

MONITORAGE HÉMODYNAMIQUE EN ANESTHÉSIE PÉDIATRIQUE

O. Raux

CHU Montpellier

PAS DE CONFLIT D'INTÉRÊT



MONITORAGE DU DÉBIT CARDIAQUE EN ANESTHÉSIE PÉDIATRIQUE

Valeur des éléments cliniques (FC, PA, diurèse, TRC, perfusion périphérique…)

PA: mesure non invasive / invasive, seuils d'hypoTA en pédiatrie ? (PAM: 40 + 1,5 x âge en années)

PVC: (in)utilité ?

Monitorage $ScvO_2$

Stratégie de remplissage (restrictif ?), prédiction réponse au remplissage

Échographie cardiaque

Monitorage des lactates

Oxymétrie tissulaire (NIRS)

Microcirculation

…

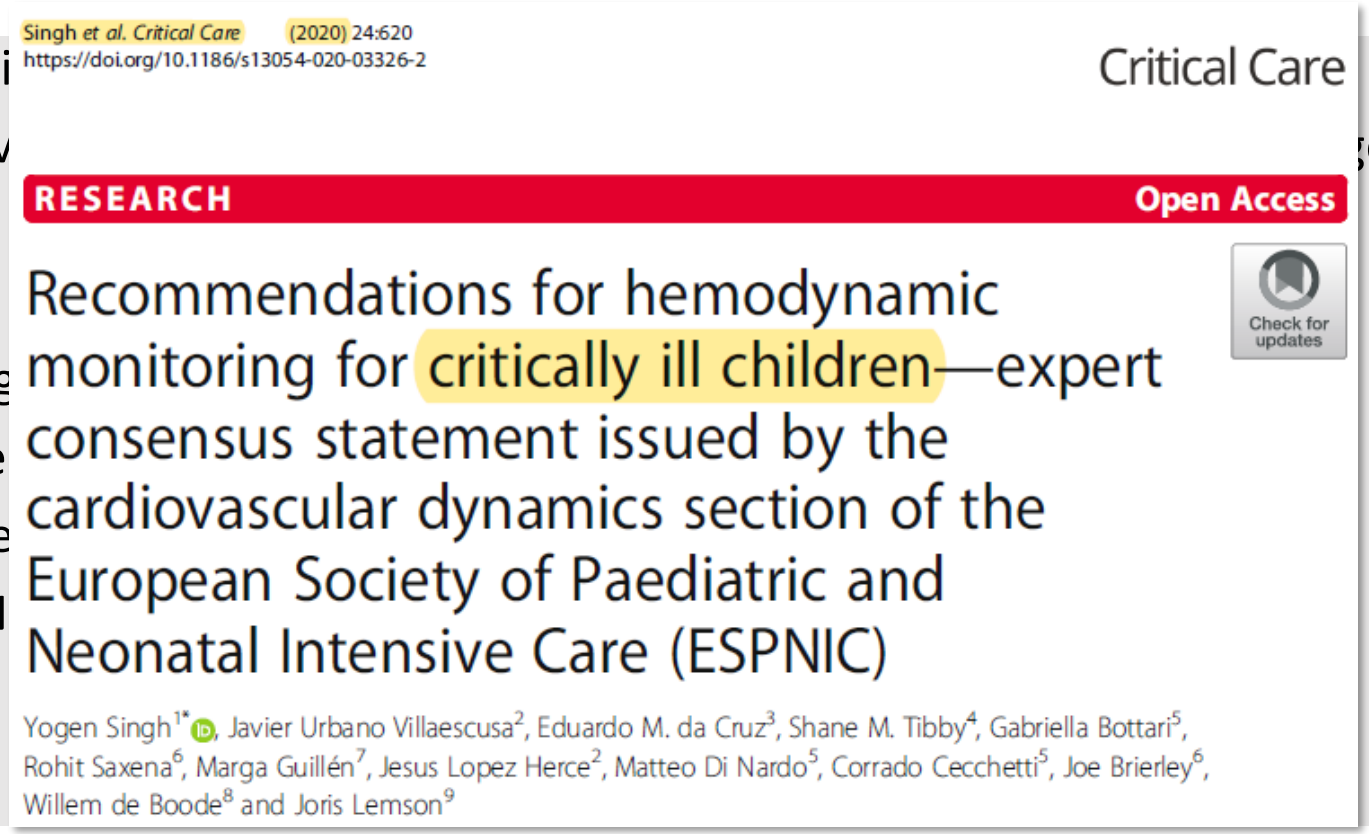
39e CONGRÈS ANNUEL DE L'ADARPEF
Association des Anesthésistes Réanimateurs Pédiatriques d'Expression Française
25 & 26 MARS 2022 MONTPELLIER Le Corum

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Singh et al. Critical Care (2020) 24:620
https://doi.org/10.1186/s13054-020-03326-2



