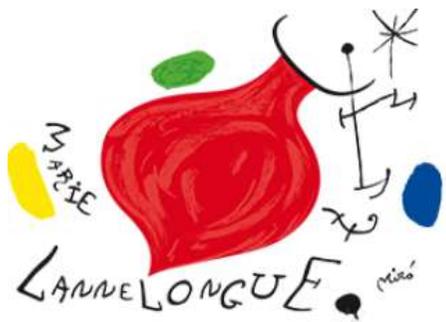


# Atteintes rénales associées aux cardiopathies congénitales

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Hôpital  
Marie Lannelongue



**Insuffisance rénale aiguë**

**Epidemiologie**

**Physiopathologie**

**Diagnostic**

**Prévention**

**Traitement**

**Insuffisance rénale chronique**

### A CASE OF CRUSH INJURY WITH RENAL FAILURE

BY

D. BEALL, Ph.D.

AND

E. G. L. BYWATERS, M.B., M.R.C.P.,

*British Postgraduate Medical School*

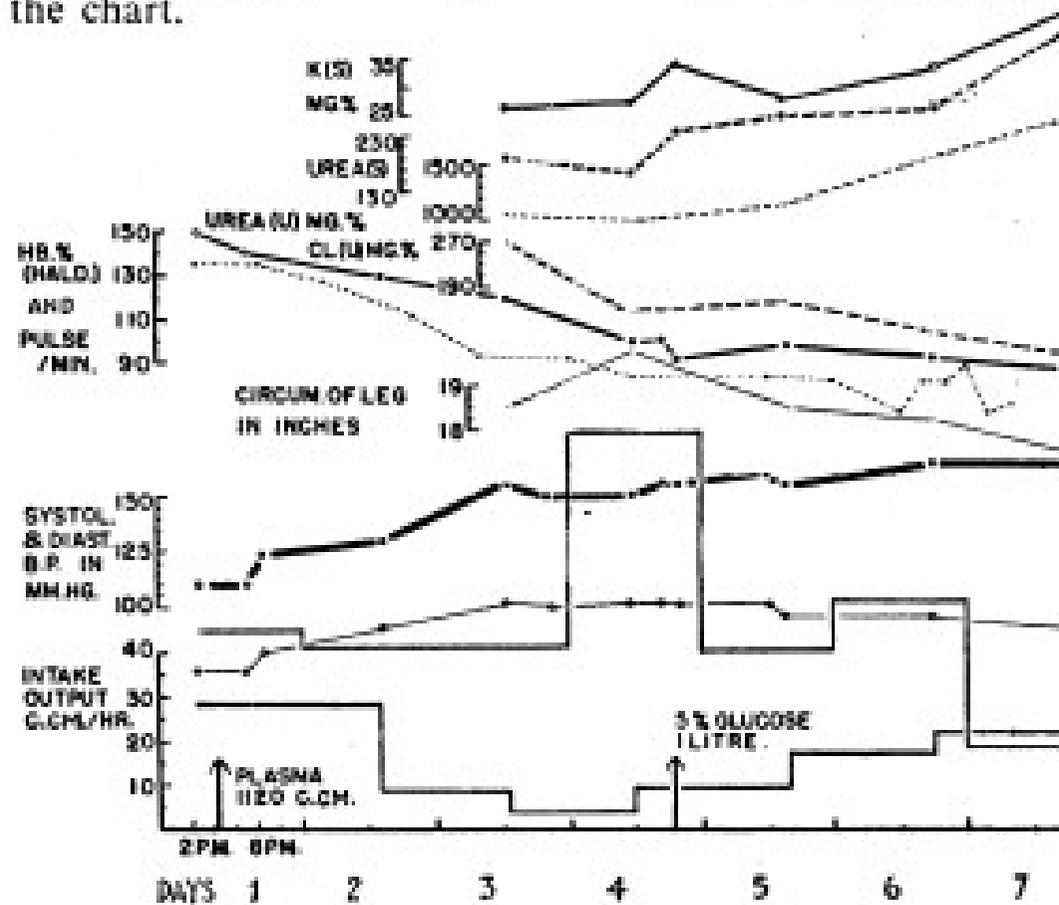
R. H. R. BELSEY, F.R.C.S.

AND

J. A. R. MILES, M.A., M.B., B.Ch.

*St. Thomas's Hospital*

fluid balance, pulse rate, and blood-pressure readings, in the chart.



## Définition IRA

	Creatinine criteria		Urine output criteria	
	RIFLE	pRIFLE and nRIFLE	RIFLE	pRIFLE
Risk	Increased creatinine x1.5 or GFR decreases >25%	Increased creatinine x1.5 or GFR decreases >25%	UO ≤0.5 mL/kg/h × 6 h	UO ≤0.5 mL/kg/h × 8 h
Injury	Increased creatinine x2 or GFR decreases >50%	Increased creatinine x2 or GFR decreases >50%	UO ≤0.5 mL/kg/h × 12 h	UO ≤0.5 mL/kg/h × 16 h
Failure	Increased creatinine x3 or GFR decreases >75% or creatinine >4 mg/dL (acute rise of >4 mg/dL)	Increased creatinine x3 or GFR decreases >75% or GFR <35 mL/min/1.73 m <sup>2</sup>	UO ≤0.3 mL/kg/h × 24 h or anuria × 12 h	UO ≤0.3 mL/kg/h × 24 h or anuria × 12 h



**Fig. 2. Total annual births of children with congenital heart disease by continent, based on Table 1 and data on total births. The panel at the side indicates the population ranges of the different countries.**

L'indidence de l'IRA postopératoire modérée/sévère est  $\approx 6$  par 1000  
**40% chez l'enfant, 50% chez le nourrisson et 60% chez le nouveau-né**

## L'IRA, est un facteur de risque indépendant de DC postopératoire

**TABLE 3. Factors independently associated with mortality in infants with acute kidney injury**

Factor	Odds ratio	95% Confidence interval	<i>P</i> value
No AKI	Reference	—	—
AKI stage I	1.3	0.4–4.1	.70
AKI stage II	5.1	1.7–15.2	.004
AKI stage III	9.5	2.9–30.7	.0002
Single ventricle	2.6	1.1–6.2	.03
Circulatory support	7.0	1.8–28	.006

# IRA grave nécessitant le recours à la dialyse

Studies reporting post-operative acute renal failure (ARF) treated with peritoneal dialysis in children operated on for congenital heart disease.

Reference	Location	Year	ARF (%)	Mortality in ARF patients (%)	n	Study design
Rigden et al. (10)	UK, London	1982	5.3	50	456	Prospective
Baxter et al. (2)	UK, London	1985	4.0	72	441	Retrospective
Gomez-Campdera et al. (7)	Spain, Madrid	1988	9.0	75	156	Retrospective
Hanson et al. (8)	USA, Colorado, Denver	1989	7.7	67	338	Retrospective
Shaw et al. (11)*	UK, Leeds	1991	2.9	68	1181	Retro-prospective
Vricella et al. (13)†	USA, California	1992	22.0	30	45	Retrospective
Giuffre et al. (6)	Canada, Toronto and Calgary	1992	1.6	58	2782	Retrospective
Picca et al. (9)	Italy, Rome	1995	2.7	79	2262	Case-control
Werner et al. (14)	Canada, Vancouver	1997	5.2	47	618	Retrospective
Sorof et al. (12)	USA, Texas, Houston	1999	5.0	20	882	Retrospective
Dittrich et al. (5)‡	Germany, Berlin	1999	14.0	27	81	Prospective
Chan et al. (4)	China, Hong Kong	2003	17.0	29	182	Retrospective
Xinjin et al. (15)	China, Beijing	2003	2.1	25	576	Retrospective
Boigner et al. (3)	Austria, Vienna	2004	5.4	40	1141	Retrospective
Baskin et al. (1)	Turkey, Ankara	2005	32.8	67	64	Retrospective
Present study	Denmark, Aarhus	2006	11.5	20	1128	Prospective

n, number of patients included in the study.

\*519 were closed heart surgeries. The incidence of ARF after open heart surgery was 3.6%.

†Neonates undergoing heart transplantation.

‡Infants of <1 year using cardiopulmonary bypass during surgery.

*Pedersen, Acta Anaesth Scand 2007*

*Necker : 2000-2008, 3014 interventions concernant 2651 nouveau-nés et nourrissons de moins d'un an, 2176 CEC, 115 ARF dialysés (5,2%).*

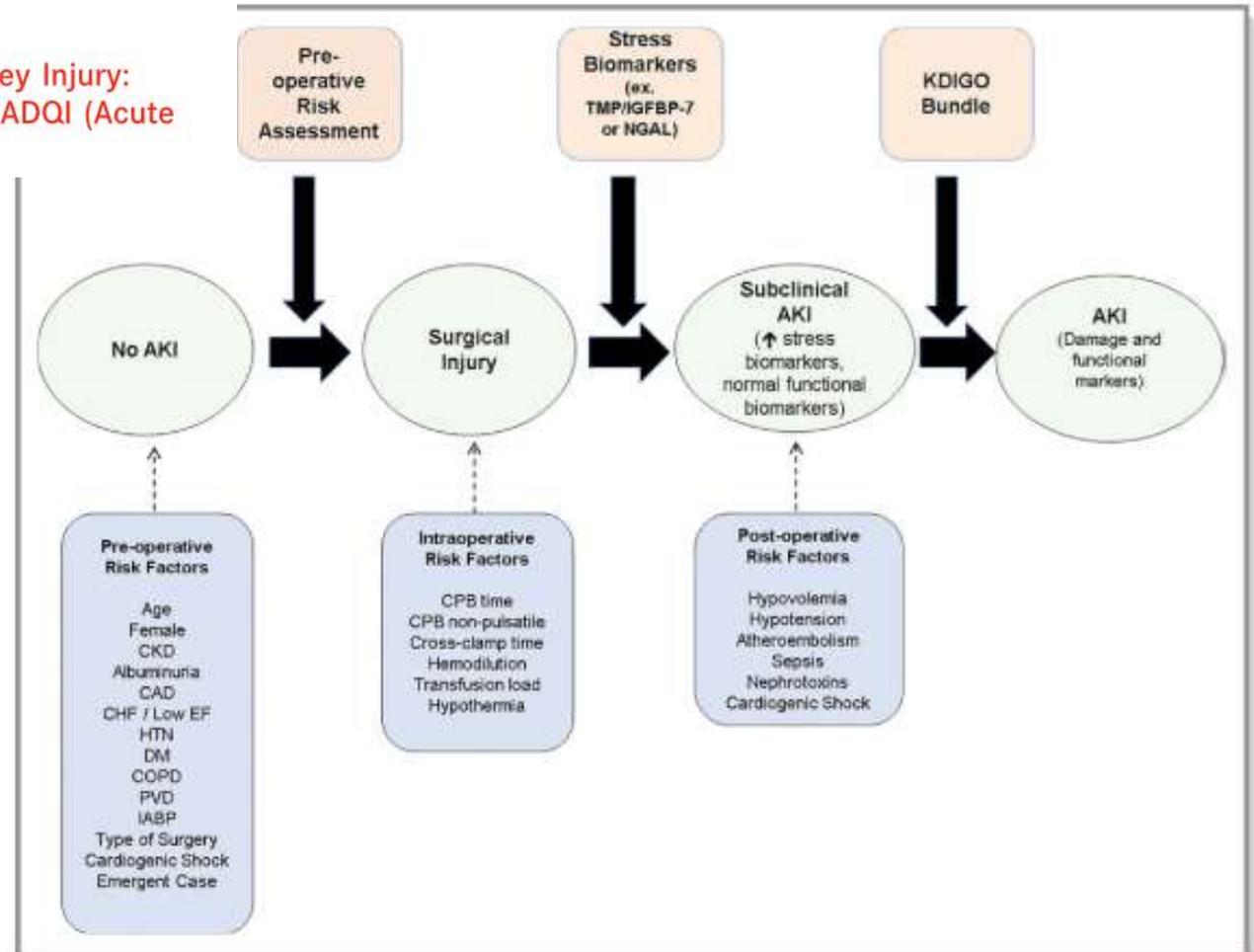
## Long-term Risk of CKD in Children Surviving Episodes of Acute Kidney Injury in the Intensive Care Unit: A Prospective Cohort Study

Outcome Variables	AKIN Stage 1	AKIN Stage 2	AKIN Stage 3	Total <sup>a</sup>
Microalbuminuria or proteinuria <sup>c</sup>	2 (4.5)	5 (10.6)	5 (14.3)	12 (9.5)
GFR <60 mL/min/1.73 m <sup>2c</sup>	0 (0)	0 (0)	1 (2.9)	1 (0.8)
GFR = 60-90 mL/min/1.73 m <sup>2</sup>	24 (54.5)	14 (29.8)	10 (28.6)	48 (38.1)
Hypertension	0 (0)	3 (6.4)	1 (2.9)	4 (3.2)
Hyperfiltration	1 (2.3)	6 (12.8)	4 (11.4)	11 (8.7)

*Mammen, Am J Kidney Dis 2012*

Cardiac and Vascular Surgery–Associated Acute Kidney Injury:  
The 20th International Consensus Conference of the ADQI (Acute  
Disease Quality Initiative) Group

- Peu de facteurs prédictifs de l'IRA
- Peu de moyens de monitoring du risque d'IRA en peropératoire
- Peu de moyens thérapeutiques une fois l'IRA installée



**Insuffisance rénale aiguë**

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Glomérule	Tubule rénal
DFG $\approx$ filtration d'un volume équivalent à la volémie / 30min	réabsorption tubulaire = 99% du DFG
Processus passif ( $VO_2 \downarrow\downarrow$ )	représente 90% de la $VO_2$ rénale
Débit sanguin cortical /	médullaire $\approx$ 10 : 1
Ht $\approx$ Ht systémique	Ht $\approx$ 50% Ht systémique
paO <sub>2</sub> = 20-60 mmHg	paO <sub>2</sub> = 15-30 mmHg (<15 dans la médullaire profonde)
Métabolisme aérobie	<p>Métabolisme anaérobie de la médullaire profonde</p> <p>Métabolisme aérobie de la <b>médullaire superficielle</b> -&gt; susceptibilité à l'hypoxie +++++</p>

## **Adaptation postnatale de la fonction rénale**

- DFG croît de 5 à 40 ml/min/1.73m<sup>2</sup> durant la première semaine
- Niveau élevé de l' Angiotensine II et de résistance vasculaire rénale

## Les facteurs de risque d'IRA

Variables	% AKI cases	Adjusted OR	95% CI	P Value
Age				
> 30 days old and ≤ 2 years old	55%	1	...	...
> 2 and < 13 years old	27%	0.28	(0.16, 0.48)	< 0.0001
≥ 13 and < 18 years old	37%	0.3	(0.10, 0.88)	0.03
RACHS-1 category				
1 or 2	38%	1	...	...
3	44%	1.47	(0.83, 2.59)	0.2
4	71%	1.93	(0.50, 7.41)	0.3
Cardiopulmonary Bypass Time (minutes)				
0–60	22%	1	...	...
61–90	36%	2.14	(0.97, 4.72)	0.06
91–120	45%	2.47	(1.08, 5.65)	0.03
121–180	51%	3.2	(1.38, 7.44)	<0.01
> 180	68%	7.57	(2.6, 21.9)	<0.01

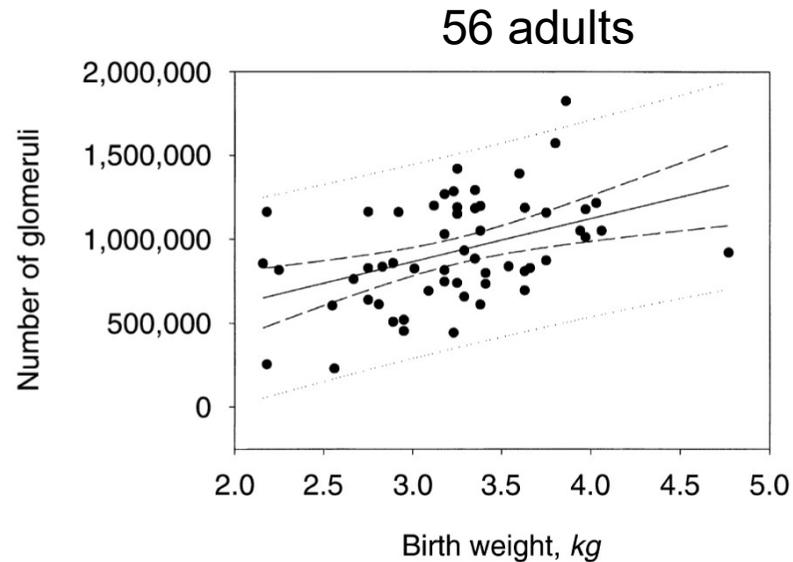
## Risk Factors for and Outcomes of Acute Kidney Injury in Neonates Undergoing Complex Cardiac Surgery

264 nouveau-nés avec chirurgie cardiaque  
Incidence IRA = **64%**

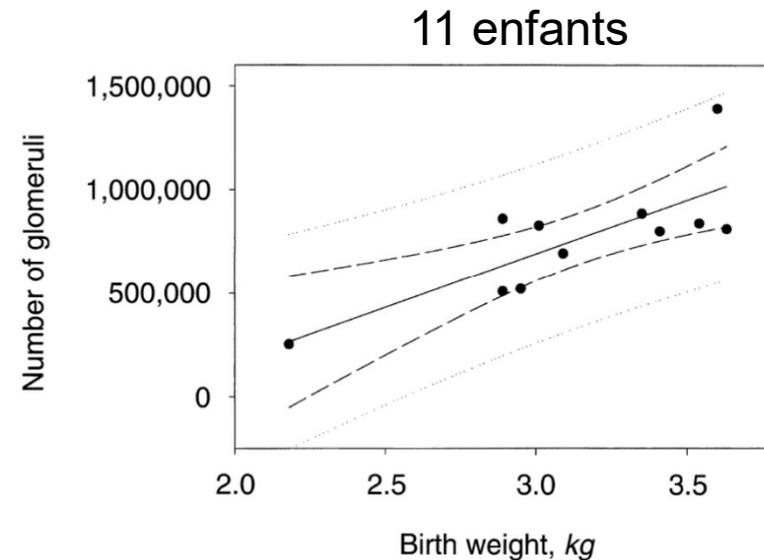
Risk factor	Adjusted OR [95% CI]
Age at surgery (days)	0.97 [0.95 – 0.99]
Gestational age (weeks)	0.83 [0.69 – 0.99]

## Capital glomérulaire et poids de naissance: existe-t-il une « réserve fonctionnelle rénale » ?

Néphrogenèse terminée à 36 SA  
1M nephrons / rein [200 000 - 2.5M]



gain de 257,426 glomerules / kg poids de naissance,  $r = 0.423$ ,  $P = 0.0012$



gain de 518,038 glomerules / kg poids de naissance,  $r = 0.773$ ,  $P = 0.0053$

Cardiac and Vascular Surgery–Associated Acute Kidney Injury:  
The 20th International Consensus Conference of the ADQI (Acute Disease Quality Initiative) Group

