Optimization of Hemodynamic Management per/by Cardiopulmonary Bypass

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Conflicts of Interest

- Direct:

  - NIRS
    - Medtronic : consultant / orateur
    - Braindex: consultant / orateur

  - CEC
    - Medtronic (Spectrum)

Stroke in Cardiac Surgery

Stroke:

- ✓ affects 3% of patients
- ✓ 3-fold ↗ the in-hospital mortality
- ✓ 10-fold ↗ the global mortality

McKhann et al. Stroke 2006

Silent stroke:

- ✓ affects > 50% of patients (detected by MRI)
- ✓ is involved in 1/3 of early POCD

Vedel et al. Circulation 2018

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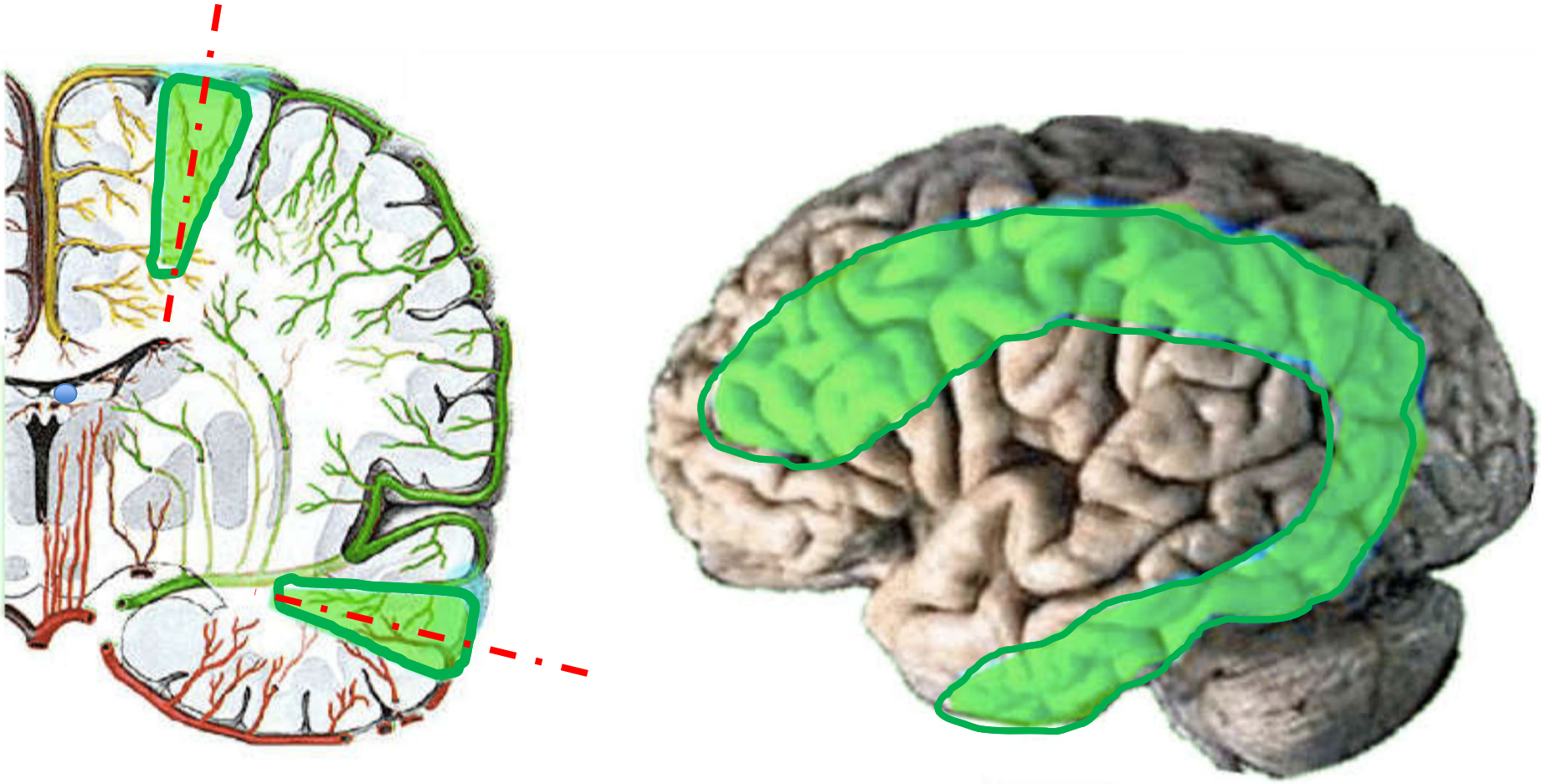
Cortical Stroke

Embolic stroke

Focal or multifocal embolization of:

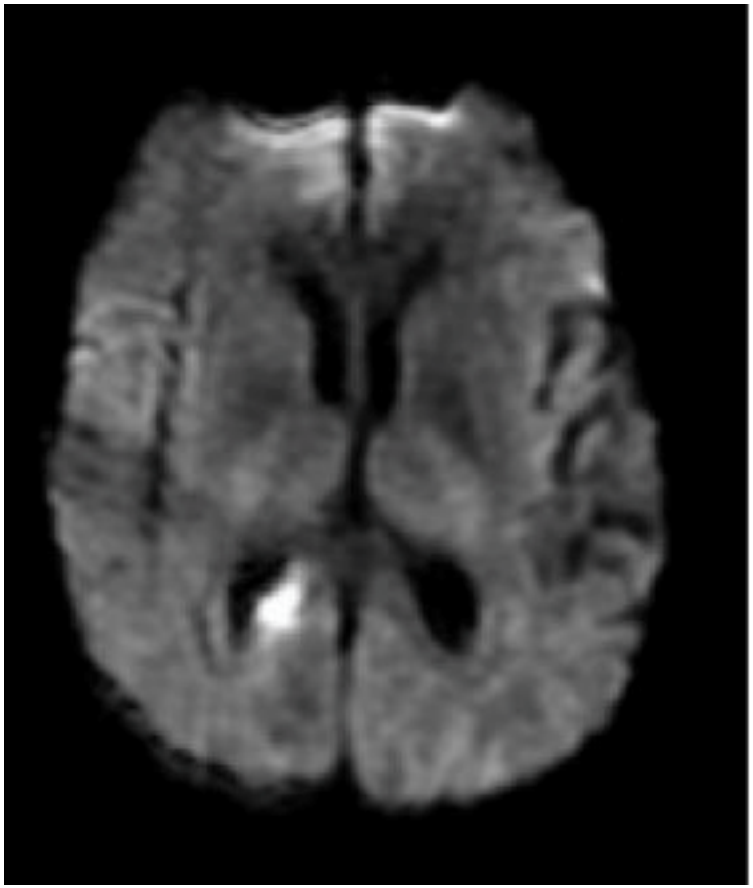
- *Atherosclerosis debris* (release into de the bloodstream by surgical manipulation of heart valve or the ascending aorta)
- *Fat or air bubbles*

Subcortical or Watershed Stroke



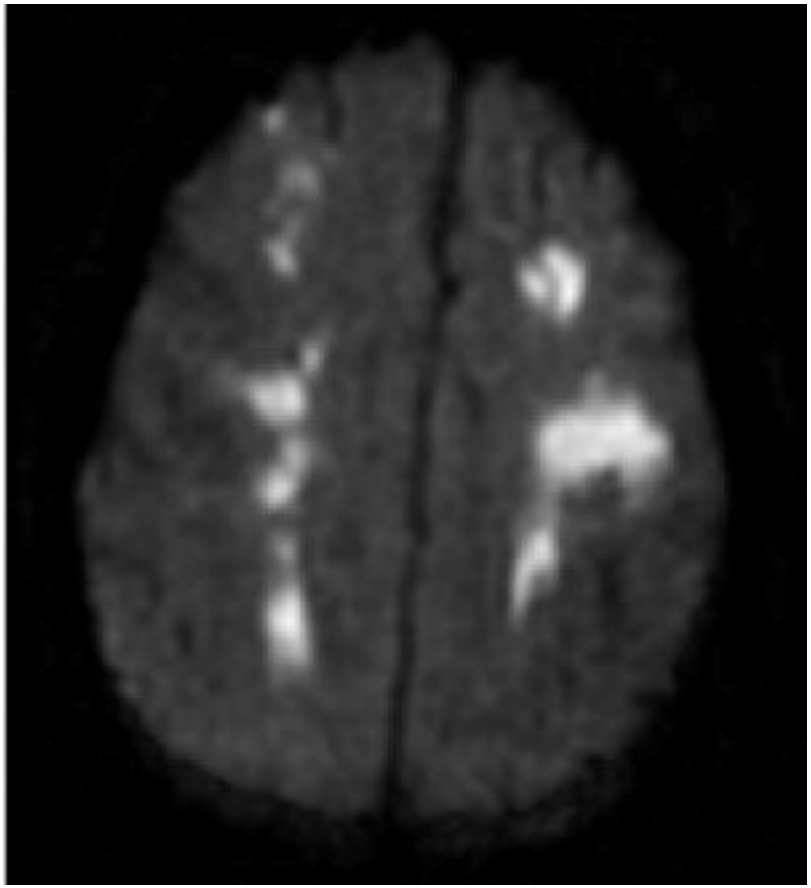
HYPOPERFUSION

MRI: Cortical and Subcortical Strokes



Acute territorial infarct

= cortical stroke



Watershed infarct

= subcortical stroke

Gottesman et al. Stroke 2006

Physiopathology of Stroke in Cardiac Surgery

With MRI, stroke after cardiac surgery involved:

- ✓ Embolic infarct alone in 25-40% of cases

Gottesman et al. Stroke 2006
Vegel et al. Circulation 2018

- ✓ Watershed infarct in ≈ 70% of cases

Vegel et al. Circulation 2018

- ✓ 
  - Unilateral watershed in ≈ 70% of cases
  - Bilateral watershed in ≈ 50% of cases

Gottesman et al. Stroke 2006

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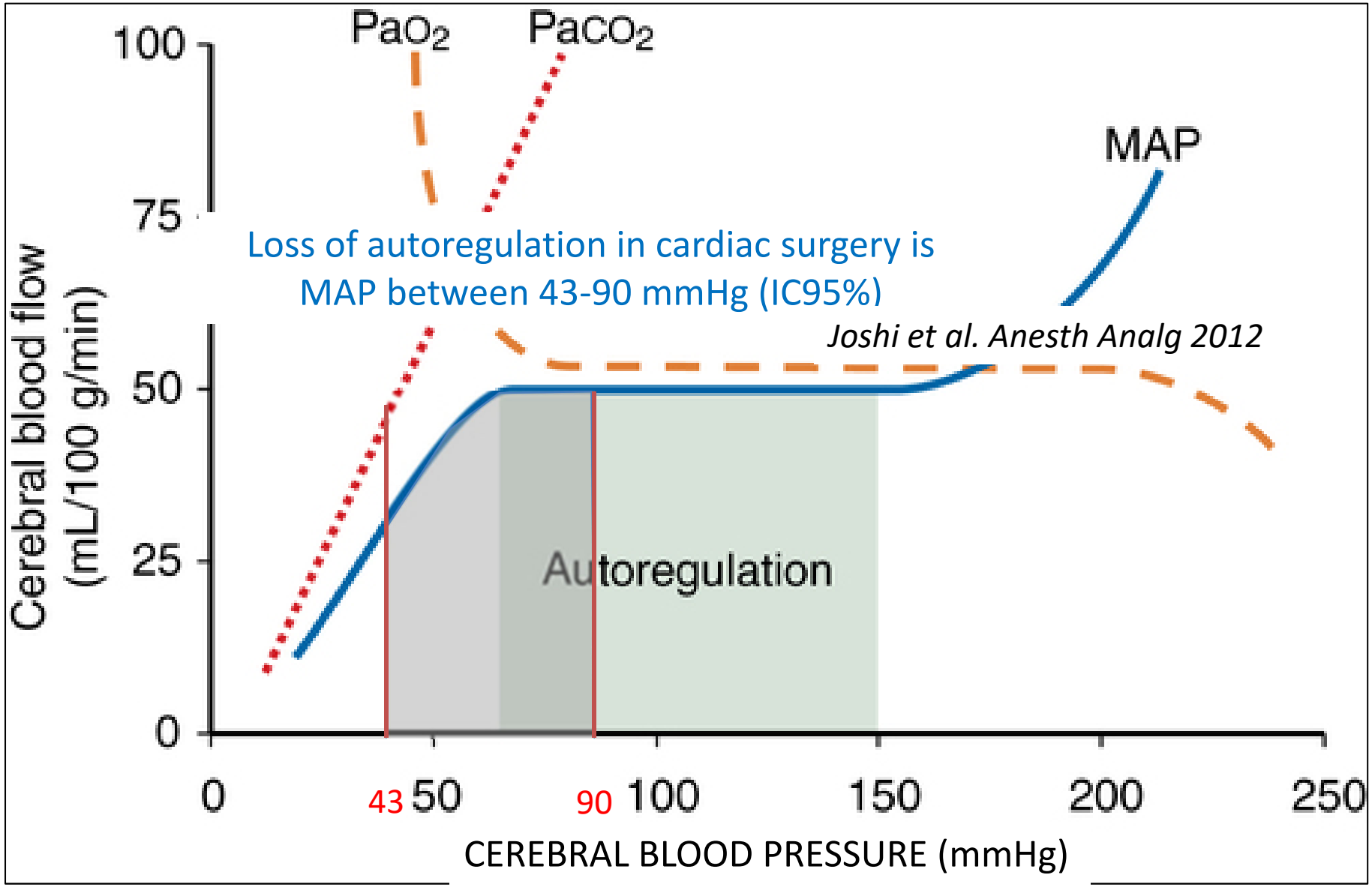
Is there a « GOOD » MAP in CPB to avoid hypoperfusion ?

Lower Limit of Brain Autoregulation



IMPROVEMENT OF OUTCOMES AFTER CORONARY ARTERY BYPASS

A randomized trial comparing intraoperative high versus low mean arterial pressure

- ✓ Single center RCT
- ✓ 248 patients (124 vs 124)
- ✓ Primary elective CABG with CPB
- ✓ [redacted]
- ✓ Phenylephrine (< 2 mg), then norepinephrine
- ✓ [redacted]
- ✓ [redacted]
- ✓ **Limits:** heterogeneous composite outcome, hypothermia, **no brain MRI assessment of new ischemic injuries**

Gold et al. JCTVS 1995

	Low MAP (n = 124)		High MAP (n = 124)		Low − high MAP		
	No.	%	No.	%	No.	%	95% CI for % difference
Fatal stroke	2	1.6	0	0.0			
Hemiparesis*	2	1.6	1	0.8			
Aphasia	3	2.4	1	0.8			
Cortical blindness	1	0.8	0	0.0			
Monocular blindness	1	0.8	0	0.0			
Other focal deficit	0	0.0	1	0.8			
Fatal cardiogenic shock	1	0.8	2	1.6			
Shock	1	0.8	0	0.0			
Myocardial infarction	4	3.2	1	0.8			
Total cardiac complications	6	4.8	3	2.4	3	2.4	−2.2, 7.1
Other death, total (not attributable to cardiac or neurologic causes)	2	1.6	0	0	2	1.6	−0.6, 3.8

Silent strokes ????

Gold et al. JCTVS 1995

	Low MAP		High MAP	
	Mean	SD	Mean	SD
CPB time				
CPB duration (min)	89.4	31.5	84.9	28.3
Aortic crossclamp duration (min)	46.7	20.0	43.1	16.7
No. of grafts	3.1	0.8	2.9	0.8
Internal mammary graft (%)	77.4	3.8	80.7	3.5
Pump flows (L/min/m²)				
MAPs (mm Hg)				
CPB (full flow)	59.2	5.4	81.8	7.8
Aortic crossclamp on (full flow)	56.5	7.1	81.2	7.8
Aortic sidebiter clamp on (for all flows)	49.6	5.8	67.1	8.8
No. of low flow intervals	7.7	3.2	9.3	3.8
Returned to CPB (%)	1.6	1.1	2.5	1.4

Low PF <2.4

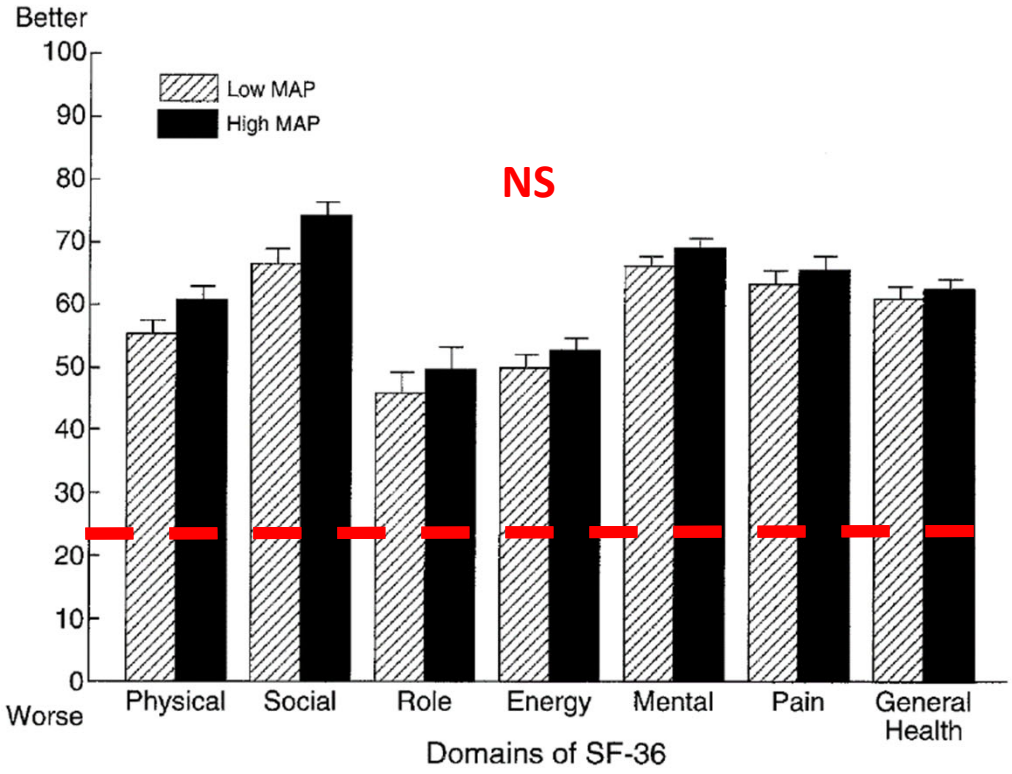
Low PAM

Low Ht < 24%

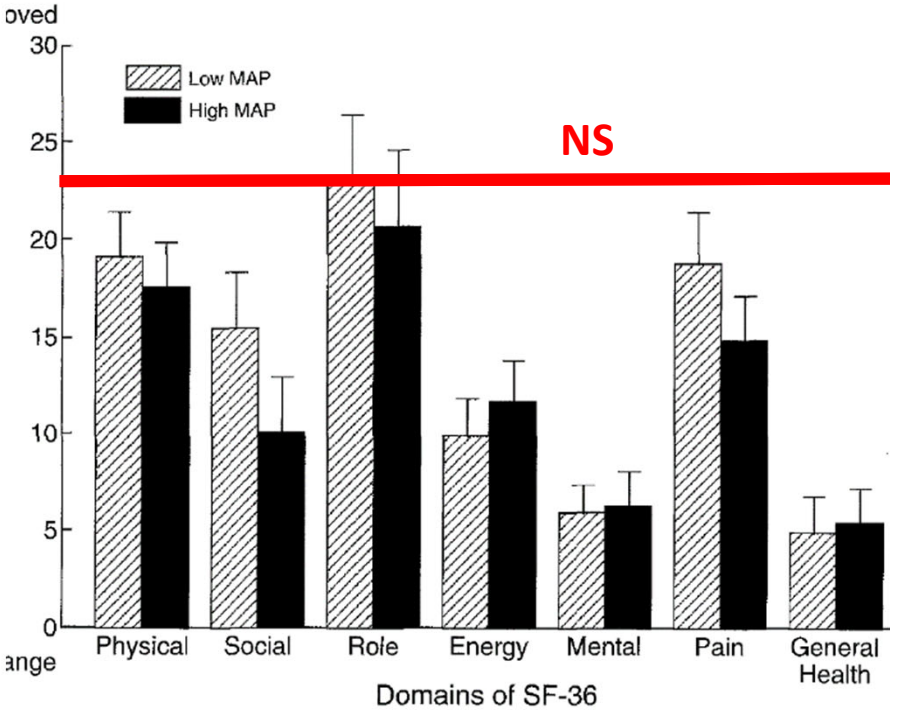
The 3 « LOW »…..not good !

Gold et al. JCTVS 1995

Preoperative status (SF36)



6 months status (SF36)



Gold et al. JCTVS 1995

High-Target Versus Low-Target Blood Pressure Management During Cardiopulmonary Bypass to Prevent Cerebral Injury in Cardiac Surgery Patients

A Randomized Controlled Trial

MRI OUTCOMES

Low-target group (n=99)
89 full MRI datasets
10 patients were unable to comply to MRI, due to:

4	Dyspnea
2	Withdrawal of consent to DWI
1	Pain
1	Pacemaker needed
1	Prolonged ICU stay
1	Logistics

High-target group (n=98)
80 full MRI datasets
18 patients were unable to comply to MRI, due to:

4	Dyspnea
4	Withdrawal of consent to DWI
4	Prolonged ICU stay
2	Delirium
1	Death in the OR
1	Stroke with hemiparesis
1	Pain
1	Logistics

- ✓ Single center RCT
- ✓ 197 patients (98 vs 99)
- ✓ CABG and/or Valvular surgery with CPB
- ✓ [redacted]
- ✓ Hypotension: Phenylephrine (< 2 mg), then norepinephrine < 0.4 µg.kg^{-1}.min^{-1}
- ✓ Hypertension: no medical treatment
- ✓ [redacted]
- ✓ [redacted]

Vedel et al. Circulation 2018

	Low-Target Group, n		High-Target Group, n		Difference (95% CI)	OR (95% CI)	*P* Value
Primary outcome							
Total volume of new cerebral lesions, mm^3							
Complete cases, median (IQR)	89	25 (0 to 118)	80	29 (0 to 143)	0 (–25 to 0.028)*		0.41
Excluding 3 outliers, median (IQR)	88	24 (0 to 118)	78	28 (0 to 134)			
Complete cases, mean (SD)	89	415 (2682)	80	488 (2539)	8 (–978 to 994)†		0.99‡
Excluding 3 outliers, mean (SD)	88	133 (313)	78	144 (265)			
Secondary outcome							
Total number of new cerebral lesions							
Complete cases, median (IQR)	89	1 (0 to 2)	80	1 (0 to 2)	0 (0 to 0)*		0.54
Complete cases, mean (SD)	99	1.82 (3.62)	98	2.25 (4.41)	0.23 (–0.99 to 1.46)†		0.71‡
Patients with new infarcts in watershed border zones, n (%)§	89	32 (36.0)	80	33 (41.3)			0.49
Symptoms on awakening	97	0	92	4			
Symptom onset between days 2 and 30	97	1	92	2			
POCD, n (%)							
At 7 d	91	21 (23.1)	78	27 (34.6)		1.76 (0.90 to 3.47)	0.12
At 90 d	89	8 (9.0)	75	5 (6.7)		0.72 (0.23 to 2.31)	0.77

Vedel et al. Circulation 2018

	Low-Target Group	High-Target Group	OR (95% CI)	*P* Value
Length of stay in ICU, h, median (IQR)	21 (20–26)	21 (19–22)		0.82
ICU stays >36 h, n (%)	11 (11.5)	12 (12.6)	1.12 (0.42–2.97)	0.82
Lactate, peak value at POD 1, mmol	2.61±1.17	2.90±1.70		0.16
Inotropes >24 h, n (%)	4 (4.1)	10 (10.4)	2.72 (0.75–12.32)	0.10
Vasopressors >24 h, n (%)	3 (3.1)	10 (10.4)	3.66 (0.90–21.37)	0.05
Time to extubation, h, median (IQR)	4.6 (2.9–6.7)	4.6 (3.2–7.9)		0.43
Atrial fibrillation, n (%)	49 (49.5)	52(53.1)	1.18 (0.65–2.16)	0.57
Creatinine, peak value, mmol/L	118.0±47.4	121.9±48.6		0.57
Hallucinations or delirium, n (%)*	7 (7.1)	10 (10.5)	1.53 (0.50–4.95)	0.45
Length of stay in cardiac surgery ward, d	6 (5–8)	6 (5–7.75)		0.92

Vedel et al. Circulation 2018

	Low-Target Group (n=98)	High-Target Group (n=97)
Hematocrit, before start of surgery, %	40.3±5.9	40.6±4.7
MAP before anesthesia induction, mm Hg	92.3±15.7	96.9±13.4
MAP below target during bypass, n (%)*	2 (2.0)	18 (18.5)
MAP above target during bypass, n (%)†	5 (5.1)	0 (0)
Hematocrit, mean level during bypass, %	31.5±3.8	33.1±4.2
Surgery time, min	184.9±50.8	194.3±66.6
Bypass time, min	94.0±33.0	105.6±77.4
Cross-clamp time, min‡	63.3±26.9	64.8±32.6
Peak lactate level during surgery, mmol	2.25±0.83	2.16±0.82
Norepinephrine infused in the OR, µg/kg	2.65±6.01	17.43±20.14
Patients receiving norepinephrine in the OR, n (%)	35 (35.7)	90 (92.7)

>> 2.4

Vedel et al. Circulation 2018

Then….