Critical Care

RESEARCH Open Access

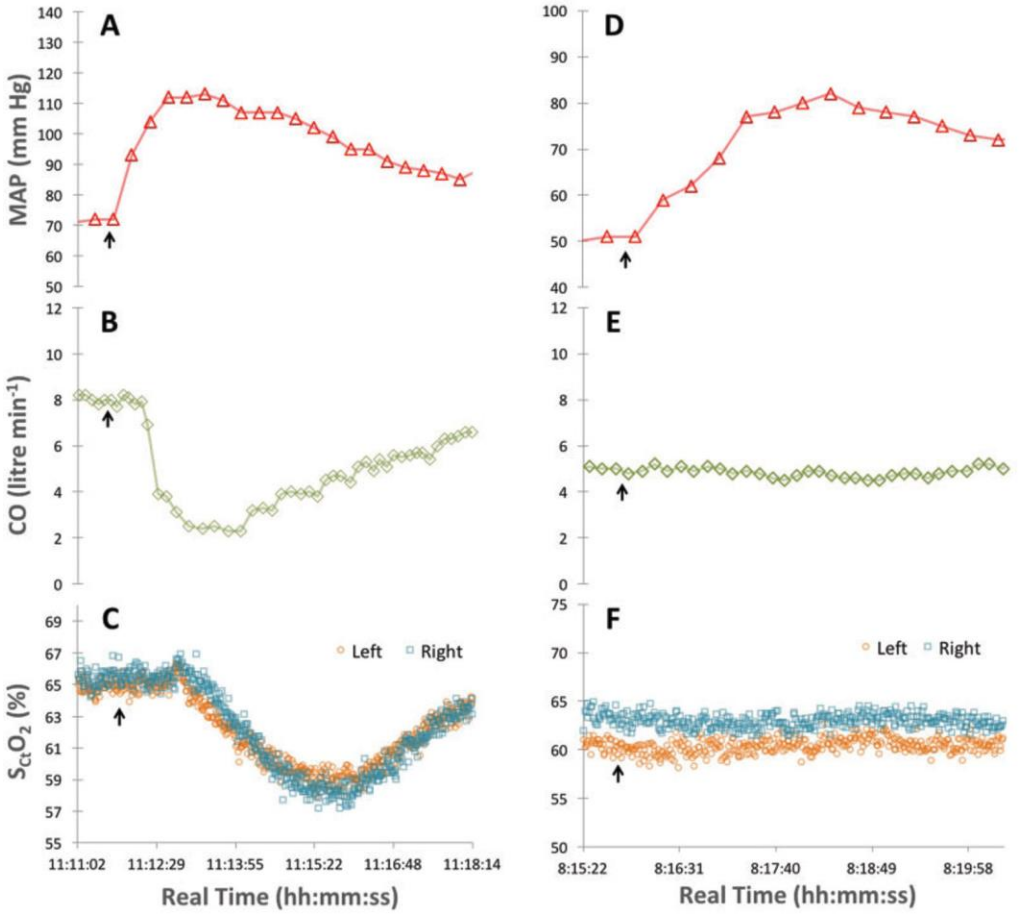
Recommendations for hemodynamic monitoring for critically ill children—expert consensus statement issued by the cardiovascular dynamics section of the European Society of Paediatric and Neonatal Intensive Care (ESPNIC)

Yogen Singh[1*], Javier Urbano Villaescusa[2], Eduardo M. da Cruz[3], Shane M. Tibby[4], Gabriella Bottari[5], Rohit Saxena[6], Marga Guillén[7], Jesus Lopez Herce[2], Matteo Di Nardo[5], Corrado Cecchetti[5], Joe Brierley[6], Willem de Boode[8] and Joris Lemson[9]

Monitorage du DC: pourquoi ?

- PA = DC x RVS
- Optimiser le DC ➔ TO_2

- GDT : Goal-Directed Therapy
- GDFT: Goal-Directed Fluid Therapy
  - Remplissage
- GDHDT: Goal-Directed Haemodynamic Therapy
  - Remplissage
  - Inotropes
  - Vasopresseurs ➔ PA