## Les facteurs de risque intra- et postopératoires:

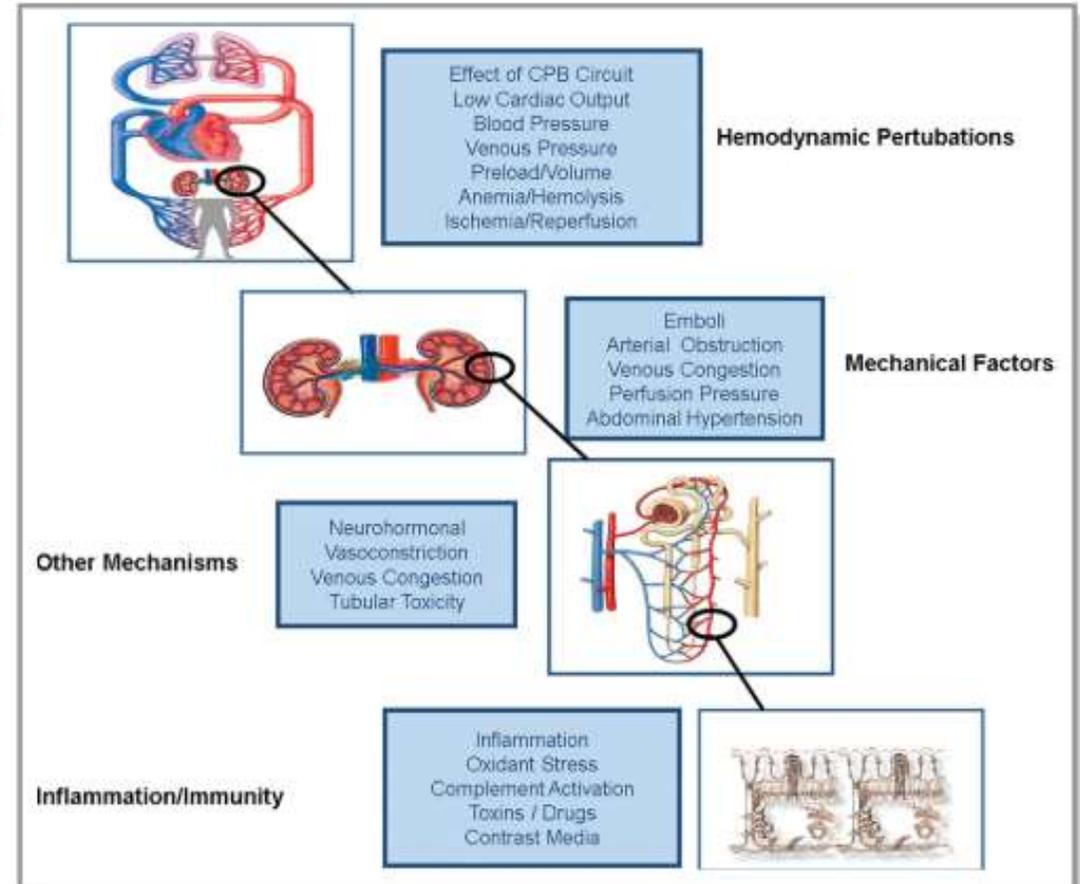
### Ischémie / Réperfusion

- Bas débit rénal, vasoconstriction rénale
- Anémie
- Hypotension
- Réchauffement après hypothermie

### Toxicité tubulaire

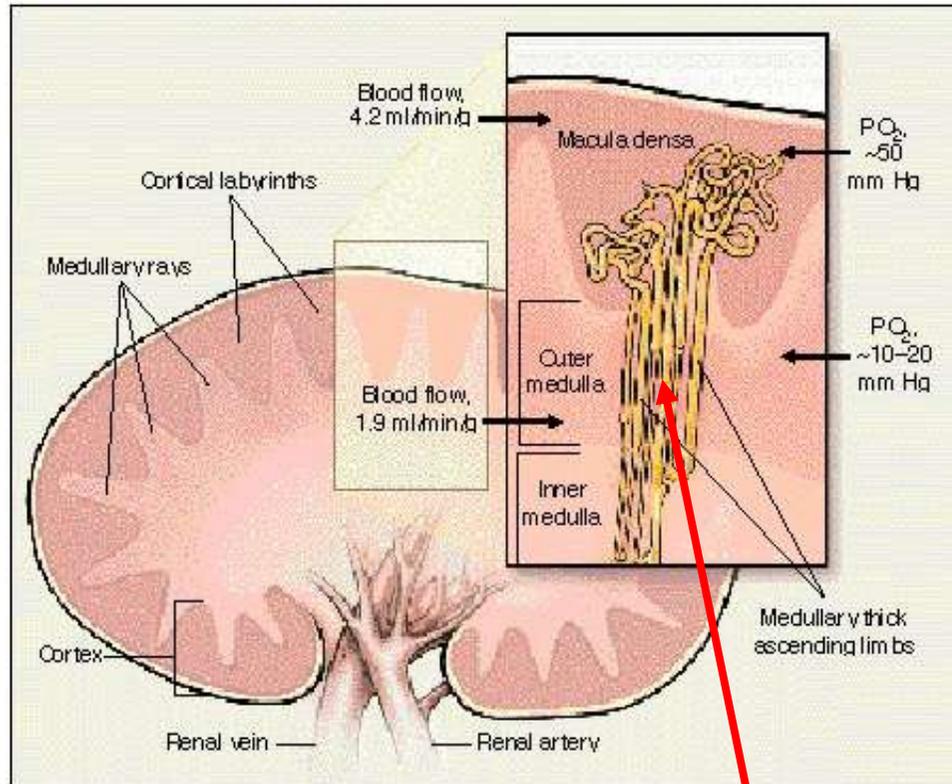
- Hémolyse, transfusions
- Inflammation, stress oxydatif

### Congestion veineuse



# L'IRA associée à la chirurgie cardiaque est due à une atteinte hypoxique de la branche ascendante de la l'anse de Henle dans la médulla externe

Dans des conditions normales

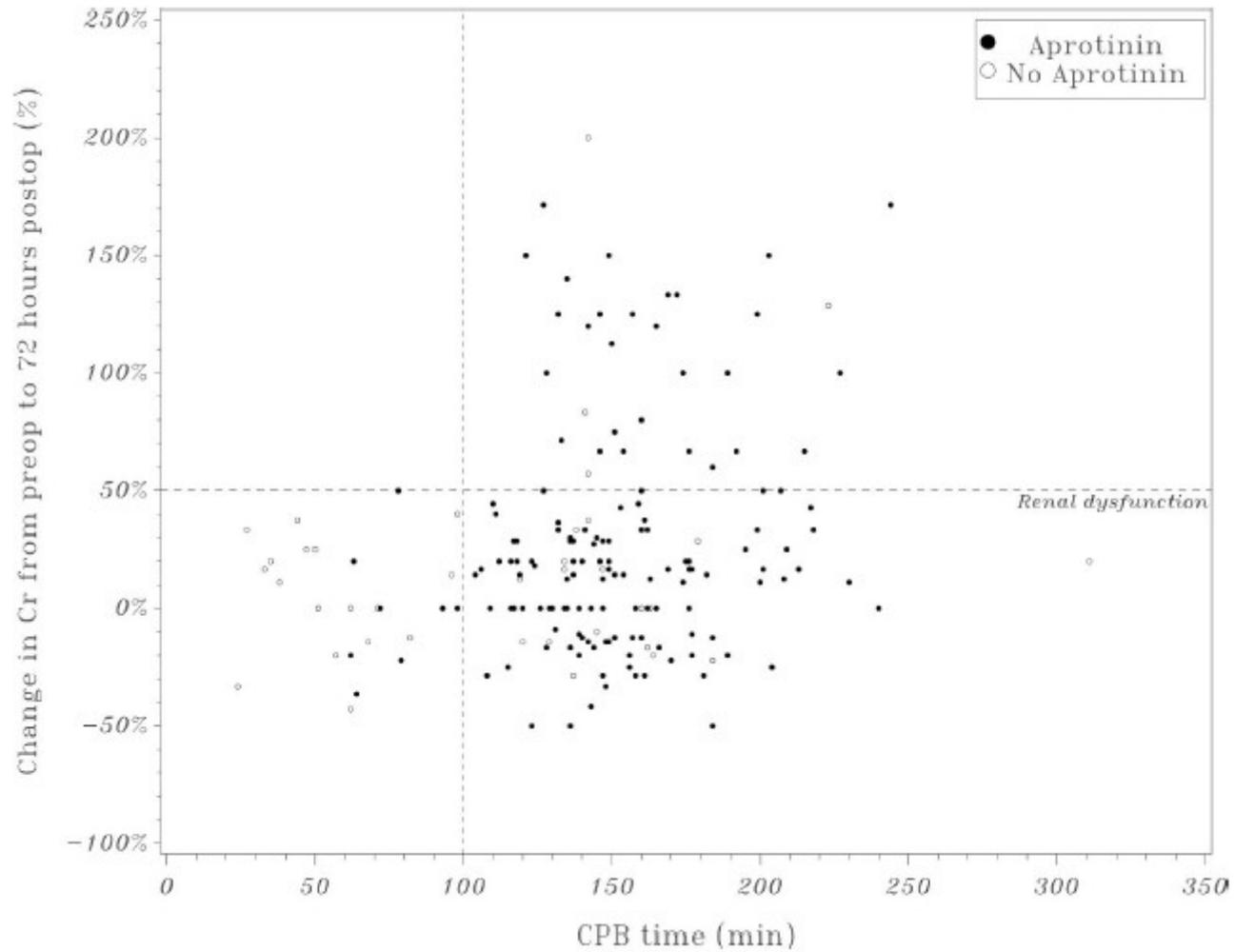


90% de la  
DO<sub>2</sub> rénale !

**IRA**

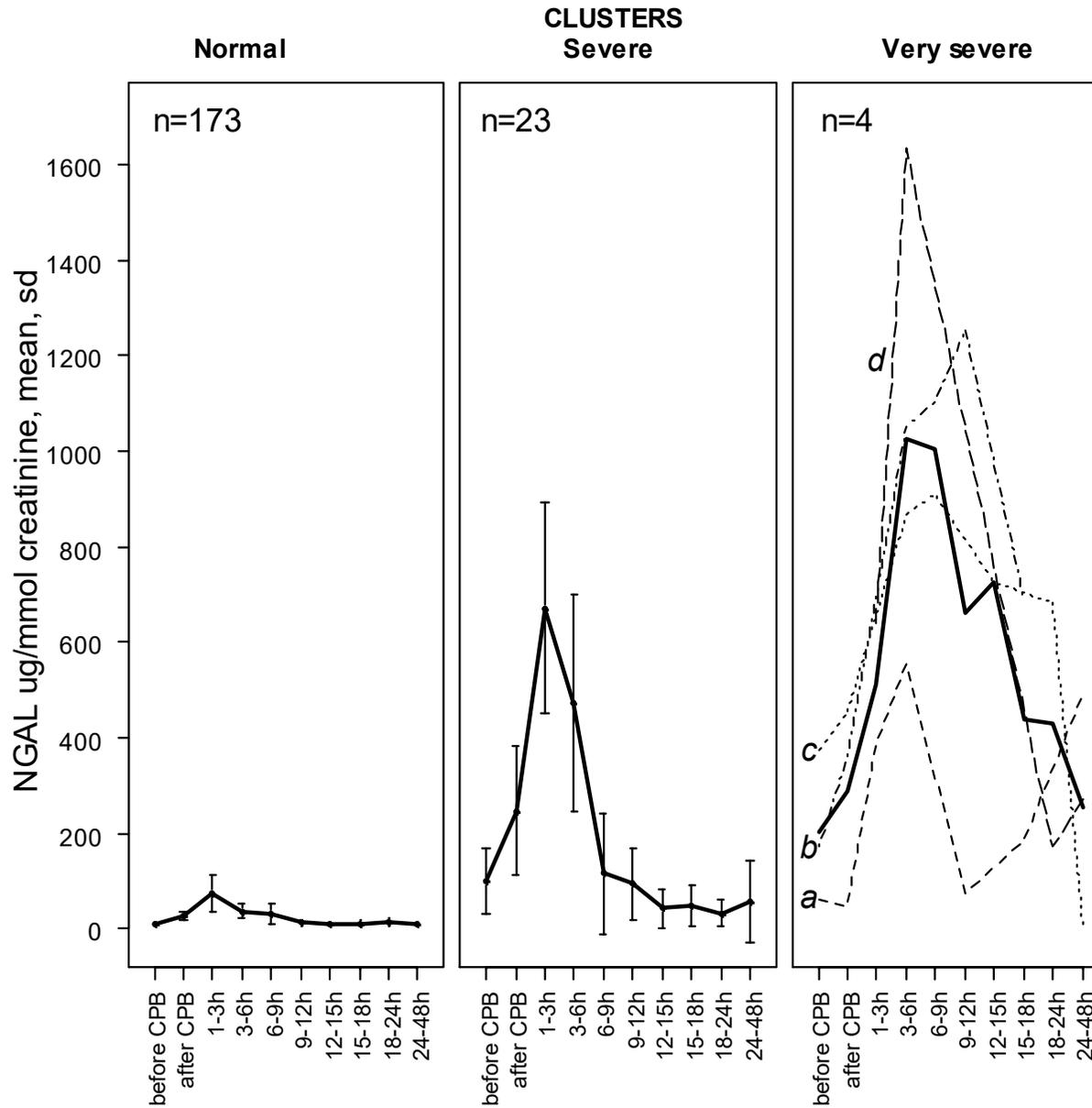
1. Vasoconstriction rénale et hypoxie tubulaire
2. Dysfonction endothéliale par réduction de la disponibilité du NO
3. Atteinte des cellules tubulaires proximales

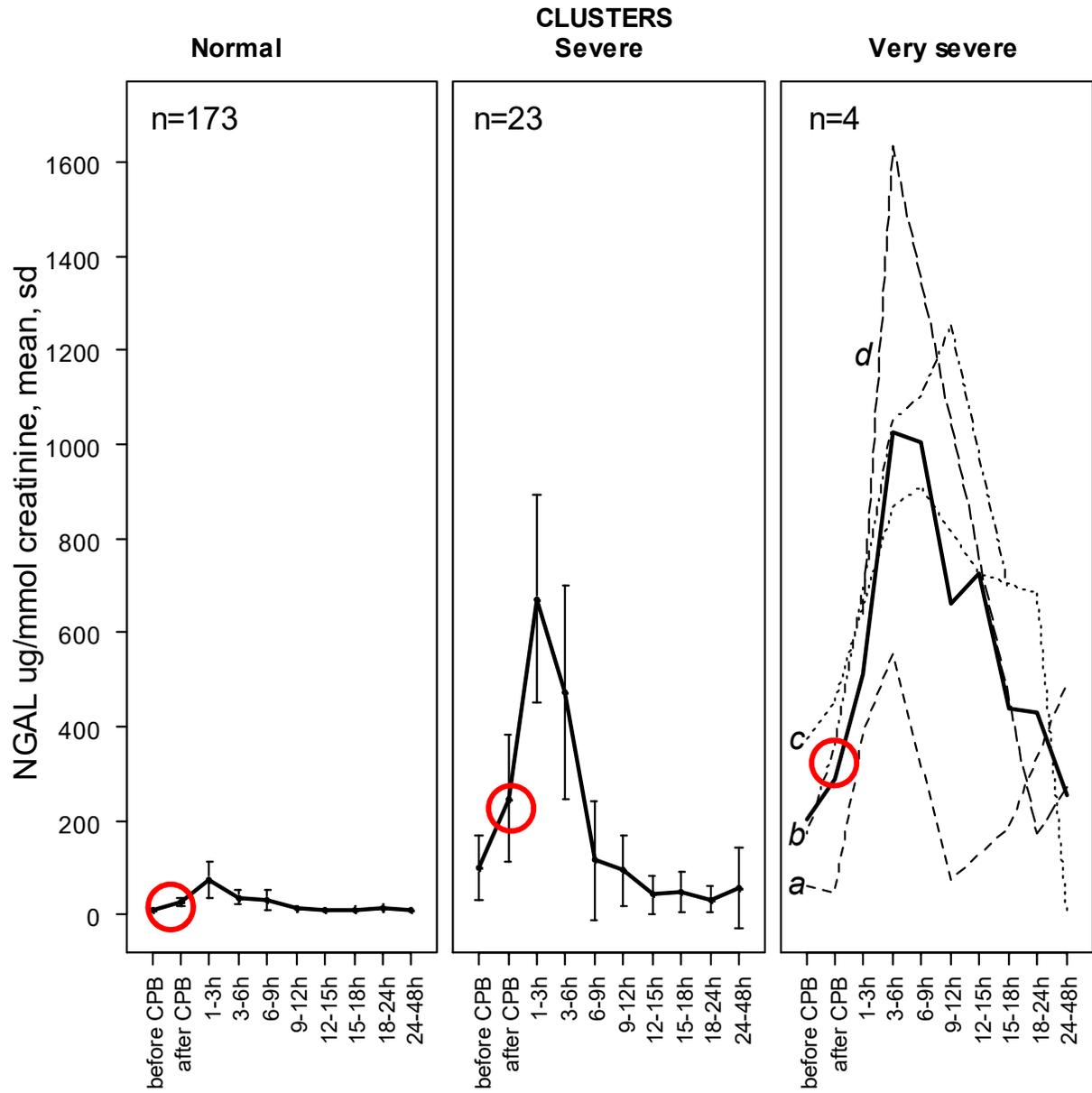
- 40% réduction de la DO<sub>2</sub> rénale
- 60% réduction du GFR
- 60% réduction de réabsorption du Na
- Pas de réduction de la VO<sub>2</sub> rénale !
- 70% augmentation de l'extraction rénale en O<sub>2</sub>



**Adjusted OR of AKI for CPB time : 1.16, 95CI :[1.05-1.29]**

*Guzzetta, Anesth Analg 2009*





NEW INVESTIGATOR AWARD IN REGULATORY AND INTEGRATIVE PHYSIOLOGY OF  
THE WATER AND ELECTROLYTE HOMEOSTASIS SECTION, 2006 |

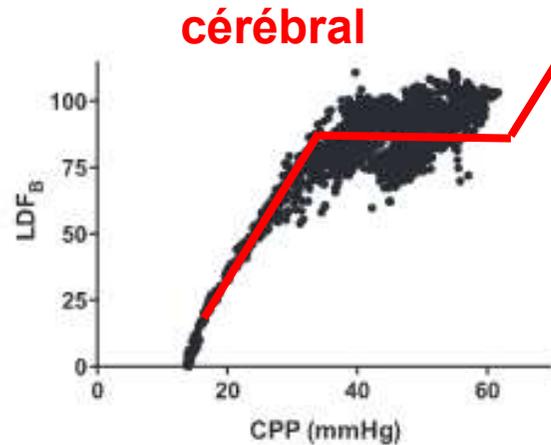
Mechanisms of renal blood flow autoregulation: dynamics and contributions

Armin Just

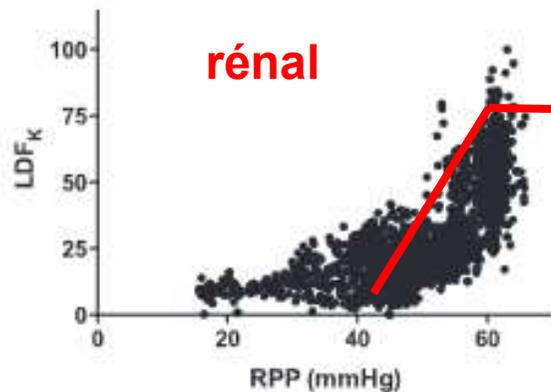
Department of Cell and Molecular Physiology, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina

Réponse myogénique	Feedback tubulo-glomérulaire	3 <sup>ème</sup> mécanisme
Vasoconstriction de l'artériole afférente en réponse à l'élévation de la pression intraluminaire	Vasoconstriction de l'artériole afférente en réponse à l'augmentation de la concentration intraluminaire de NaCl au niveau de la macula densa	?..... vasodilatation lors de chutes du DSR
<10 sec	< 1 min	< 1 min
-> régulent la balance hydro-électrolytique -> protègent l'intégrité du glomérule -> régulent la VO <sub>2</sub> rénale		

