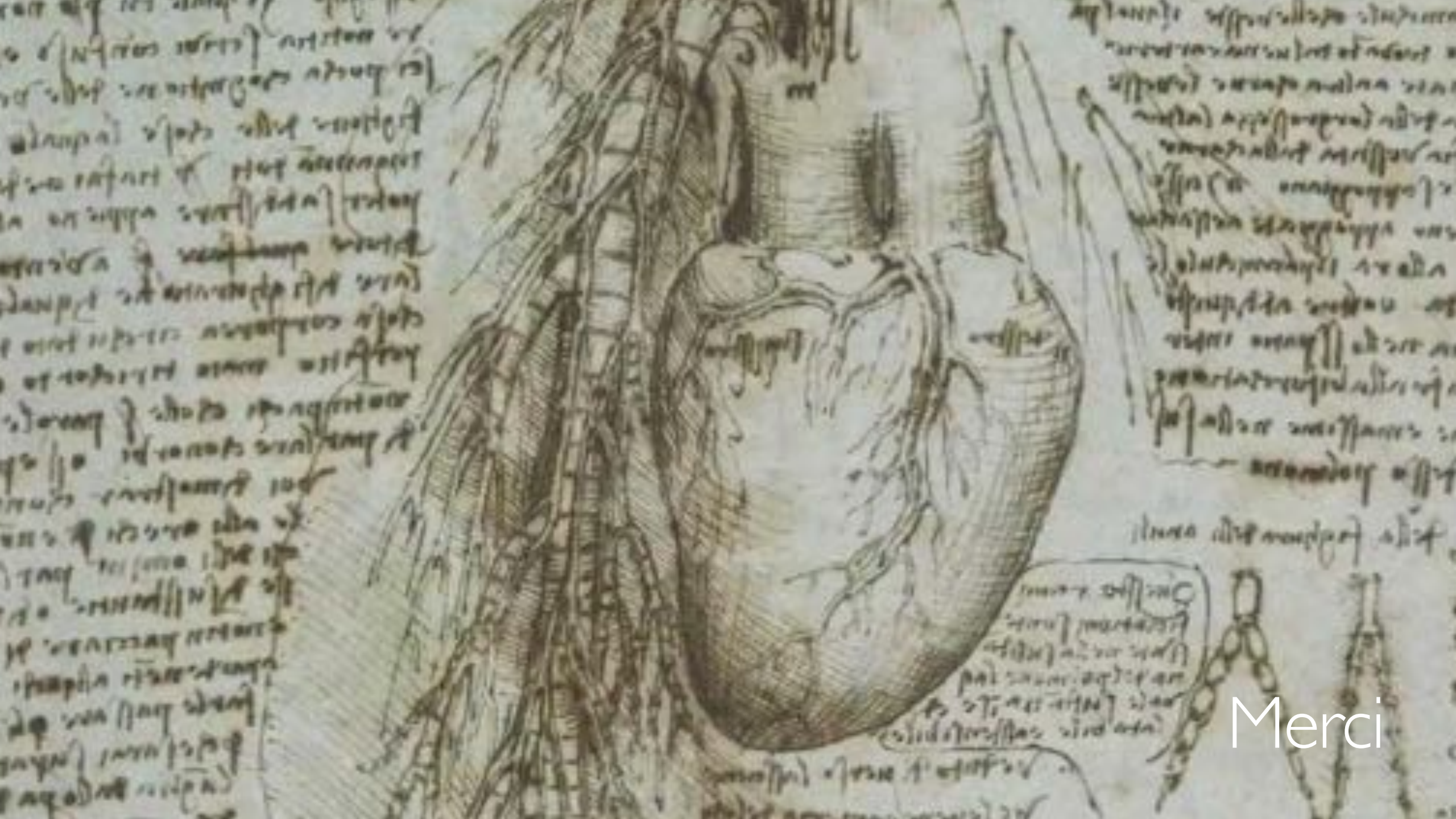




Dedicated to all those who trust us with their lives and loved ones while we continue to learn







Merci