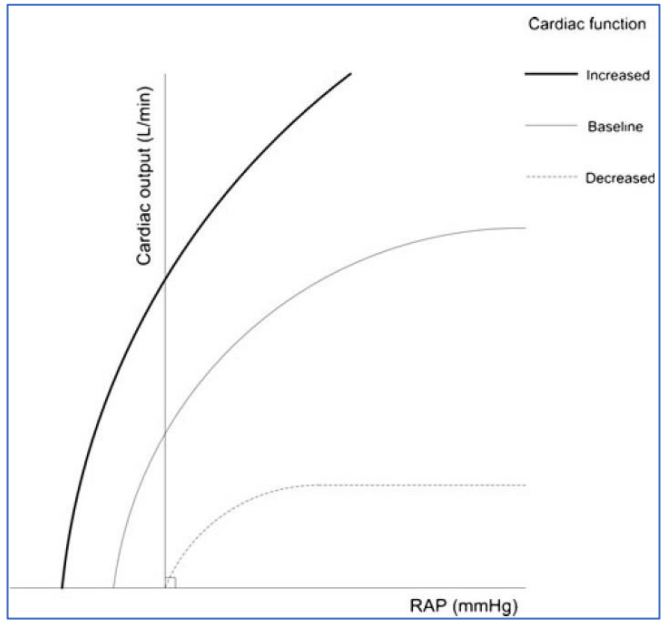


Meng, BJA 2016

DC & remplissage: réponse au remplissage

Cherpanath , Neth Heart J 2013

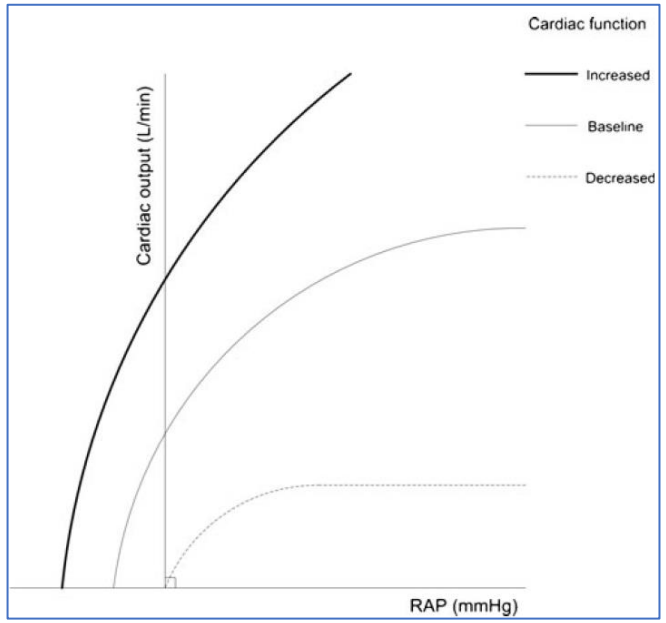
Franck-Starling



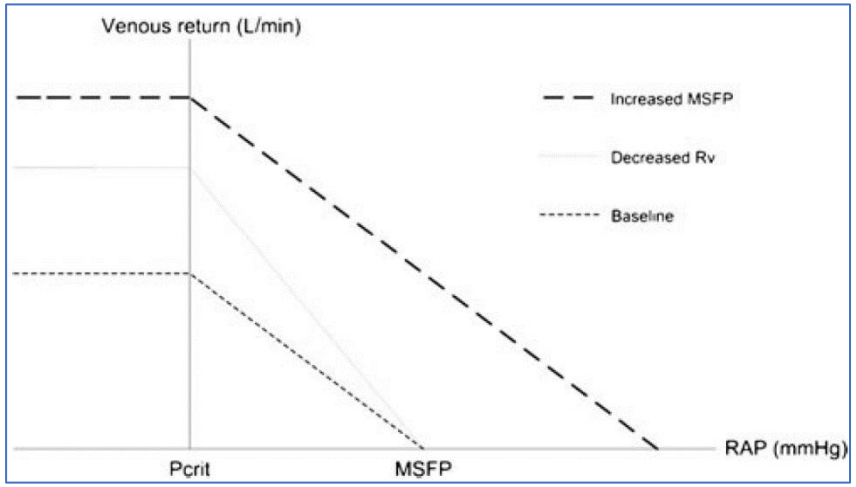
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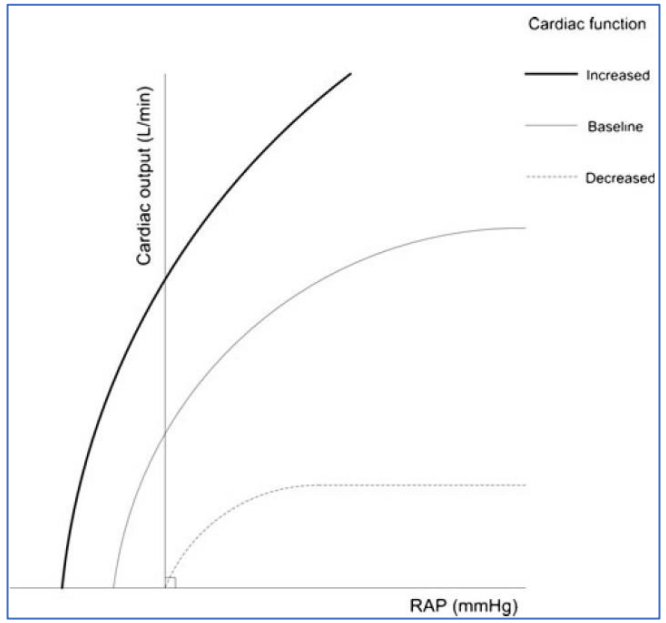
Guyton



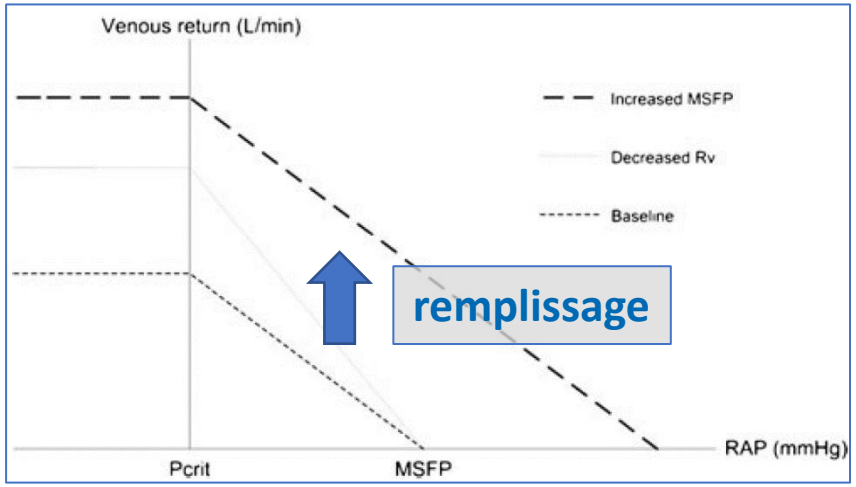
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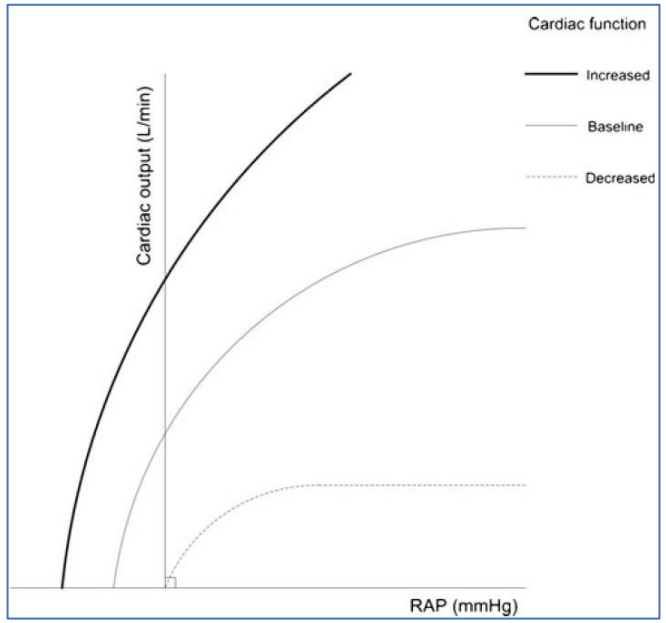