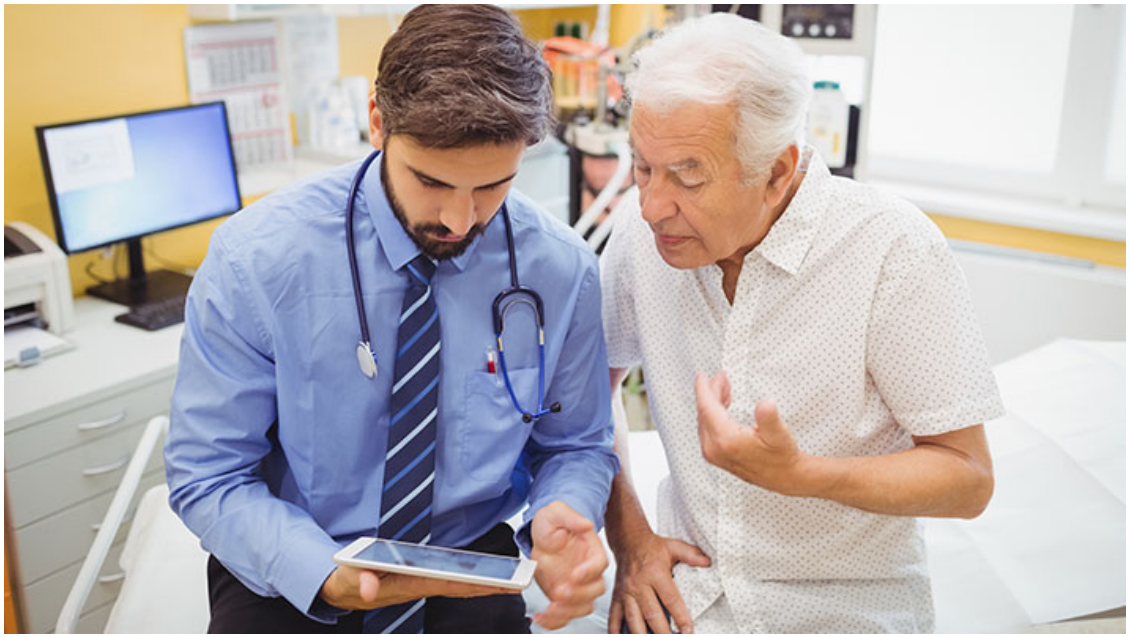
Need to be avoided:

- ✓ Low MAP WITH Low Pump Flow
- ✓ High MAP WITH High flow

But we can probably do it better….

	Low-Target Group, n		High-Target Group, n		Difference (95% CI)	OR (95% CI)	*P* Value
Primary outcome							
Total volume of new cerebral lesions, mm^3							
Complete cases, median (IQR)	89	25 (0 to 118)	80	29 (0 to 143)	0 (–25 to 0.028)*		0.41
Excluding 3 outliers, median (IQR)	88	24 (0 to 118)	78	28 (0 to 134)			
Complete cases, mean (SD)	89	415 (2682)	80	488 (2539)	8 (–978 to 994)†		0.99‡
Excluding 3 outliers, mean (SD)	88	133 (313)	78	144 (265)			
Secondary outcome							
Total number of new cerebral lesions							
Complete cases, median (IQR)	89	1 (0 to 2)	80	1 (0 to 2)	0 (0 to 0)*		0.54
Complete cases, mean (SD)	99	1.82 (3.62)	98	2.25 (4.41)	0.23 (–0.99 to 1.46)†		0.71‡
Stroke, n (%)		1 (1.1)		6 (7.0)		6.64 (0.78 to 310.75)	0.06
Symptoms on awakening	97	0	92	4			
Symptom onset between days 2 and 30	97	1	92	2			

Vedel et al. Circulation 2018



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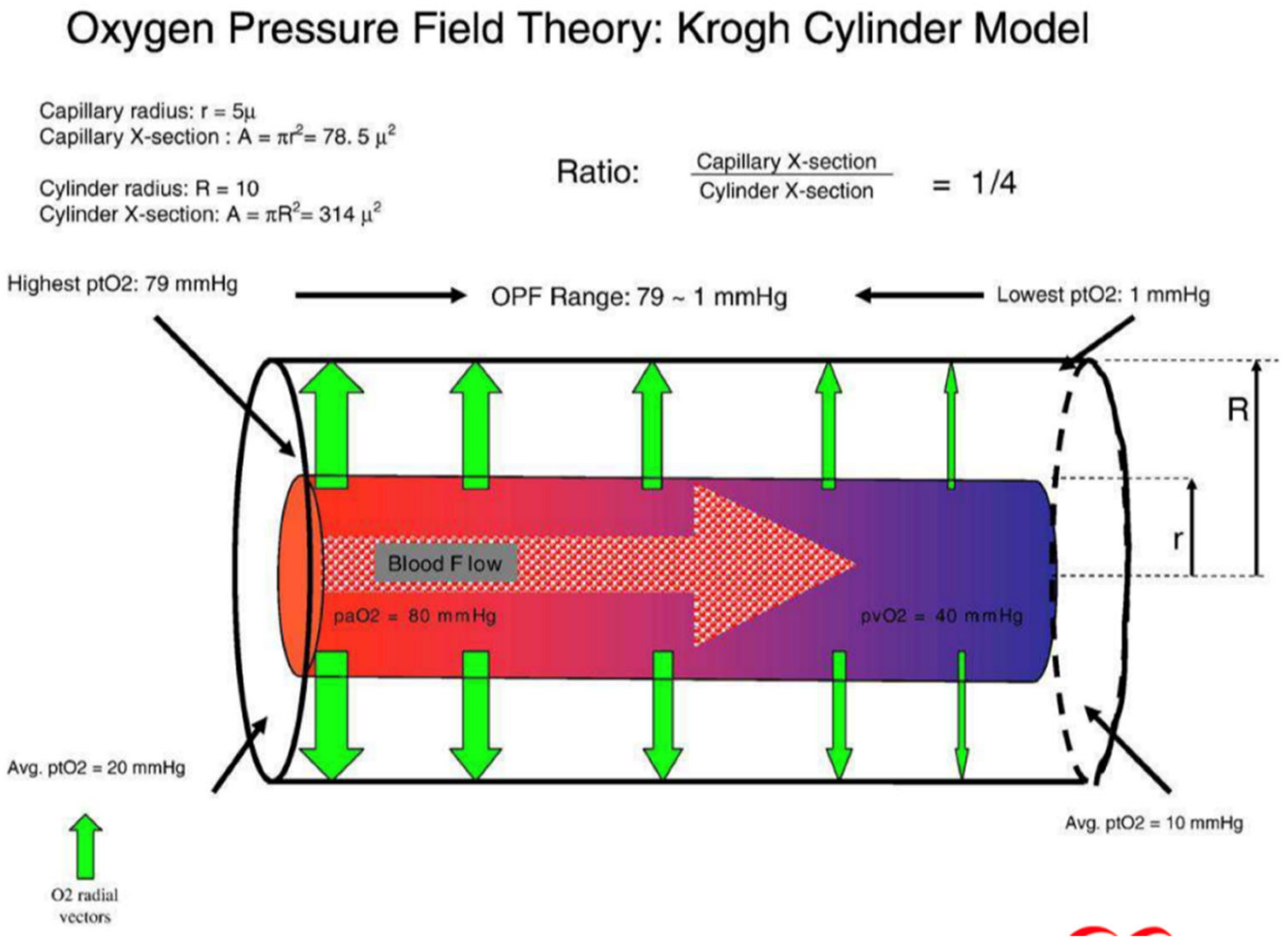
The « adapted » Pump Flow:

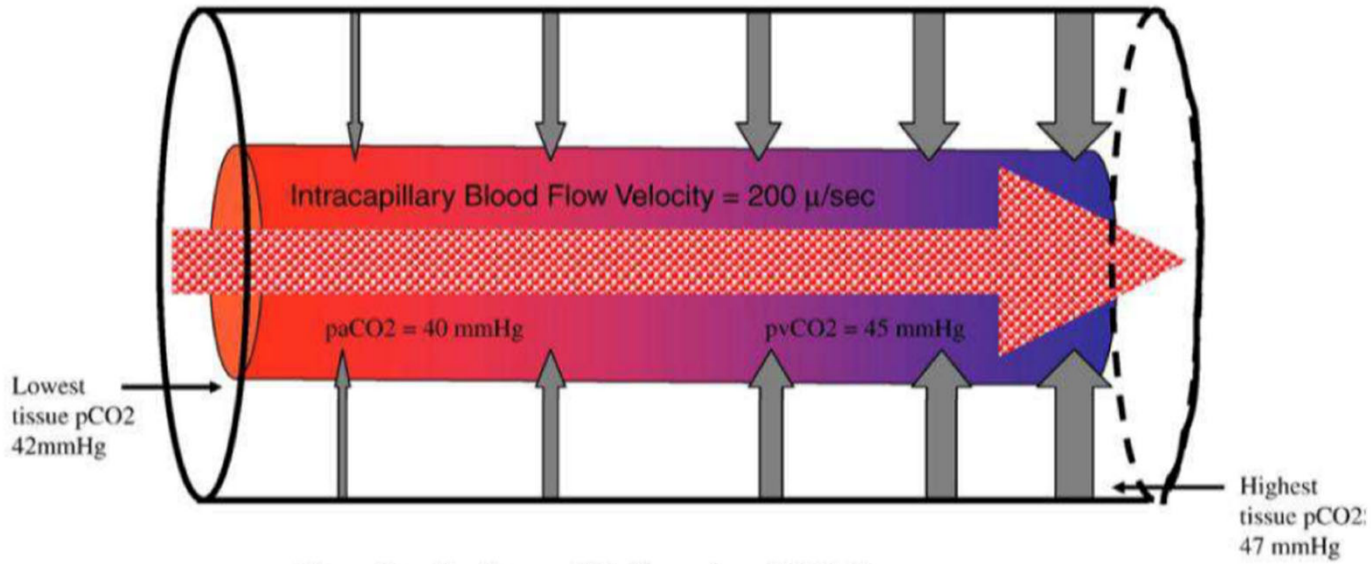
Role of the **G**oal **D**irected **P**erfusion

Tissular perfusion: DO_2



De Somer et al. Crit Care 2018

Tissular perfusion: VCO_2

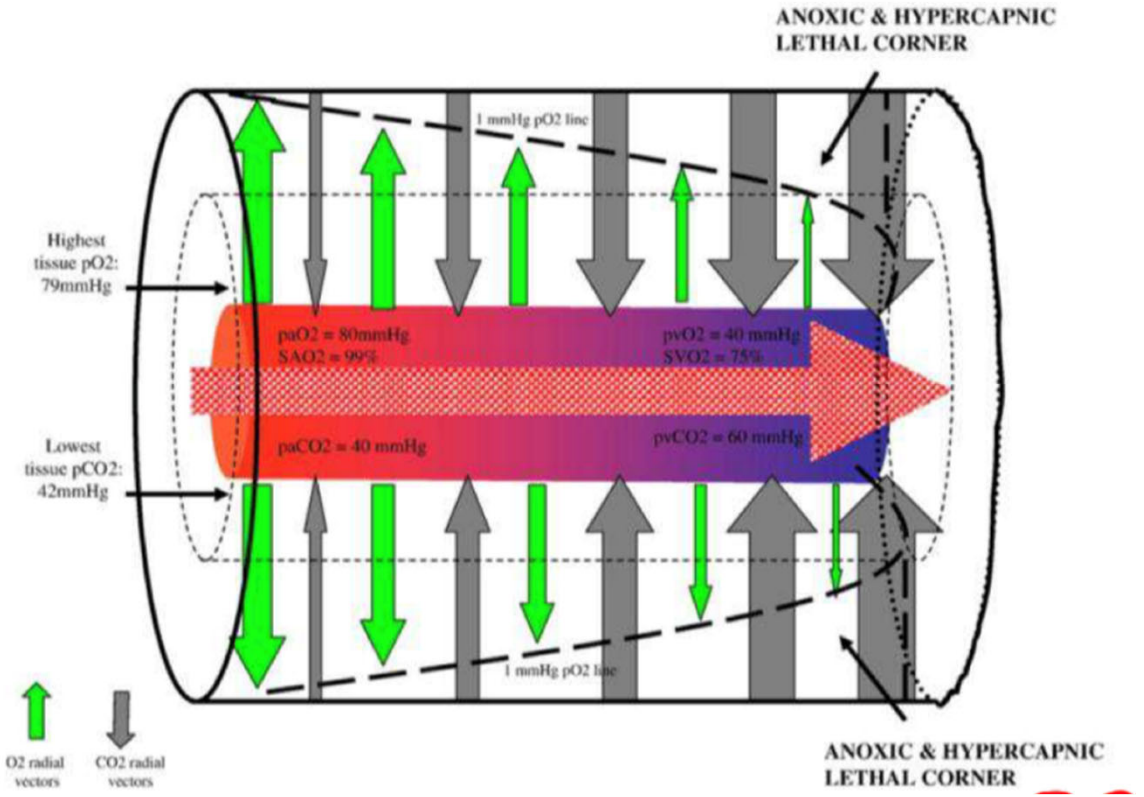


Cardiac Index = 12.9 ÷ p(v-a)CO2

CI = 12.9 ÷ 5 = 2.6 L/min

De Somer et al. Crit Care 2018

Tissular perfusion: VCO_2

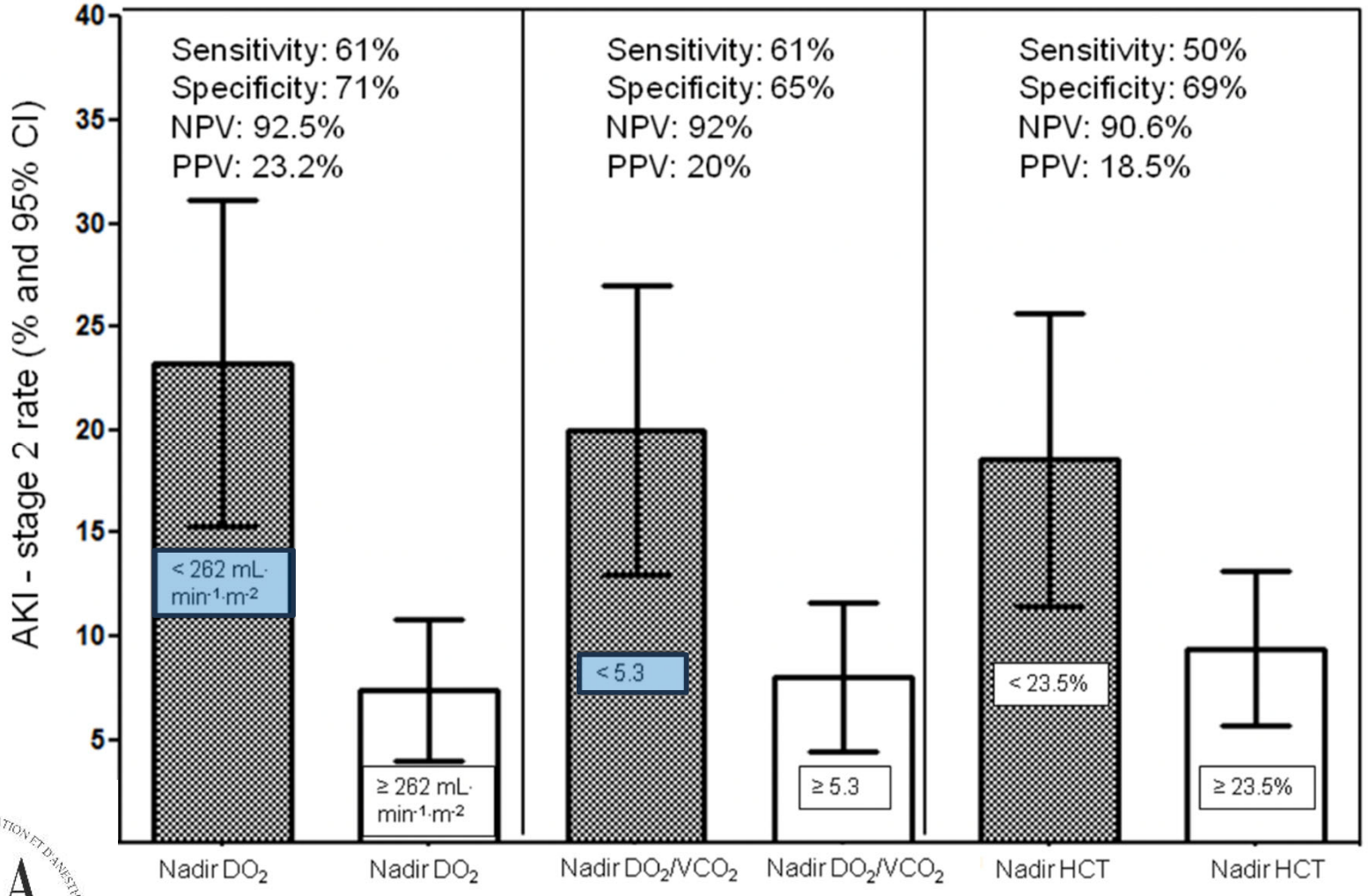


De Somer et al. Crit Care 2018

O2 delivery and CO2 production during cardiopulmonary bypass as determinants of acute kidney injury: time for a goal-directed perfusion management?

- Prospective study, retrospective analysis
- 359 patients
- DO_2 and DO_2/VCO_2
- IC 2.4-2.8 L/min/m^2
- T: 30-34°C
- CGR if <6-7g/dL
- Objective: Association DO_2 &DO_2/VCO_2 and AKI (AKI stages) for the first 48 hours after surgery
- Multivariable logistic regression models