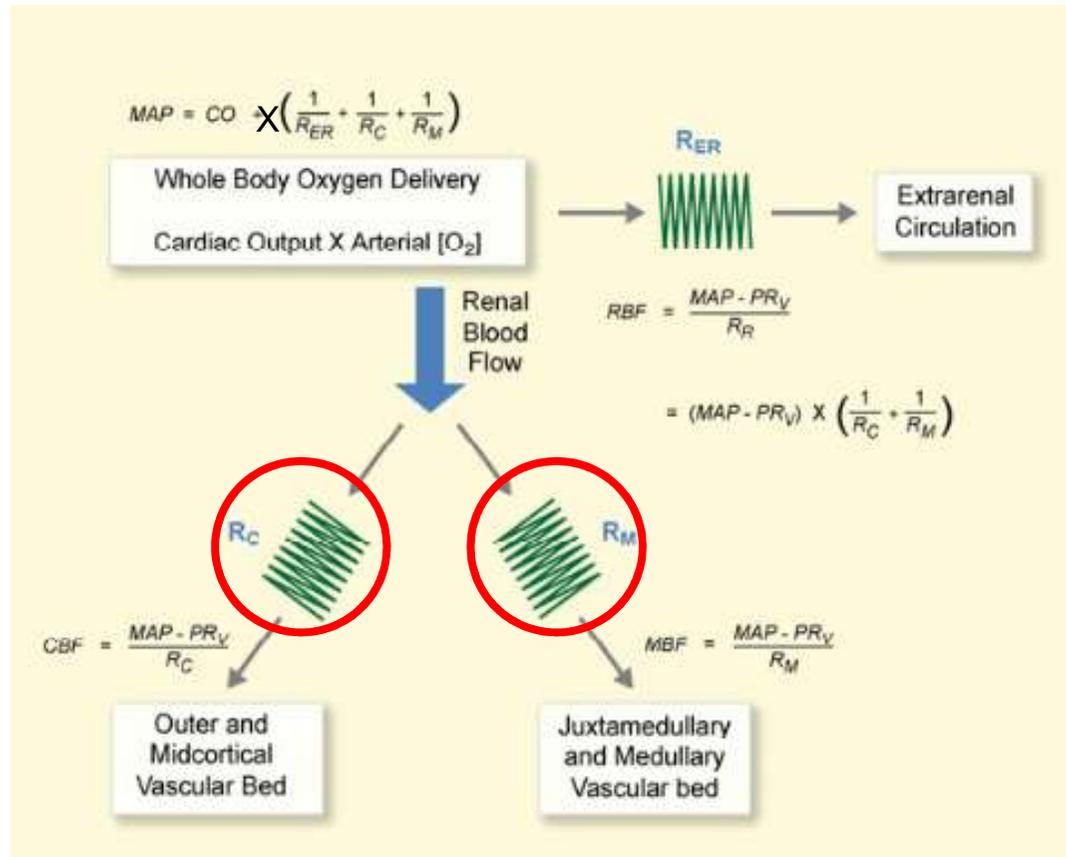
## RBF pressure autoregulation is impaired in advance of CBF autoregulation



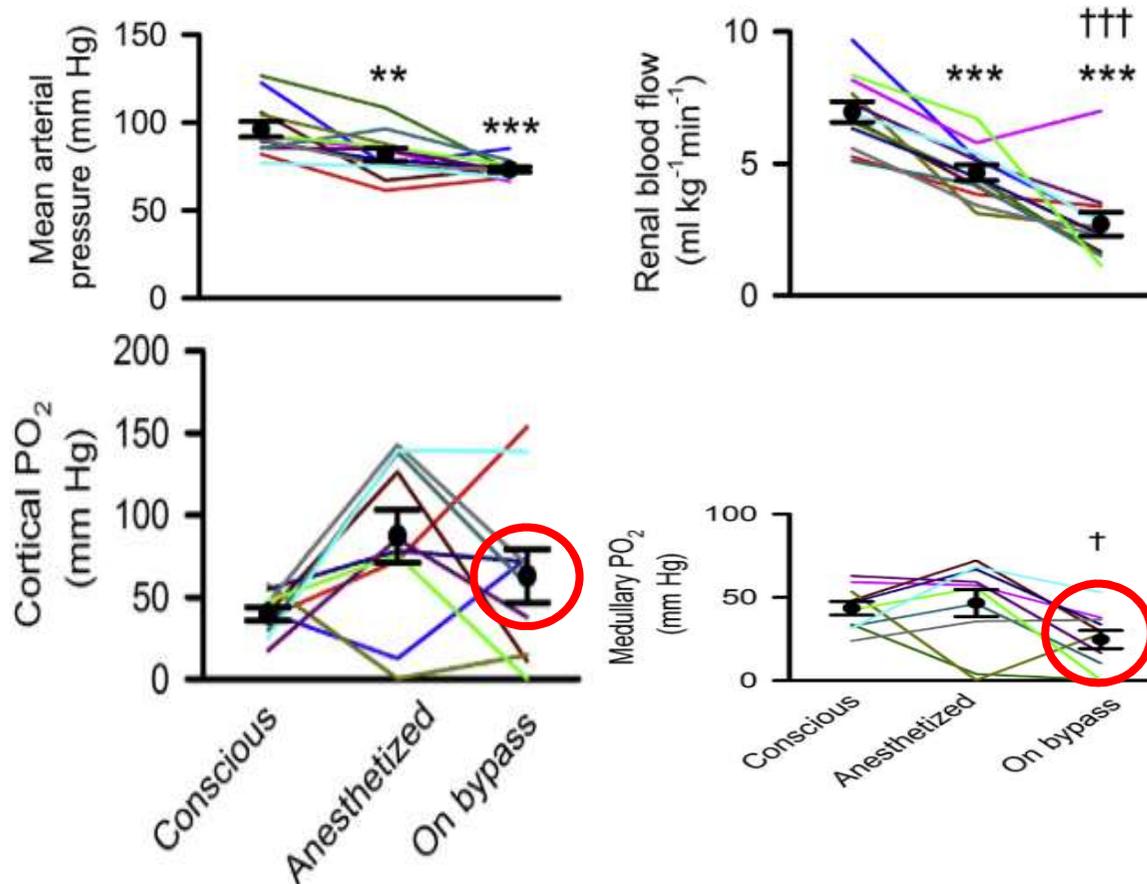
compared with cerebral laser-Doppler measurements. Renal blood flow decreased to 75%, 50%, and 25% of baseline at perfusion pressures of 60, 45, and 40 mmHg, respectively, whereas in the brain these decrements occurred at pressures of 30, 25, and 15 mmHg, respectively. The RVx compared favorably to the renal laser-Doppler



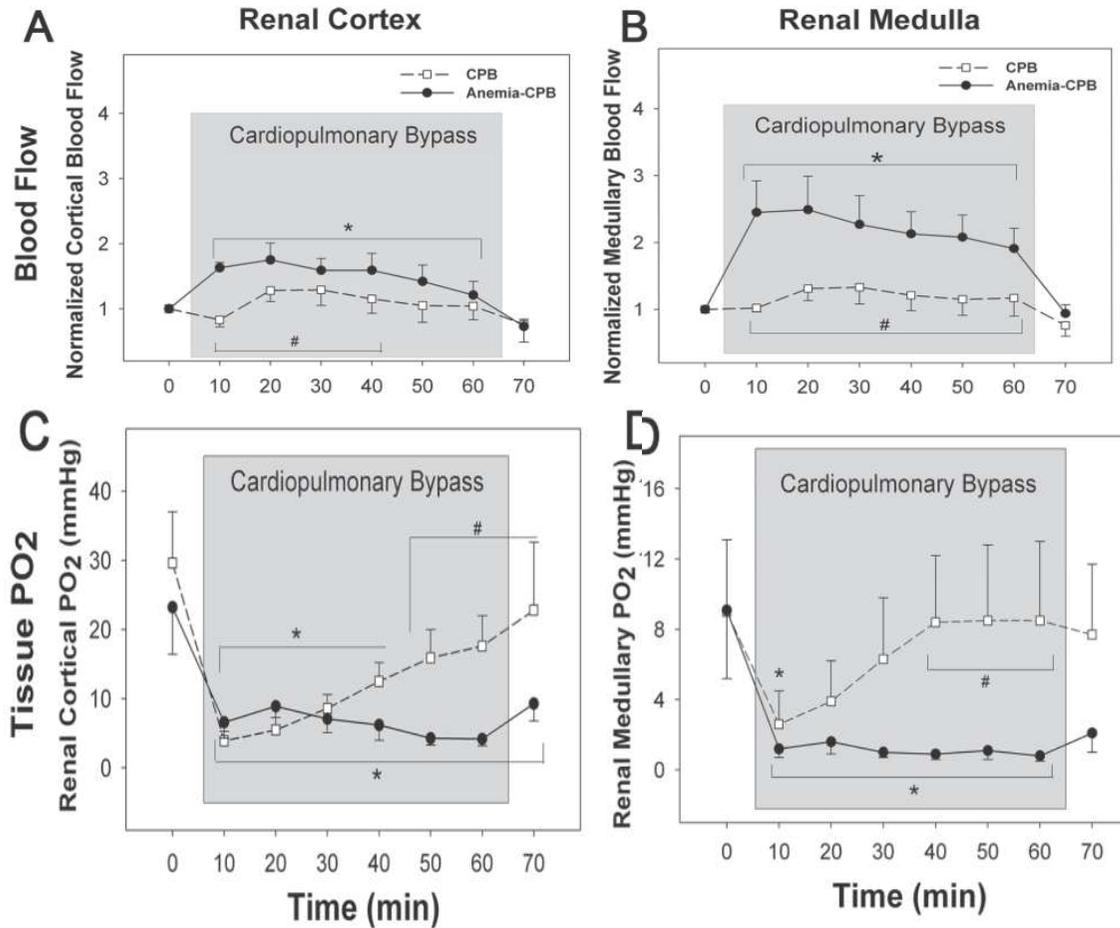
## Differential control between the cortical and medullary blood flow during CPB



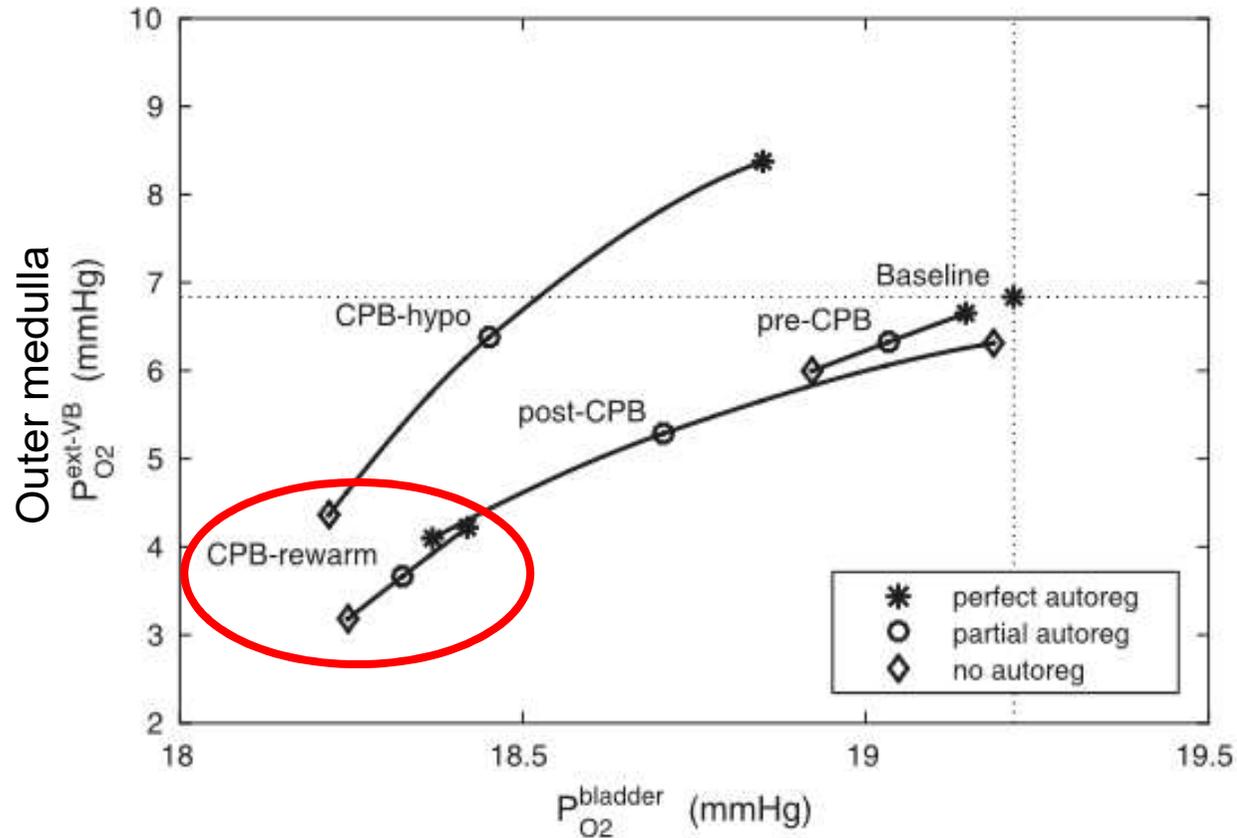
## Ischémie médulalire lors du départ en CEC



# L'anémie augmente le risque d'atteinte rénale durant la CEC



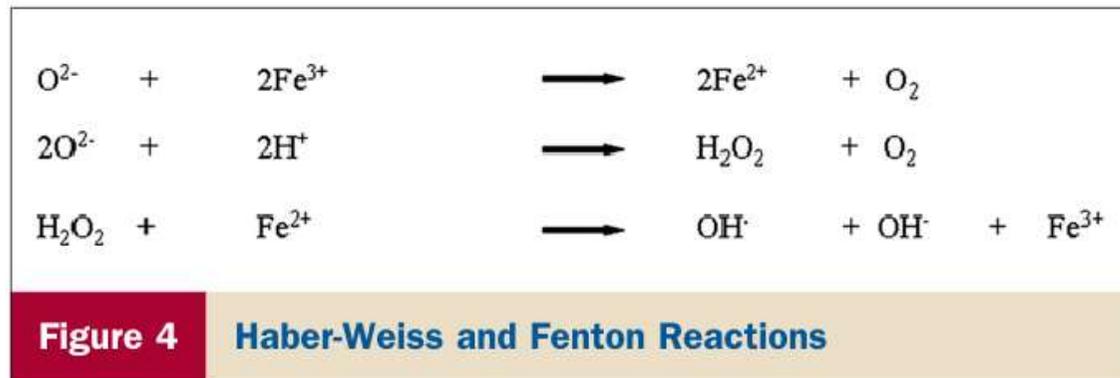
## L'ischémie médullaire est aggravée durant la période de réchauffement



Le risque de développer une IRA augmente de 34% par 10 min passés avec une ligne artérielle  $> 37^{\circ} C$

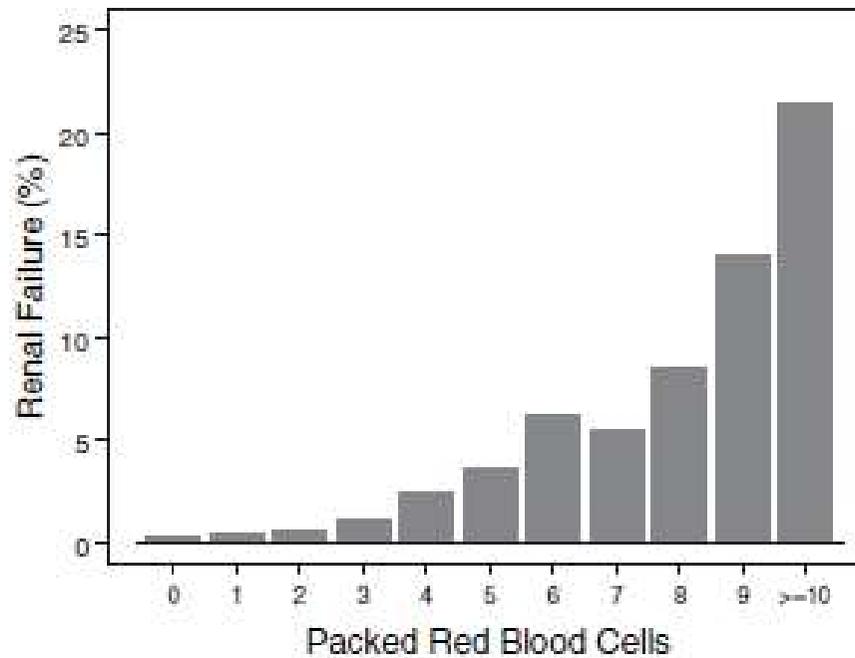
## Cardiac surgery-related AKI : a pigment nephropathy ?

- **Obstruction tubulaire / précipitation de l'Hb libre** dans un environnement acide
- **L'Hb libre est filtrée** passivement à travers le glomérule et entraîne la **peroxydation des membranes tubulaires**



- **L'Hb libre est un agent chélateur pour le NO libre**, ce qui entraîne une vasoconstriction

## Le risque lié aux transfusions chez l'adulte



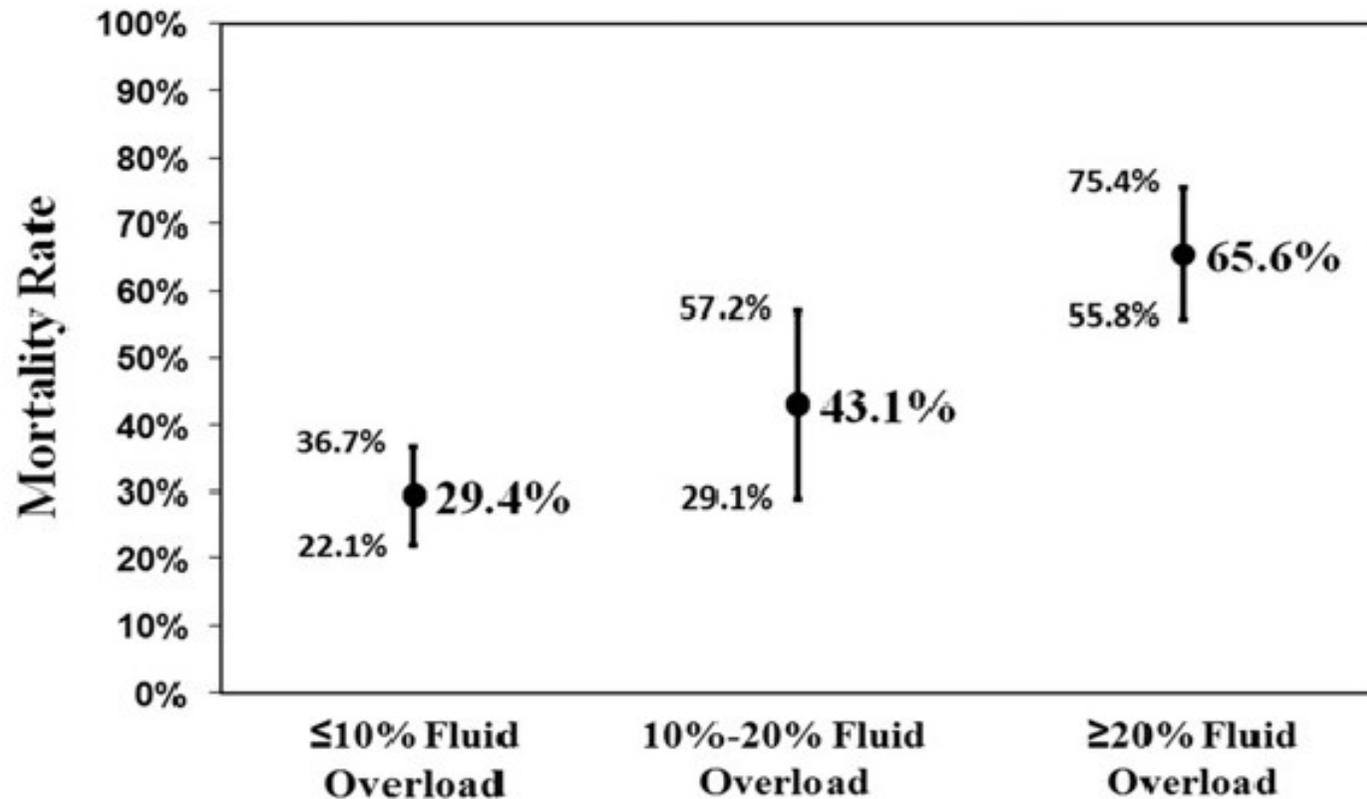
OR = 1.22 [1.19–1.26],  $p < 0.001$  pour chaque CGR additionnel