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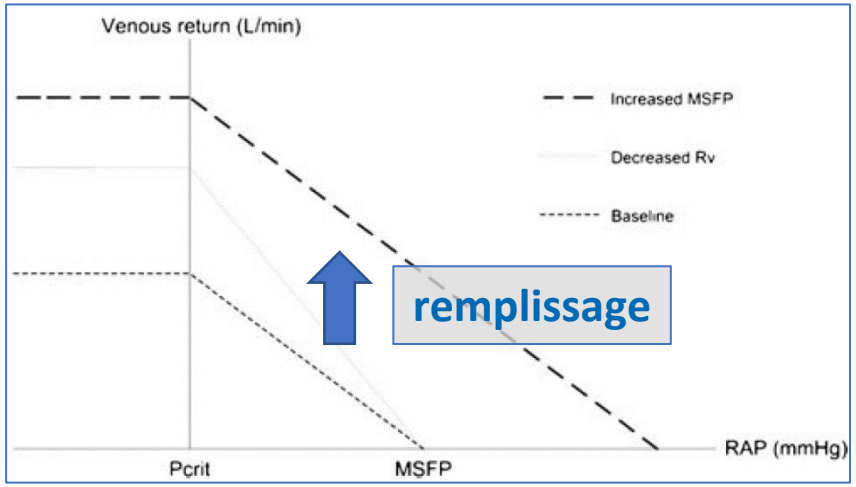
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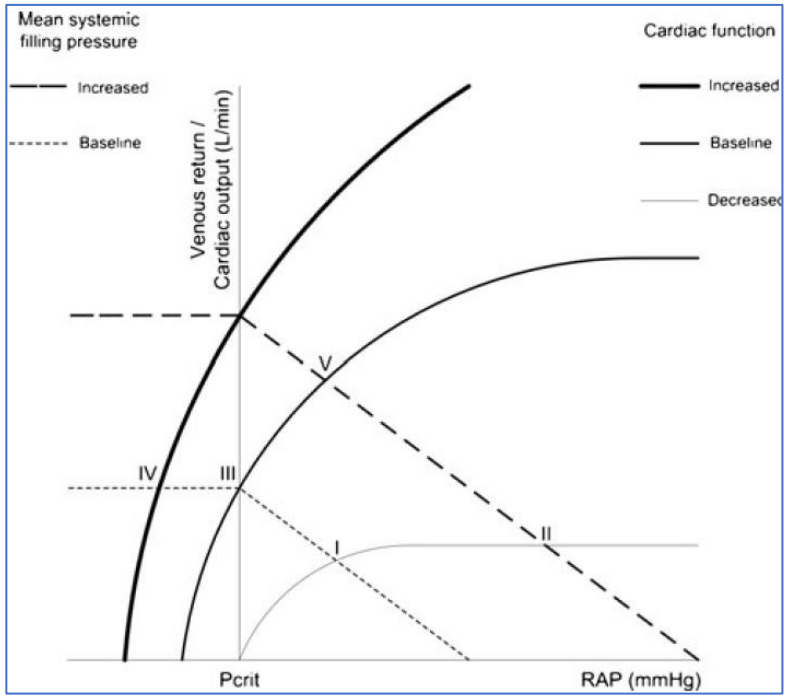
« le cœur pompe ce qu'il reçoit »

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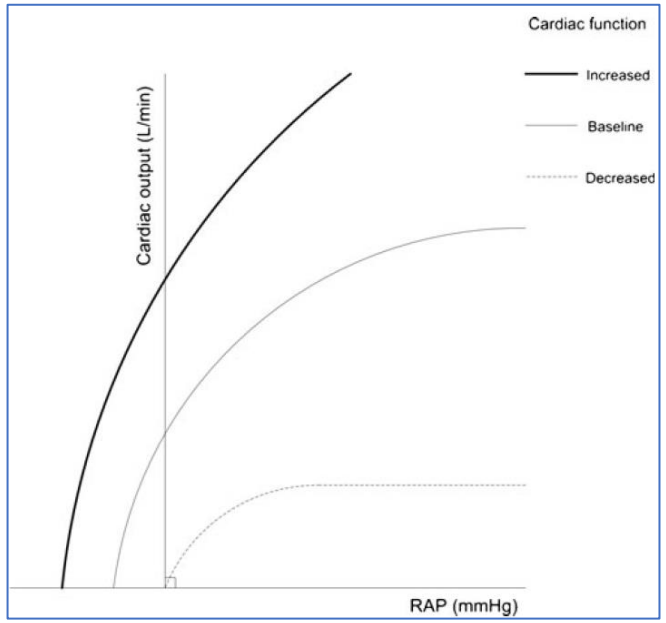