De Somer et al. Crit Care 2011

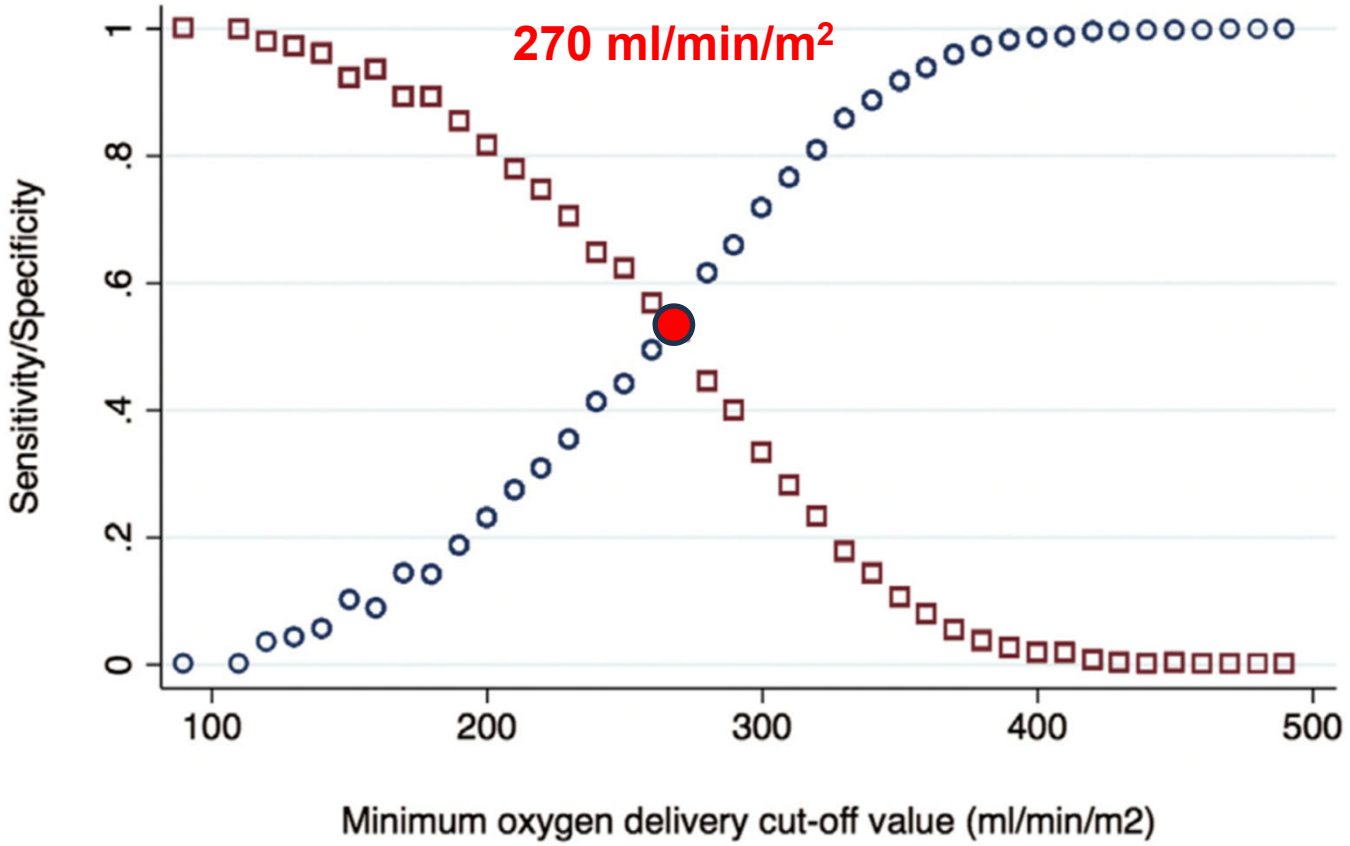


De Somer et al. Crit Care 2011

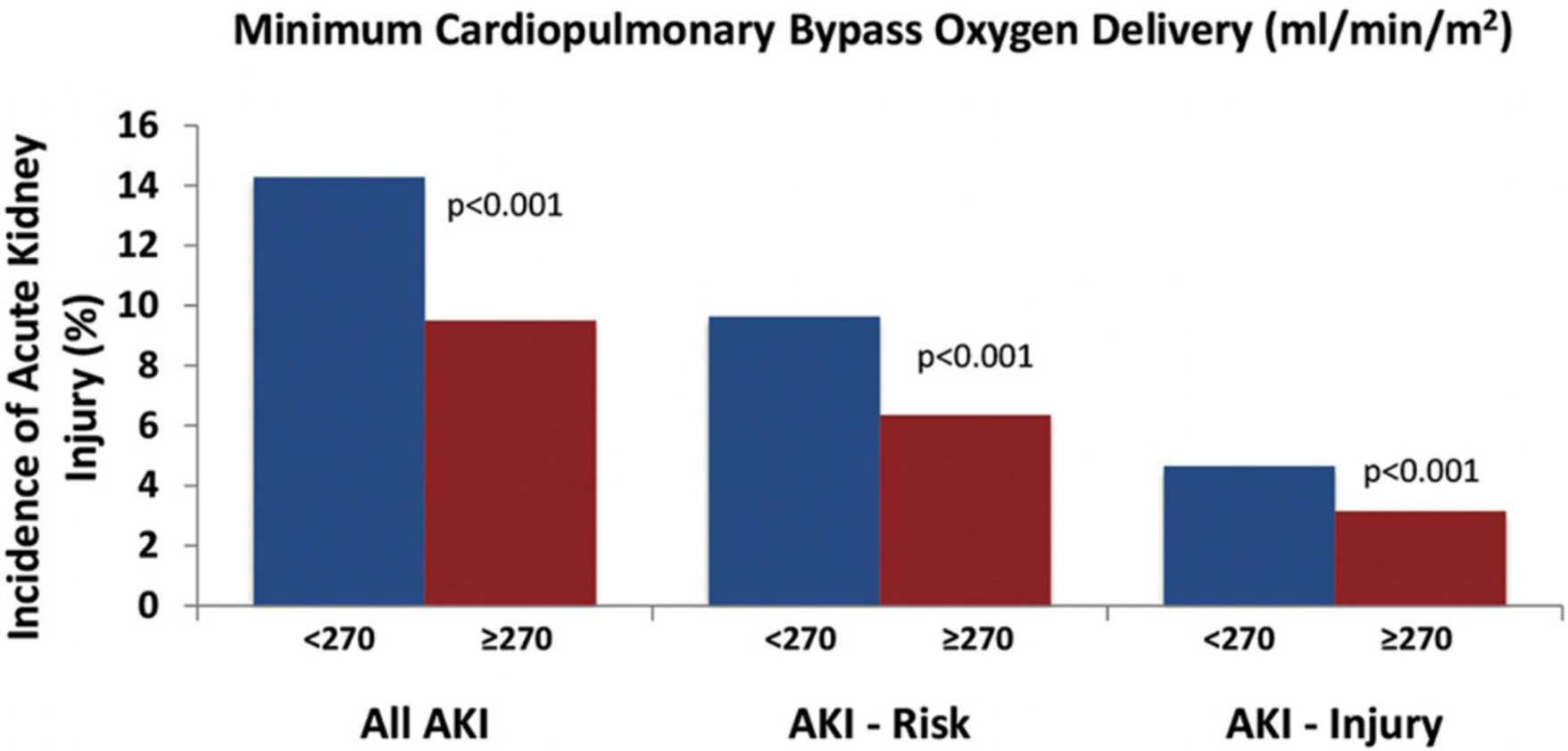
Predictive Capacity of Oxygen Delivery During Cardiopulmonary Bypass on Acute Kidney Injury

- Prospective database (9 Australia and New Zeland center)
- Retrospective analysis
- 19 410 patients with CPB
- For 2008 to 2016 in (9 Australia and New Zeland center)
- T°: ?
- Objective: Multivariate logistic regression for calculating the optimal minimal DO_2 value to predict postoperative AKI (RIFLE score)

Newland et al. Ann Thorac Surg 2019



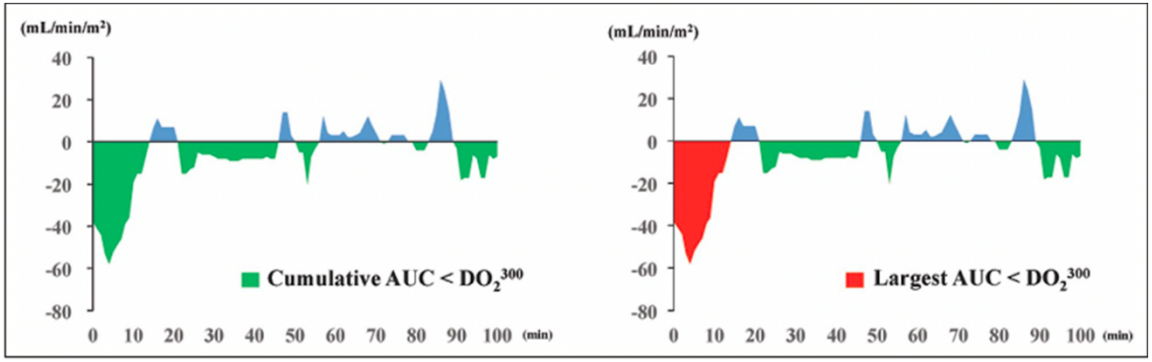
Newland et al. Ann Thorac Surg 2019



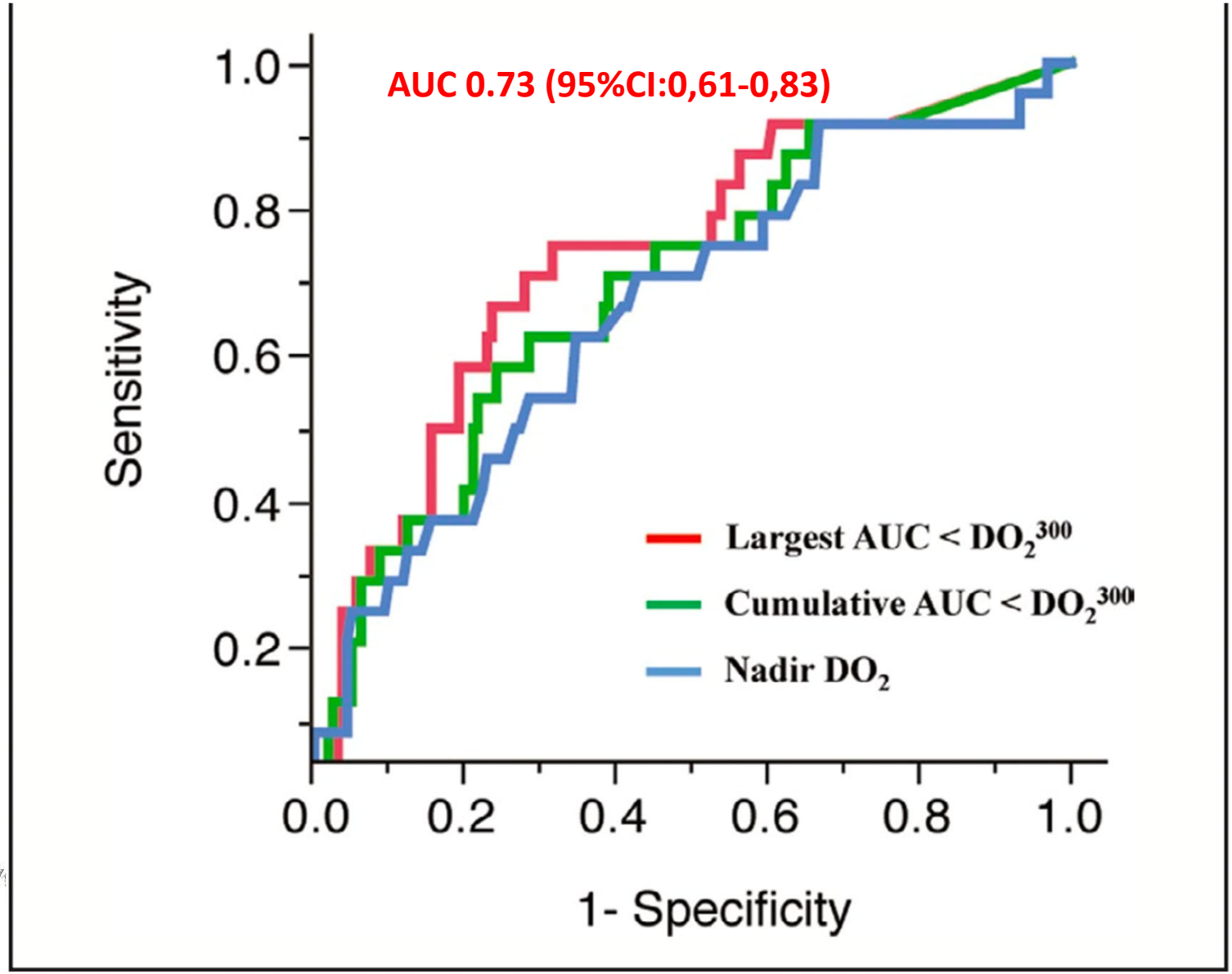
Newland et al. Ann Thorac Surg 2019

A Better Predictor of Acute Kidney Injury After Cardiac Surgery: The Largest Area Under the Curve Below the Oxygen Delivery Threshold During Cardiopulmonary Bypass

- Prospective study
- 202 patients between 2017 and 2019
- Threshold : 300 ml/min/m^2
- T = 34°C
- AKI (KDIGO)
- CI: 2.5 mL/min/m^2
- CGR: <8g/dL
- Objective: correlation between AUC < 300 ml/min/m^2 & AKI



Oshita et al. J Am Heart Assoc 2020



Oshita et al. J Am Heart Assoc 2020

A pilot goal-directed perfusion initiative is associated with less acute kidney injury after cardiac surgery

- Before/After study
- 88 control patients (2010-2015) matched 1:1 to 88 patients with GDP (>2015) with propensity score analysis
- IC: for DO_2 > 300 ml/min/m^2 vs 1.8-2.2 L/min/m^2
- T: 28-34°C
- CGR if Hb < 8g/dL
- Outcome: AKI (KDIGO) for the first 72 hours after surgery

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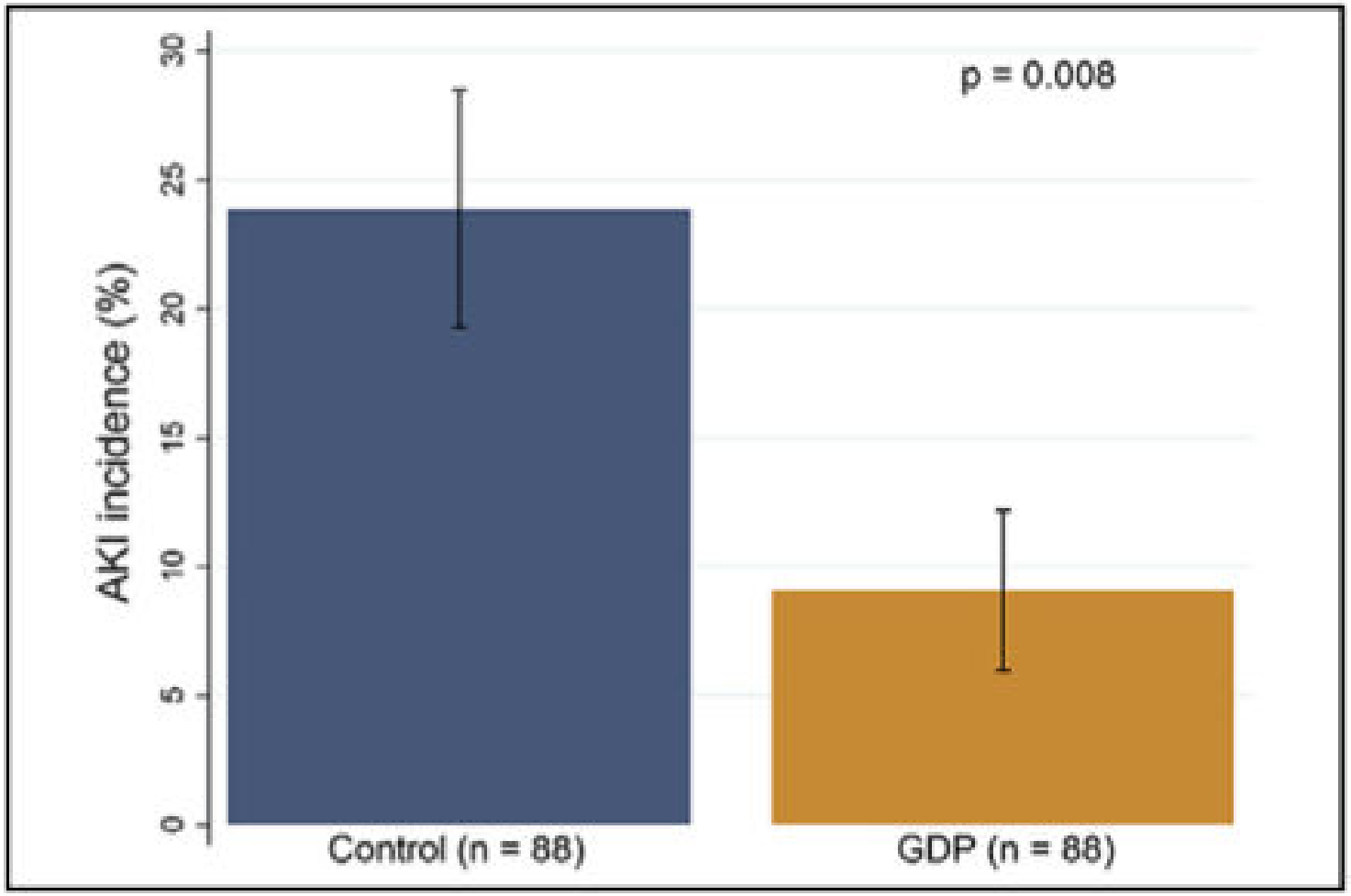
Magruder et al. J Thorac Cardiovasc Surg 2017

	Controls	Goal-directed perfusion patients	*P* value
Crystalloid prime volume (median mL, IQR)	650 (500–1000)	800 (500–1000)	.28
PRBC in prime (%, n)	9.5 (8)	14.8 (13)	.35
Received any mannitol in prime (%, n)	91.7 (77/84)	17.1 (15/88)	**<.001**
Total phenylephrine administered (median mg ± IQR)	1.5 (0.7–3.25)	0.65 (0.2–2.4)	**.001**
Heparin drip used in OR	0	50.6 (45/88)	**<.001**
Nadir temperature on CPB (°C ± SD)	32 ± 3	33 ± 3	**.02**
Hemoconcentrator used (%, n)	46.4 (39/84)	98.9 (87/88)	**<.001**
Volume exchanged with hemoconcentrator (median L ± IQR)	2.0 (1.2–3.0)	6.0 (4.3–9.0)	**<.001**
Nadir Hb on CPB (mg/dL ± SD)	9.0 ± 1.8	8.7 ± 2.0	.46
Nadir pump flow/m^2 (L/min/m^2 BSA ± SD)	1.9 ± 0.3	2.4 ± 0.4	**<.001**
Nadir DO2 (mL O_2/min/m^2 BSA ± SD)	240 ± 64	302 ± 62	**<.001**

Magruder et al. J Thorac Cardiovasc Surg 2017



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Magruder et al. J Thorac Cardiovasc Surg 2017

Correlating oxygen delivery on cardiopulmonary bypass with Society of Thoracic Surgeons outcomes following cardiac surgery

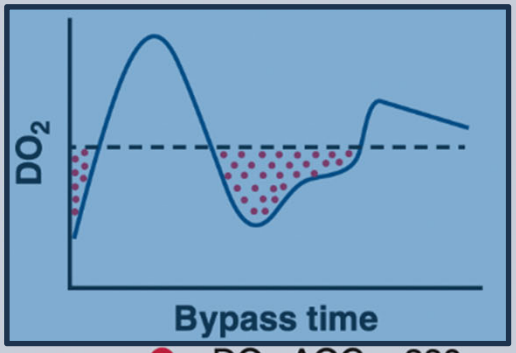
- Retrospective analysis study
- 834 patients between 2019 to 2020
- AUC DO_2 < 280 ml/min/m^2
- Composite Outcome: correlation with mortality, renal failure, prolonged ventilation > 24h, stroke, Wound infection and reoperation

Magruder et al. J Thorac Cardiovasc Surg 2022

Oxygen delivery on bypass and STS outcomes

Methods

- Adult cardiac surgery patients
- Primary outcome: STS composite morbidity/mortality
- Oxygen delivery (DO_2): area over curve but under threshold



Results

- 834 patients undergoing STS index operations (43% isol. CAB)
- DO_2 < 280-AOC independently associated w/ **STS M/M** (P = .02 non-isol CAB, P = .07 overall)
- DO_2 < 280-AOC independently associated w/ **prolonged ventilation > 24h** (P = .04) and **AKI < 72h** (P = .04)
- Component associations with **flow** thresholds >> Hb thresholds

Implications

- Oxygen delivery associated with adverse outcomes
- Conduct of intraoperative perfusion may be important (especially flow)
- Further study will clarify relationship with individual performance measures

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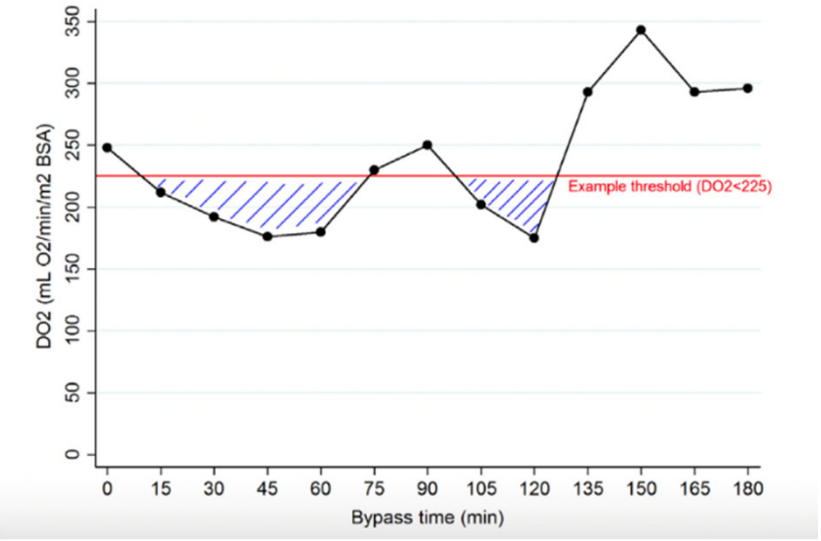
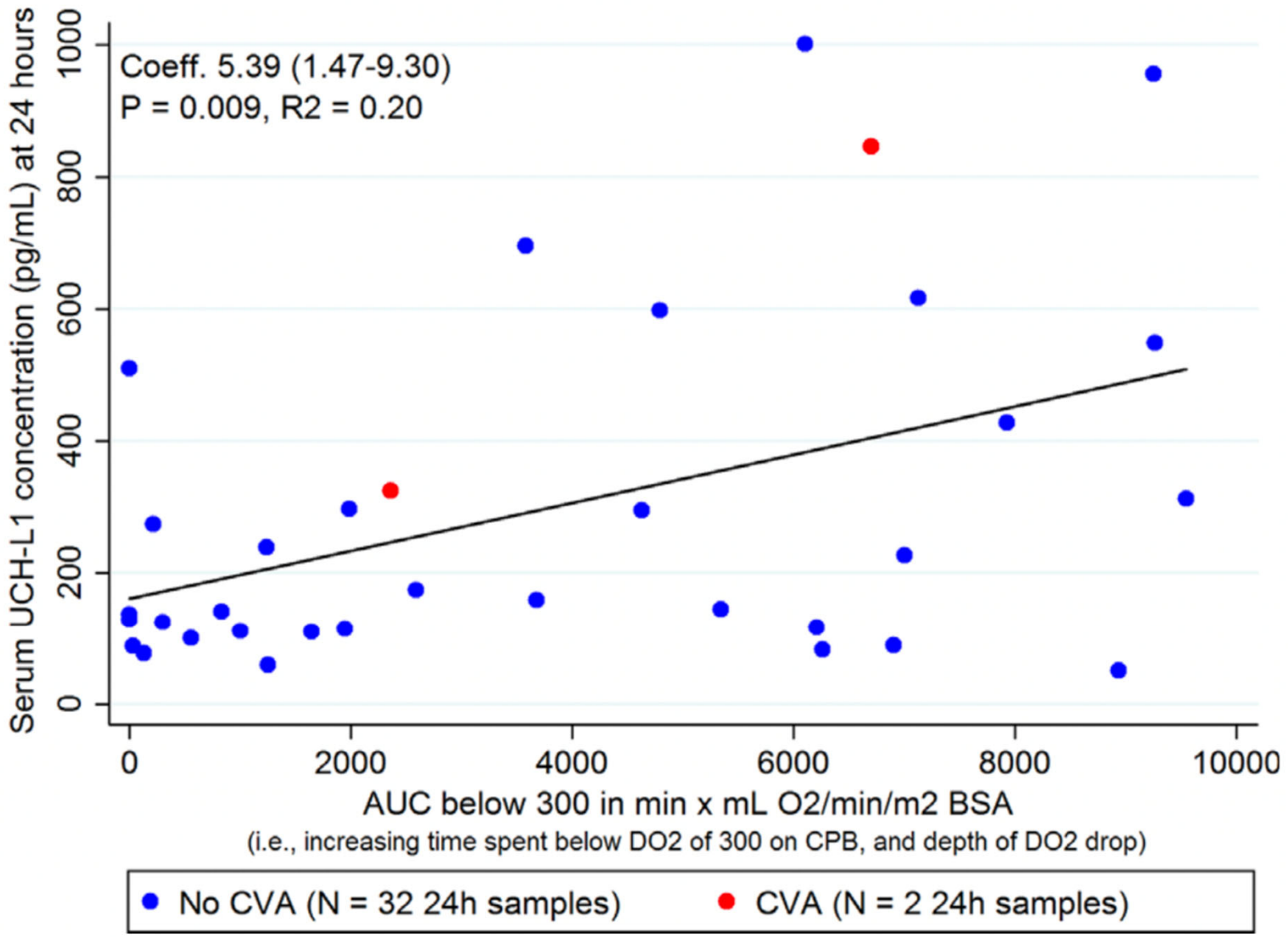
Magruder et al. J Thorac Cardiovasc Surg 2022