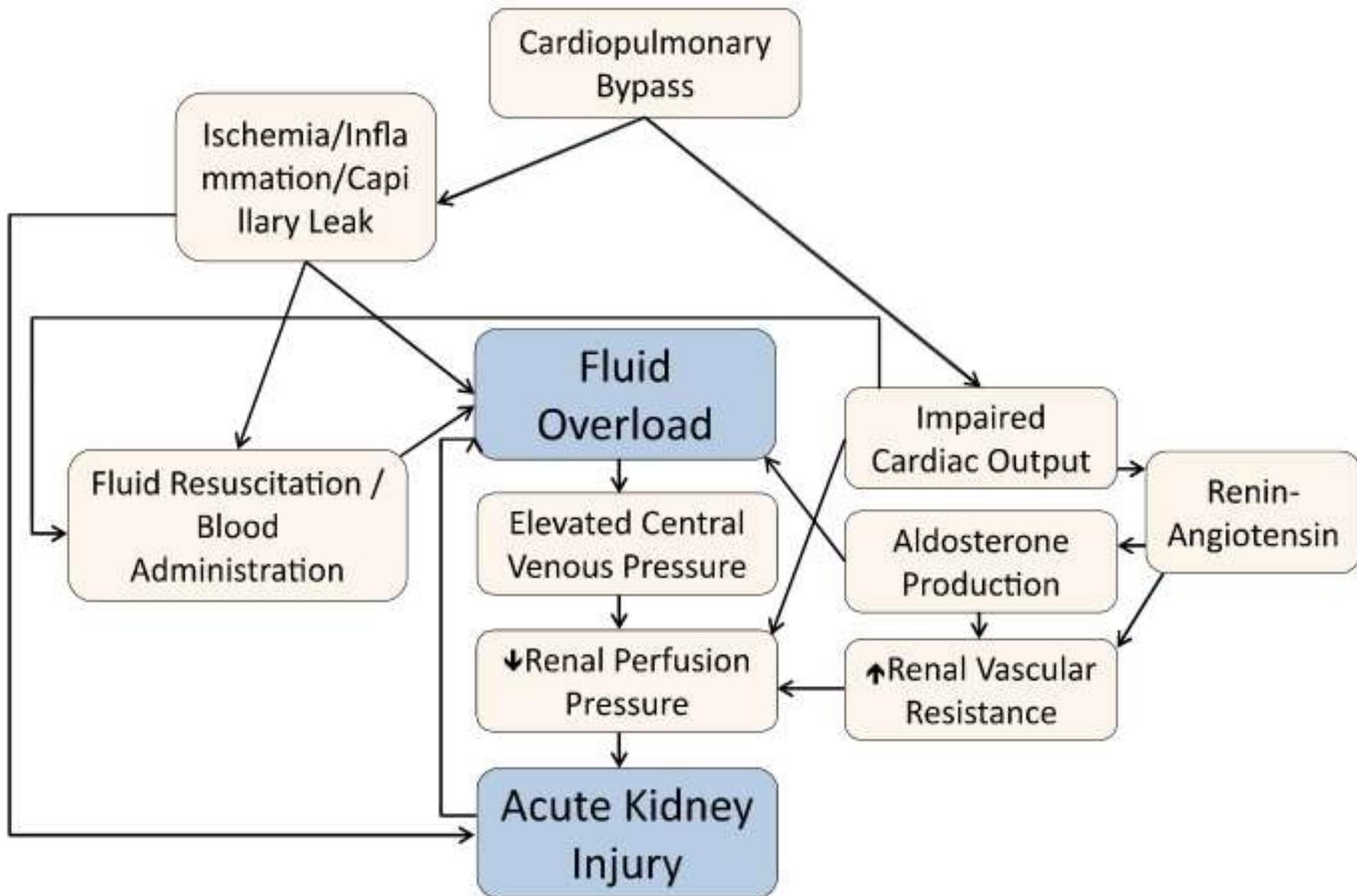
## Impact of contrast exposure from computed tomography angiography on acute kidney injury after neonatal cardiopulmonary bypass surgery

**Results:** Fifty-six neonates were analyzed. AKI developed in 42 (75%) of patients; severe AKI (KDIGO stages 2 and 3) occurred in 18 (32%). Patient characteristics were similar at baseline and at time of CTA between those with and without severe AKI. Patients with severe AKI had longer CPB time, lower postoperative urine output, higher peak serum creatinine, and longer hospital length of stay. When considering intervals between CTA and CPB surgery  $\leq 1$  day (n = 19),  $\leq 3$  days (n = 28), and  $> 3$  days (n = 28); there was no difference in AKI incidence nor postoperative outcomes among these three interval cohorts.

**Conclusion:** Routine exposure to CTA and CPB surgery in close succession does not appear to increase the risk of AKI after neonatal cardiac surgery. Though other risks need to be weighed (eg, sedation, intubation, radiation exposure), this result may enable more liberal utilization of CTA for preoperative surgical planning of congenital heart operations in patients with unclear or complex anatomy.

# Fluid Overload and Mortality in Children Receiving Continuous Renal Replacement Therapy: The Prospective Pediatric Continuous Renal Replacement Therapy Registry





**Insuffisance rénale aiguë**

**Epidemiologie**

**Physiopathologie**

**Diagnostic et monitoring peropératoire**

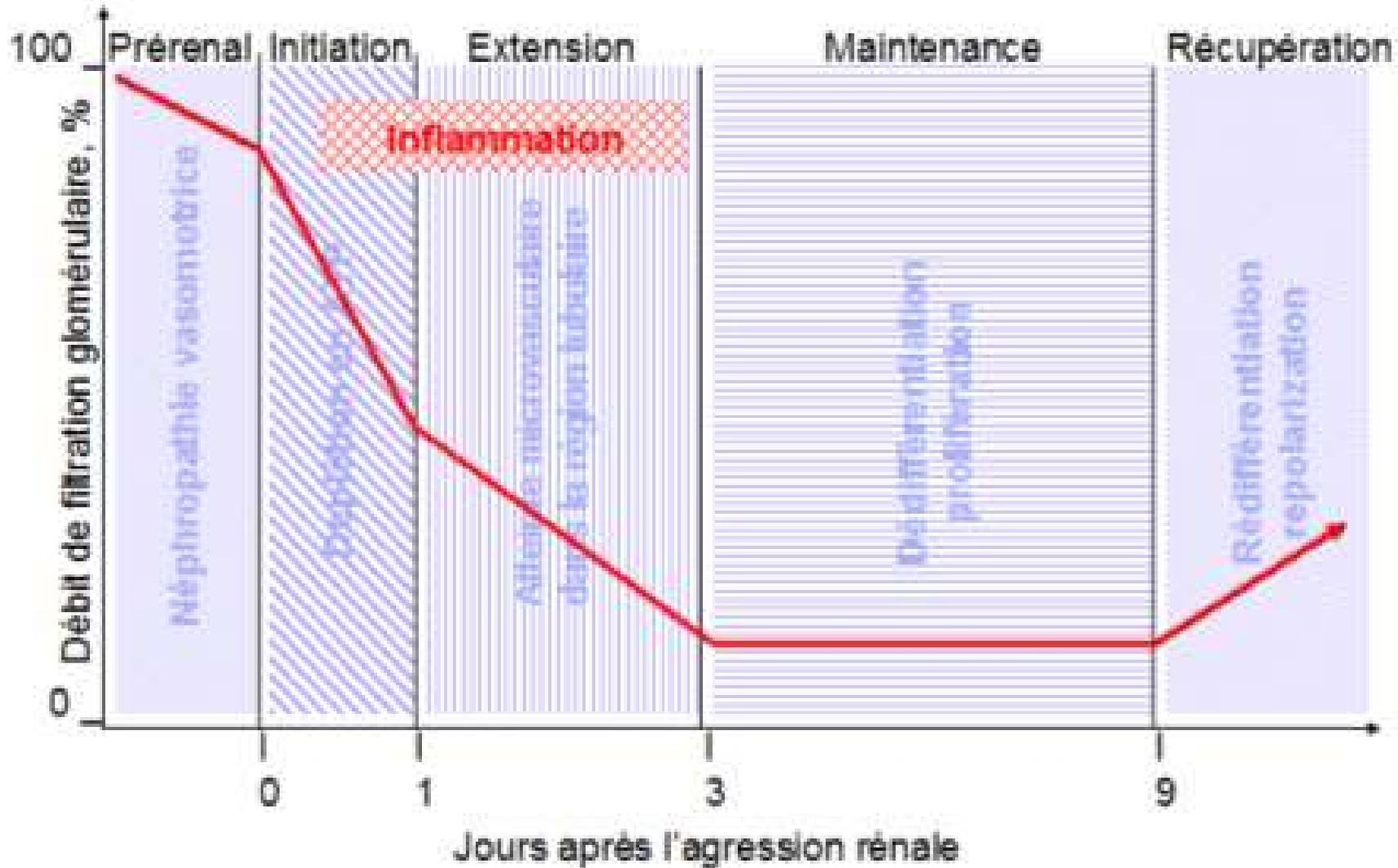
**Prévention**

**Traitement**

**Insuffisance rénale chronique**

# Evolution de l'IRA par ischémie-reperfusion

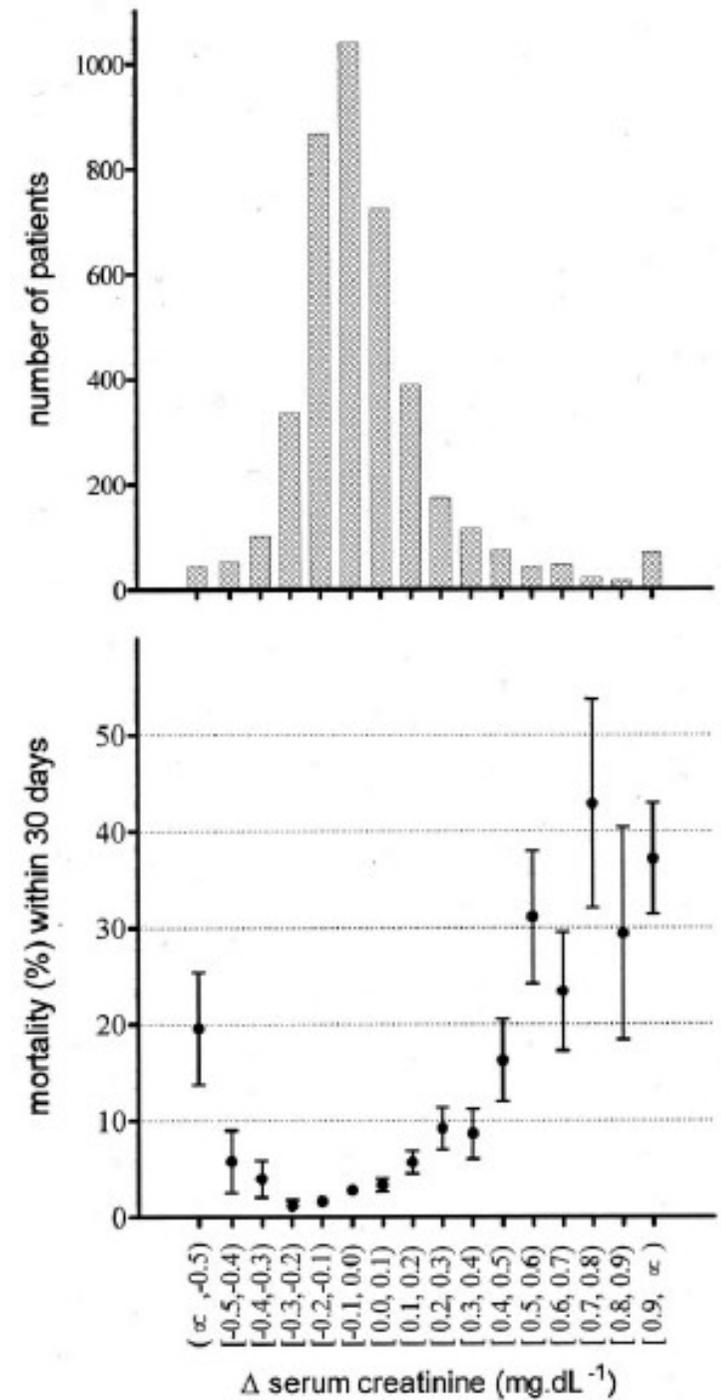
La lésion initiale se situe au niveau tubulaire



## Définition IRA

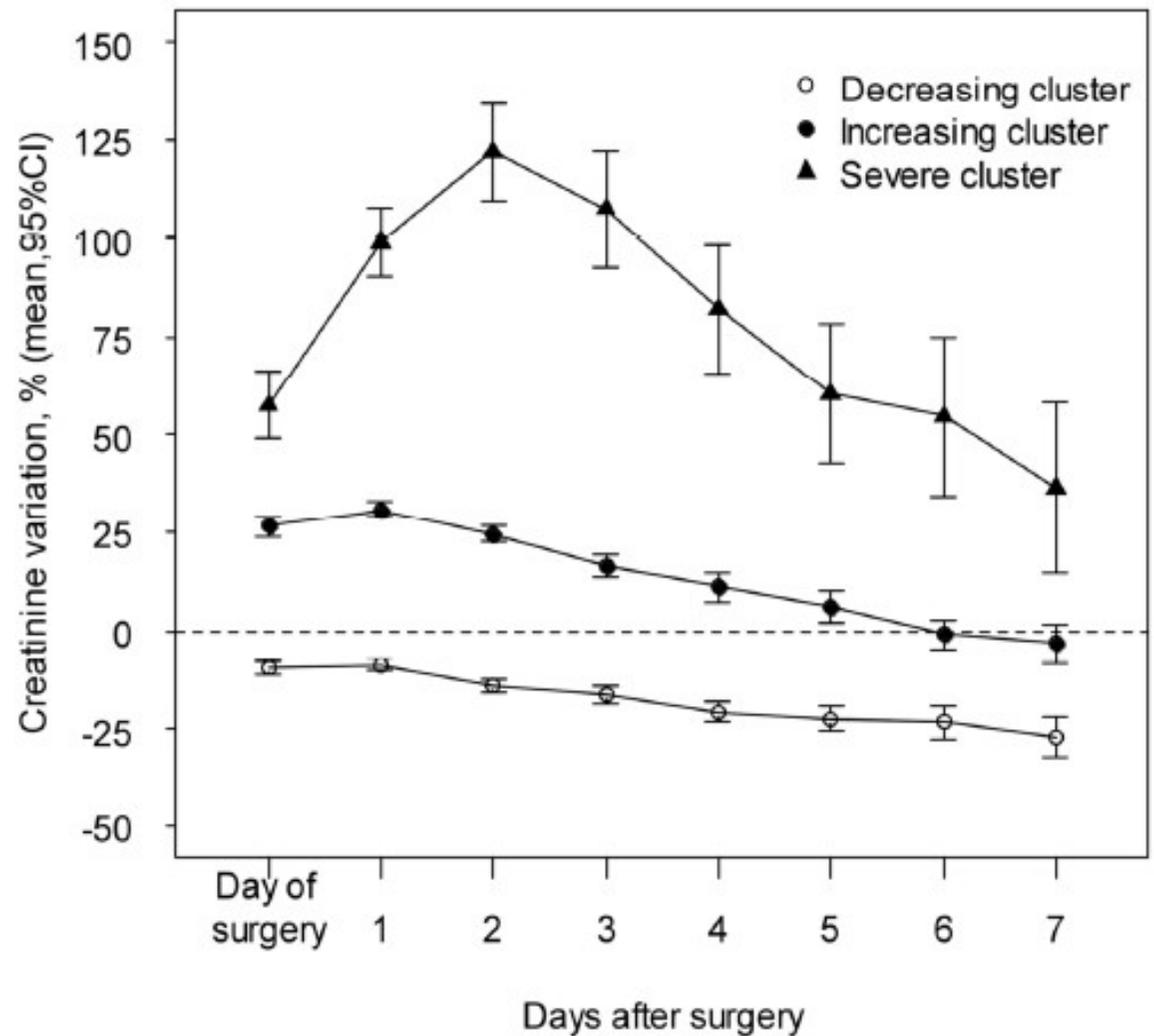
	Creatinine criteria		Urine output criteria	
	RIFLE	pRIFLE and nRIFLE	RIFLE	pRIFLE
Risk	Increased creatinine x1.5 or GFR decreases >25%	Increased creatinine x1.5 or GFR decreases >25%	UO ≤0.5 mL/kg/h × 6 h	UO ≤0.5 mL/kg/h × 8 h
Injury	Increased creatinine x2 or GFR decreases >50%	Increased creatinine x2 or GFR decreases >50%	UO ≤0.5 mL/kg/h × 12 h	UO ≤0.5 mL/kg/h × 16 h
Failure	Increased creatinine x3 or GFR decreases >75% or creatinine >4 mg/dL (acute rise of >4 mg/dL)	Increased creatinine x3 or GFR decreases >75% or GFR <35 mL/min/1.73 m <sup>2</sup>	UO ≤0.3 mL/kg/h × 24 h or anuria × 12 h	UO ≤0.3 mL/kg/h × 24 h or anuria × 12 h

# Problèmes posés par la créatinine plasmatique pour le diagnostic de l'IRA chez l'adulte



Lassnigg, *J Am Soc Nephrol*, 2004

## La créatinine plasmatique pour le diagnostic de l'IRA chez le nourrisson



*Necker-Enfants Malades*

Variable	"Decreasing cluster" (n = 503)	"Increasing cluster" (n = 423)	P-value *	"Severe cluster" (n = 90)	P-value *
Number of blood product units on the day of surgery	3.5 ± 1.3	3.7 ± 1.5	0.017	5.4 ± 2.4	< 0.001
Required delayed sternal closure	37 (7.4)	68 (16.1)	< 0.001	54 (60)	< 0.001
Required postoperative ECMO	3 (0.6)	6 (1.4)	0.35	6 (6.7)	< 0.001
Required postoperative peritoneal dialysis	10 (2.0)	35 (8.3)	< 0.001	47 (52.2)	< 0.001

## Définition IRA néonatale

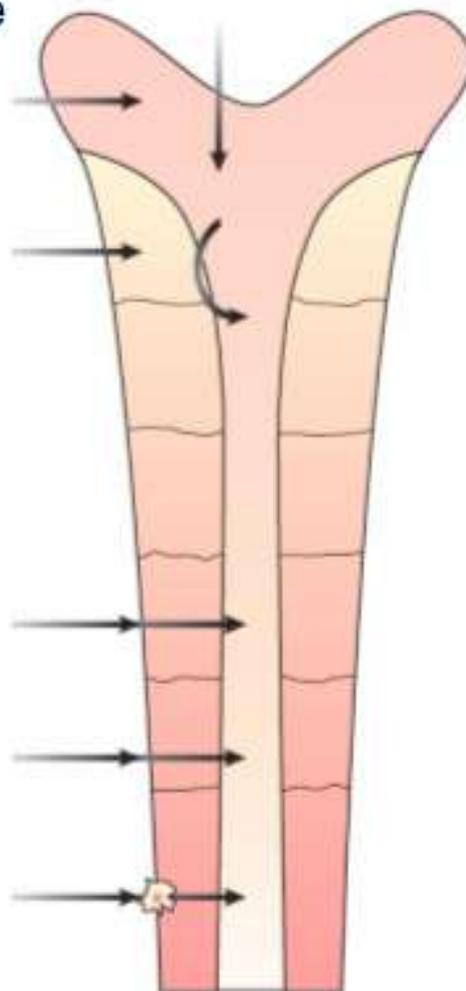
	Creatinine criteria		Urine output criteria		
	RIFLE	pRIFLE and nRIFLE	RIFLE	pRIFLE	nRIFLE
Risk	Increased creatinine x1.5 or GFR decreases >25%	Increased creatinine x1.5 or GFR decreases >25%	UO ≤0.5 mL/kg/h × 6 h	UO ≤0.5 mL/kg/h × 8 h	UO <1.5 mL/kg/h for 24 h
Injury	Increased creatinine x2 or GFR decreases >50%	Increased creatinine x2 or GFR decreases >50%	UO ≤0.5 mL/kg/h × 12 h	UO ≤0.5 mL/kg/h × 16 h	UO <1.0 mL/kg/h for 24 h
Failure	Increased creatinine x3 or GFR decreases >75% or creatinine >4 mg/dL (acute rise of >4 mg/dL)	Increased creatinine x3 or GFR decreases >75% or GFR <35 mL/min/1.73 m <sup>2</sup>	UO ≤0.3 mL/kg/h × 24 h or anuria × 12 h	UO ≤0.3 mL/kg/h × 24 h or anuria × 12 h	UO <0.7 mL/kg/h for 24 h or anuria for 12 h

Filtration des déchets azotés  
créatinine

Filtration des protéines  
plasmatiques par altération de  
la barrière glomérulaire  
albumine