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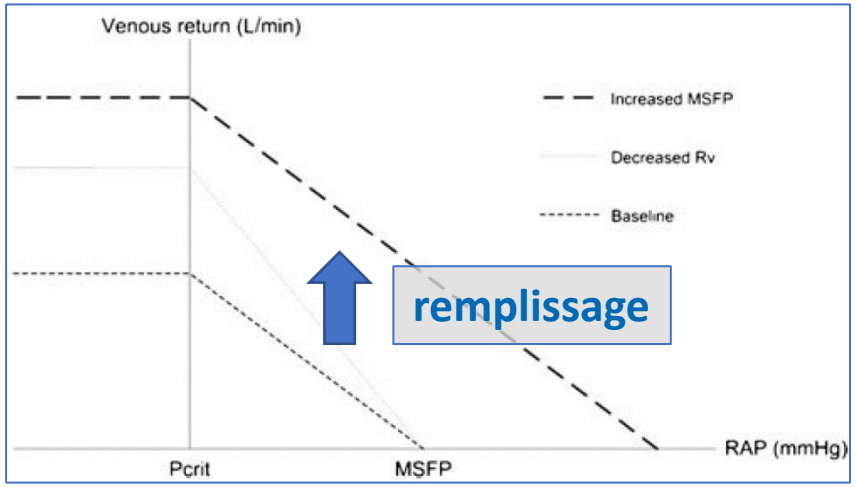
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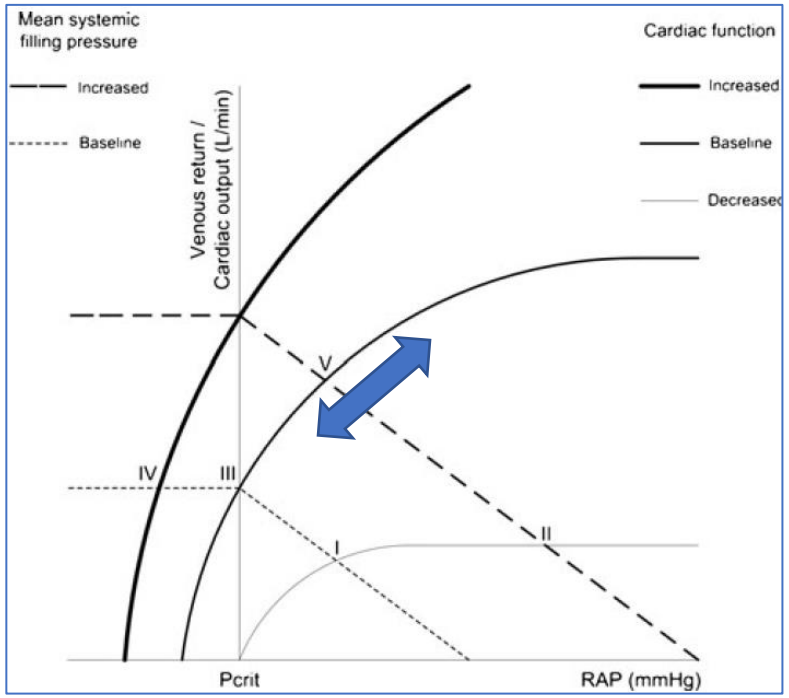
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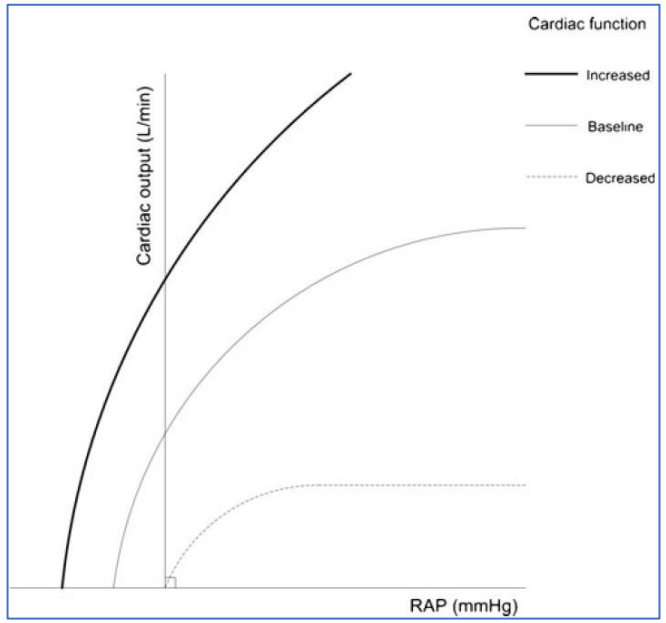


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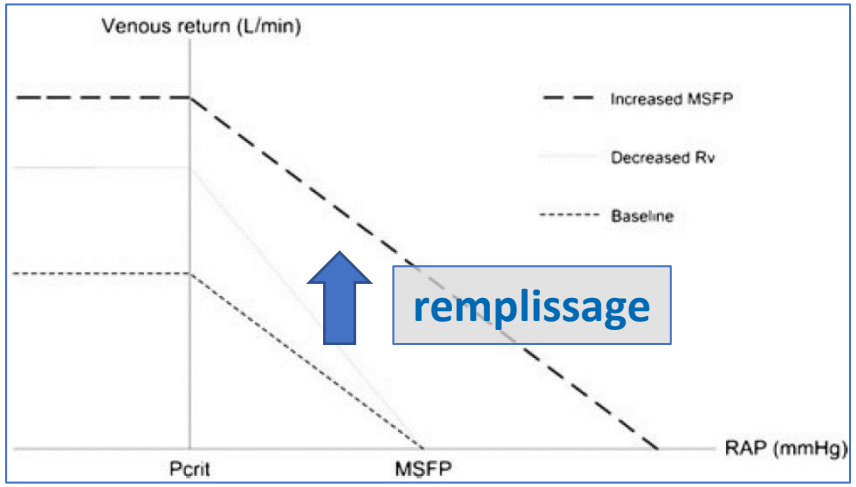
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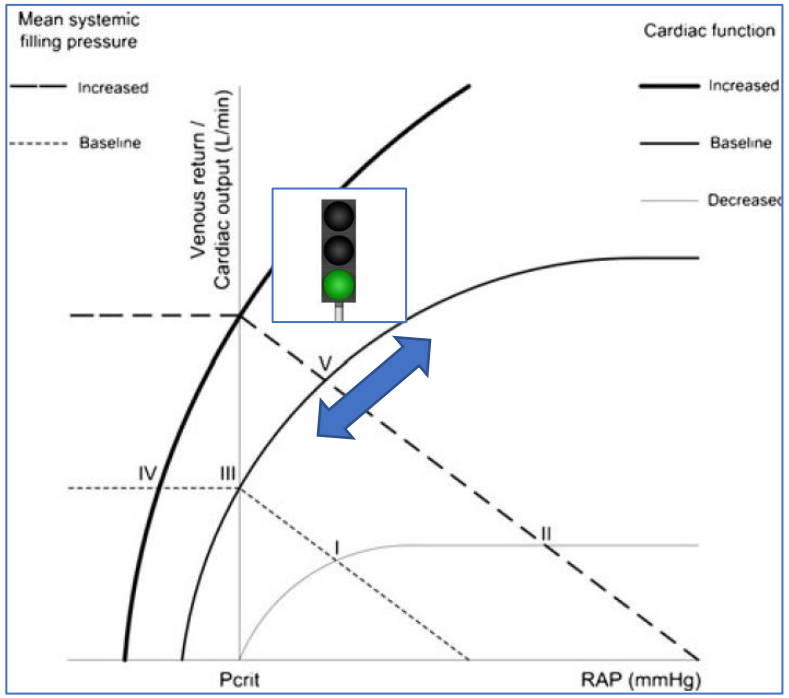
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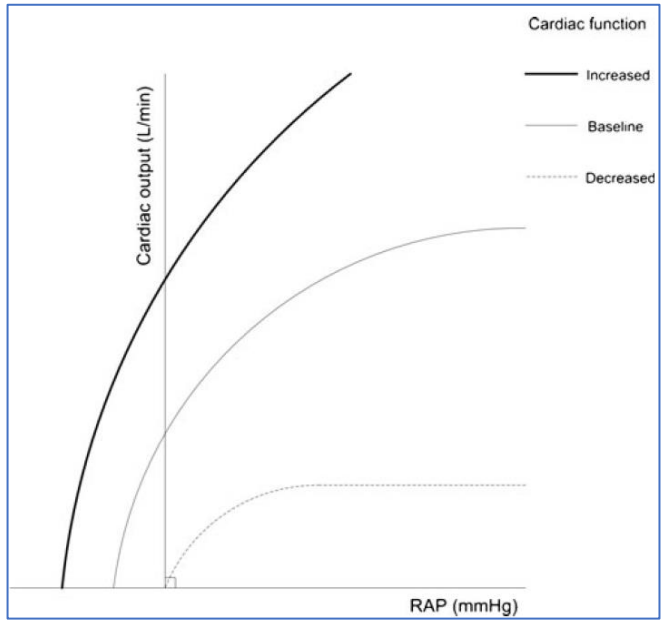