Correlating Oxygen Delivery During Cardiopulmonary Bypass With the Neurologic Injury Biomarker Ubiquitin C-Terminal Hydrolase L1 (UCH-L1)

- Retrospective study
- 43 patients
- UCH-L1 levels at 6 and 24 hours after CPB cessation
- Objective: AUC DO_2 < 225 ml/min/m^2 correlated to stroke with TDM and IRM



Magruder et al. J Cardiothorac Vasc Anesth 2018



Magruder et al. J Cardiothorac Vasc Anesth 2018

Goal-directed perfusion to reduce acute kidney injury: A randomized trial

- RCT (multicenter study)
- 326 patients
- DO_2 > 280 ml/min/m^2
- IC 2.4-3.0 L/min/m^2 vs 2.4 L/min/m^2
- T: 32-34°C
- CEC > 60 min or < 90th percentile of the CPB time distribution
- CGR if DO_2 < 280 ml/min/m^2 and Sv02 < 68 and/or Oxygen extraction rate > 40%
- Outcome: AKI (AKIN) for the first 48 hours after surgery

Ranucci et al. J Thorac Cardiovasc Surg 2018

Variable	GDP arm (n = 156)	Control arm (n = 170)
Type of surgery, n (%)		
Isolated coronary surgery	44 (28.2)	42 (24.7)
Other isolated procedure	40 (25.6)	65 (38.2)
Double procedure	63 (40.4)	54 (31.8)
Triple procedure	9 (5.8)	9 (5.3)
Ascending aorta	20 (13.0)	25 (14.7)
CPB duration, min, median (IQR)	116 (95-144)	109 (86-144)
Aortic cross clamp-time duration, min, median (IQR)	84 (65-108)	82 (65-113)
Lowest temperature on CPB, °C, median (IQR)	33 (32-34)	33 (32-34)
Nadir oxygen delivery, $mL \cdot min^{-1} \cdot m^{-2}$, median (IQR)†	315 (290-350)	301 (270-345)
Delta creatinine, mg/dL, median (IQR)	−0.04 (−0.08 to 0.19)	0.07 (−0.08 to 0.30)
Priming volume, mL, median (IQR)	930 (800-1262)	930 (653-1260)

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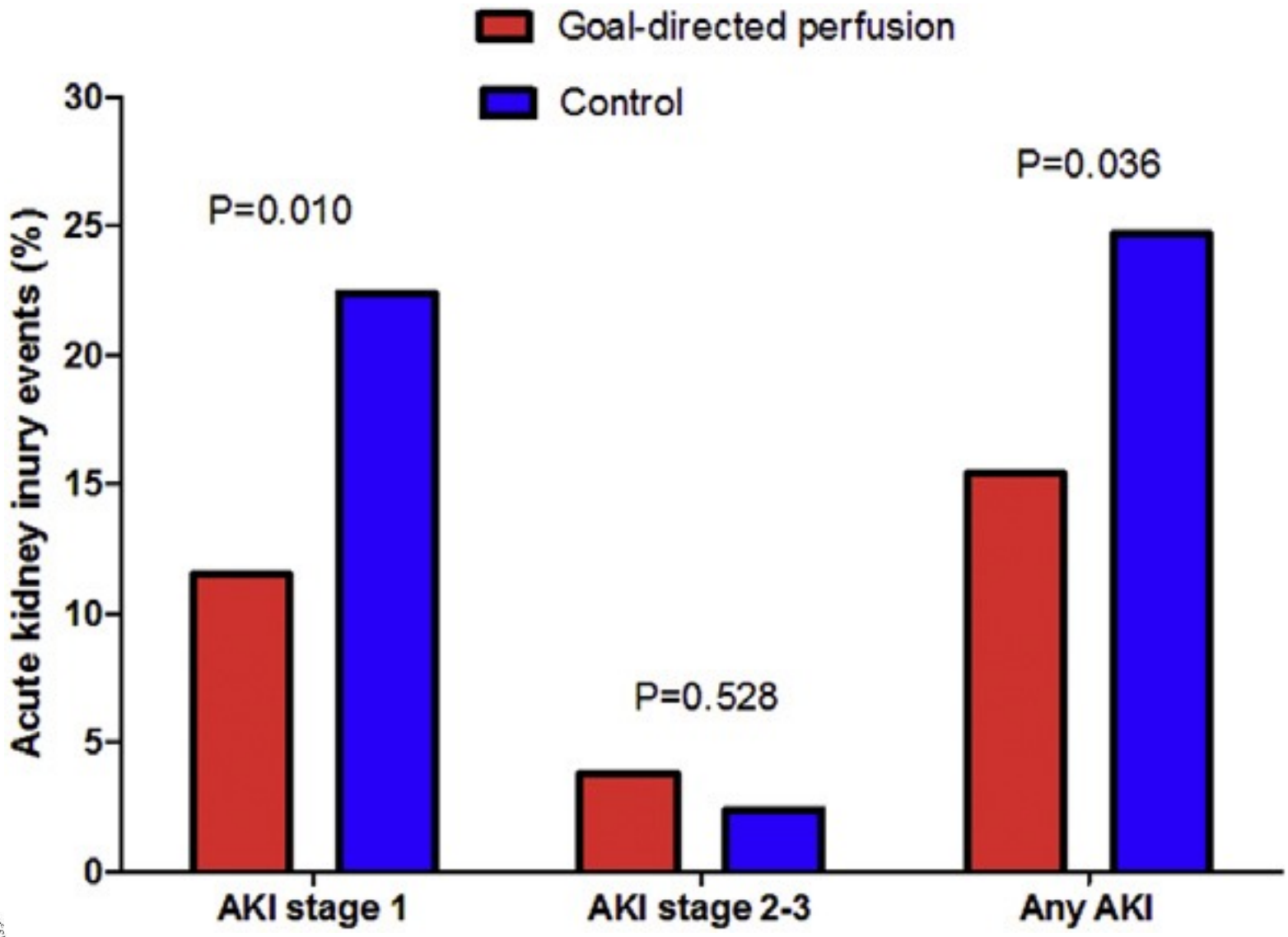
Ranucci et al. J Thorac Cardiovasc Surg 2018



Ranucci et al. J Thorac Cardiovasc Surg 2018

Oxygen delivery-guided perfusion for the prevention of acute kidney injury: A randomized controlled trial

- RCT (1 center)
- 300 patients
- DO_2 > 300 ml/min/m^2
- IC 2.6-3.0 L/min/m^2 vs 2.6 L/min/m^2
- T >35°C
- CGR if <7g/dL
- Outcome: AKI (KDIGO) for the first 48 hours after surgery

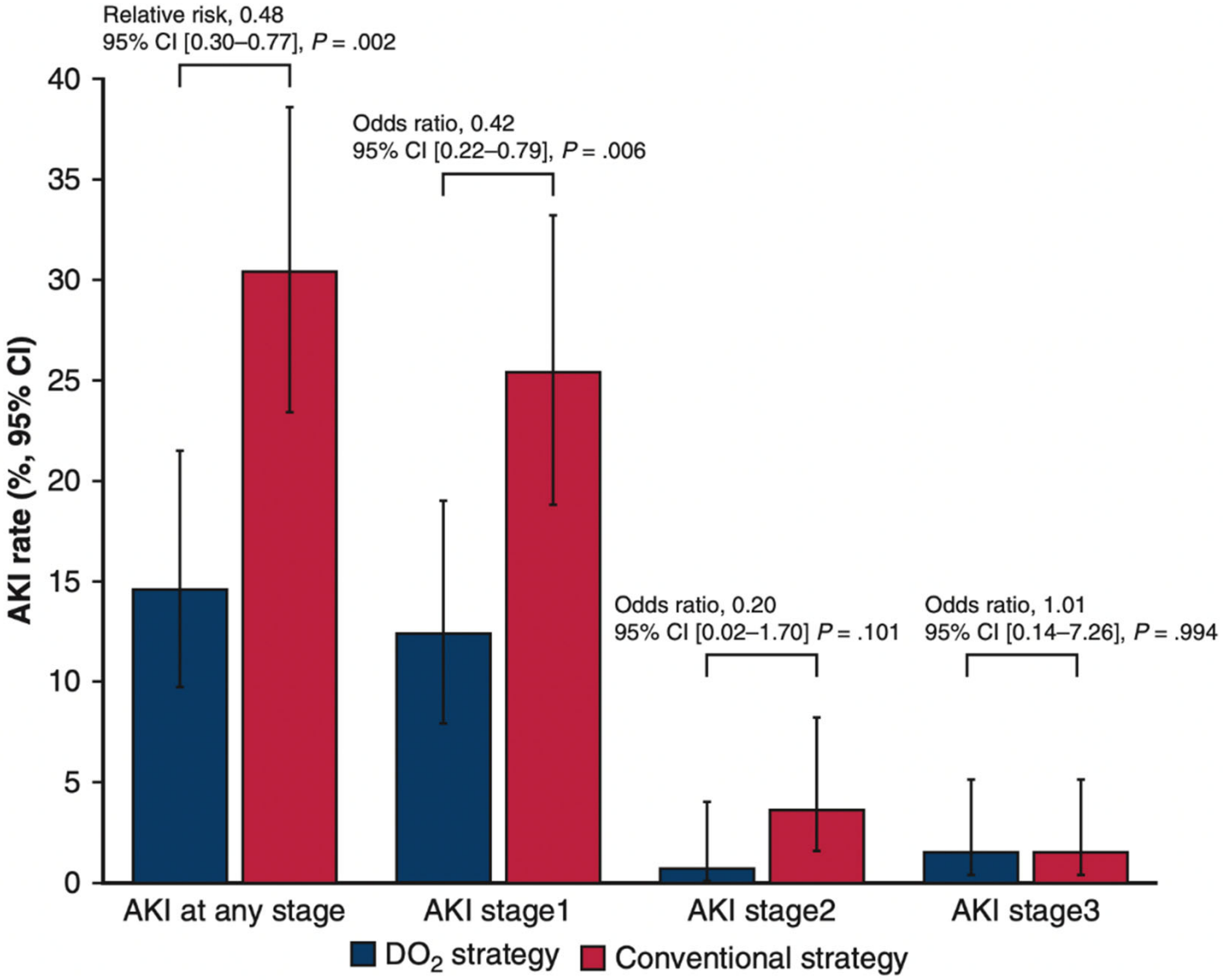
Mukaida et al. J Thorac Cardiovasc Surg 2023

Variables	Intervention		
	DO_2 strategy n = 137	Conventional strategy n = 138	*P* value
Surgical procedure			.956
CABG + valve	14 (10.2%)	13 (9.4%)	
CABG + valve + TA replacement	1 (0.7%)	2 (1.5%)	
Valve	97 (70.8%)	104 (75.4%)	
Valve + TA replacement	14 (10.2%)	11 (8.0%)	
TA replacement	2 (1.5%)	1 (0.7%)	
Adult congenital	4 (2.9%)	3 (2.2%)	
Cardiac tumor	5 (3.7%)	4 (2.9%)	
Redo operation	9 (6.6%)	8 (5.8%)	.790
Perfusion time (min)	120 (103 to 161)	124 (101 to 166)	.897
Crossclamp time (min)	99 (79 to 133)	100 (80 to 134)	.889

Mukaida et al. J Thorac Cardiovasc Surg 2023

Variables	Intervention		
	DO_2 strategy n = 137	Conventional strategy n = 138	*P* value
Nadir rectal temperature (°C)	34.9 (34.8 to 34.9)	34.9 (34.9 to 34.9)	.125
Nadir Hct (%)	23.9 (22.6 to 25.6)	23.8 (22.1 to 25.2)	.161
Postoperative lactate (mmol/L)	1.0 (0.8 to 1.2)	1.1 (0.8 to 1.3)	.426
Fluid balance			
On CPB (mL)	883 (−74 to 2067)	641 (−464 to 1430)	.069
Overall (mL)	2132 (1338 to 3381)	1974 (875 to 3444)	.253
Urine output			
On CPB (mL)	1500 (770 to 2800)	1225 (715 to 2250)	.162
Overall (mL)	2350 (1405 to 3575)	1985 (1250 to 3013)	.213
Median PI (L/min/m^2)	2.82 (2.73 to 2.89)	2.63 (2.61 to 2.68)	<.001
Total dose of phenylephrine during CPB (mg)	2.6 (1.6 to 4.0)	3.0 (1.7 to 4.1)	.228
AUC < DO_2i^{300}	56 (0 to 229)	703 (57 to 2244)	<.001
Time < DO_2i^{300} (min)	2.7 (0.0 to 8.0)	20.3 (3.6 to 59.0)	<.001
AUC < SvO_2^{70}	0 (0 to 4)	3 (0 to 19)	<.001
Time < SvO_2^{70} (min)	0.0 (0.0 to 0.5)	0.7 (0.0 to 2.7)	<.001
AUC < MAP^{60}	505 (308 to 828)	673 (438 to 1054)	<.001
Time < MAP^{60} (min)	19 (12.3 to 33.8)	24.8 (17.2 to 36.2)	.005

Mukaida et al. J Thorac Cardiovasc Surg 2023



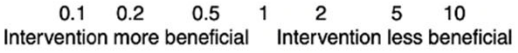
Mukaida et al. J Thorac Cardiovasc Surg 2023

Prevention of cardiac surgery-associated acute kidney injury: a systematic review and meta-analysis of non-pharmacological interventions

- 601 patients
- AKI: KDIGO and AKIN score
- DO_2: < 280 ml/min/m^2 and < 300 ml/min/m^2

RR 0,55 (IC95%: 0,40-0,76)

Intervention	Number of RCTs	Number of events/patients Intervention group	Number of events/patients Control group	RR	CI (95%)	I2	Phet
Goal Directed Perfusion	2	44/293	84/308	0.55	[0.40; 0.76]	0%	0.44
Pulsatile flow during CPB	10	121/968	194/1025	0.69	[0.48; 0.99]	53%	0.01
Minimally invasive extracorporeal circulation	14	46/787	67/830	0.78	[0.54; 1.13]	0%	0.33
Epidural Analgesia	4	18/443	20/460	0.83	[0.27; 2.58]	56%	0.07
Remote Ischemic Preconditioning	31	855/3890	932/3848	0.86	[0.78; 0.95]	23%	0.07
Tight glycemic control	10	53/1350	76/1403	0.86	[0.55; 1.35]	26%	0.25
KDIGO care bundle	3	142/323	162/339	0.91	[0.65; 1.27]	64%	0.08
Hyperoxia during CPB	3	134/359	139/363	0.95	[0.80; 1.13]	5%	0.57
Restrictive transfusion strategie	6	956/4144	944/4145	1.02	[0.92; 1.12]	3%	0.67
High• Target arterial pressure	3	53/289	42/288	1.19	[0.84; 1.70]	0%	0.19

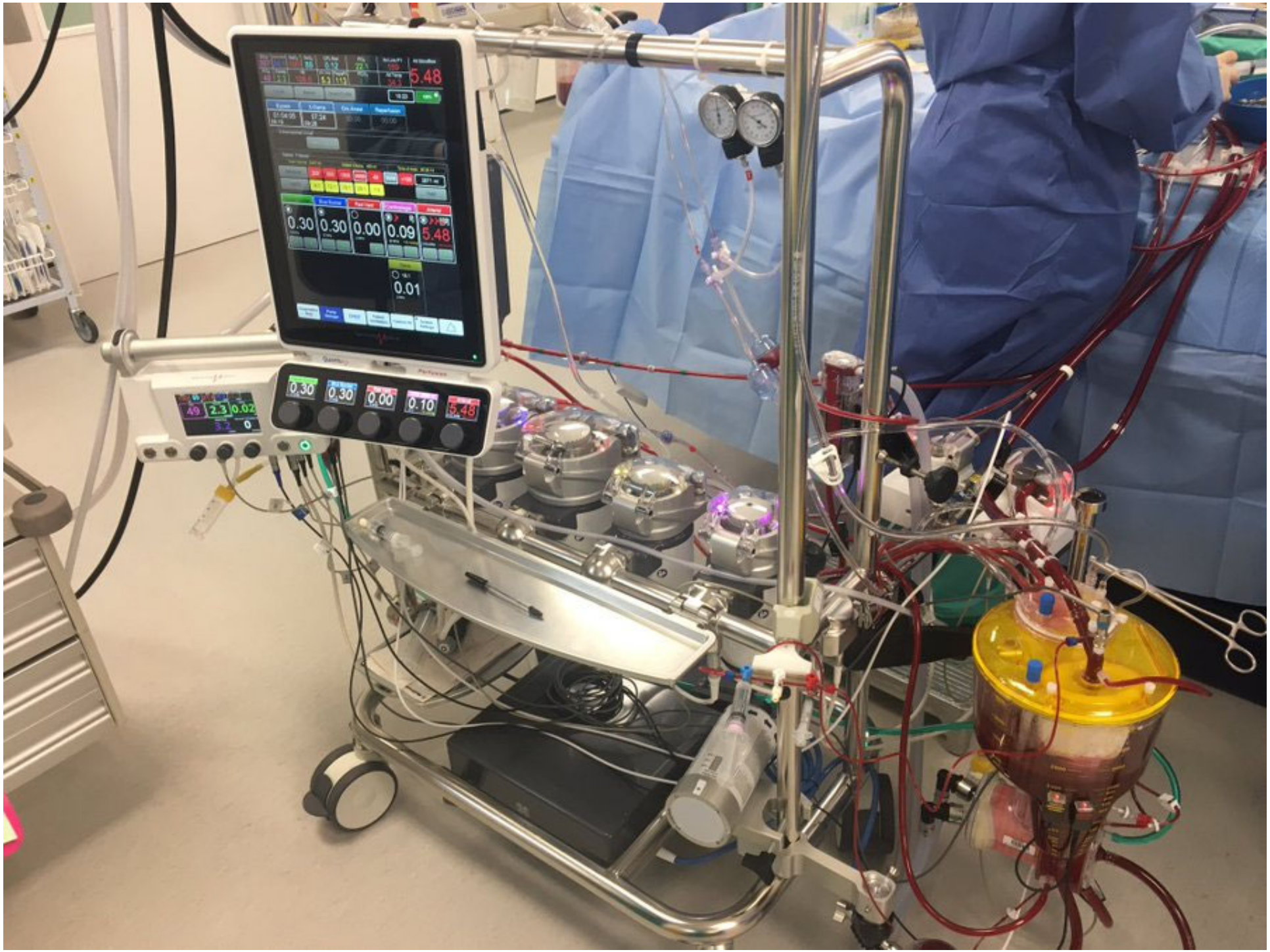


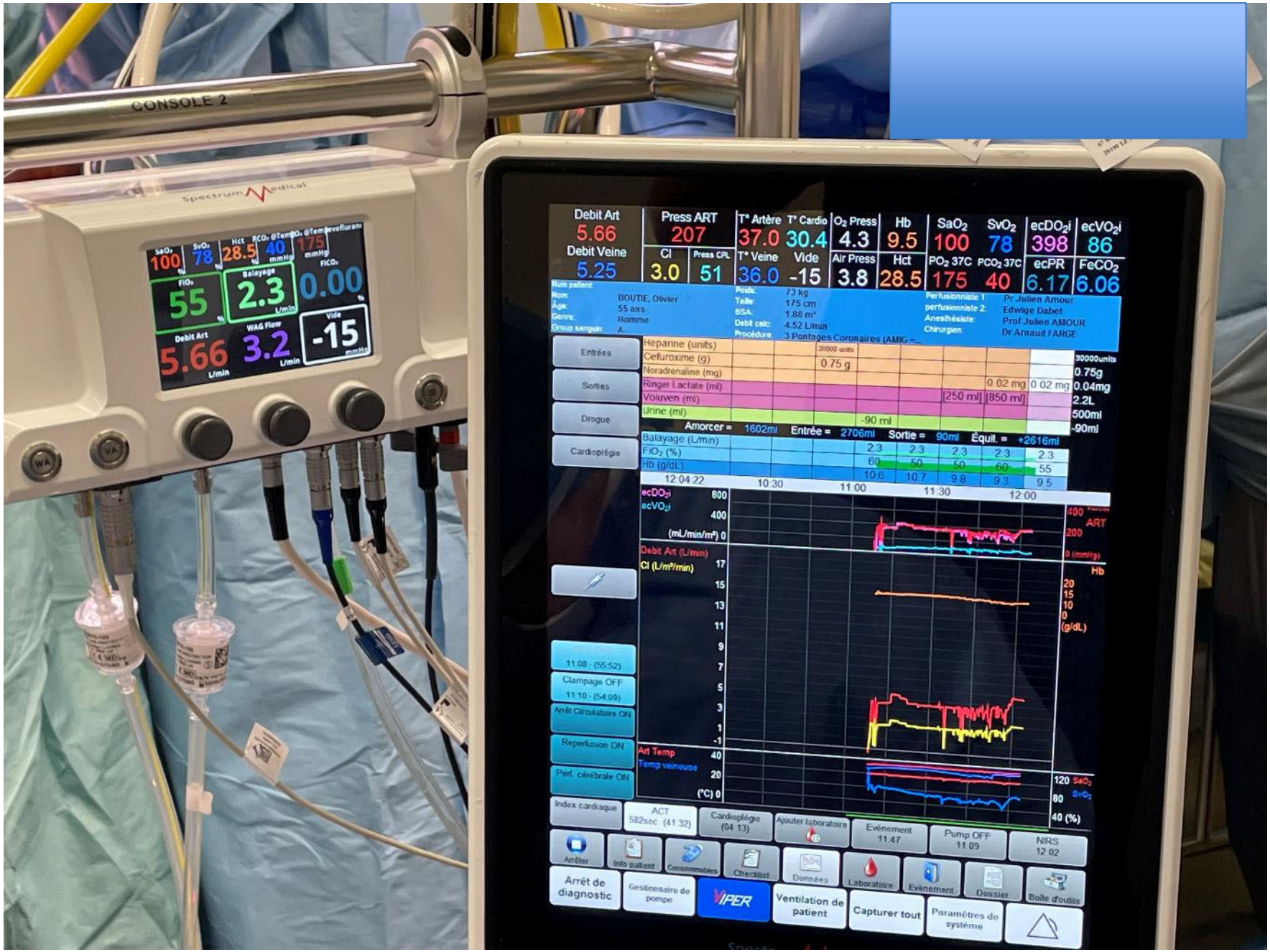
Hariri et al. Crit Care 2023

2024 EACTS/EACTAIC/EBCP Guidelines on cardiopulmonary bypass in adult cardiac surgery

Recommendations	Class[a]	Level[b]
GDP is recommended to reduce the postoperative rate of early stages of acute kidney injury.	I	A
It is recommended that GDP be aimed at limiting the nadir of DO_2 and the length of CPB time with low DO_2 values.	I	B
It may be considered that individualized DO_2 based on preoperative risk factors, peripheral oxygenation and pulse pressure, be identified preoperatively and maintained during CPB.	IIb	B
It is recommended that a minimal value of DO_2 of 280 ml/min/m^2 be used to reduce the risk of AKI stage 1.	I	A
It should be considered to maintain GDP with a lower threshold of DO_2 between 280 and 300 ml/min/m^2 during normothermic CPB in order to improve clinical outcomes.	IIa	B