Altération de la réabsorption  
tubulaire  
cystatine C

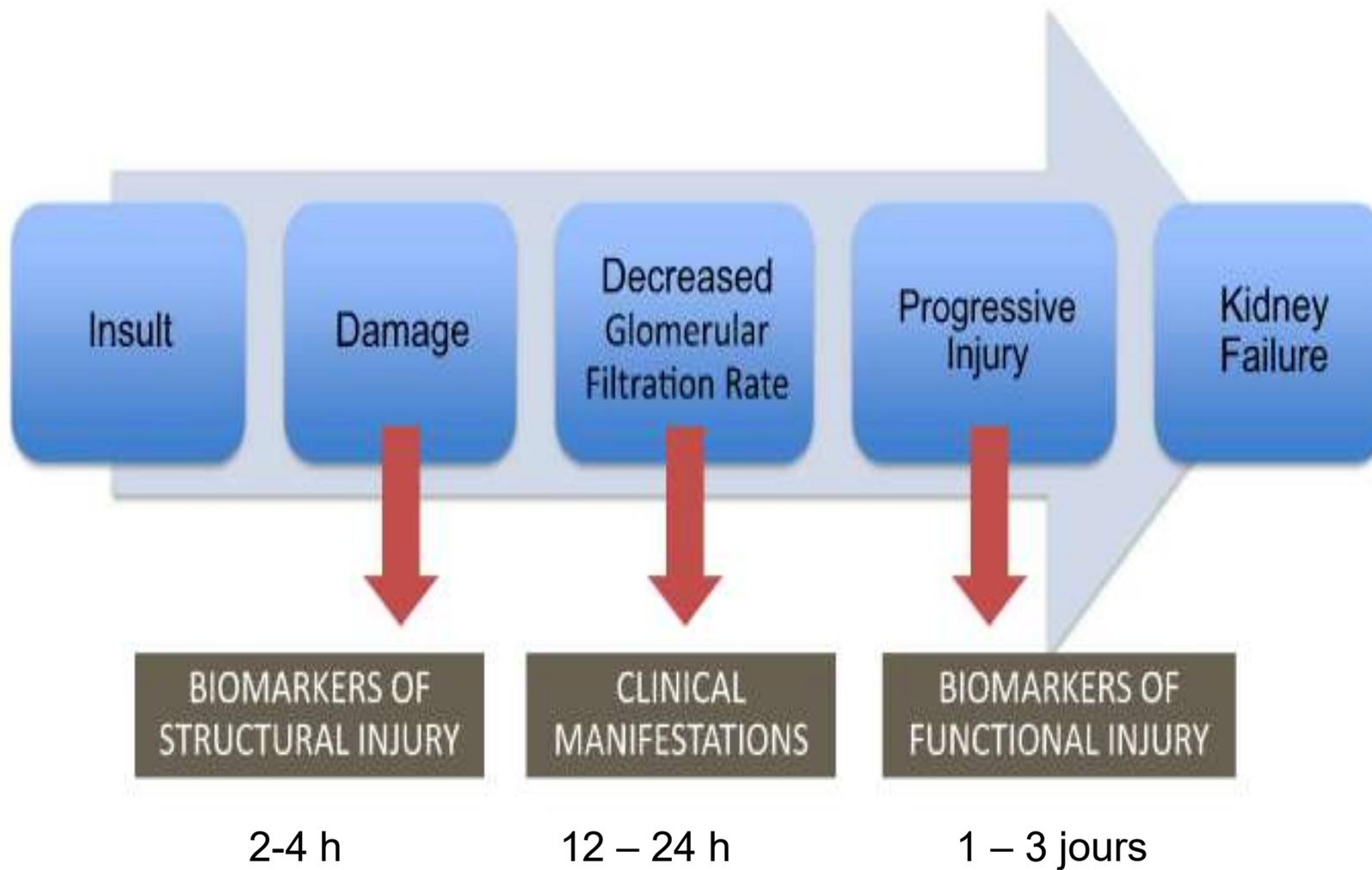
Protéines tubulaires  
- inductibles par l'ischémie  
KIM-1  
- libérées par la destruction  
endothéliale  
L-FABP  
- sécrétées par les cellules  
inflammatoires en réponse  
à l'ischémie  
NGAL, IL-18



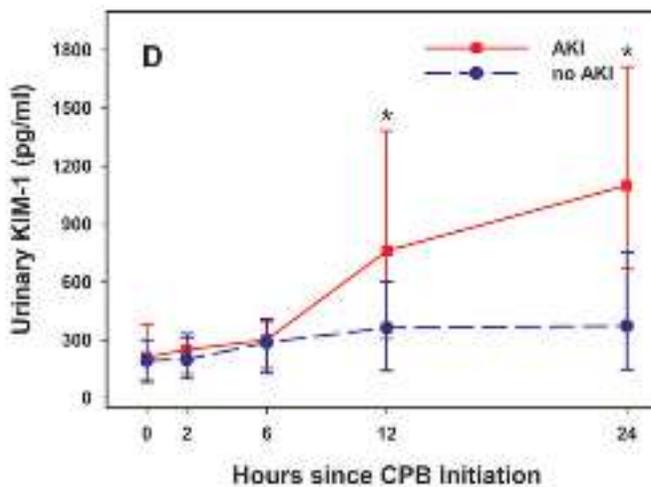
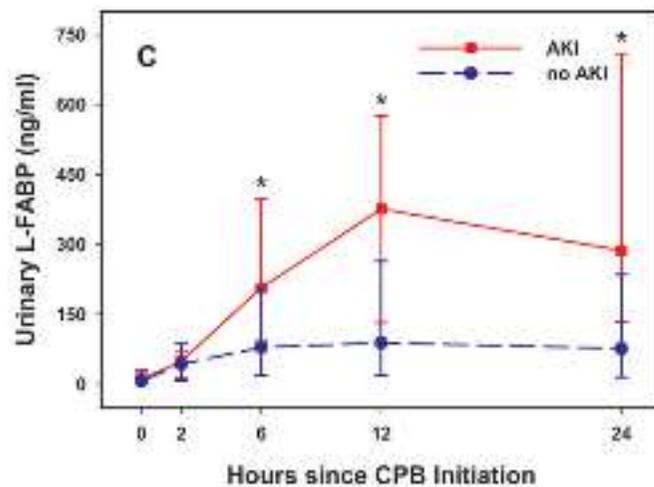
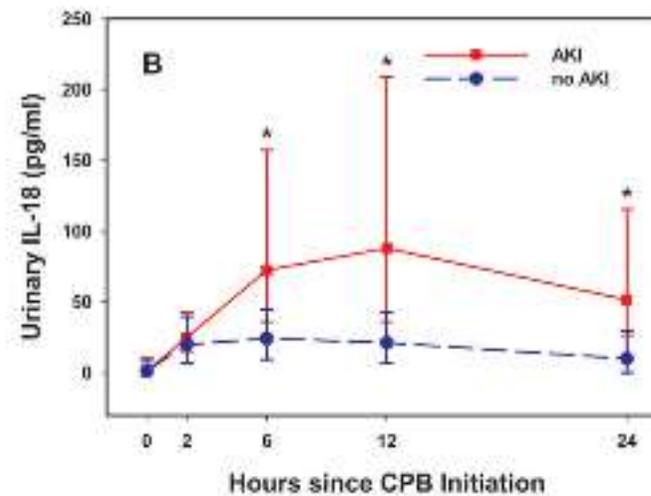
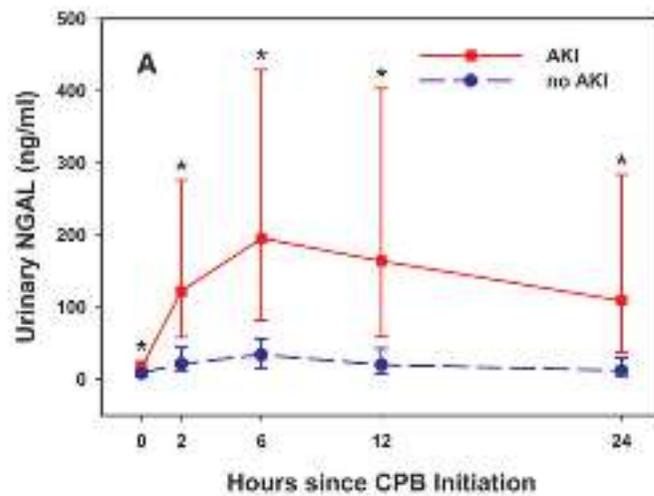
*Briggs JP. Kidney Int. 2008*

## Biomarqueurs rénaux

1. Marqueurs de la filtration glomérulaire =  
**marqueurs fonctionnels** (inuline, créatinine, cystatine C, albuminurie)
2. Marqueurs de l'atteinte tubulaire =  
**marqueurs lésionnels** (NGAL, KIM-1, LFAB, IL-18)



# Temporal Relationship and Predictive Value of Urinary Acute Kidney Injury Biomarkers After Pediatric Cardiopulmonary Bypass



Krawczeski JACC 2011

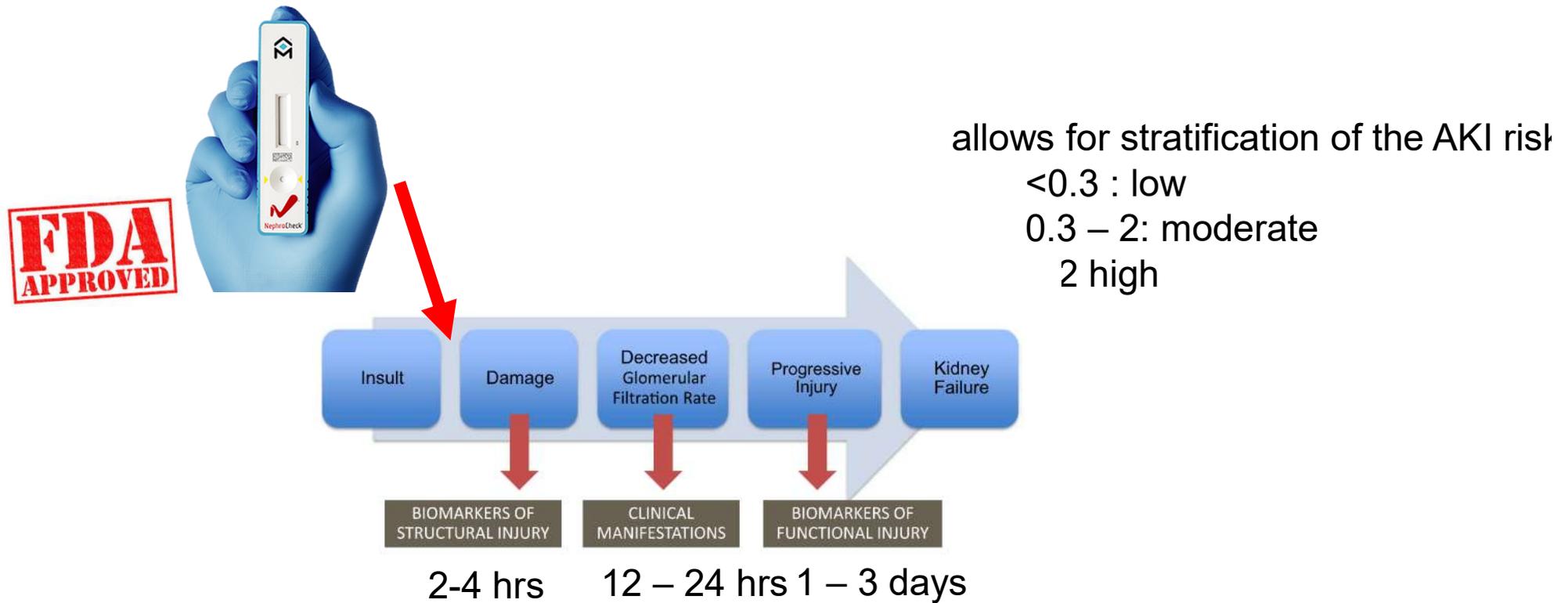
# Cell-cycle arrest and acute kidney injury: the light and the dark sides

John A. Kellum<sup>1</sup> and Lakhmir S. Chawla<sup>2</sup>

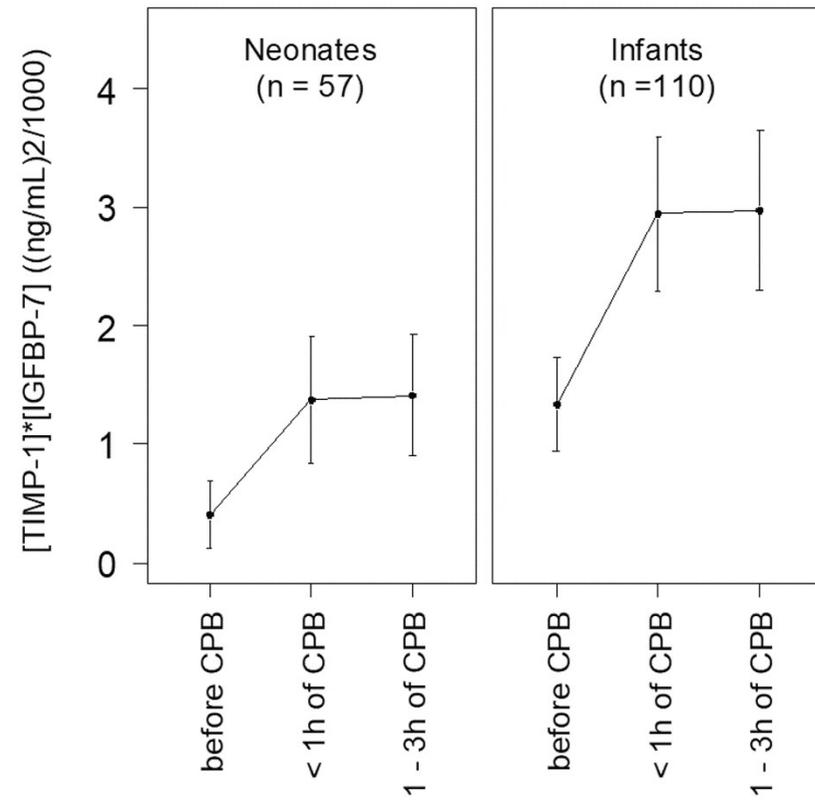
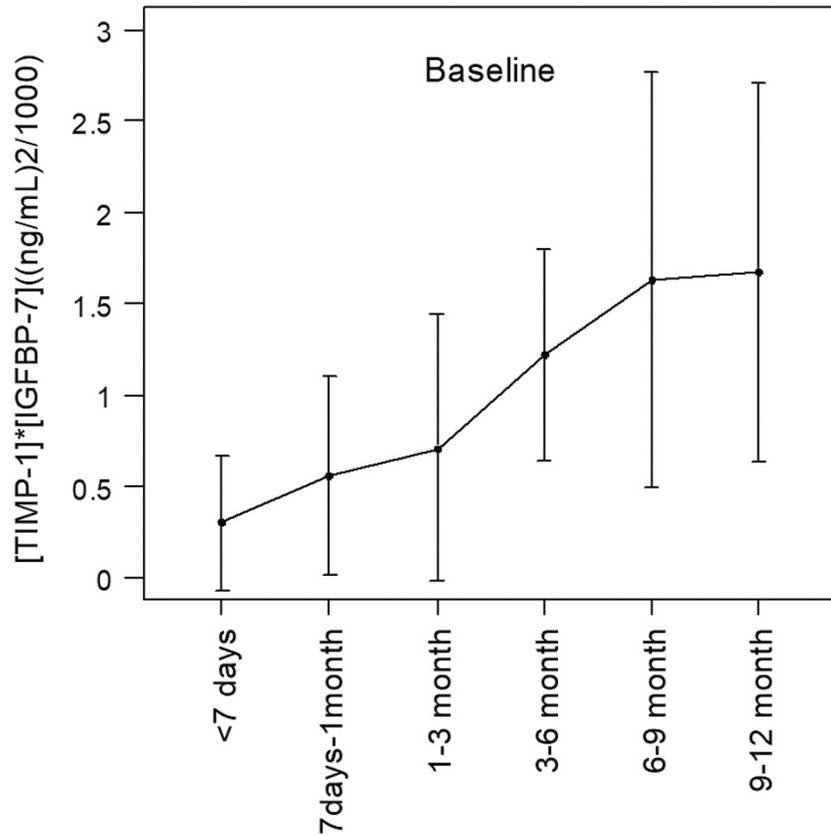
Tissue inhibitor of metalloproteinases-2 (TIMP-2)  
Insulin-like growth factor-binding protein 7 (IGFBP-7)

	population	[TIMP-2 * IGFBP-7] threshold
Gist Pediatr Nephrol 2016	94, average 154 days old	> 0.78 ROC area = 0.71
Meersch Plos ONE 2014	51 patients 1.5 – 3 years old	> 0.70 ROC area = 0.85

# Tissue inhibitor of metalloproteinase-2 and Insuline-like growth factor-binding protein-7 [TIMP-2]\*[IGFBP67] recommended by the guidelines for care following cardiac surgery



## Nephrocheck chez le NN et nourrisson



## AKI biomarkers : approx 350 reports/year over the last 10 years ...

**PubMed.gov**

AKI biomarkers

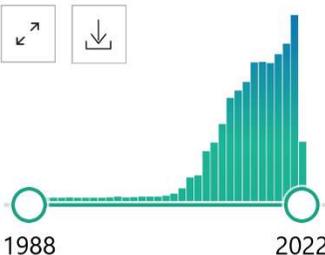
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RESULTS BY YEAR



[Cell-Free DNA, Neutrophil extracellular traps \(NETs\), and Endothelial Injury in Coronavirus Disease 2019- \(COVID-19-\) Associated Acute Kidney Injury.](#)

1

Cite Henry BM, de Oliveira MHS, Cheruiyot I, Benoit J, Rose J, Favaloro EJ, Lippi G, Benoit S, Share P, Pote Shakked N.

Mediators Inflamm. 2022 Apr 22;2022:9339411. doi: 10.1155/2022/9339411. eCollection 2022.