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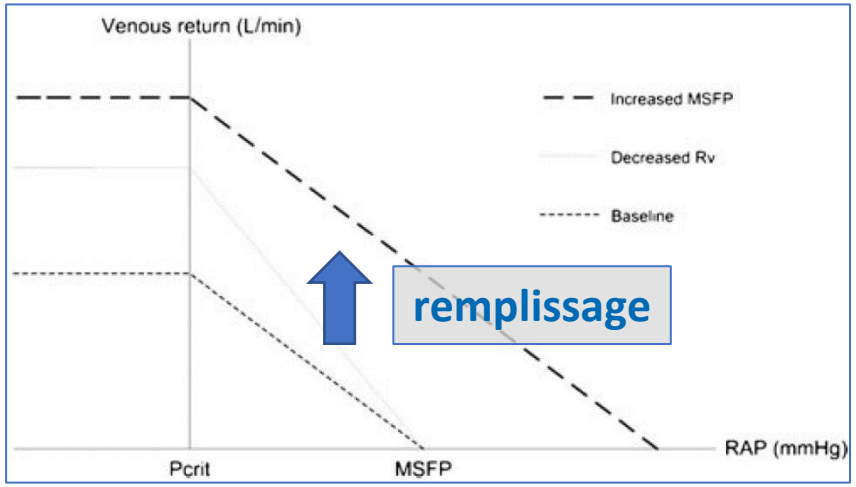
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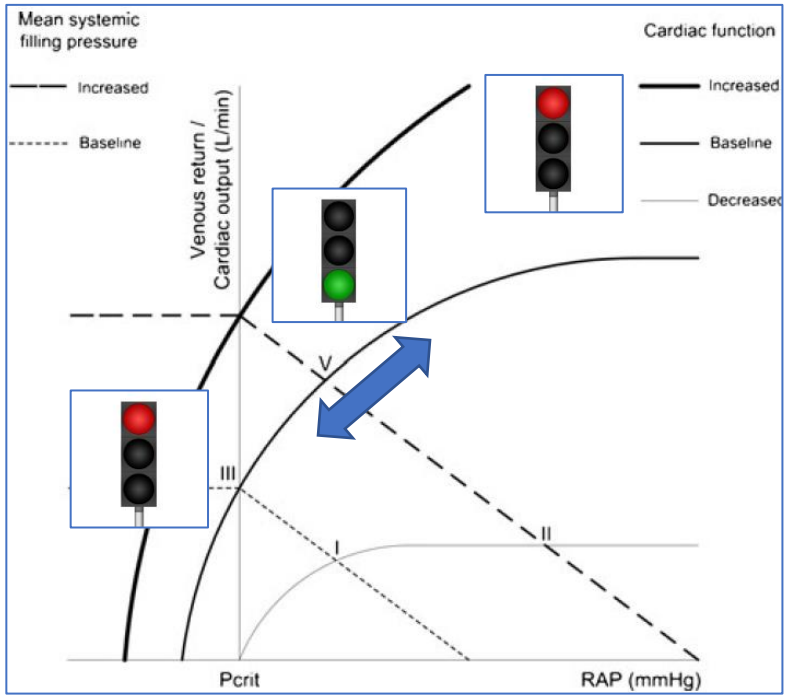
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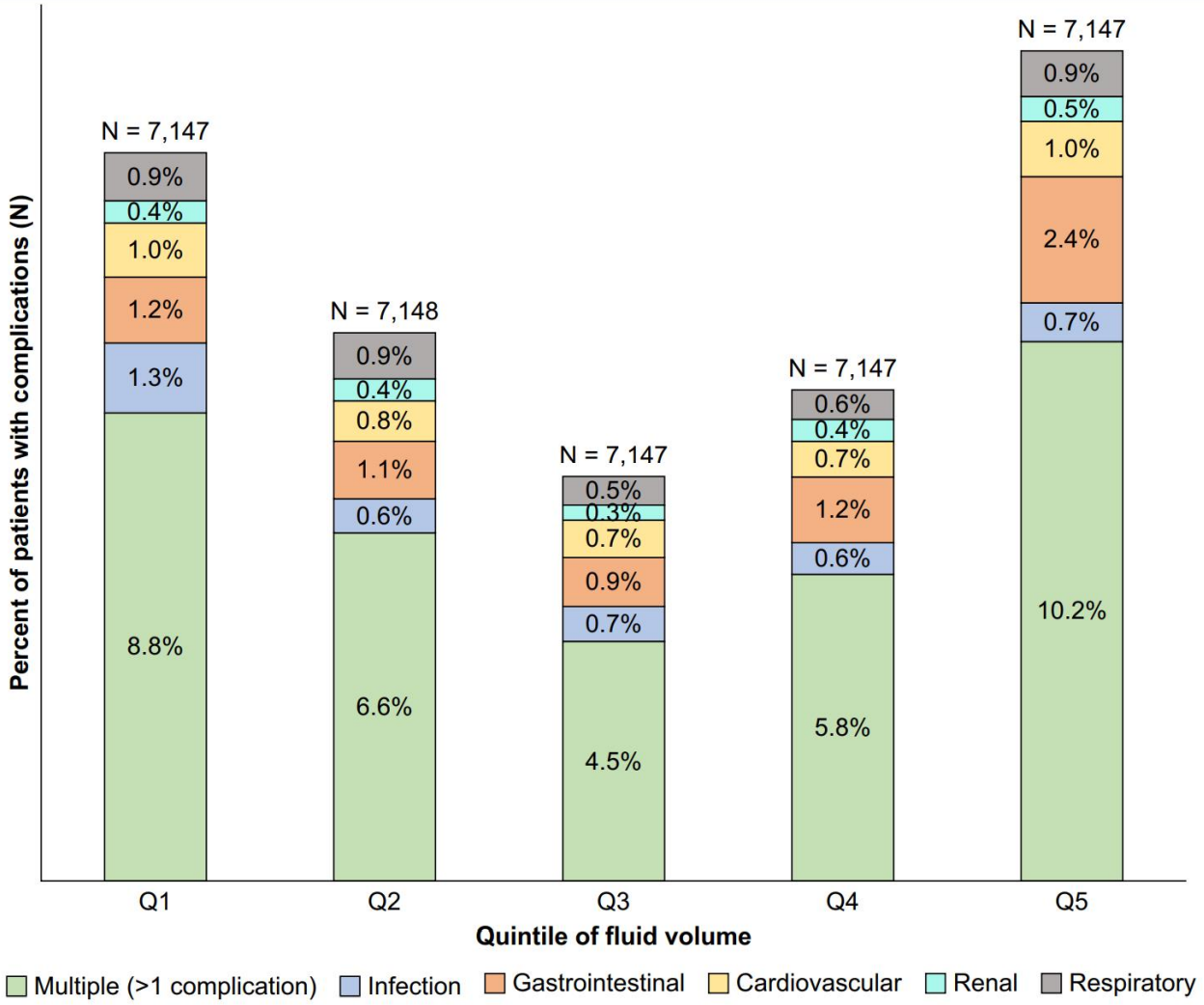
Association between perioperative fluid management and patient outcomes: multicenter retrospective study