Wahba et al. Eur J Cardiothorac Surg 2025

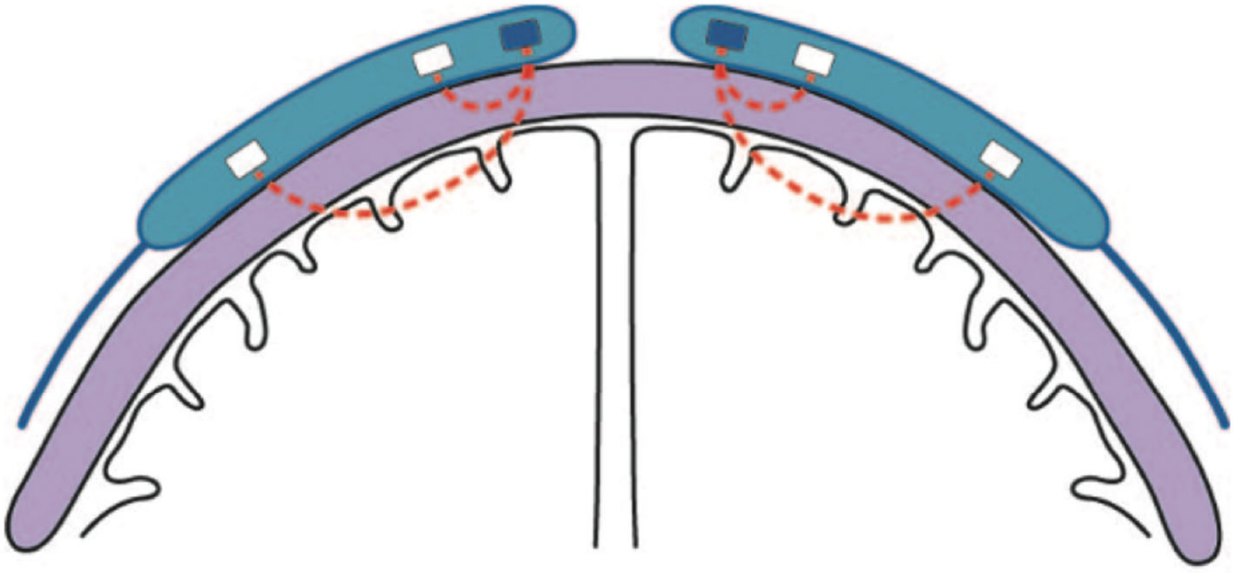

5.48
0.30
0.30
0.00
0.09
5.48
0.01
0.30
0.30
0.00
0.10
5.48
49
2.3
0.02


CONSOLE 2
Spectrum Medical
Debit Art 5.66
Press ART 207
T° Artère 37.0
T° Cardio 30.4
O2 Press 4.3
Hb 9.5
SaO2 100
SvO2 78
ecDO2i 398
ecVO2i 86
Debit Veine 5.25
CI 3.0
Press CPL 51
T° Veine 36.0
Vide -15
Air Press 3.8
Hct 28.5
PO2 37C 175
PCO2 37C 40
ecPR 6.17
FeCO2 6.06
Num patient:
Nom: BOUTIE, Olivier
Âge: 55 ans
Genre: Homme
Group sanguin: A
Poids: 73 kg
Taille: 175 cm
BSA: 1.88 m²
Débit calc: 4.52 L/min
Procédure: 3 Pontages Coronaires (AMG –
Perfusionniste 1: Pr Julien Amour
perfusionniste 2: Edwige Dabet
Anesthésiste: Prof Julien AMOUR
Chirurgien: Dr Arnaud FARGE
Entrées
Sorties
Drogue
Cardioplégie
Heparine (units)
Cefuroxime (g)
Noradrenaline (mg)
Ringer Lactate (ml)
Voluven (ml)
Urine (ml)
Amorcer = 1602ml Entrée = 2706ml Sortie = 90ml Equil. = +2616ml
Balayage (L/min)
FiO2 (%)
Hb (g/dL)
12:04:22
10:30
11:00
11:30
12:00
ecDO2i
ecVO2i
(mL/min/m²)
Débit Art (L/min)
CI (L/m²/min)
Art Temp
Temp veineuse
(°C)
ART
Hb
(g/dL)
SaO2
SvO2
(%)
11:08 - (55:52)
Clampage OFF
11:10 - (54:09)
Arrêt Circulatoire ON
Reperfusion ON
Perf. cérébrale ON
Index cardiaque
ACT
582sec. (41:32)
Cardioplégie
(04:13)
Ajouter laboratoire
Evénement
11:47
Pump OFF
11:09
NIRS
12:02
Arrêter
Info patient
Consommables
Checklist
Données
Laboratoire
Evénement
Dossier
Boîte d'outils
Arrêt de diagnostic
Gestionnaire de pompe
VIPER
Ventilation de patient
Capturer tout
Paramètres de système

The « adapted » cerebral perfusion: **NIRS** to detect loss of autoregulation ?

A Multicenter Pilot Study Assessing Regional Cerebral Oxygen Desaturation Frequency During Cardiopulmonary Bypass and Responsiveness to an Intervention Algorithm

Balachundhar Subramanian, MD,* Charles Nyman, BS,†‡ Maria Fritock, MD,§ Rebecca Y. Klinger, MD,‖ Roman Sniecinski, MD,¶ Philip Roman, MD,# Julie Huffmyer, MD,** Michelle Parish, BSN,†† Gayane Yenokyan, PhD,‡‡ and Charles W. Hogue, MD††



ANESTHESIA & ANALGESIA®

Subramanian et al. Anesthesiology 2016

Monitoring Brain Oxygen Saturation During Coronary Bypass Surgery: A Randomized, Prospective Study

John M. Murkin, MD, FRCPC*

Sandra J. Adams, RN*

Richard J. Novick, MD, FRCSC§

Mackenzie Quantz, MD, FRCPS§

Daniel Bainbridge, MD, FRCPC*

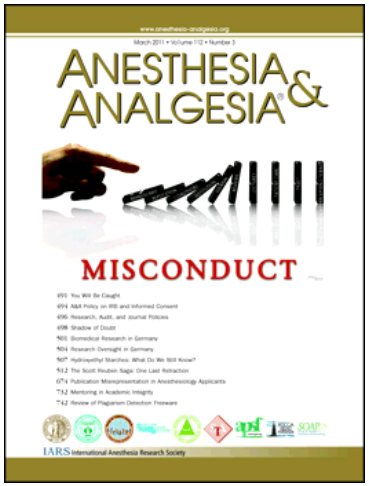
Ivan Iglesias, MD*

Andrew Cleland, RRT‡

Betsy Schaefer, BSc*

Beverly Irwin, RN*

Stephanie Fox, RRT§



Murkin et al. Anesth Analg 2007

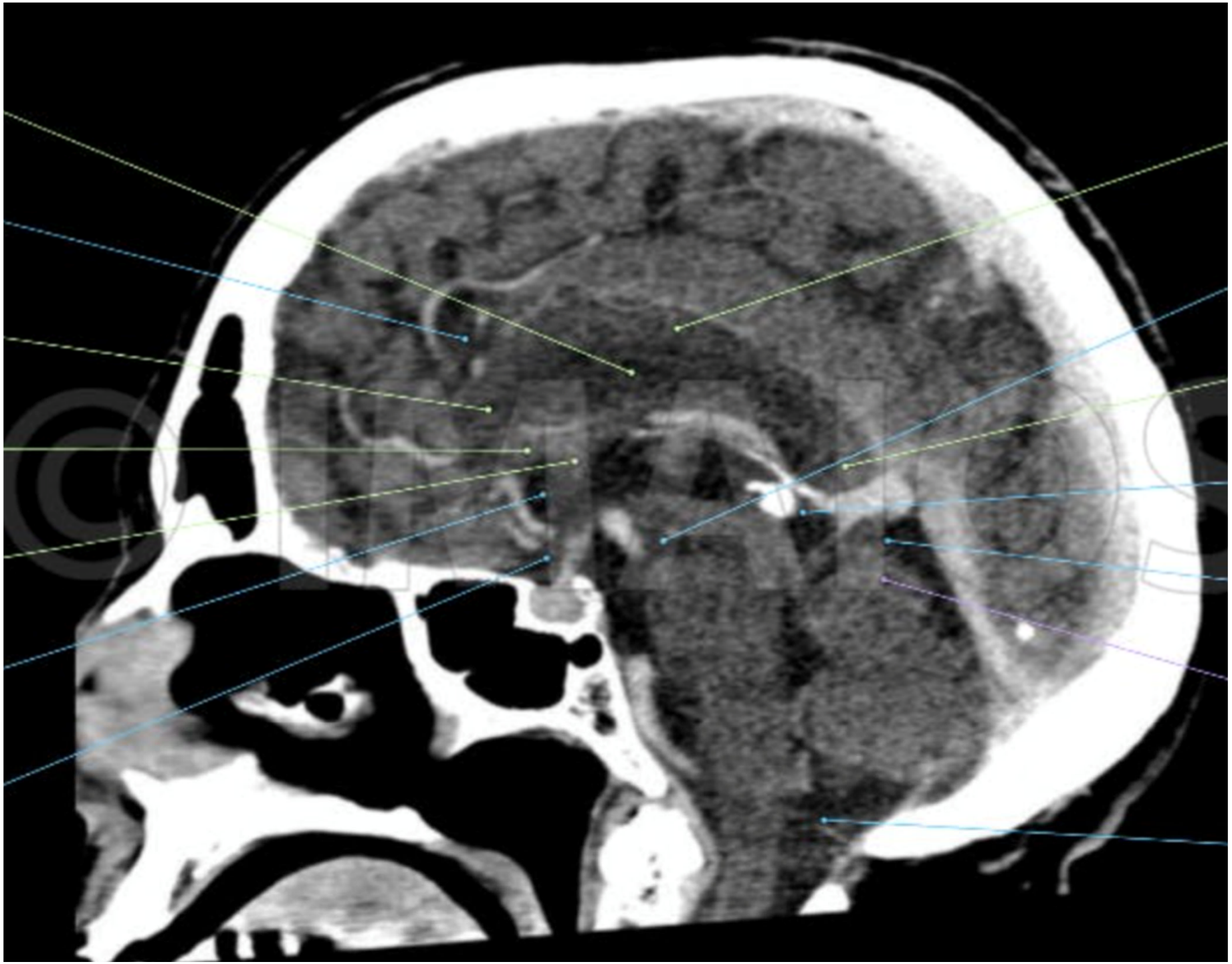
Cerebral Oxygen Desaturation Predicts Cognitive Decline and Longer Hospital Stay After Cardiac Surgery

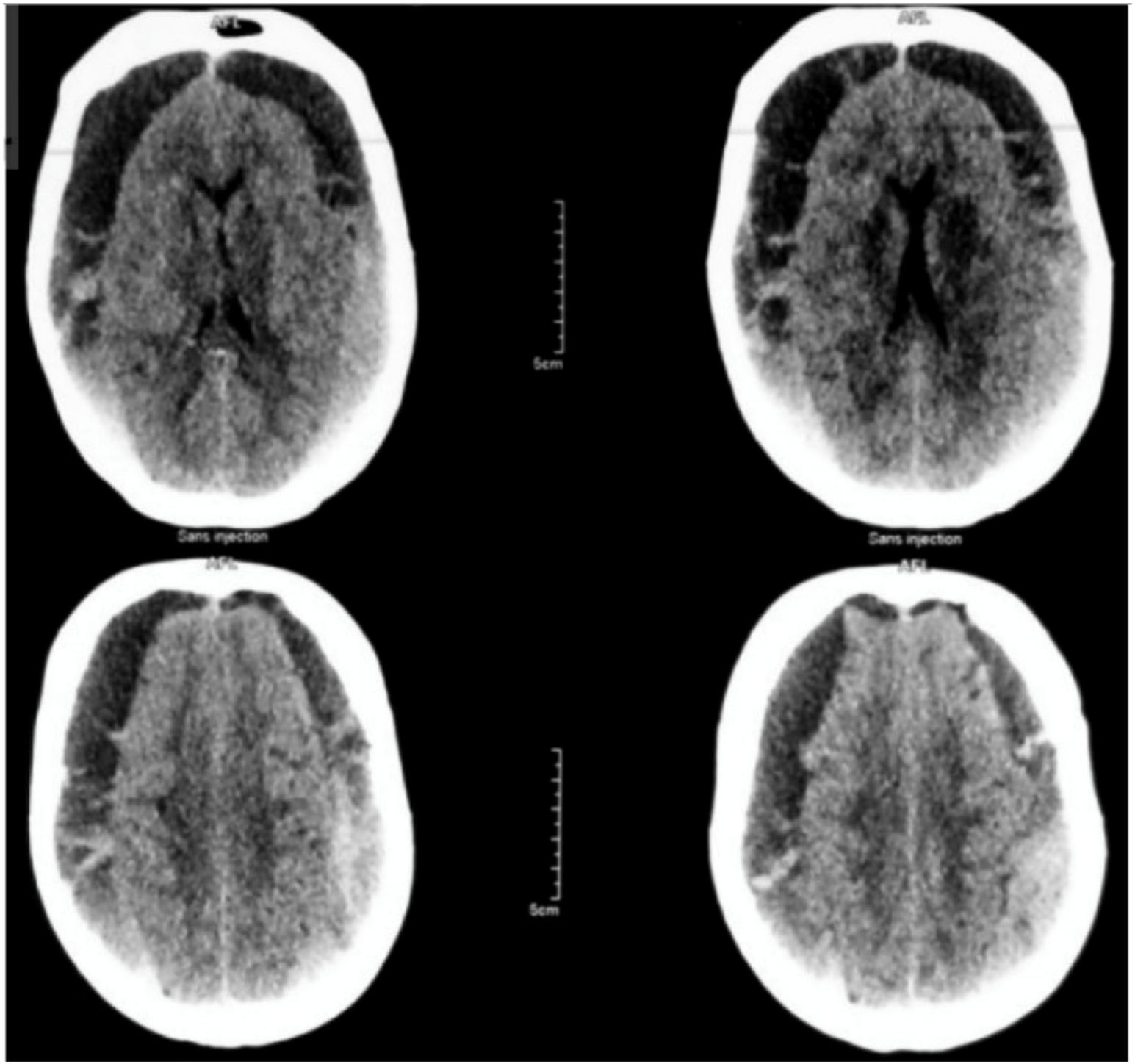
James P. Slater, MD, Theresa Guarino, RN, Jessica Stack, BS, Kateki Vinod, BA, Rami T. Bustami, PhD, John M. Brown III, MD, Alejandro L. Rodriguez, MD, Christopher J. Magovern, MD, Thomas Zaubler, MD, Kenneth Freundlich, PhD, and Grant V.S. Parr, MD

Slater et al. Ann thorac Surg 2009


IPRA
CHIRURGIE CARDIAQUE PARIS SUD
PHILIPS
50
100
11
92/56
(65)
SOMANETICS
11.10.17 09:51:24 ADULTE %rSO2
G 72
SSI
2 HEURES
D 74
SSI
2 HEURES
ALARME BASSE AUTO
LIGNE DE BASE + EU
RESUME AUC
MAR/ARR ALARM AUDIO
MENU SUIVANT
20%
Volume
MASIMO
*ADULTE
9:45
O2 Front Gauche


Medtronic
58
0%
63
0%
Monitorage volume et apnée désactivé
Paw cmH2O
l/min
CO2
Débit
Paw
Vol. ml
Resp




AFL
Sans injection
AFL
5cm
AFL
Sans injection
AFL
5cm


MASIMO
MASIMO
SAFB-SM

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CHIRURGIE CARDIAQUE PARIS SUD


03/15/2022 9:39:56 AM
MENU
95
59
BL
55
63
BL
15
33
33
09:00
09:30
L
CURRENT
CHANGE
59
0 %
R
CURRENT
CHANGE
58
8 %
Medtronic


03/18/2022 10:32:56 AM
MENU
95
45
BL
55
47
BL
15
10:00
10:30
33
33
L
CURRENT
CHANGE
49
9 %
R
CURRENT
CHANGE
44
6 %
Medtronic

Table 3. Efficacy of Interventions to Correct Decrements in Regional Cerebral Oxygen Saturation ($rSco_2$) of >20% from Baseline for the 340 Clinician-Identified Events

61% rSO_2 ↘ during CPB….

	Intervention-corrected $rSco_2$ desaturation
Treat hypotension	67 (29.8%)
Increase FIO_2%	35 (15.6%)
Normalize CPB flow	32 (14.2%)
RBC transfusion	31 (13.8%)
Decrease CPB “Sweep Speed”	25 (11.1%)
Deepen anesthesia	24 (10.7%)
Adjust CPB cannula	18 (8.0%)
Reposition head to midline	6 (2.7%)

….resolved in 92%!

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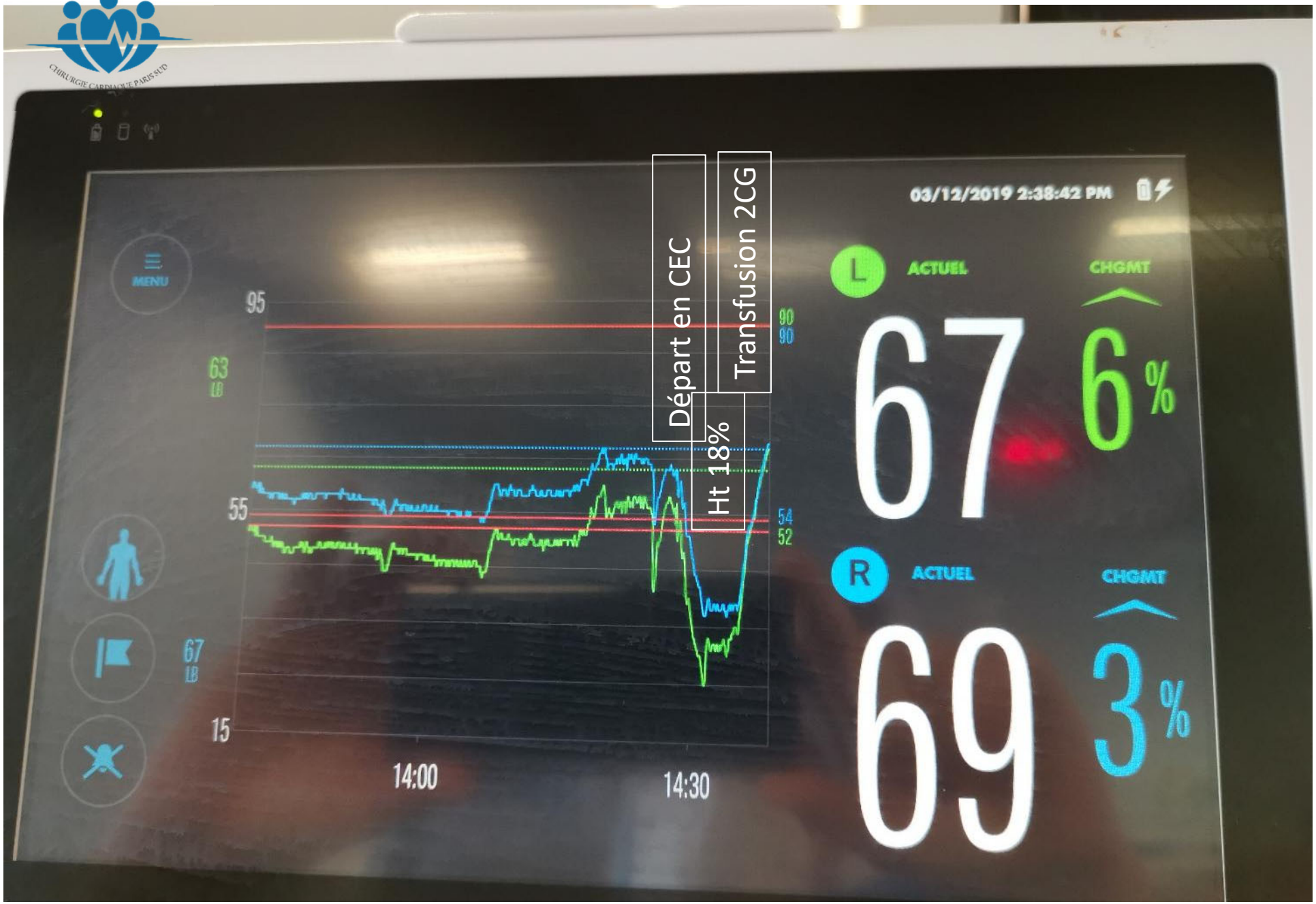
Subramanian et al. Anesthesiology 2016

PF: 2.4 L.min^{-1}.m^{-2}

PF: 3 L.min^{-1}.m^{-2}

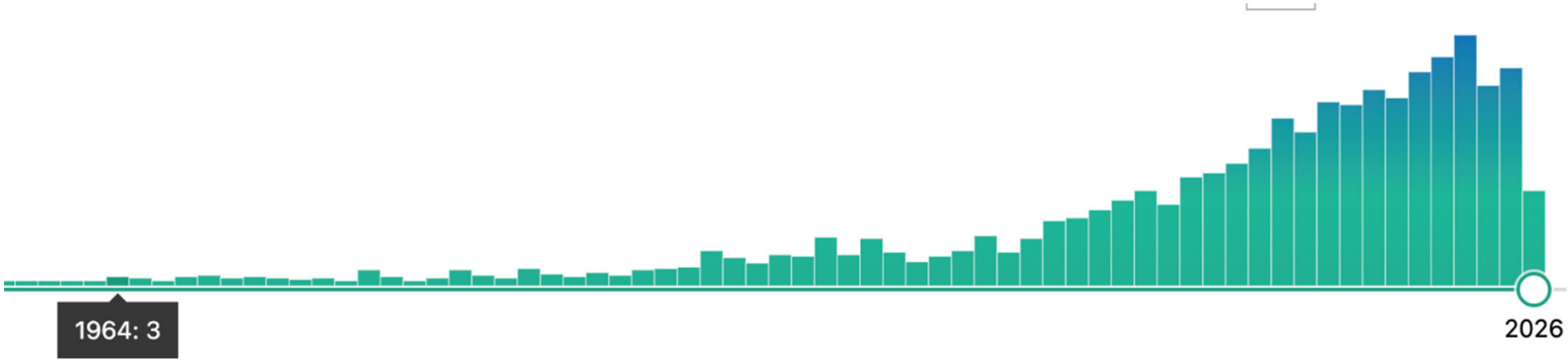

Départ en CEC
Transfusion 2CG
Ht 18%
03/12/2019 2:38:42 PM
MENU
95
63
LB
55
67
LB
15
14:00
14:30
90
90
54
52
L
ACTUEL
67
CHGMT
6 %
R
ACTUEL
69
CHGMT
3 %

The « GOOD » strategy:
GDP & **NIRS** ?