PMID: 35497096 [Free PMC article.](#)

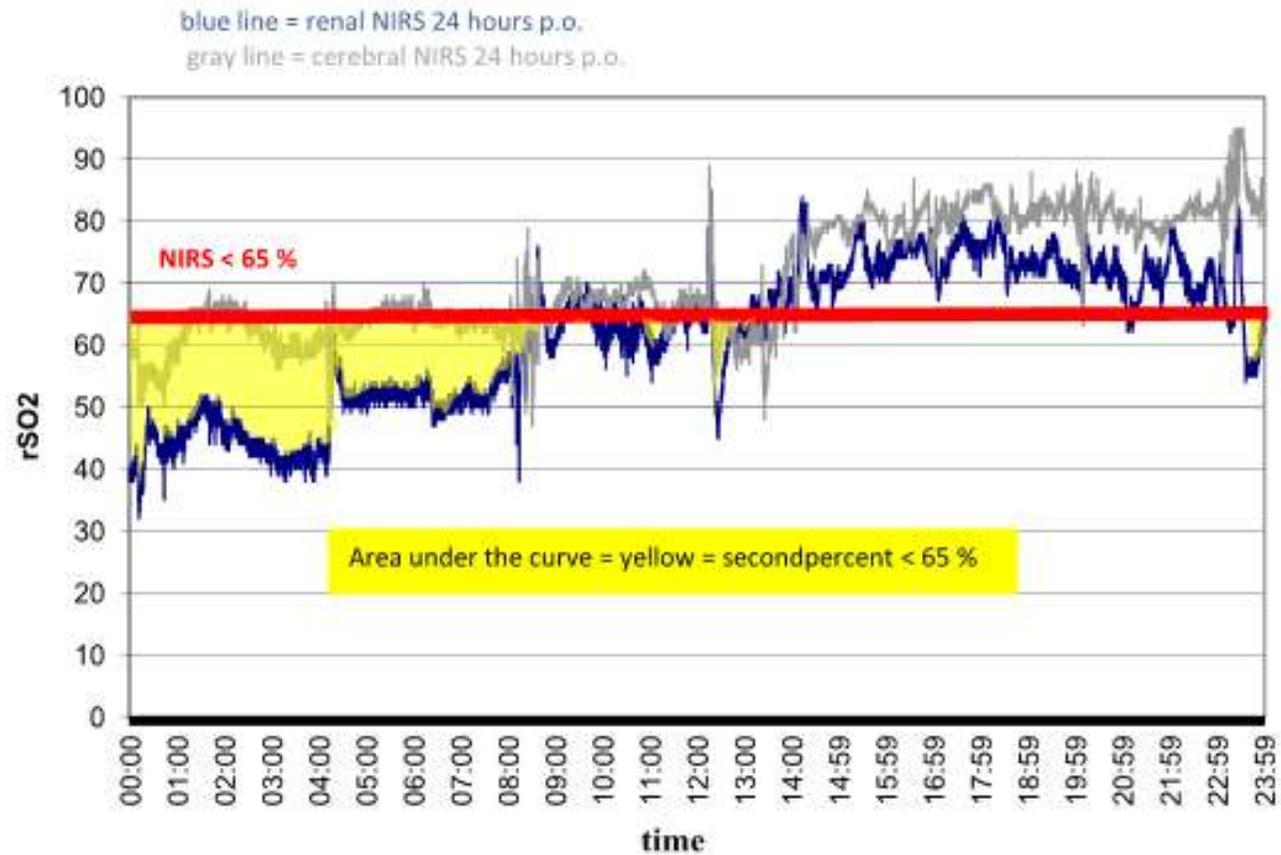
**Figure 2. Proposed New Definition of Acute Kidney Injury**

Functional criteria	Stage	Damage criteria
No change or sCr level increase <0.3 mg/dL and no UO criteria	1S	Biomarker positive
Increase of sCr level by $\geq 0.3$ mg/dL for $\leq 48$ h or $\geq 150\%$ for $\leq 7$ days and/or UO <0.5 mL/kg/h for >6 h	1A	Biomarker negative
	1B	Biomarker positive
Increase of sCr level by >200% and/or UO <0.5 mL/kg/h for >12 h	2A	Biomarker negative
	2B	Biomarker positive
Increase of sCr level by >300% ( $\geq 4.0$ mg/dL with an acute increase of $\geq 0.5$ mg/dL) and/or UO <0.3 mL/kg/h for >24 h or anuria for >12 h and/or acute KRT	3A	Biomarker negative
	3B	Biomarker positive

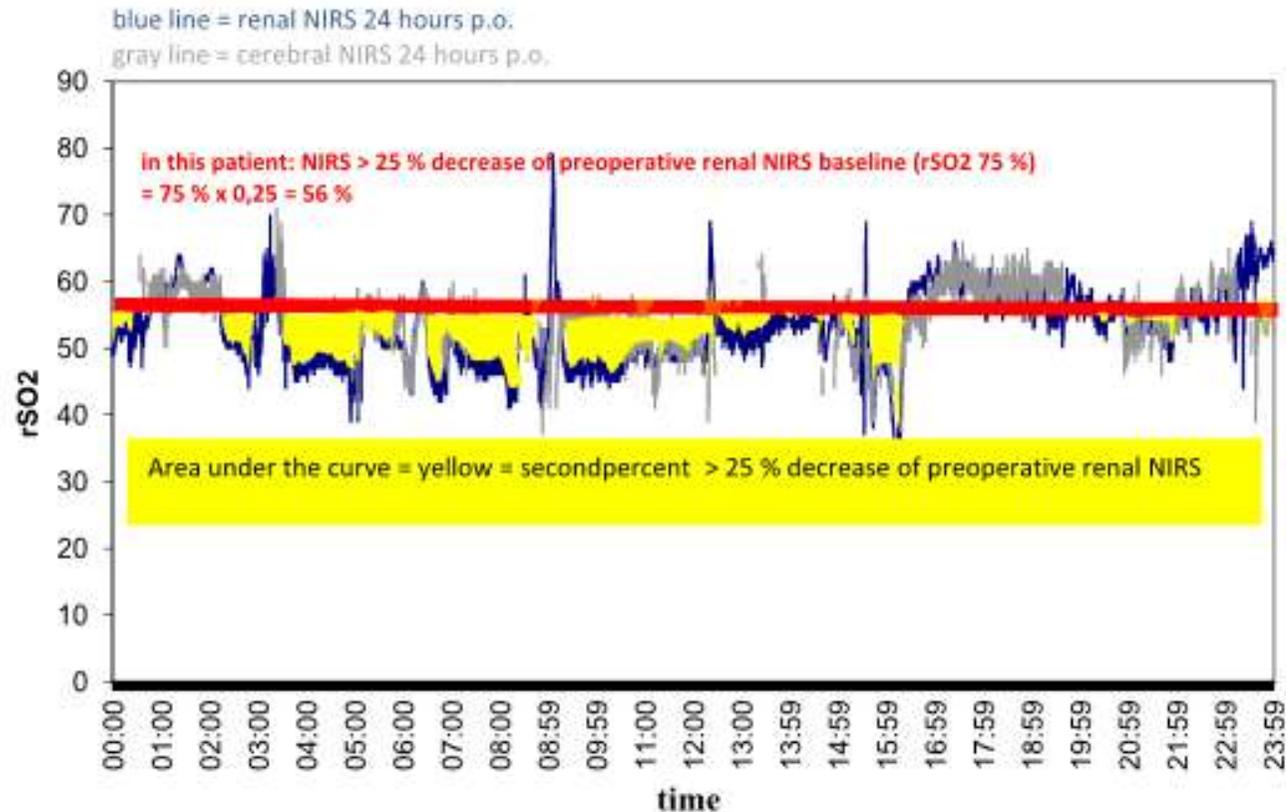
## Monitoring de l'oxygénation rénale durant la CEC

- Les index globaux d'oxygénation ( $\text{SaO}_2$ ,  $\text{SvO}_2$ , lactate,  $\text{DO}_2$ ) ne sont pas le reflet de l'oxygénation rénale
- NIRS rénale
- $\text{PO}_2$  vésicale

# Intraoperative renal near-infrared spectroscopy indicates developing acute kidney injury in infants undergoing cardiac surgery with cardiopulmonary bypass: a case-control study



# Intraoperative renal near-infrared spectroscopy indicates developing acute kidney injury in infants undergoing cardiac surgery with cardiopulmonary bypass: a case-control study



## Monitoring de la perfusion

### La NIRS

- Positionnement des canules
- Monitoring des circulations régionales  
OER cérébrtal = 35%, OER somatique (rénal) = 10-15%

→ **le gradient  $rSO_2$  somatique-cérébral est normalement 10-15%**

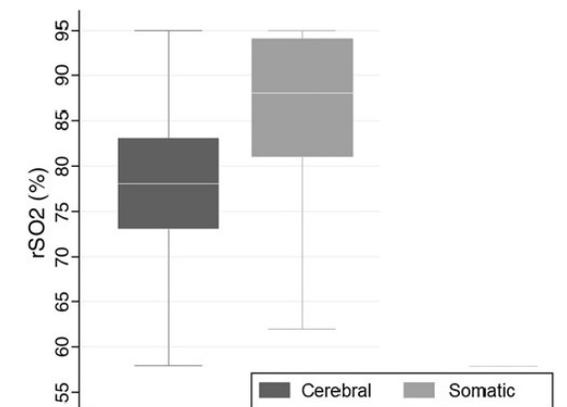
La circulation cérébrale est sous le contrôle de l'autorégulation du DSC

La circulation somatique (rénale) est sous contrôle adrénergique

→ **le gradient  $rSO_2$  somatique-cérébral se réduit lors de la stimulation sympathique (état de choc)**

*Bernal, J Pediatr Surg 2010*

Cerebral and somatic near-infrared spectroscopy in normal newborns

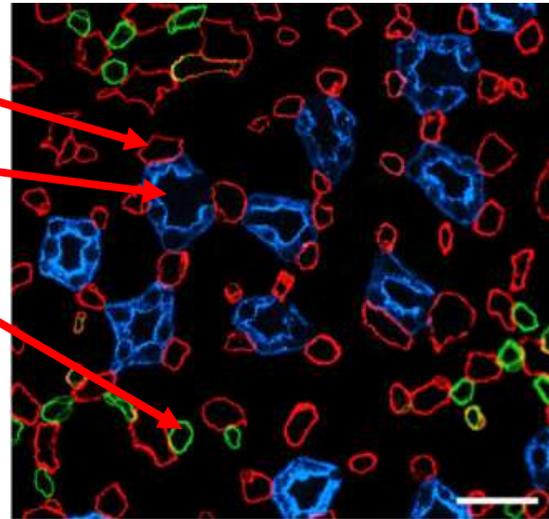


## Urine oxygen tension: a clinical window on the health of the renal medulla ?

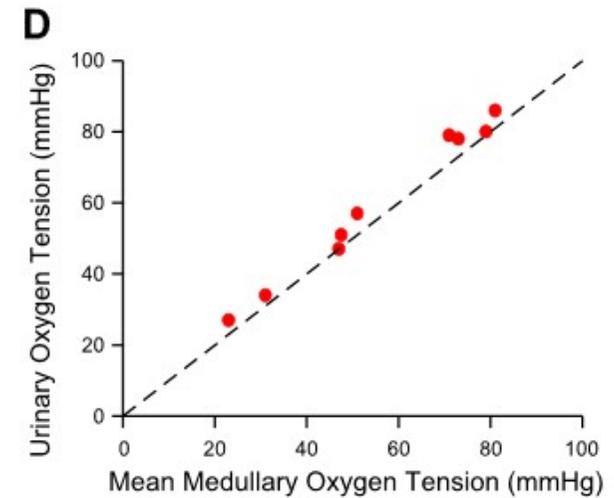
Ascending vasa recta

Collecting ductus

Descending vasa recta

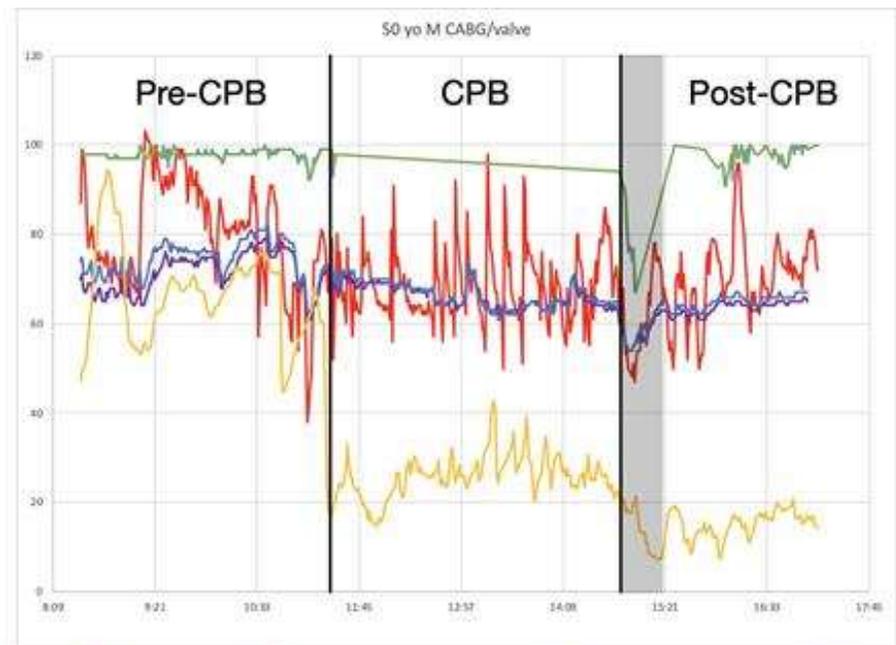
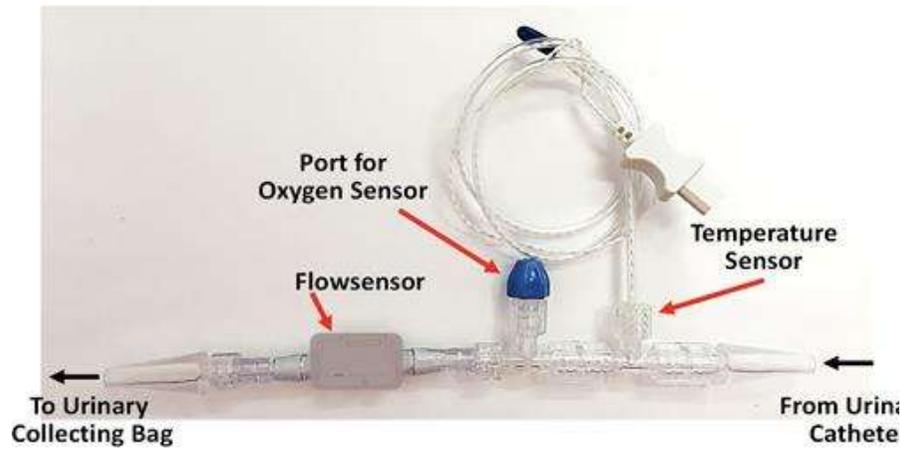


30 $\mu$ m



## La PO2 urinaire per-CEC prédit l'IRA post-CEC

86 adults with cardiac surgery



— MAP — SpO2 — R-Cerebral Oximetry — L-Cerebral Oximetry — Urine Oxygen

HR 0.82 / 10mmHg increase in urine pO<sub>2</sub>

Silverton, Anesthesiology 2021

**Insuffisance rénale aiguë**

**Epidemiologie**

**Physiopathologie**

**Diagnostic**

**Biomarqueurs**

**Prévention**

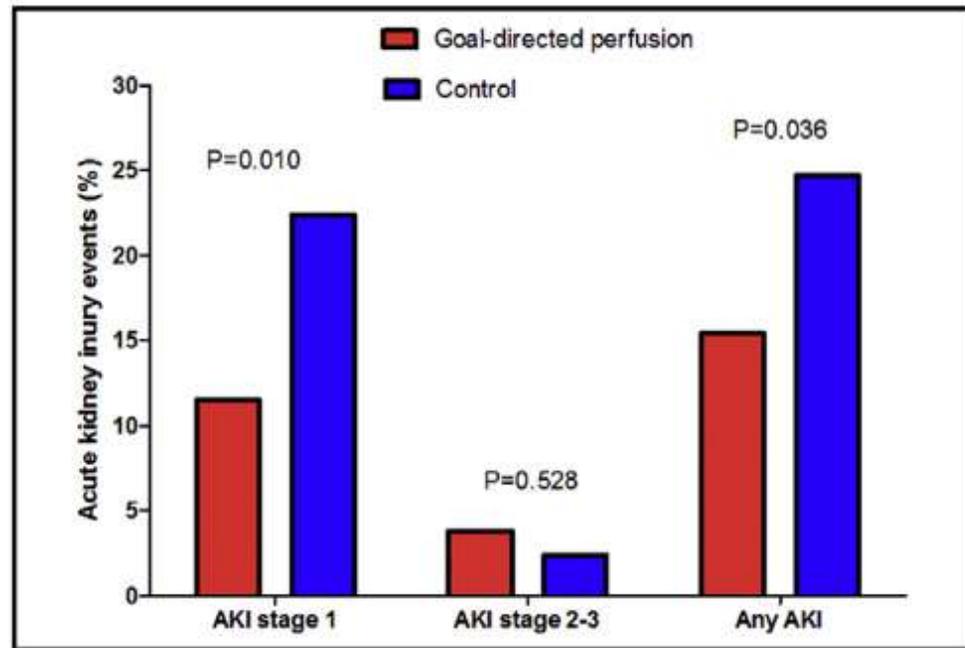
**Traitement**

**Insuffisance rénale chronique**

## DO<sub>2</sub>-directed perfusion to reduce cardiac surgery-related -AKI

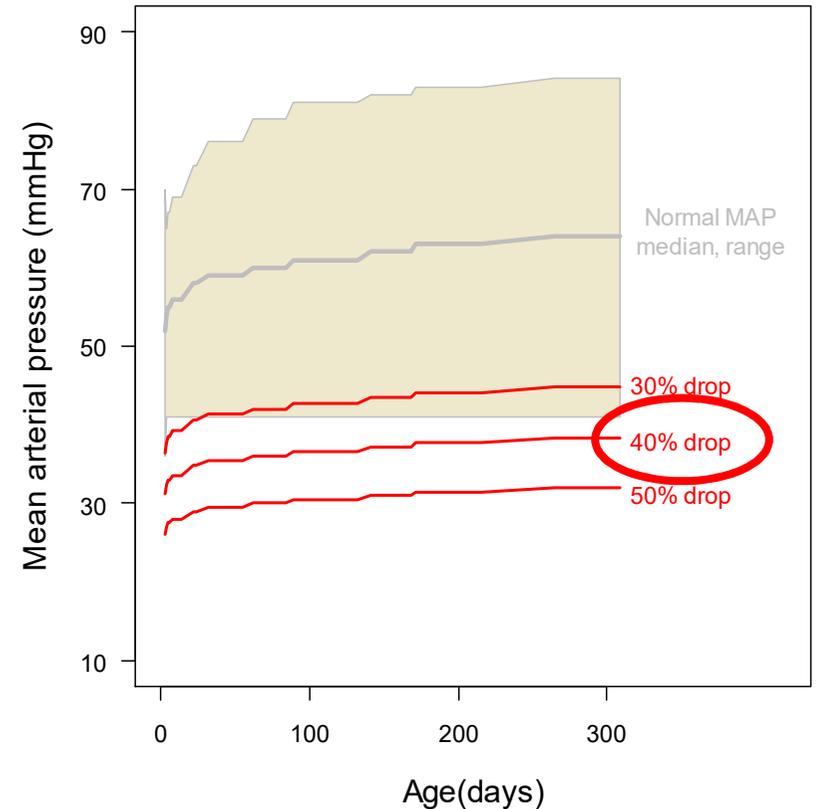
Goal : maintain DO<sub>2</sub> > 280 ml/min/m<sup>2</sup> during CPB in adults

Critical DO<sub>2</sub> in infants ? in neonates ?



## Mainenir la pression de perfusion en CEC > 60% de la PAM pour l'âge

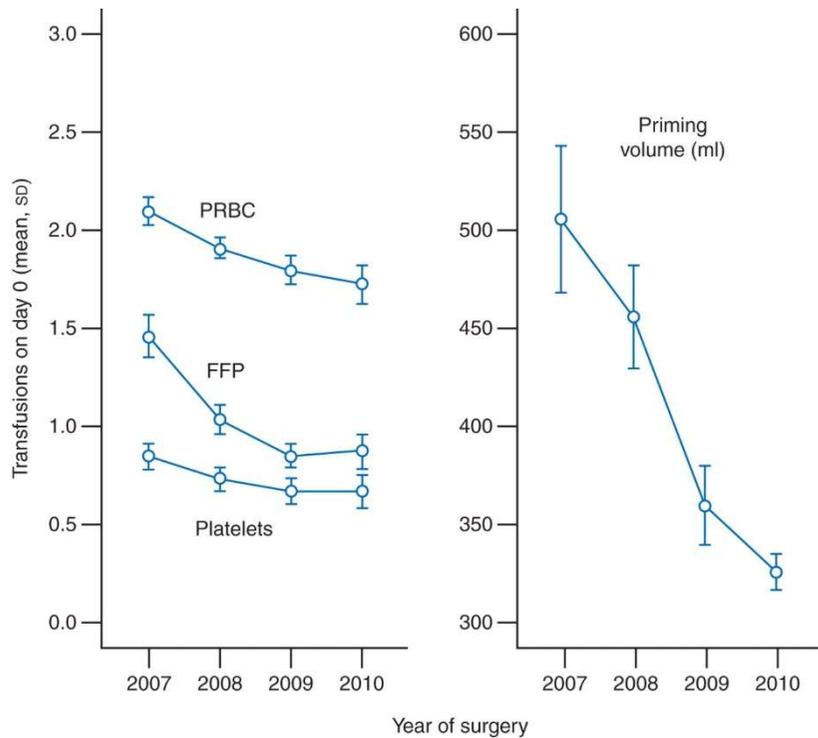
drop. A more than 40% pressure drop for 19.5 min provided a 0.65 negative predictive value for high uNGAL, and a more than 50% pressure drop for 5.4 min provided a 0.67 negative predictive value. The link between uNGAL



The Society of Thoracic Surgeons, The Society of Cardiovascular Anesthesiologists, and The American Society of ExtraCorporeal Technology: Clinical Practice Guidelines for Cardiopulmonary Bypass—Temperature Management during Cardiopulmonary Bypass

- 3. Surgical teams should limit arterial outlet blood temperature to  $<37^{\circ}\text{C}$  to avoid cerebral hyperthermia. (Class I, Level C)**
- ii. To achieve the desired temperature for separation from bypass, it is reasonable to maintain a rewarming rate  $\leq .5^{\circ}\text{C}/\text{min}$ . (Class IIa, Level B)**