Miller, BJA 2021

Database 35 700 patients, chirurgies variées non cardiaque

Incidence des complications significatives (hospit > 7 j) en ft volume de perf le jour de l'intervention (24 1ères h)

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Q4: 2300-3200 ml
Q5: 3200-7900 ml



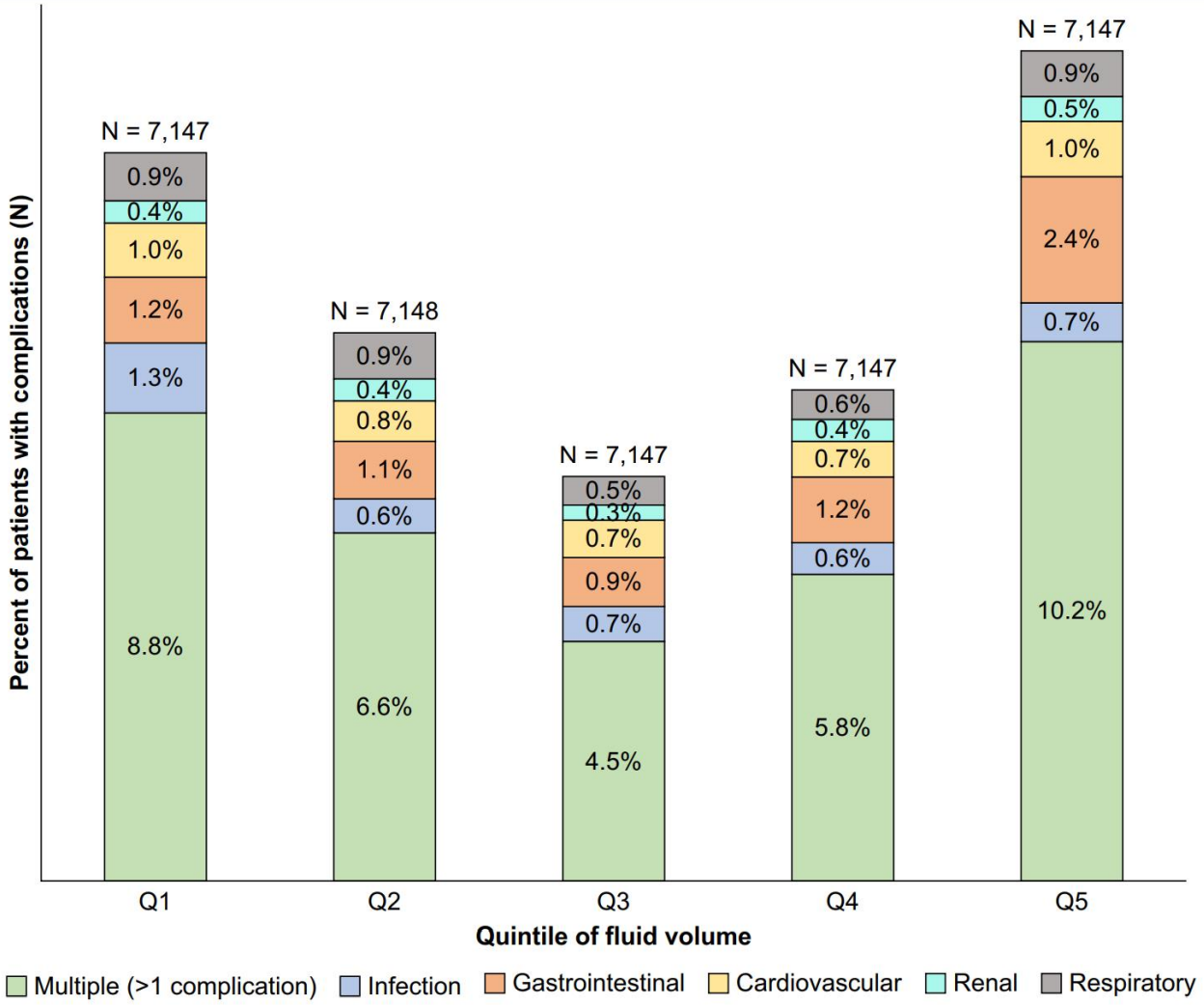
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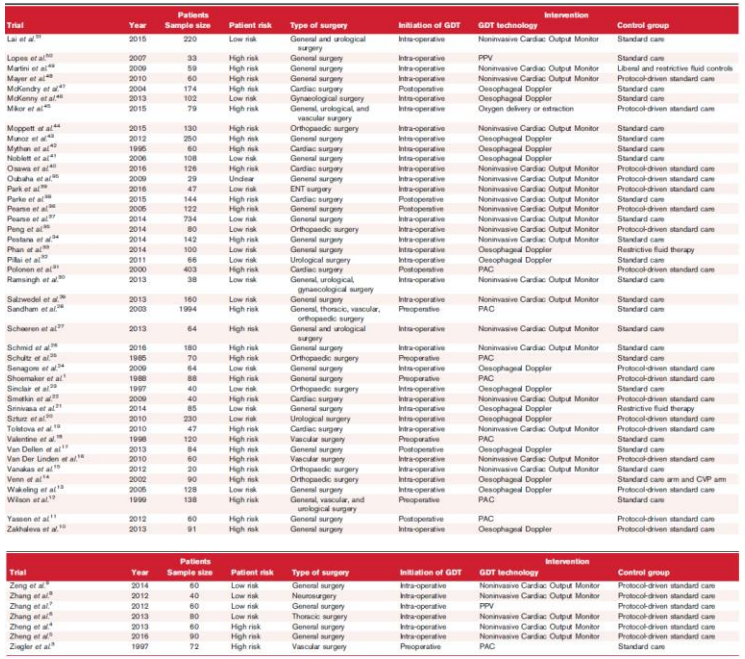
COURBE en U