03/15/2023 11:10:55 AM
L CURRENT
CHANGE
63
7 %
R CURRENT
CHANGE
59
6 %
95
59
55
63
15
10:30
11:00
Medtronic


Spectrum Medical
100 %
70 %
28.3 %
37 mmHg
211 mmHg
FIO2
60 %
Balayage
2.3 L/min
0.00 %
Debit Art
4.24 L/min
WAG Flow
3.2 L/min
Vide
-30 mmHg
WA
VA
Debit Art
4.24
Debit Veine
5.03
Press ART
150
CI
2.4
Press CPL
47
Circuit
Cristalloïde
CEC
42:55
11:08
Clampage
41:12
11:10
Circuit extracorporel
Initialisation

« red blood-cell AND tranfusion AND cardiac surgery »



Because the effect of restrictive versus liberal red-cell transfusion strategy on clinical outcomes in patients undergoing cardiac surgery remains unclear.....

Mazer et al. NEJM 2017

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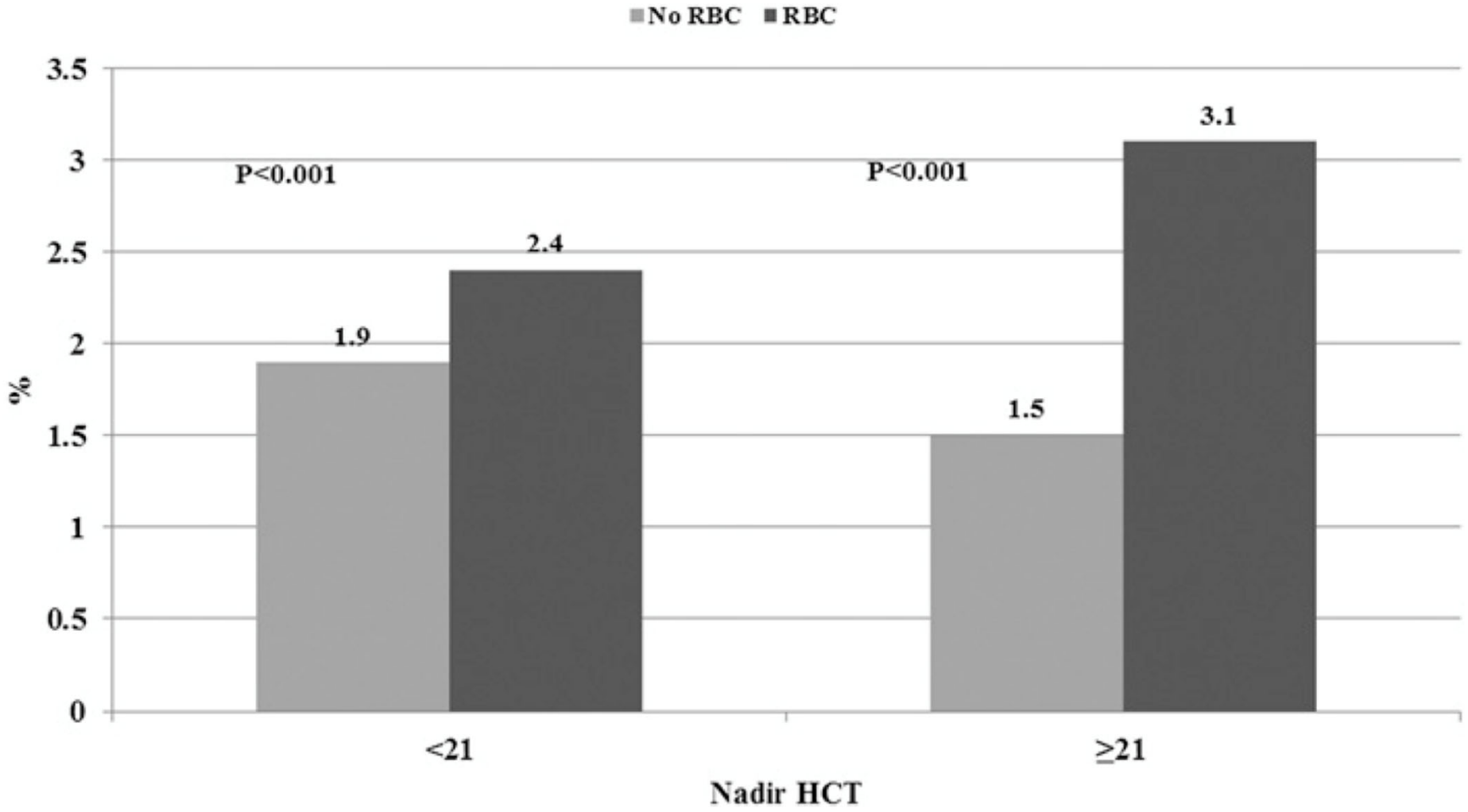
The Relationship between Intra-Operative Transfusions and Nadir Hematocrit on Post-Operative Outcomes after Cardiac Surgery

Joshua B. Goldberg, MD;* Kenneth G. Shann, CCP;† David Fitzgerald, CCP;‡ John Fuller, CCP;§ Theron A. Paugh, CCP;¶†† Timothy A. Dickinson, MS, CCP;|| Gaetano Paone, MD, MHSA;** Richard L. Prager, MD;¶†† Donald S. Likosky, PhD;¶†† for the PERForm Registry and the Michigan Society of Thoracic and Cardiovascular Surgeons Quality Collaborative

- ✓ 18 886 patients opérés cardiaques

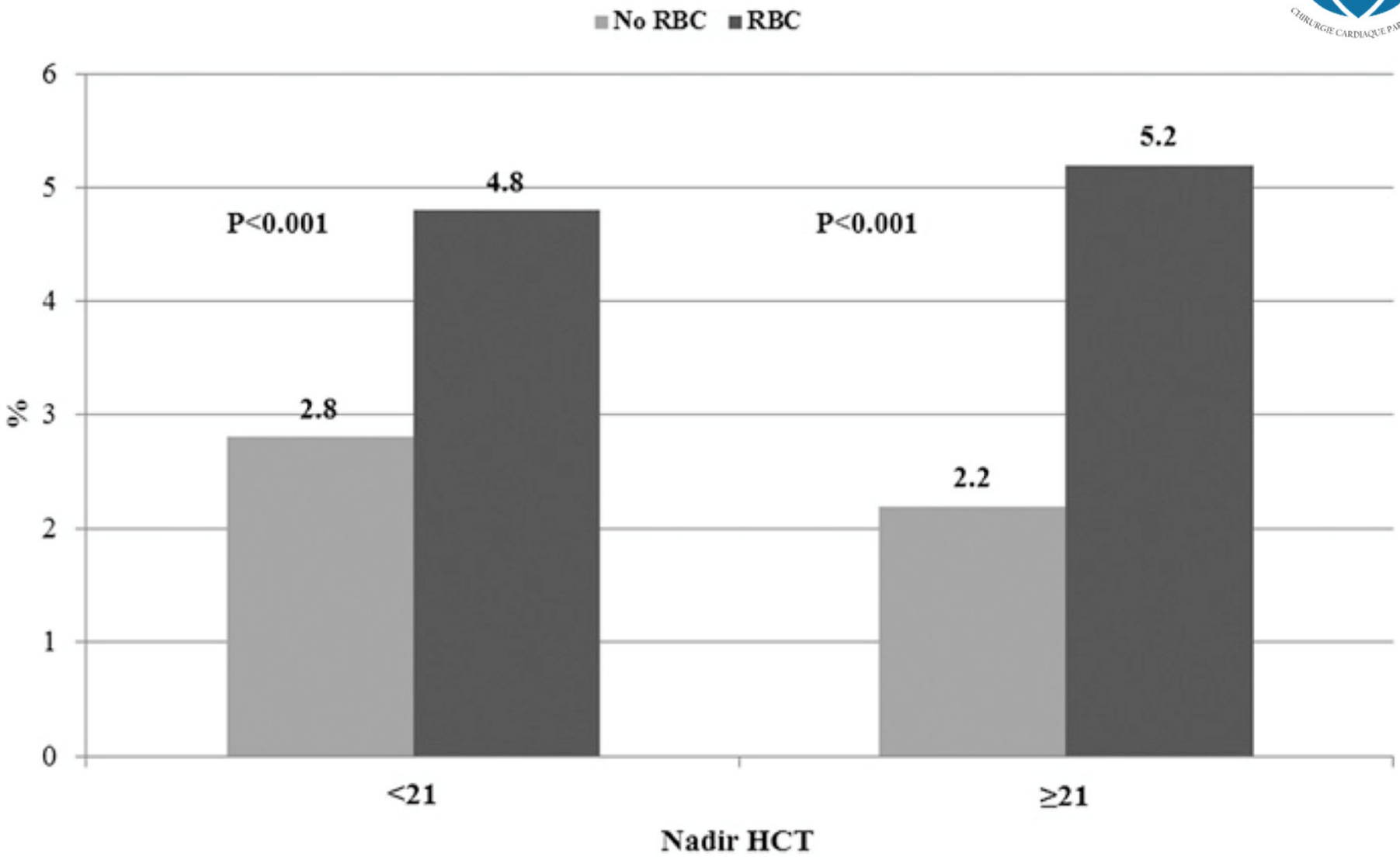
Golberg et al. J Extra Corpol Technol 2016

Accident vasculaire cérébral



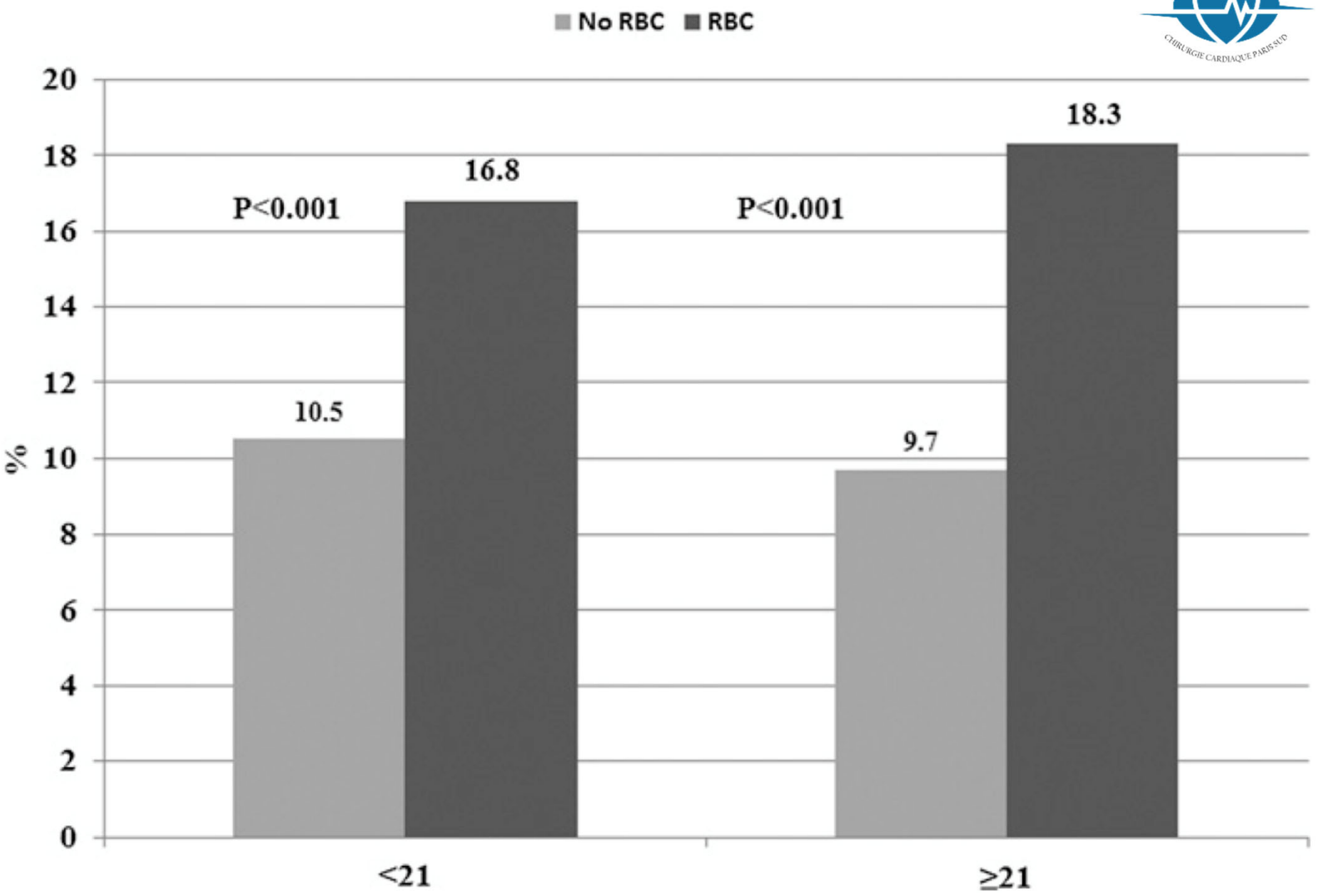
Golberg et al. J Extra Corpol Technol 2016

Insuffisance Rénale

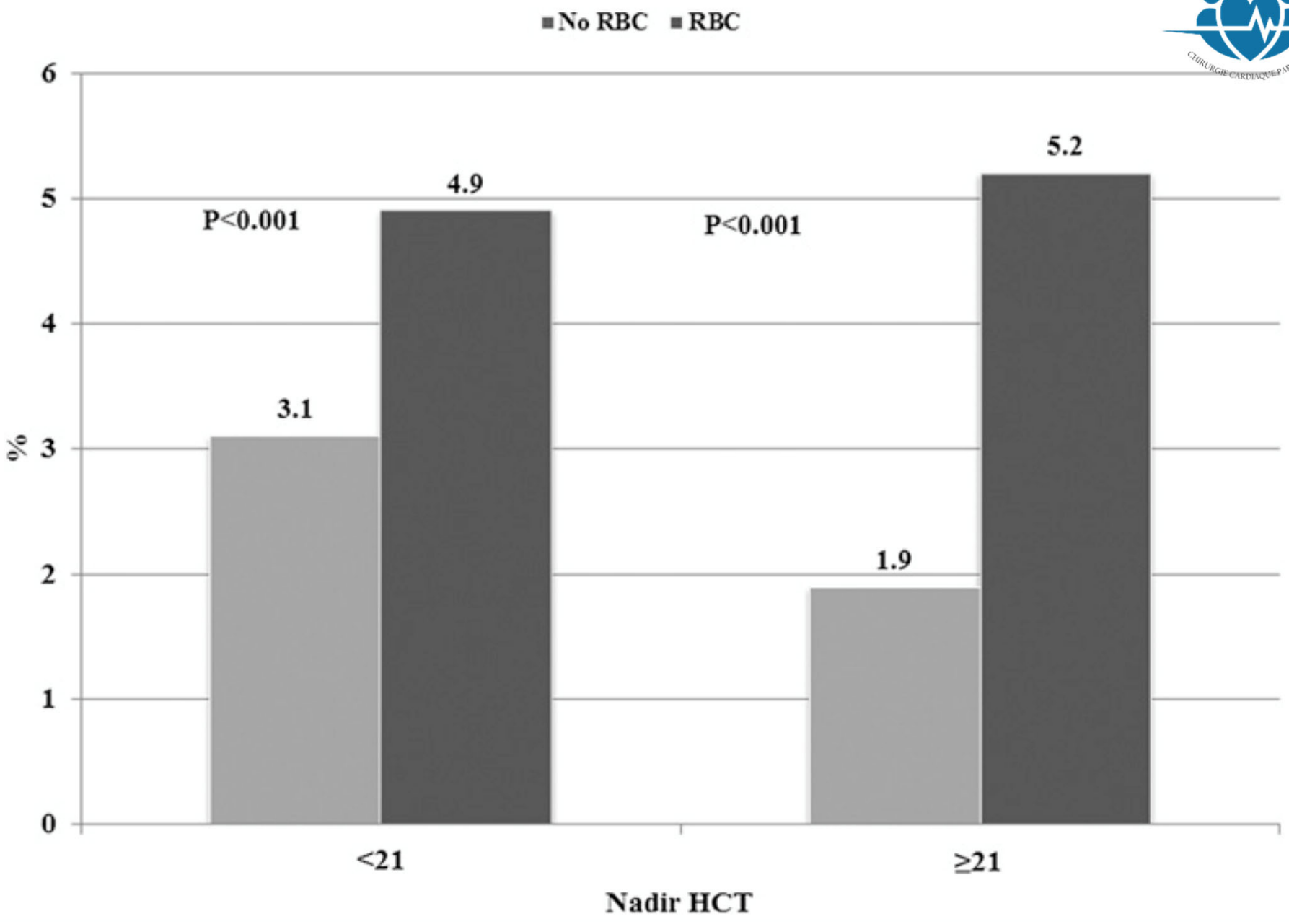


Golberg et al. J Extra Corpol Technol 2016

Ventilation prolongée

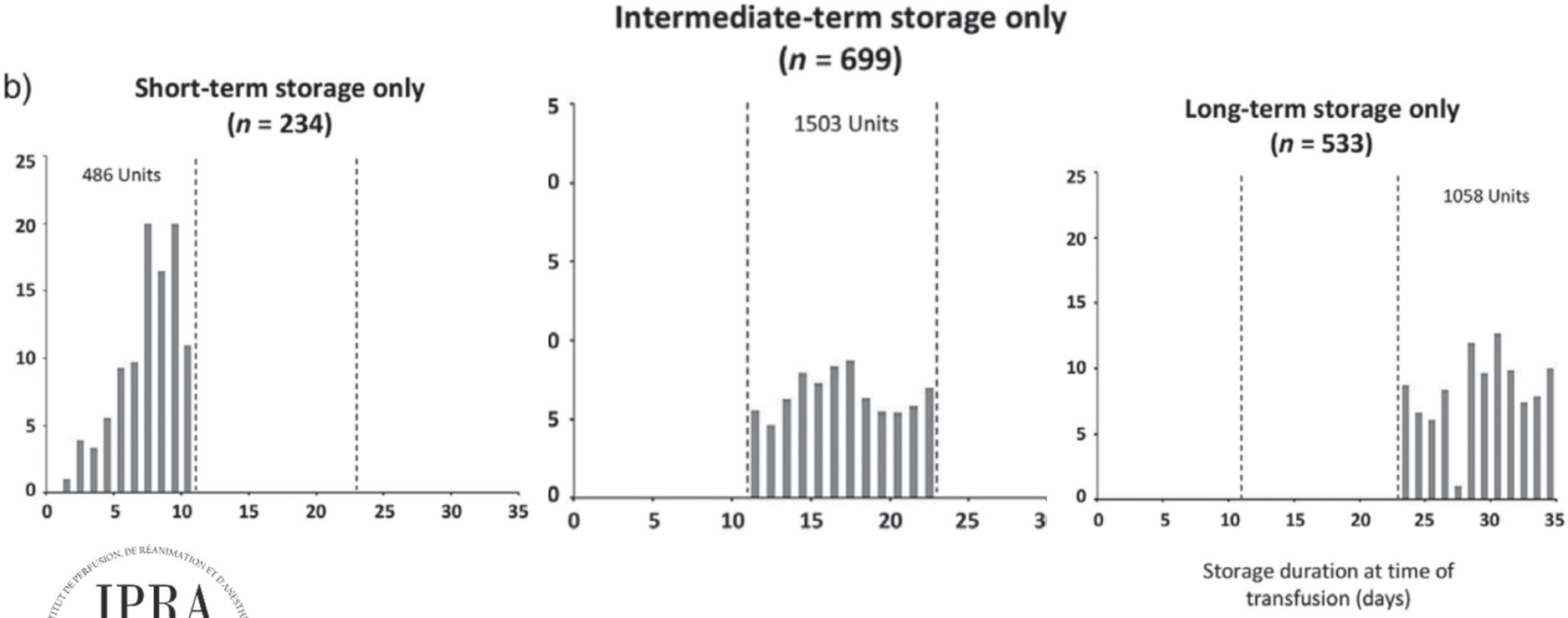


Mortalité

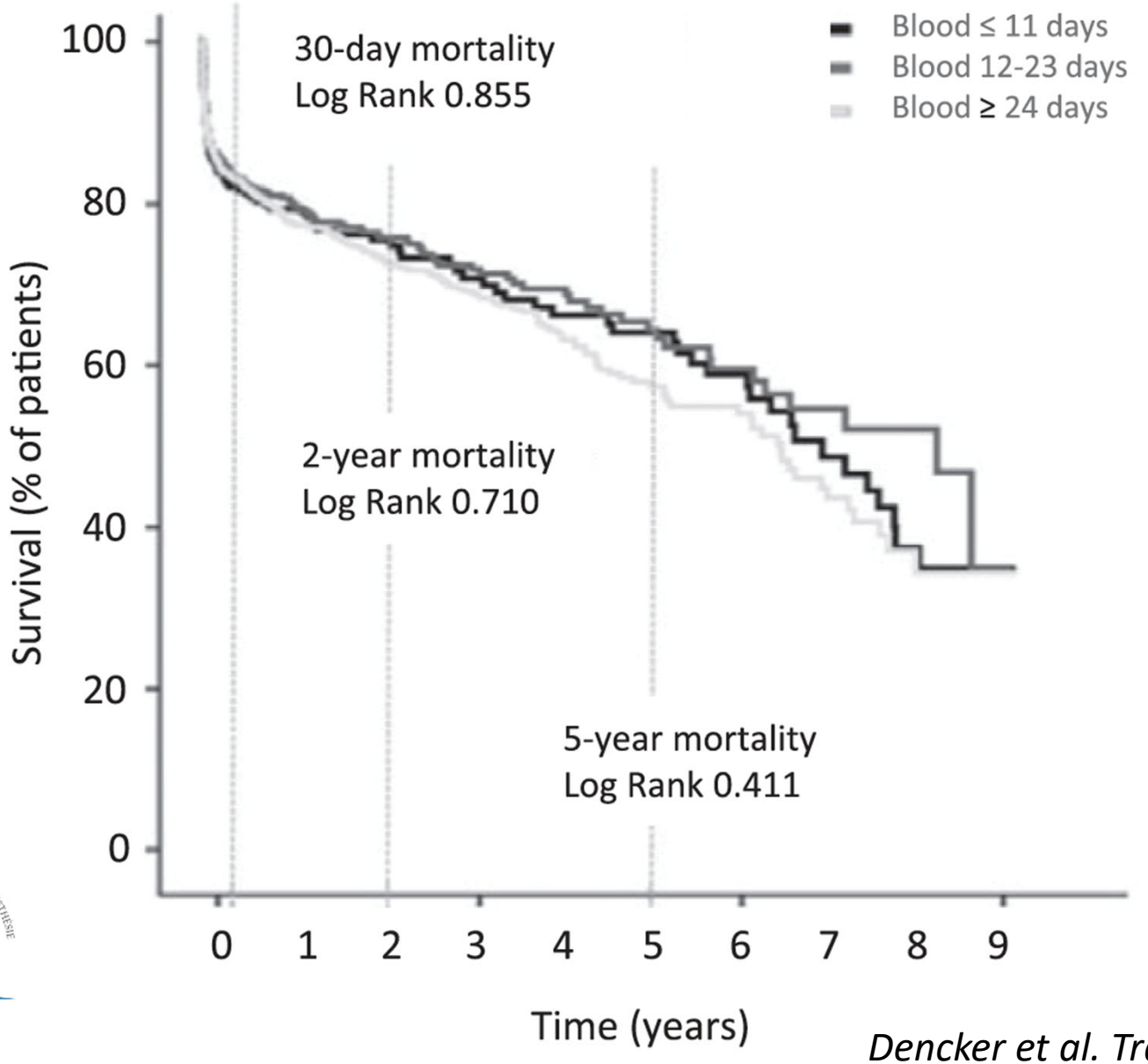


Red blood cell storage duration and long-term mortality in patients undergoing cardiac intervention: a Danish register study