## Éviter l'anémie et éviter les transfusions ... Miniaturization des circuits de CEC

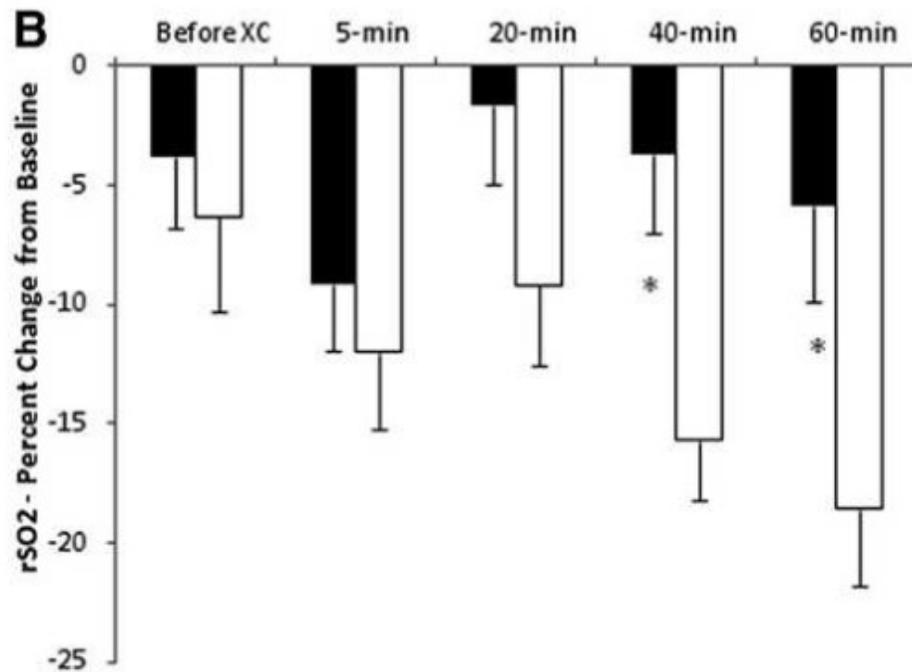
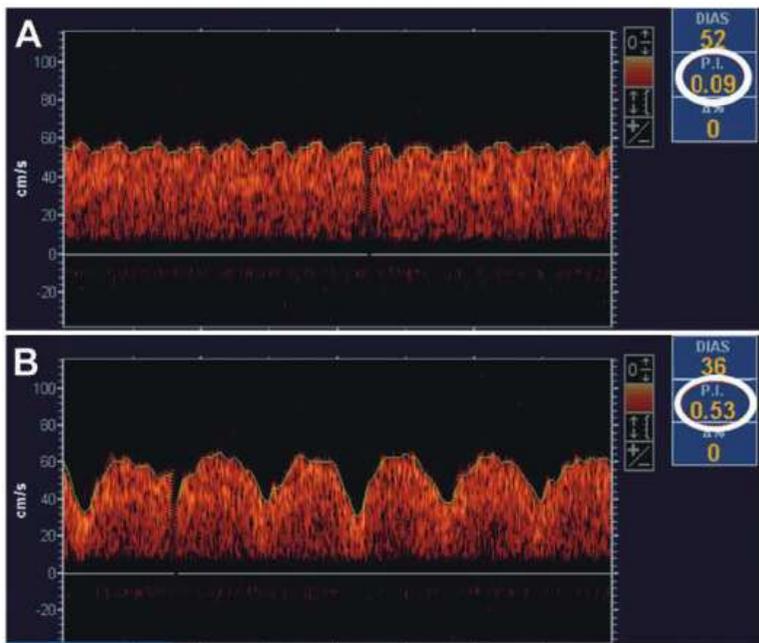


Variable	AKI		Severe AKI requiring dialysis	
	Adjusted OR (95% CI)	P-value	Adjusted OR (95% CI)	P-value
Use of aprotinin	0.62 (0.35–1.08)	0.09	1.40 (0.47–4.20)	0.54
Number of PRBC transfusions on day 0	1.64 (1.12–2.41)	0.01	2.07 (1.13–3.73)	0.02
Number of FFP transfusions on day 0	2.28 (1.68–3.09)	<0.001	3.11 (1.95–4.97)	<0.001
Number of platelet transfusions on day 0	1.33 (0.93–1.92)	0.12	2.20 (1.21–4.01)	0.01

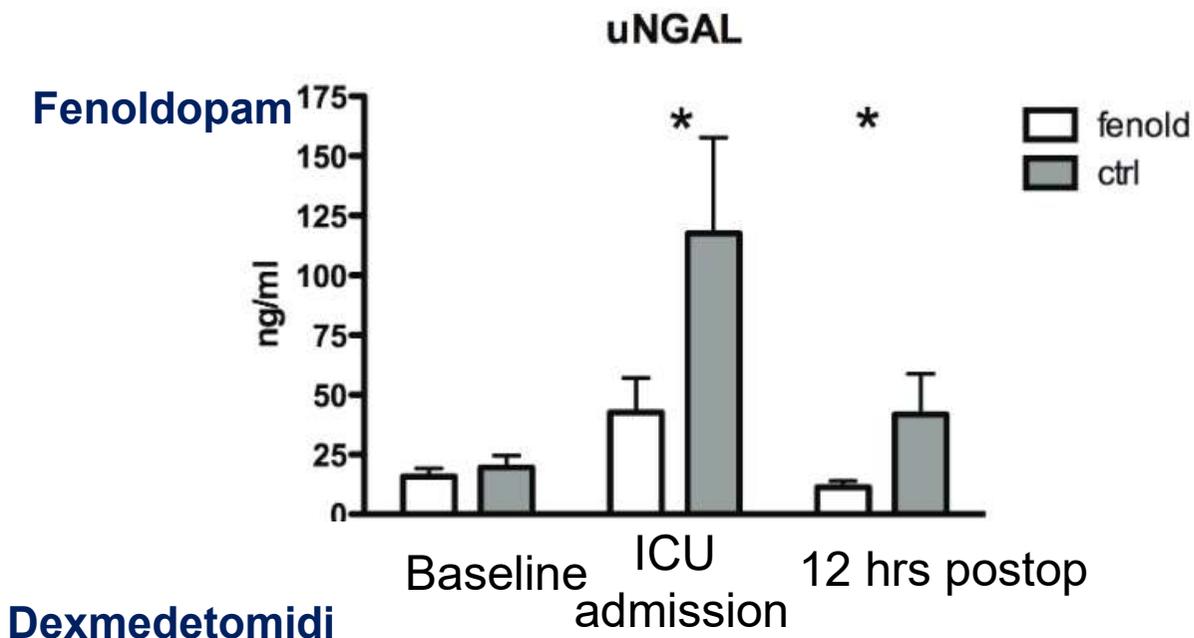
## **Duration of red blood cell storage and outcomes in pediatric cardiac surgery: an association found for pump prime blood**

**Conclusions** The storage time of the red blood cells used for priming the cardiopulmonary bypass circuit in cardiac operations on newborns and young infants is an independent risk factor for major postoperative morbidity. Pulmonary complications, acute renal failure, and infections are the main complications associated with increased red blood cell storage time.

## Le débit pulsé améliore la rSO<sub>2</sub> cérébrale (... et la rSO<sub>2</sub> rénale ?)



## Renal vasodilators reduce the incidence of CS-AKI in infants



Kidney Injury or Creatinine Change Description	Dexmedetomidine (n = 102)	No Dexmedetomidine (n = 102)	p
AKI of any severity, %	24 (24)	36 (37)	OR, 0.54 (95% CI, 0.29–0.99; p = 0.046) <b>adjusted OR, 0.43</b> (95% CI, 0.27–0.98; p = 0.048)

## Sodium Bicarbonate and Renal Function after Cardiac Surgery

and covariates (odds ratio [OR], 99% confidence interval [CI]: Bicarbonate *vs.* Control, 1.11 [0.77–1.60],  $P = 0.45$ ). There was, however, a significant study-adjusted benefit in elective coronary artery bypass surgery patients in terms of renal replacement therapy (Bicarbonate *vs.* Control, OR: 0.38 [99% CI: 0.25–0.58],  $P < 0.0001$ ) and the development of an Acute Kidney Injury Network grade = 3 (Bicarbonate *vs.* Control, OR: 0.45 [99% CI: 0.43–0.48],  $P < 0.0001$ ).

# Autres stratégies dans la prévention de l'IRA

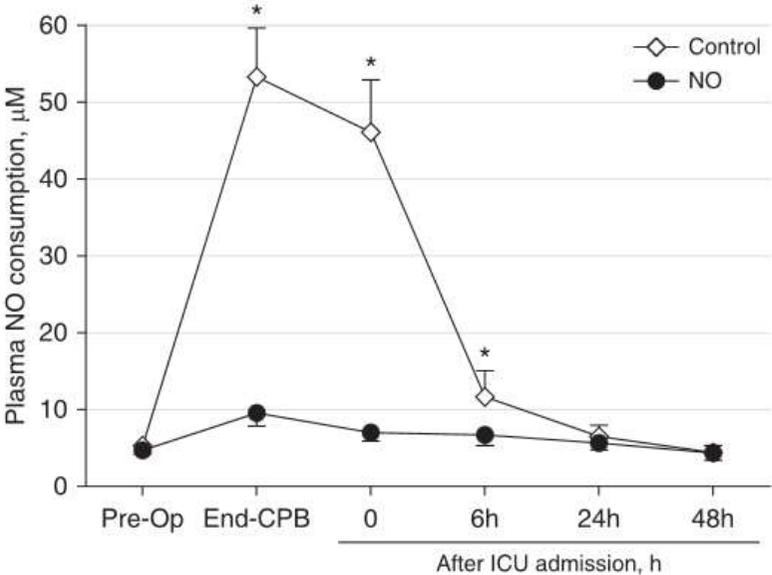
SPECIAL REPORT



Cardiac and Vascular Surgery–Associated Acute Kidney Injury:  
The 20th International Consensus Conference of the ADQI (Acute  
Disease Quality Initiative) Group

Timing	Strategy	Population	Recommended	Not Recommended
Intraoperative	Volatile anesthetic agents (vs propofol)	Cardiac	2C	...
	Avoidance of hyperthermia	Cardiac	2C	...
	Pulsatile CPB	Cardiac	2D*	...
	Avoidance of hemodilution	Cardiac	2C	...
	MAP >75	Cardiac	...	More research needed
	Intraoperative ultrafiltration	Cardiac	...	More research needed

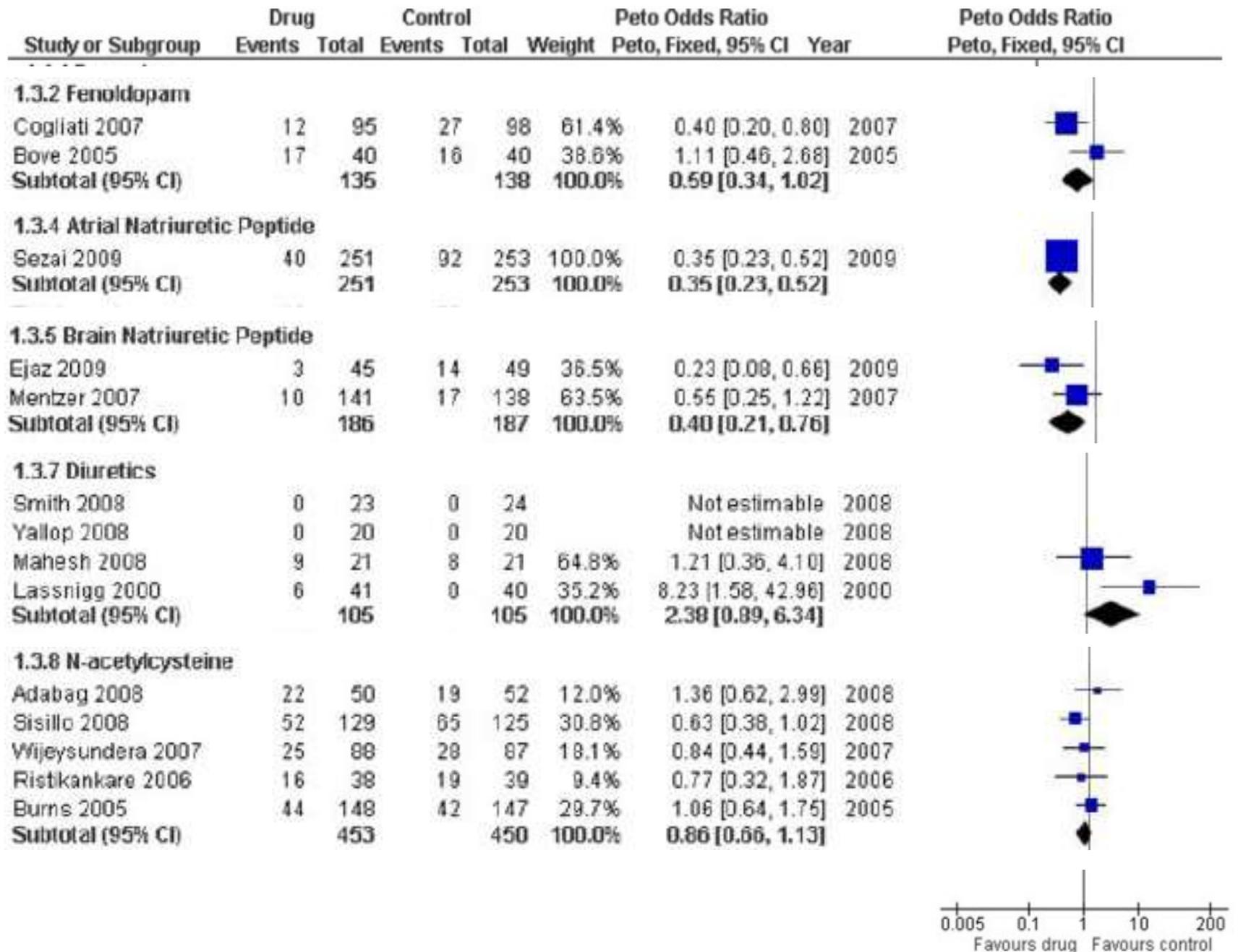
# L'administration intra- et postopératoire de l'NO chez l'adulte réduit le risque d'IRA et de IRC stade 3 chez l'adulte



RR for CS-AKI within 1 week = 0.78  
[0.62 – 0.97]  
RR for stage 3 CKD within 1 year = 0.59  
[0.36 – 0.96]

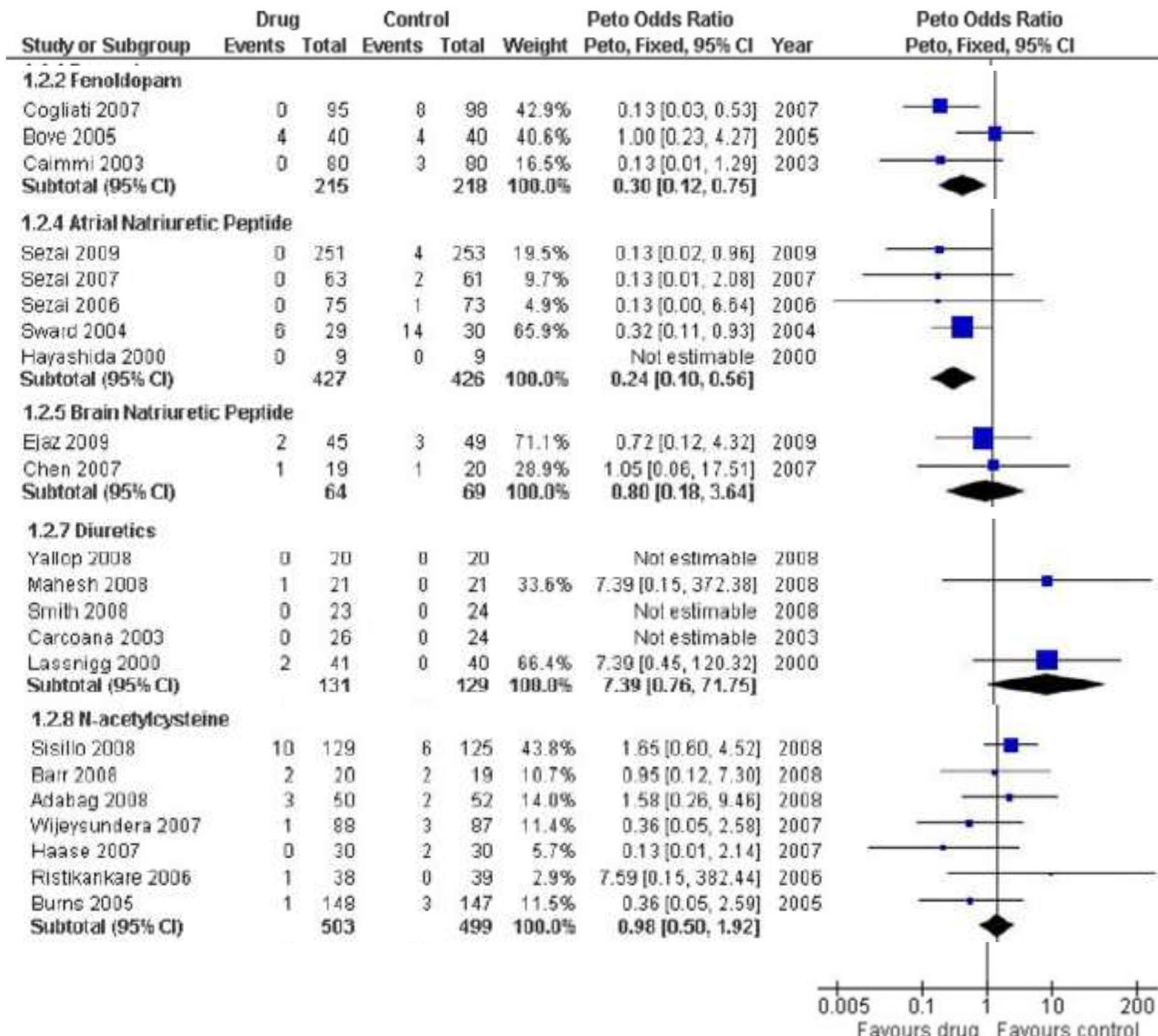
# Effet estimé / risque d'IRA lors d'une utilisation à titre préventif

Patel,  
Heart Fail Rev  
2011



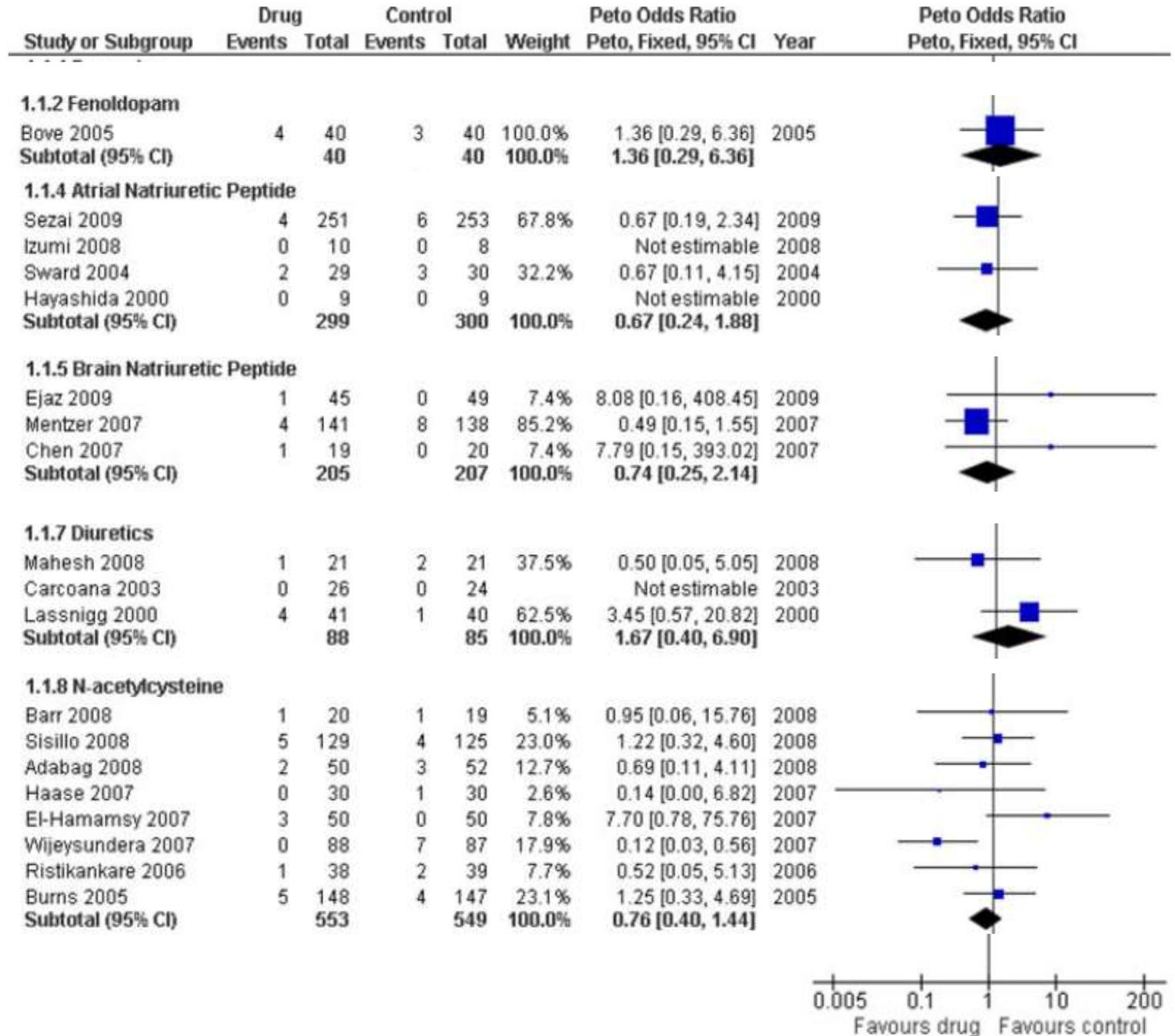
# Effet estimé / recours à la dialyse lors d'une utilisation à titre préventif