D. Dencker,[1] F. Pedersen,[2] T. Engstrøm,[2] T. V. Schroeder,[3] L. Lönn,[1] P. I. Johansson[4,5] & O. De Backer[2]



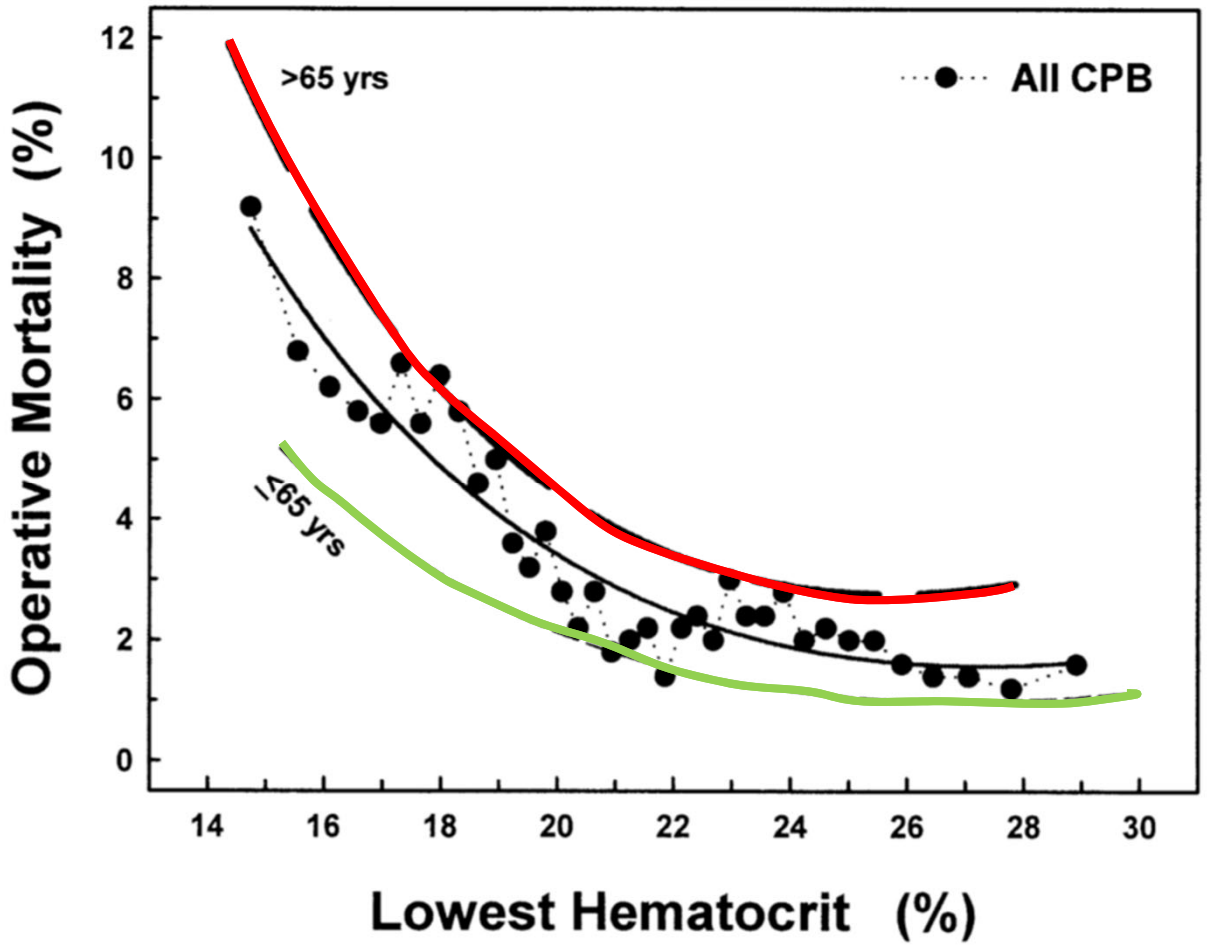
Dencker et al. Transf Med 2017



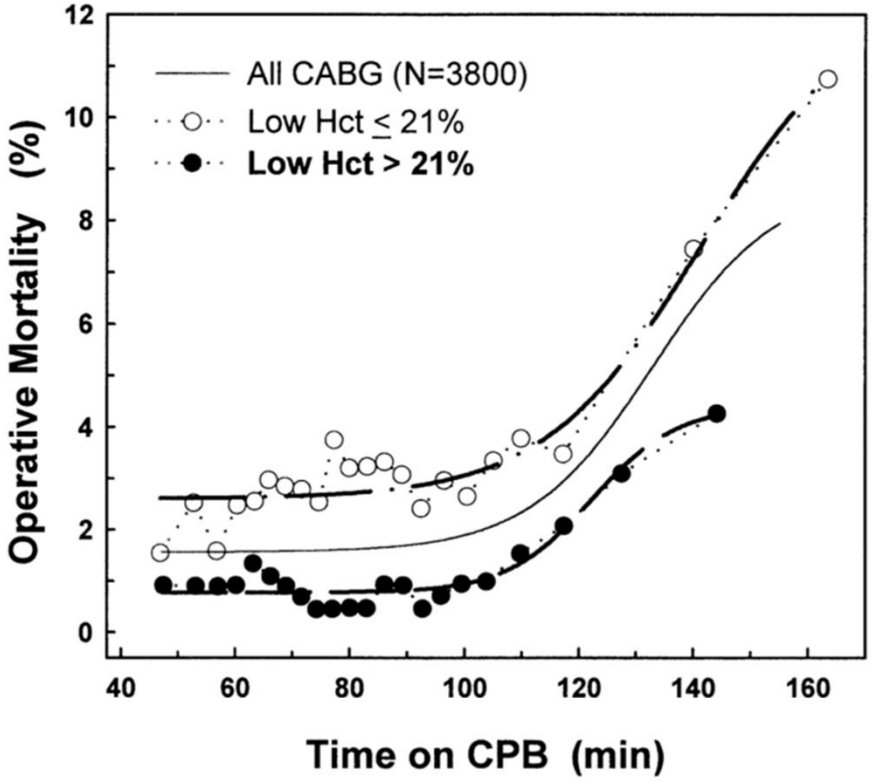
Dencker et al. Transf Med 2017

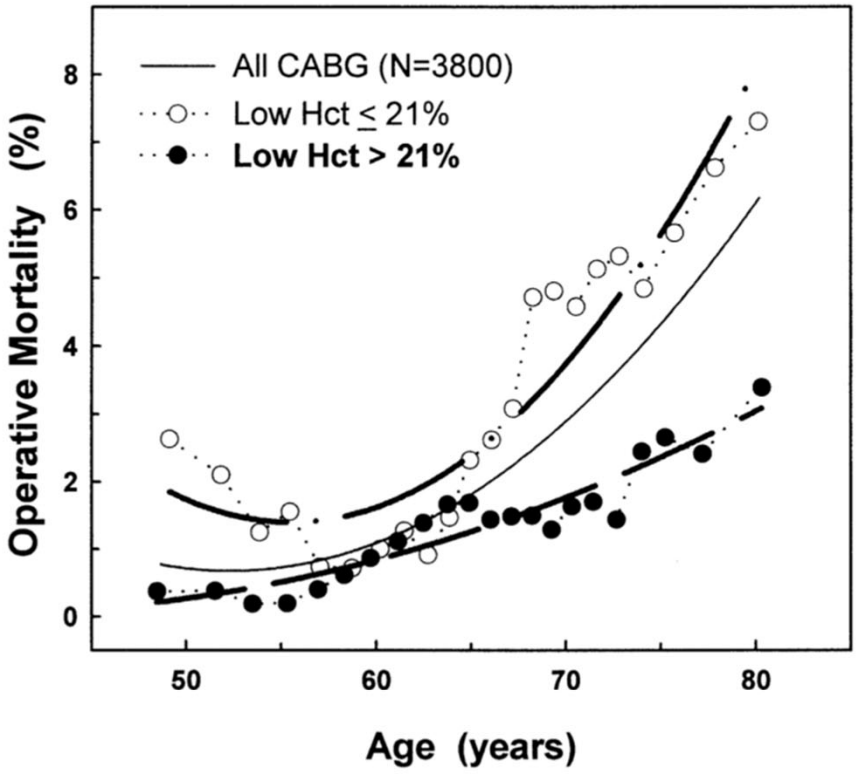
Adverse effects of low hematocrit during cardiopulmonary bypass in the adult: Should current practice be changed?

Robert H. Habib, PhD[a,b,c]
Anoar Zacharias, MD[a,b,c]
Thomas A. Schwann, MD[a,b,c]
Christopher J. Riordan, MD[a,b,c]
Samuel J. Durham, MD[a,b,c]
Aamir Shah, MD[a,b,c]

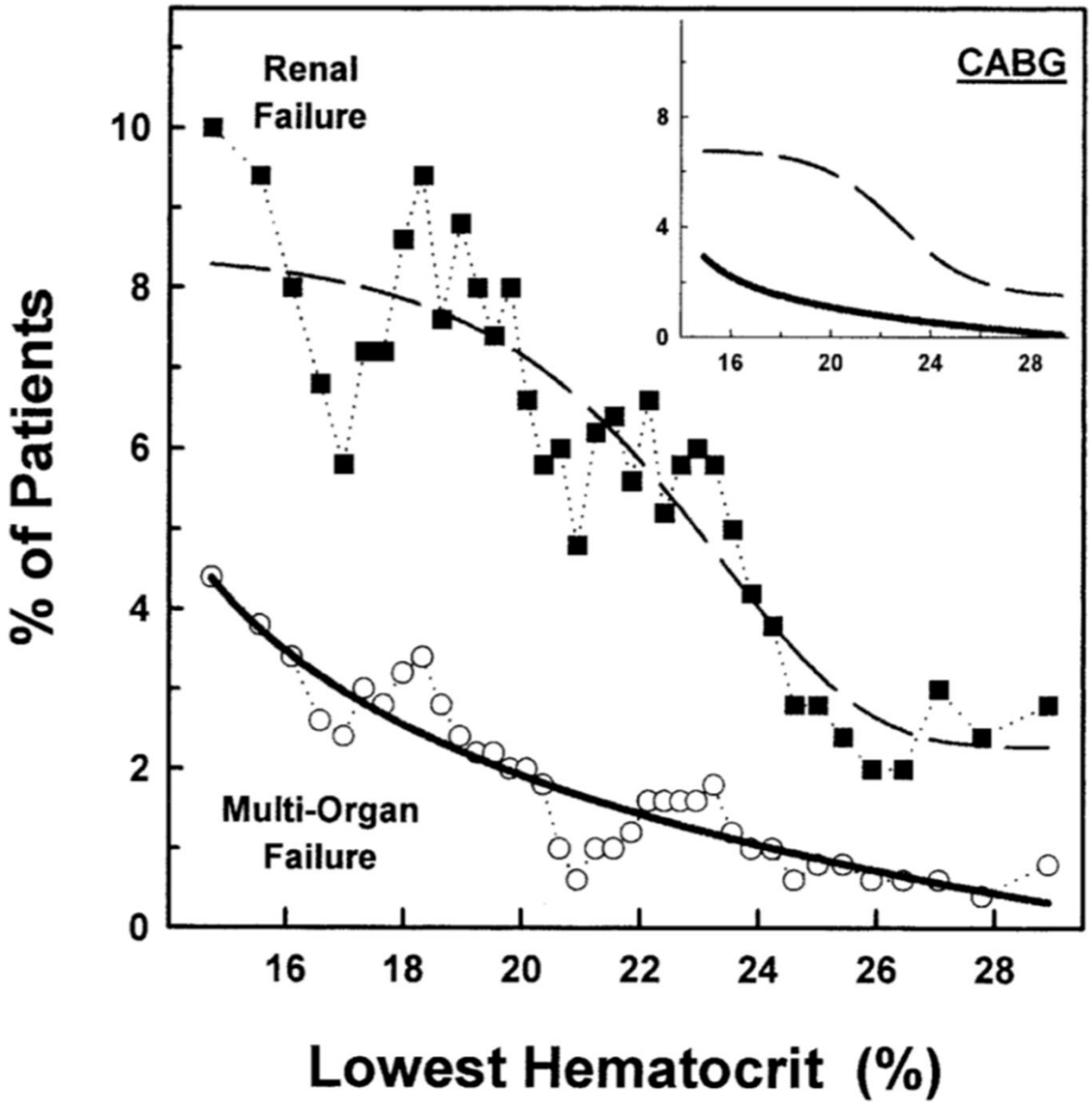


Habib et al. J Thorac Cardiovasc Surg 2003





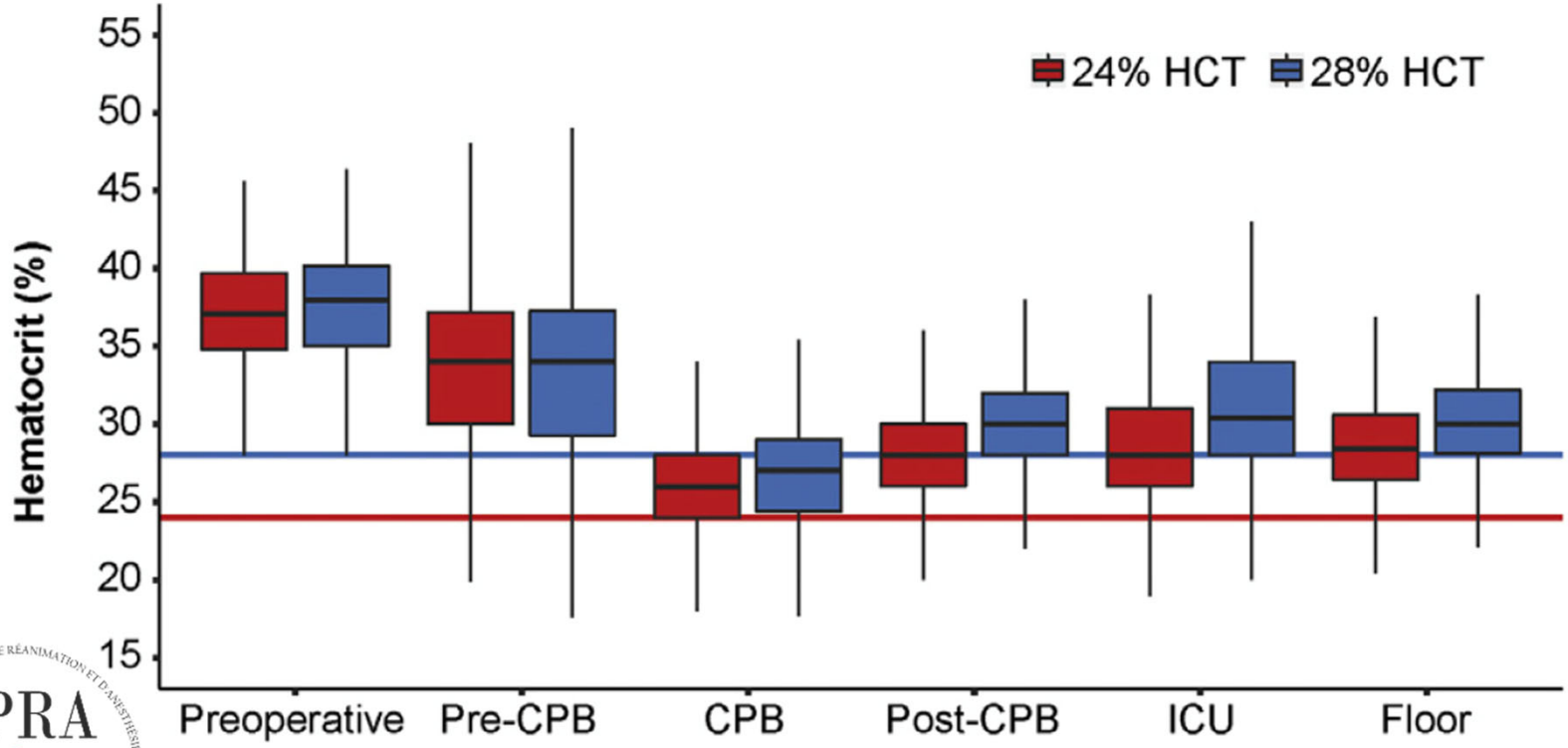
Habib et al. J Thorac Cardiovasc Surg 2003



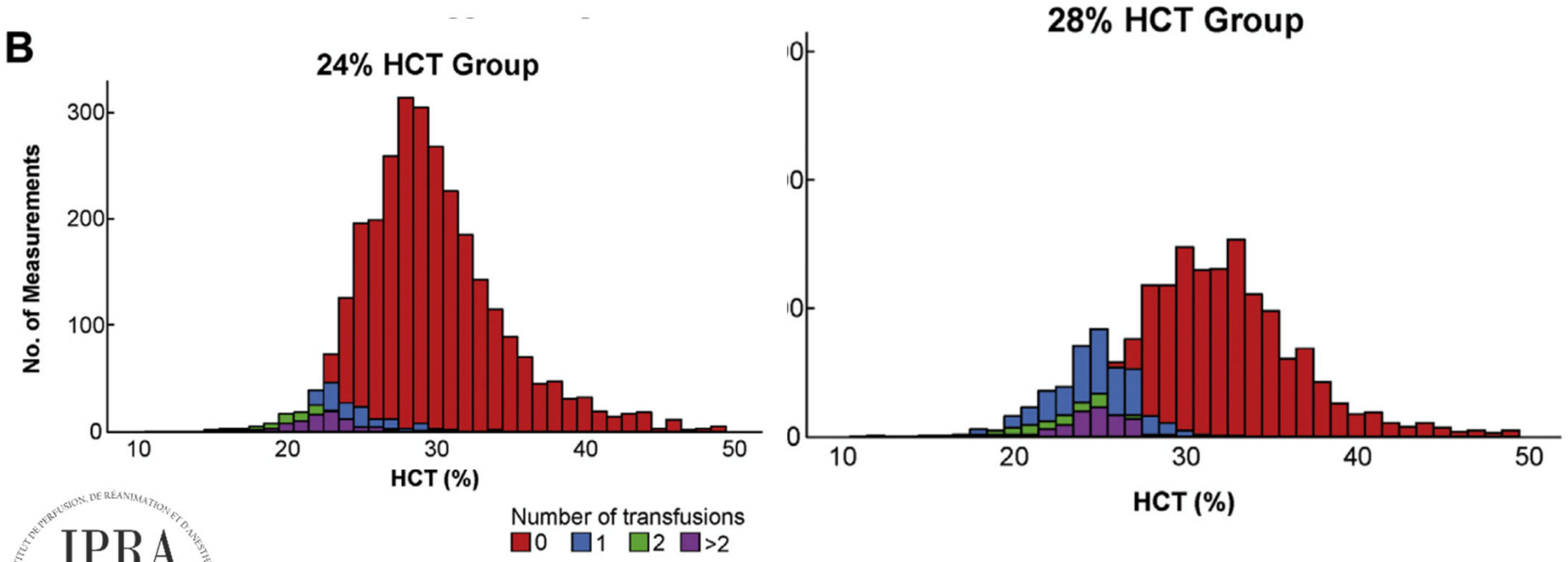
Habib et al. J Thorac Cardiovasc Surg 2003

A Randomized Clinical Trial of Red Blood Cell Transfusion Triggers in Cardiac Surgery

Colleen G. Koch, MD, MBA, Daniel I. Sessler, MD, Edward J. Mascha, PhD, Joseph F. Sabik, III, MD, Liang Li, PhD, Andra I. Duncan, MD, Nicole M. Zimmerman, MS, and Eugene H. Blackstone, MD



Koch et al. Ann Thorac Surg 2017



Koch et al. Ann Thorac Surg 2017

Morbidity	HCT Trigger 24% (n = 363)	HCT Trigger 28% (n = 354)	
Composite	59 (16)	68 (19)	
Mortality or multisystem organ failure	3 (0.8)	6 (1.7)	
Neurologic morbidity	1 (0.3)	3 (0.8)	
Pulmonary morbidity	23 (6.3)	19 (5.4)	
Renal morbidity	6 (1.6)	7 (2.0)	**NS**
Infectious morbidity	1 (0.3)	1 (0.3)	
Cardiac arrhythmia	36 (10)	50 (14)	
Asystole	2 (0.6)	1 (0.3)	
Gastrointestinal morbidity	5 (1.4)	2 (0.6)	
Reoperative morbidity	9 (2.5)	10 (2.8)	
Vascular morbidity	0 (0)	3 (0.8)	

Koch et al. Ann Thorac Surg 2017

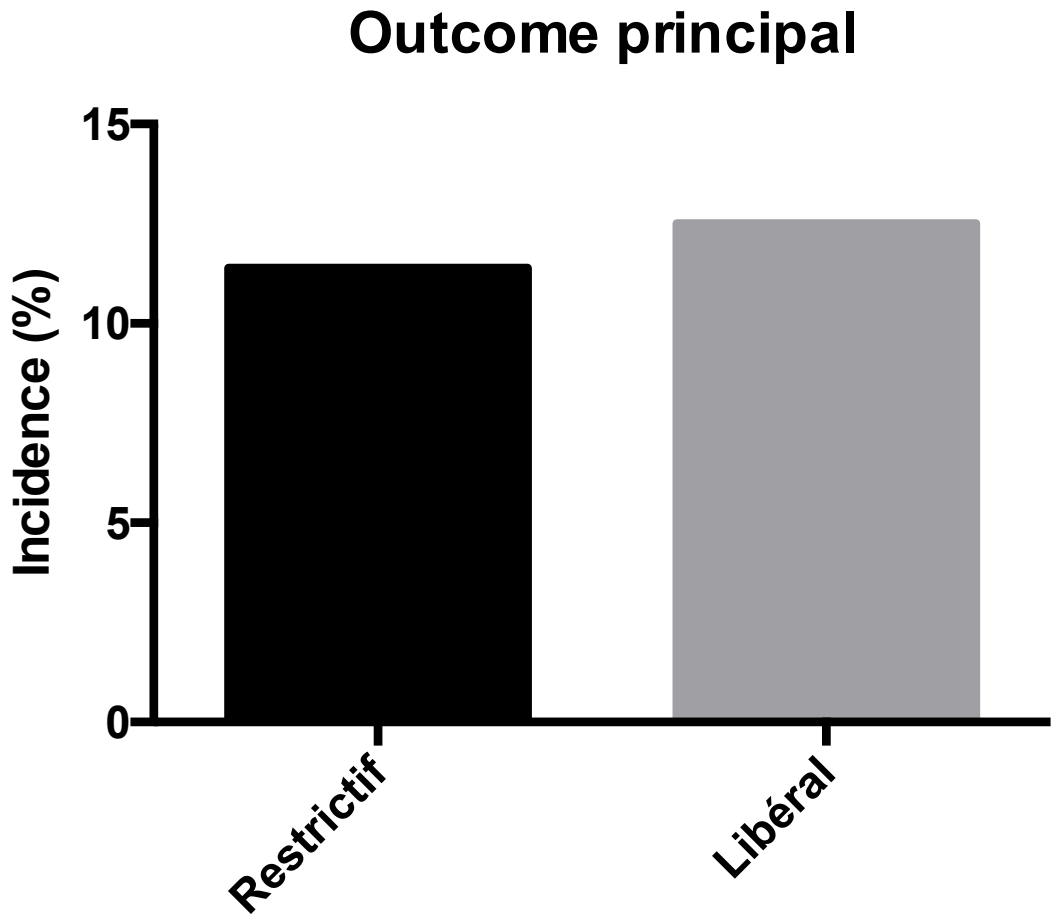
The NEW ENGLAND JOURNAL of MEDICINE

Restrictive or Liberal Red-Cell Transfusion for Cardiac Surgery.

Mazer CD[1], Whitlock RP[1], Fergusson DA[1], Hall J[1], Belley-Cote E[1], Connolly K[1], Khanykin B[1], Gregory AJ[1], de Médicis É[1], McGuinness S[1], Royse A[1], Carrier FM[1], Young PJ[1], Villar JC[1], Grocott HP[1], Seeberger MD[1], Fremes S[1], Lellouche F[1], Syed S[1], Byrne K[1], Bagshaw SM[1], Hwang NC[1], Mehta C[1], Painter TW[1], Royse C[1], Verma S[1], Hare GMT[1], Cohen A[1], Thorpe KE[1], Jüni P[1], Shehata N[1]; TRICS Investigators and Perioperative Anesthesia Clinical Trials Group.

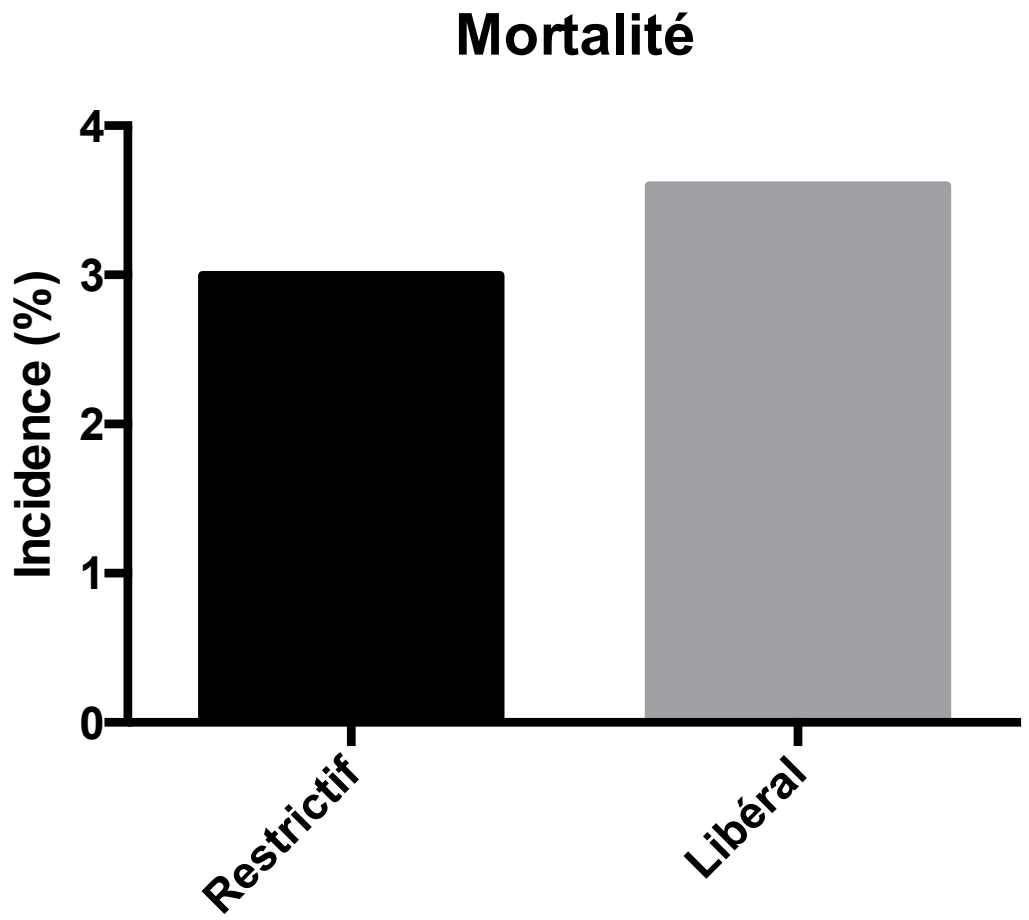
- ✓ 5243 patients opérés cardiaques à moyen et haut risque opératoire (Euroscore I > 6)
- ✓ Transfusion si:
  - restrictif: Hb < 7,5g/dL
  - libéral: Hb > 9,5 g/dL (OR ou ICU) et > 8,5g/dL hors ICU
- ✓ Outcome principal:
  - décès, IDM, AVC, IRA avec EER à l'hôpital ou dans les 28 jours
- ✓ Outcome II^{aire}:
  - Transfusion

Mazer et al. NEJM 2017



NS

Mazer et al. NEJM 2017



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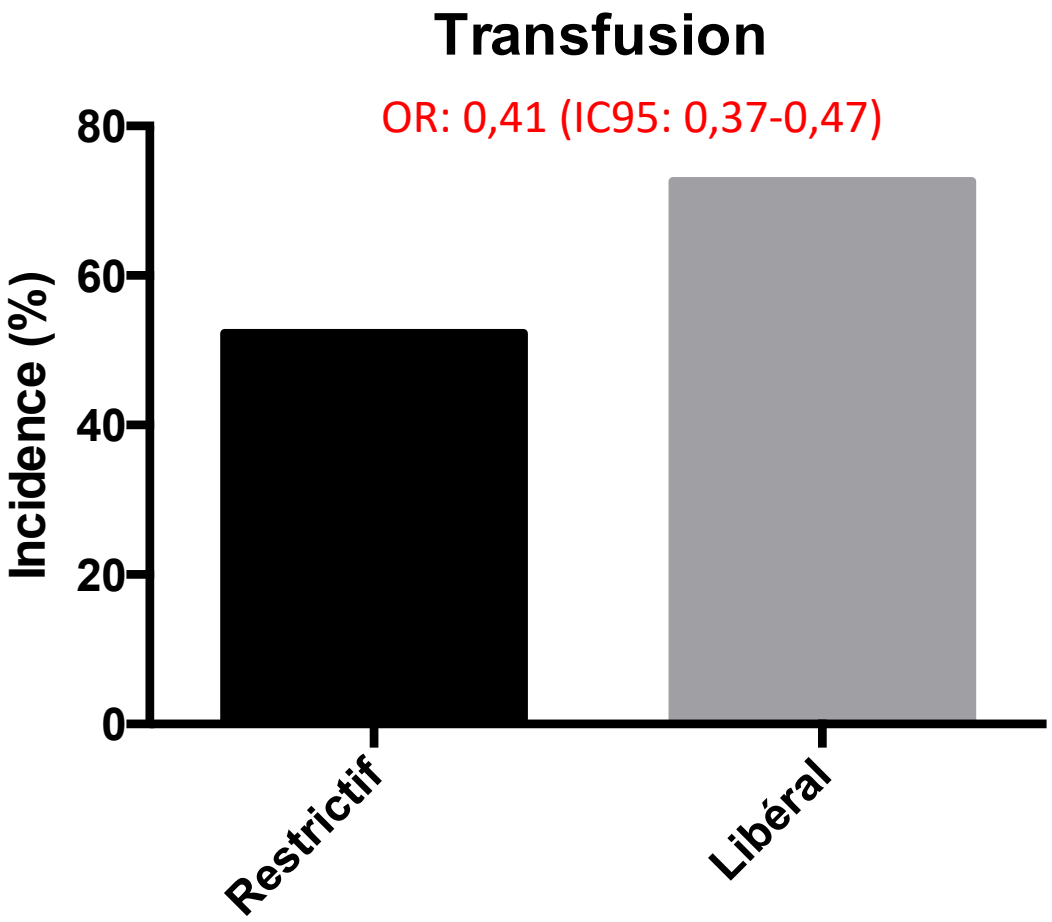
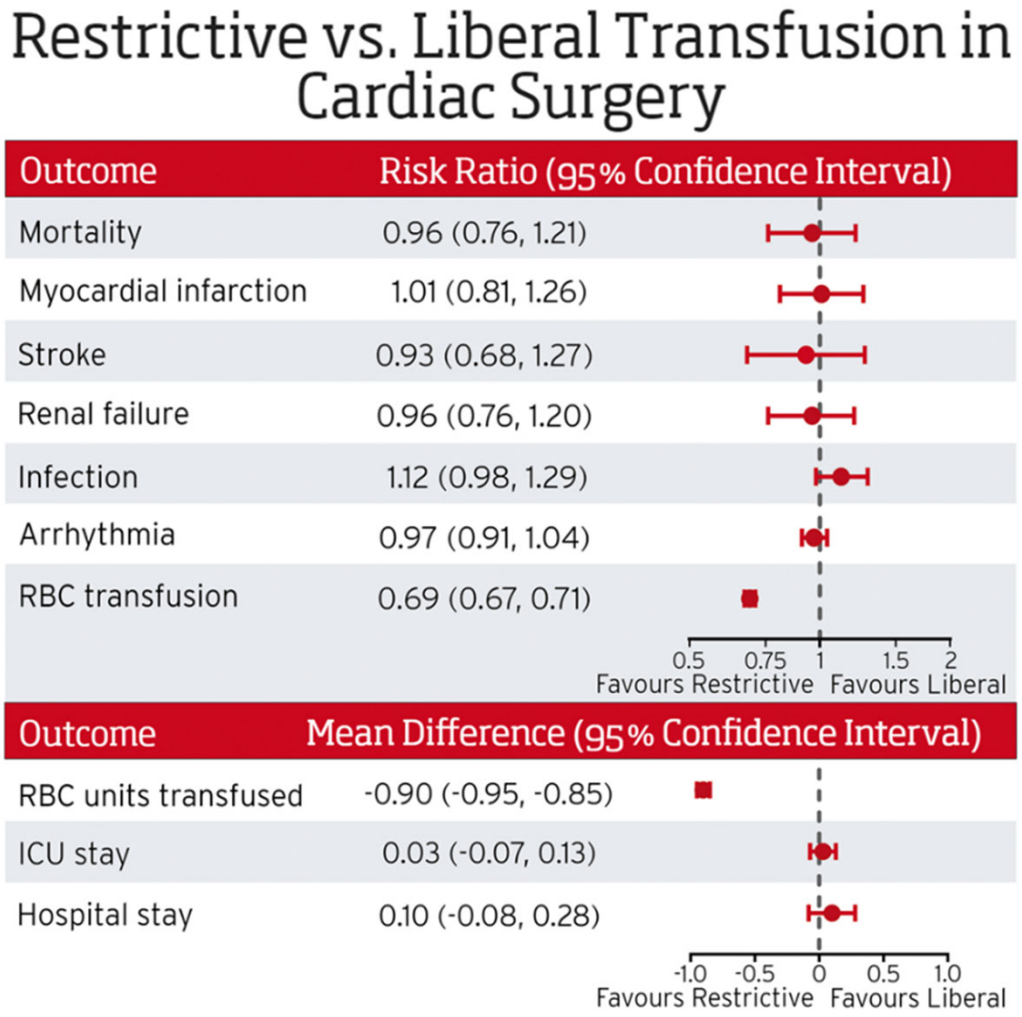
Mazer et al. NEJM 2017



p<0,01

Mazer et al. NEJM 2017

Restrictive compared with liberal red cell transfusion strategies in cardiac surgery: a meta-analysis



Mazer et al. Eur Heart J 2019

2024 EACTS/EACTAIC/EBCP Guidelines on cardiopulmonary bypass in adult cardiac surgery

Recommendations	Class[a]	Level[b]	Ref[c]
PRBC transfusions			
It is recommended that PRBCs be transfused during CPB if the Hb value is <6.0 g/dl.	I	C	

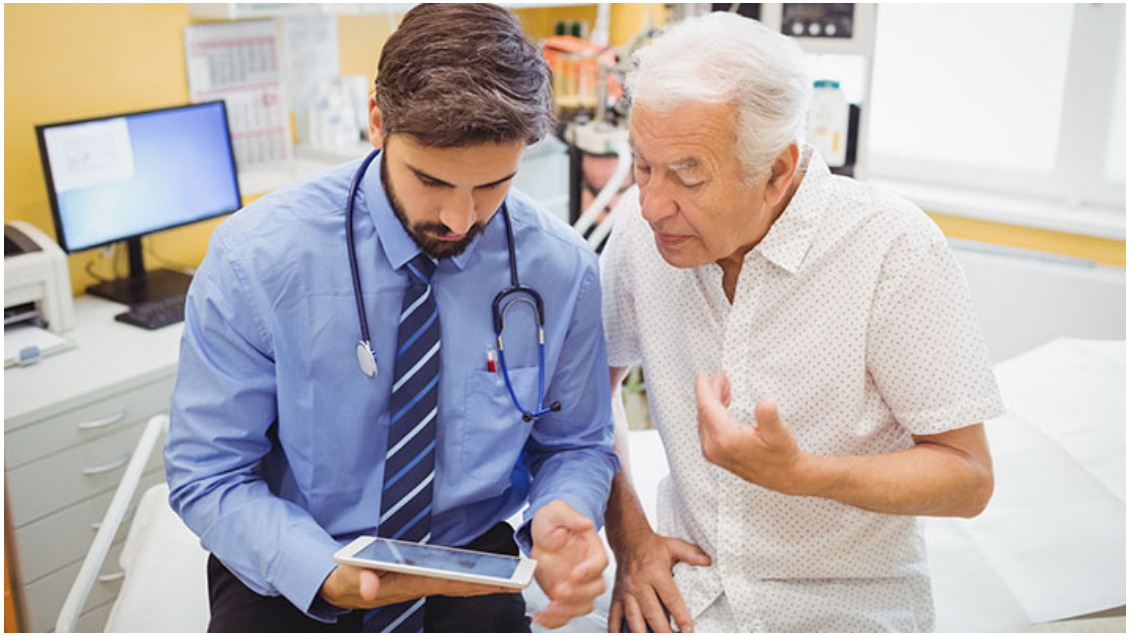
Recommendations	Class[a]	Level[b]	Ref[c]
For HCT values between 18% and 24%, PRBCs may be transfused based on an assessment of the adequacy of tissue oxygenation. [d]	IIb	B	243
PRBCs should not be transfused during CPB if the HCT is >24%.	III	C	

Wabha et al. Interdisc CardioVasc Thor Surg 2025

2024 EACTS/EACTAIC Guidelines on patient blood management in adult cardiac surgery in collaboration with EBCP

Restrictive transfusion triggers (≤75 g/L) are recommended over liberal triggers (≤90 g/L) if the clinical condition of the patient allows it.	I	A	(443, 444, 446, 447)

Casselman et al. EACTA/EACTS/EBCP 2025



INSTITUT DE PERFUSION, DE RÉANIMATION ET D'ANESTHÉSIE

IPRA

CHIRURGIE CARDIAQUE PARIS SUD

2019 EACTS/EACTA/EBCP guidelines on cardiopulmonary bypass in adult cardiac surgery

Authors/Task Force Members[a], Gudrun Kunst[1,2,*,†], Milan Milojevic[3,4,*,†], Christa Boer[5], Filip M. J. J. De Somer[6], Tomas Gudbjartsson[7], Jenny van den Goor[8], Timothy J. Jones[9], Vladimir Lomivorotov[10], Frank Merkle[11], Marco Ranucci[12], Luc Puis[13,*,†], Alexander Wahba[14,15,*,†] EACTS/EACTA/EBCP Committee Reviewers[b,c], Peter Alston[16], David Fitzgerald[17], Aleksandar Nikolic[18], Francesco Onorati[19], Bodil Steen Rasmussen[20] and Staffan Svenmarker[21]

included transfusion strategies after CPB. A retrospective study showed that, during CPB, PRBC transfusions are effective if the SvO_2 is <68%

Ranucci et al. Perfusion 2011

Kunst et al. BJA 2019

2017 EACTS/EACTA Guidelines on patient blood management for adult cardiac surgery

The Task Force on Patient Blood Management for Adult Cardiac Surgery of the European Association for Cardio-Thoracic Surgery (EACTS) and the European Association of Cardiothoracic Anaesthesiology (EACTA)

Existing guidelines suggest transfusing PRBCs if the Hb is <6.0 g/dl[244] and an acceptable HCT value between 21% and 24% if the DO_2 is maintained above 273 ml/min/m^2.[2]

Pagano et al. Eur J Cardiothor Surg 2018

liberal transfusion trigger during CPB; however, in the presence of a low Hb value, the DO_2 is preserved by increasing the pump flow.[203] FFP has been used during CPB as a source of

De Somer et al. Crit Care 2011


ADULTE
08/11/2024 17:16:11
MENU
95
67
LB
55
64
LB
15
16:30
17:00
ACTUEL
CHGMT
59
12%
ACTUEL
CHGMT
56
13%
Medtronic

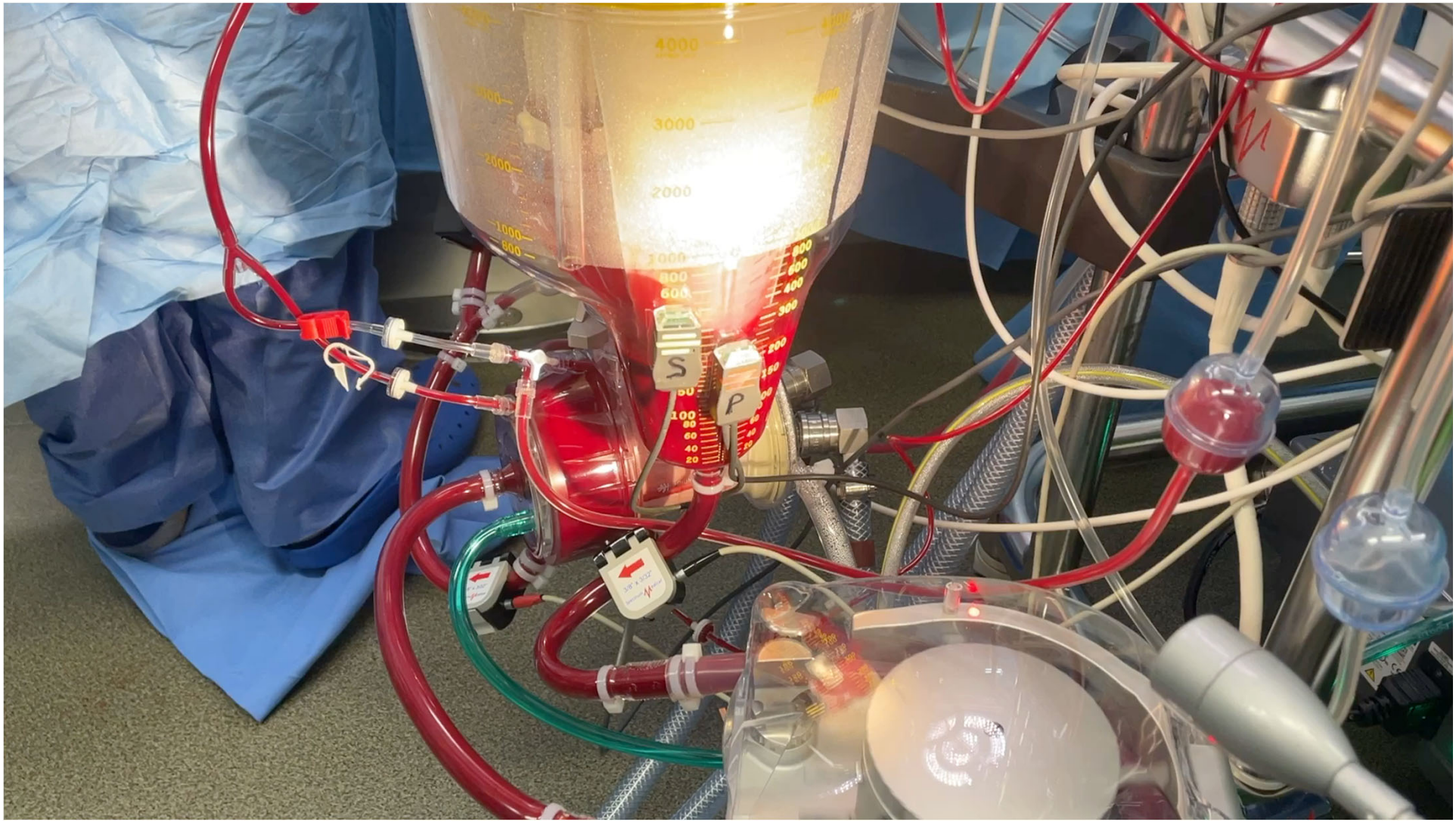

4000
3000
2000
1000
800
600
400
300
200
100
80
60
40
20
S
P

Table 3. Efficacy of Interventions to Correct Decrements in Regional Cerebral Oxygen Saturation ($rSco_2$) of >20% from Baseline for the 340 Clinician-Identified Events

61% rSO_2 ↘ during CPB….

….resolved in 92%!

	Intervention-corrected $rSco_2$ desaturation
Treat hypotension	67 (29.8%)
Increase FIO_2%	35 (15.6%)
Normalize CPB flow	32 (14.2%)
RBC transfusion	31 (13.8%)
Decrease CPB "Sweep Speed"	25 (11.1%)
Deepen anesthesia	24 (10.7%)
Adjust CPB cannula	18 (8.0%)
Reposition head to midline	6 (2.7%)

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Subramanian et al. Anesthesiology 2016


143
CTH
146
CT
1.0
CTR
18.8
CS
17.2
PCS
1.6
FCS
HEMODYNAMICS
Quantra


ID PT :
lebreton
dominique
Démarrer :
17:48
Écoulé :
0:10:06
Statut :
Terminé
Nouveau
0000
18:02
150 s
109 s
60 s
143 s
480 s
CTH
164 s
113 s
60 s
198 s
480 s
CT
1,4
0,5
0,5
1,4
CTR
33,2 hPa
13 hPa
2 hPa
14,5 hPa
65 hPa
CS
29,8 hPa
14,2 hPa
2 hPa
13,0 hPa
50 hPa
PCS
3,7 hPa
1,9 hPa
0,2 hPa
1,5 hPa
30 hPa
FCS
Type de cartouche :
QPlus

Take Home Messages

A « good» hemodynamic management during CPB is a "case by case" strategy :

- ✓adapted to the patient (not to the physician)
- ✓Pump flow ++++
- ✓DO_2, $D0_2/VC0_2$, Ht….
- ✓MAP is the last step (MAP ≈ 50 mmhg)
- ✓Adapted transfusion

Crucial and modern tools are:

- ✓GDP
- ✓NIRS