Patel,  
Heart Fail Rev  
2011



# Effet estimé / mortalité lors d'une utilisation à titre préventif

Patel,  
Heart Fail Rev  
2011



**Insuffisance rénale aiguë**

**Epidemiologie**

**Physiopathologie**

**Diagnostic**

**Biomarqueurs**

**Prévention**

**Traitement**

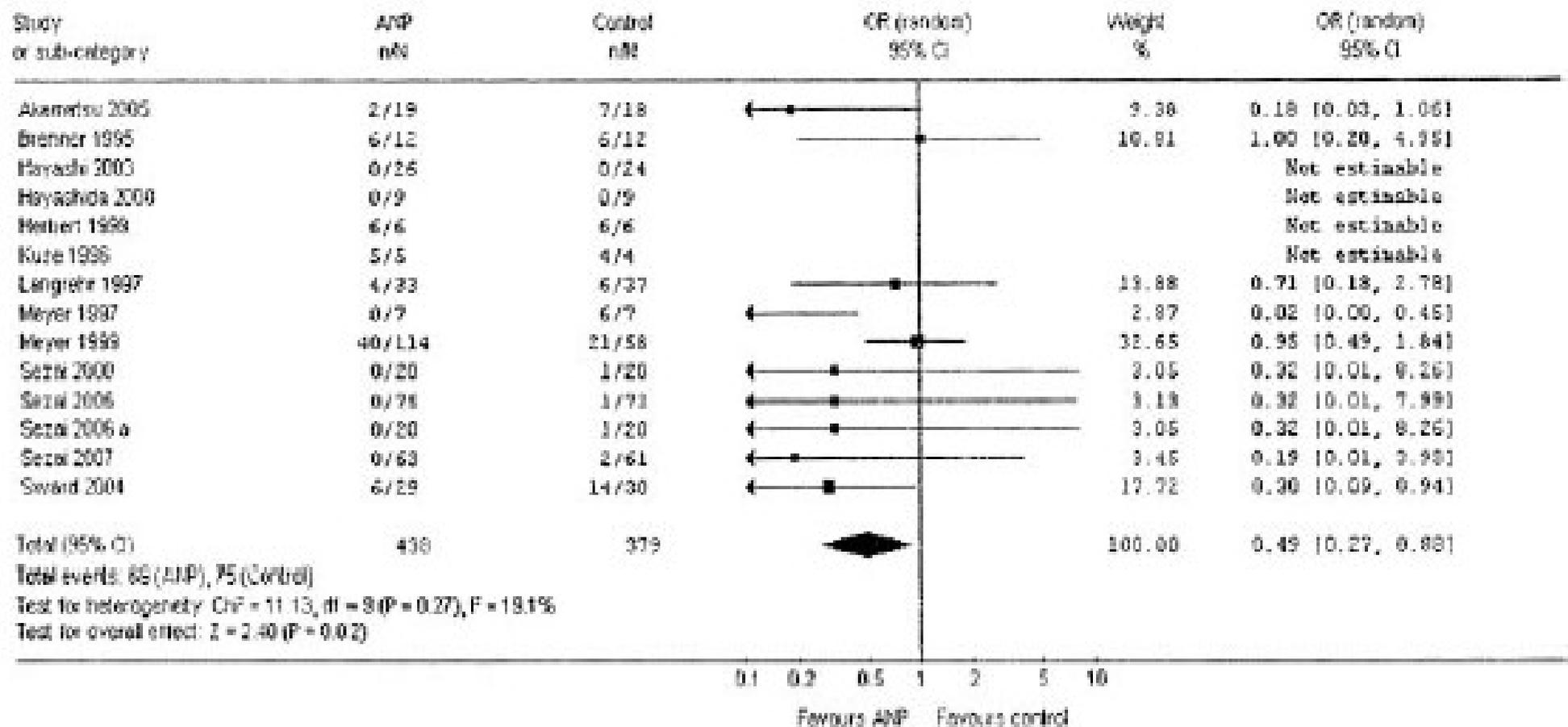
**Insuffisance rénale chronique**

# ANP

## Effet estimé sur le recours à la dialyse lors d'une utilisation à titre curatif après une chirurgie lourde

Nigwekar,  
*Clin J Am Soc Nephrol*  
 2009

Review: ANP in acute kidney injury (version 08)  
 Comparison: 07 ANP in major surgery  
 Outcome: 03 Need for RRT



## Les moyens de l'épuration extra-rénale (EER)

- DP (peritoneal dialysis) : gradient osmotique et de concentration
- Méthodes d'épuration continues CRRT :
  - CVVH (continuous veno-venous hemofiltration) : gradient de pression hydrostatique
  - CVVHD (continuous veno-venous hemodialysis) : gradient de concentration
  - CVVHDF (continuous veno-venous hemodiafiltration) : les deux
- HDI (intermittent hemodialysis) : gradient de pression hydrostatique et de concentration

Liquide de dialysat en pédiatrie : iso-osmotique, tampon bicarbonate

## Choix d'un mode d'EER en pédiatrie

Mode d'EER	DP	CRRT	HDI
Avantages, indications	Correction rapide d'une hyperkaliémie Surcharge hydrique modérée Facilité de la voie d'accès	Correction rapide d'une hyperkaliémie Surcharge hydrique majeure (OAP, sepsis) : hémofiltration Clearance des grosses molécules : dialyse	Correction rapide d'une hyperkaliémie Surcharge hydrique majeure (OAP, sepsis) Clearance des grosses molécules
Contre-indications	Défaut de paroi, hernie diaphragmatique Infection, tumeur, chirurgie abdominale récente ECUN Dérivation ventriculo-péritonéale Mauvaise tolérance dans les cardiopathies précharge-dépendantes	Coagulopathie	Coagulopathie Instabilité hémodynamique

## La dialyse péritonéale chez le nourrisson < 1an

- Assure une ultrafiltration d'environ 4ml/kg/h chez le nouveau-né et 2,5-3,5 ml/kg/h chez le nourrisson
- Assure une clearance de la créatinine de 2 à 20ml/min/1,73m<sup>2</sup> chez le nouveau-né
- *Necker Enfants –Malades, 2000-2008* : une complication grave de la DP à été enregistrée pour 25.4jours de DP

## Indications de L'EER à Necker

- **L'oligurie** : diurèse  $< 2\text{ml/kg/h}$  ( $1\text{ml/kg/h}$ ) qui persiste au-delà de **4heures** malgré l'optimisation de la précharge, des constantes hémodynamiques
- La surcharge hydrique
- Le contexte de bas débit
- Les complications métaboliques

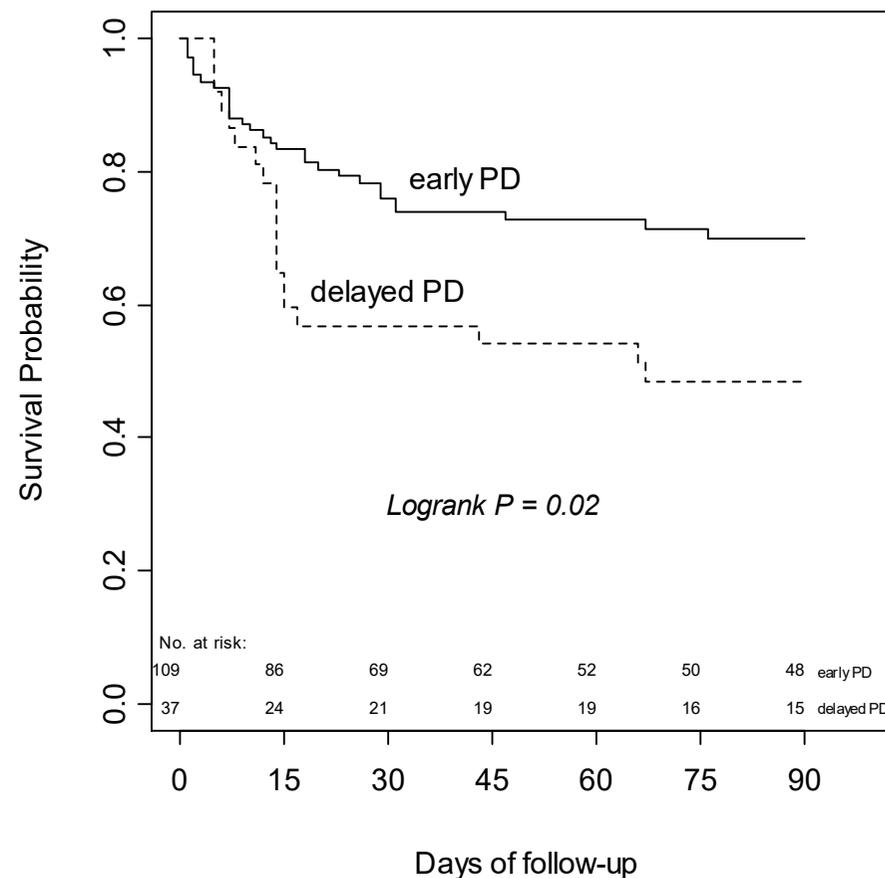
# Time to initiation of peritoneal dialysis and short-term outcome in neonates and infants with acute kidney injury following congenital cardiac surgery

3550 patients <1 an opérés entre 2000-2009, parmi lesquels 146 ont été dialysés

Délai avant début de la dialyse: 0 – 21 jours, médiane 1 jour

Mortalité à 30 jours: 28.1%

Mortalité globale: 36.6%



HR ajusté sur l'année: 0.52 [0.29 – 0.85]

**Insuffisance rénale aiguë**

**Epidemiologie**

**Physiopathologie**

**Diagnostic**

**Biomarqueurs**

**Prévention**

**Traitement**

**Insuffisance rénale chronique**

# L'atteinte rénale chronique dans les cardiopathies congénitales

## Prevalence, Predictors, and Prognostic Value of Renal Dysfunction in Adults With Congenital Heart Disease

Konstantinos Dimopoulos, MSc, MD; Gerhard-Paul Diller, MD; Evdokia Koltsida, MD; Antonia Pijuan-Domenech, MD; Sofia A. Papadopoulou, MD; Sonya V. Babu-Narayan, BSc, MRCP; Tushar V. Salukhe, BSc, MRCP; Massimo F. Piepoli, MD, PhD; Philip A. Poole-Wilson, MD, FRCP; Nicky Best, BSc, MSc, PhD; Darrel P. Francis, MA, MD, MRCP; Michael A. Gatzoulis, MD, PhD

**Background**—Renal insufficiency in patients with ischemic heart disease and acquired heart failure is associated with higher mortality and morbidity. We studied the prevalence of renal dysfunction in adult patients with congenital heart disease (ACHD) and its relation to outcome.

**Methods and Results**—A total of 1102 adult patients with congenital heart disease (age  $36.0 \pm 14.2$  years) attending our institution between 1999 and 2006 had creatinine concentration measured. Glomerular filtration rate (GFR) was calculated with the Modification of Diet in Renal Disease equation. Patients were divided into groups of normal GFR ( $\geq 90 \text{ mL} \cdot \text{min}^{-1} \cdot 1.73 \text{ m}^{-2}$ ), mildly impaired GFR (60 to  $89 \text{ mL} \cdot \text{min}^{-1} \cdot 1.73 \text{ m}^{-2}$ ), and moderately/severely impaired GFR ( $< 60 \text{ mL} \cdot \text{min}^{-1} \cdot 1.73 \text{ m}^{-2}$ ). Survival was compared between GFR groups by Cox regression. Median follow-up was 4.1 years, during which 103 patients died. Renal dysfunction was mild in 41% of patients and moderate or severe in 9%. A decrease in GFR was more common among patients with Eisenmenger physiology, of whom 72% had reduced GFR ( $< 90 \text{ mL} \cdot \text{min}^{-1} \cdot 1.73 \text{ m}^{-2}$ ,  $P < 0.0001$  compared with the remainder), and in 18%, this was moderate or severe ( $P = 0.007$ ). Renal dysfunction had a substantial impact on mortality (propensity score-weighted hazard ratio 3.25, 95% CI 1.54 to 6.86,  $P = 0.002$  for moderately or severely impaired versus normal GFR).

**Conclusions**—Deranged physiology in adult patients with congenital heart disease is not limited to the heart but also affects the kidney. Mortality is 3-fold higher than normal in the 1 in 11 patients who have moderate or severe GFR reduction. (*Circulation*. 2008;117:2320-2328.)

## Critères KDIGO 2012

1. L'estimation du DFG doit se faire par une équation utilisant la créatinine, et si le DFG estimé est pathologique, il est conseillé de le vérifier en utilisant une équation utilisant la cystatine

bedside CKiD equation :  $eGFR_{CKiD} = 0.413 * \frac{\text{height}}{sCr}$

Zappitelli equation:  $eGFR_{ZAP} = (507.76 * e^{0.003 * \text{height}}) / sCysC^{0.635} * \text{creat}^{0.547}$

2. L'estimation de la fonction rénale comprend, au même titre que la mesure/estimation du DFG, la mesure de l'albuminurie

## Prognosis of CKD by GFR and albuminuria category

### Prognosis of CKD by GFR and Albuminuria Categories: KDIGO 2012

				Persistent albuminuria categories		
				Description and range		
				A1	A2	A3
				Normal to mildly increased	Moderately increased	Severely increased
				<30 mg/g <3 mg/mmol	30-300 mg/g 3-30 mg/mmol	>300 mg/g >30 mg/mmol
GFR categories (ml/min/1.73 m <sup>2</sup> ) Description and range	G1	Normal or high	≥90	Green	Yellow	Orange
	G2	Mildly decreased	60-89	Green	Yellow	Orange
	G3a	Mildly to moderately decreased	45-59	Yellow	Orange	Red
	G3b	Moderately to severely decreased	30-44	Orange	Red	Red
	G4	Severely decreased	15-29	Red	Red	Red
	G5	Kidney failure	<15	Red	Red	Red

Green: low risk (if no other markers of kidney disease, no CKD); Yellow: moderately increased risk; Orange: high risk; Red, very high risk.

# Facteurs de risque IRC dans les cardiopathies congénitales

## 1. La cyanose / viscosité

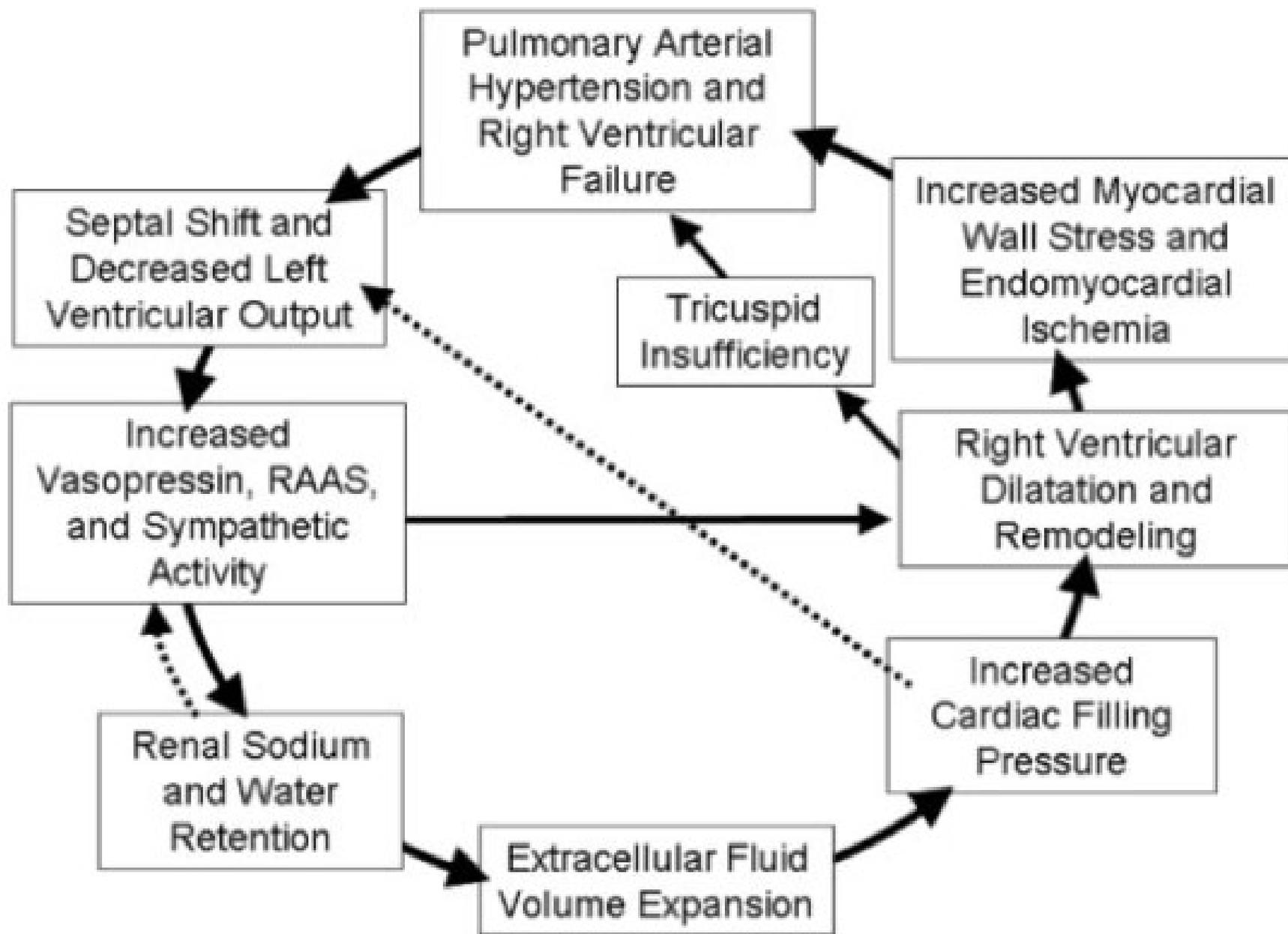
- hyperfiltration glomérulaire -> glomérulomégalie -> protéinurie
- augmentation des résistances vasculaires postcapillaires -> protéinurie tubulaire

## 2. La défaillance du ventricule systémique (syndrome cardio-rénal)

- Bas débit chronique -> stimulation du système rénine – angiotensine-aldostérone -> rétention hydro-sodé

## 3. Défaillance du VD

- Clearance créatinine corrélée avec la résistance vasculaire pulmonaire et la PVC (*Anne, Int J Cardiol 2009*)



## Conclusions



L'IRA est une complication sévère après chirurgie cardiaque pédiatrique

La découverte des nouveaux biomarqueurs de l'IRA représente un progrès majeur, permettant un diagnostic précoce

Il n'existe, à présent, aucune thérapie spécifique pour prévenir, atténuer ou accélérer la récupération de la fonction rénale en pédiatrie; la miniaturisation des circuits de CEC diminue son incidence

Le traitement de l'IRA reste conservateur; l'instauration précoce de la dialyse dans l'IRA grave améliore la survie

Le dépistage de l'IRC devrait faire partie du bilan de routine des patients porteurs de cardiopathie congénitale