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A systematic review and meta-analysis — *Chong, Eur J Anaesthesiol 2018*

95 études contrôlées randomisées, 11 700 patients

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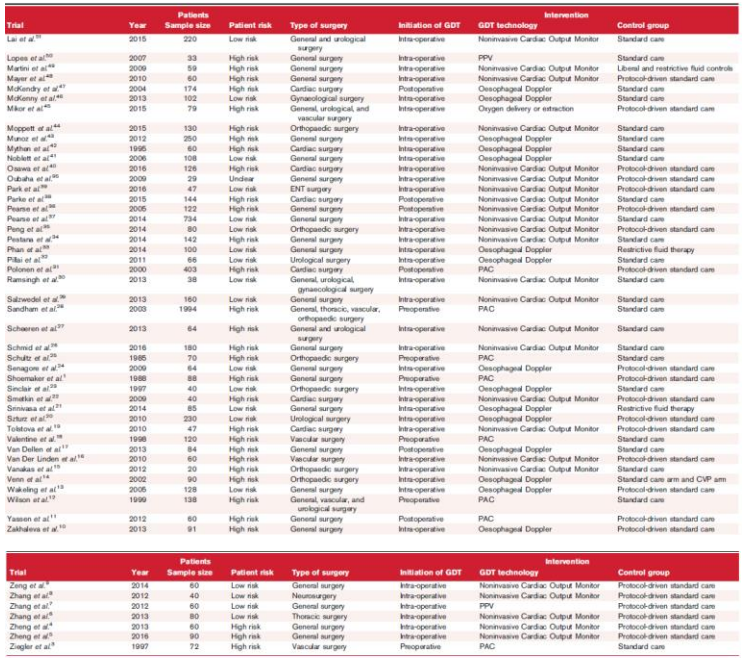
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- 13 études = PAC
- 23 études = DTO
- **52 études = analyse onde de PA**
- 7 études = diverses (PPV, O2ER, échoG)



↘ Morbi-mortalité postopératoire & durée de séjour

Faible niveau de preuve

Hétérogénité: type de moniteur, protocole & objectif de GDT

Outcomes	Illustrative comparative risks (95% CI) Assumed risk (standard care group)	Corresponding risk reduction in GDT group (95% CI)	Relative effect (95% CI)	Number of subjects (number of studies)	Quality of the evidence (GRADE)
Mortality	52 per 1000 patients	18 (7 to 26) events avoided per 1000 patients	0.66 (0.50 to 0.87)	5550 (52)	⊕⊕ low[a]
Arrhythmia	109 per 1000 patients	30 (10 to 47) events avoided per 1000 patients	0.70 (0.55 to 0.91)	3269 (33)	⊕⊕ low[a]
CHF	28 per 1000 patients	Not significantly different	0.61 (0.33 to 1.12)	2125 (17)	⊕⊕ low[a]
Pneumonia	93 per 1000 patients	27 (7 to 43) events avoided per 1000 patients	0.69 (0.52 to 0.92)	2776 (29)	⊕⊕ low[a]
Wound infection	111 per 1000 patients	55 (39 to 67) events avoided per 1000 patients	0.48 (0.37 to 0.63)	3593 (32)	⊕⊕ low[a]
AKI	141 per 1000 patients	35 (11 to 55) events avoided per 1000 patients	0.73 (0.58 to 0.92)	4310 (37)	⊕⊕ low[a]
Hospital LoS	The mean hospital LoS ranged across control groups from 1.2 to 29 days	The mean hospital LoS was 0.90 (0.48 to 1.32) days shorter in the GDT group		8797 (62)	⊕ very low[a,b]

Analyse en sous-groupes (↘ mortalité):

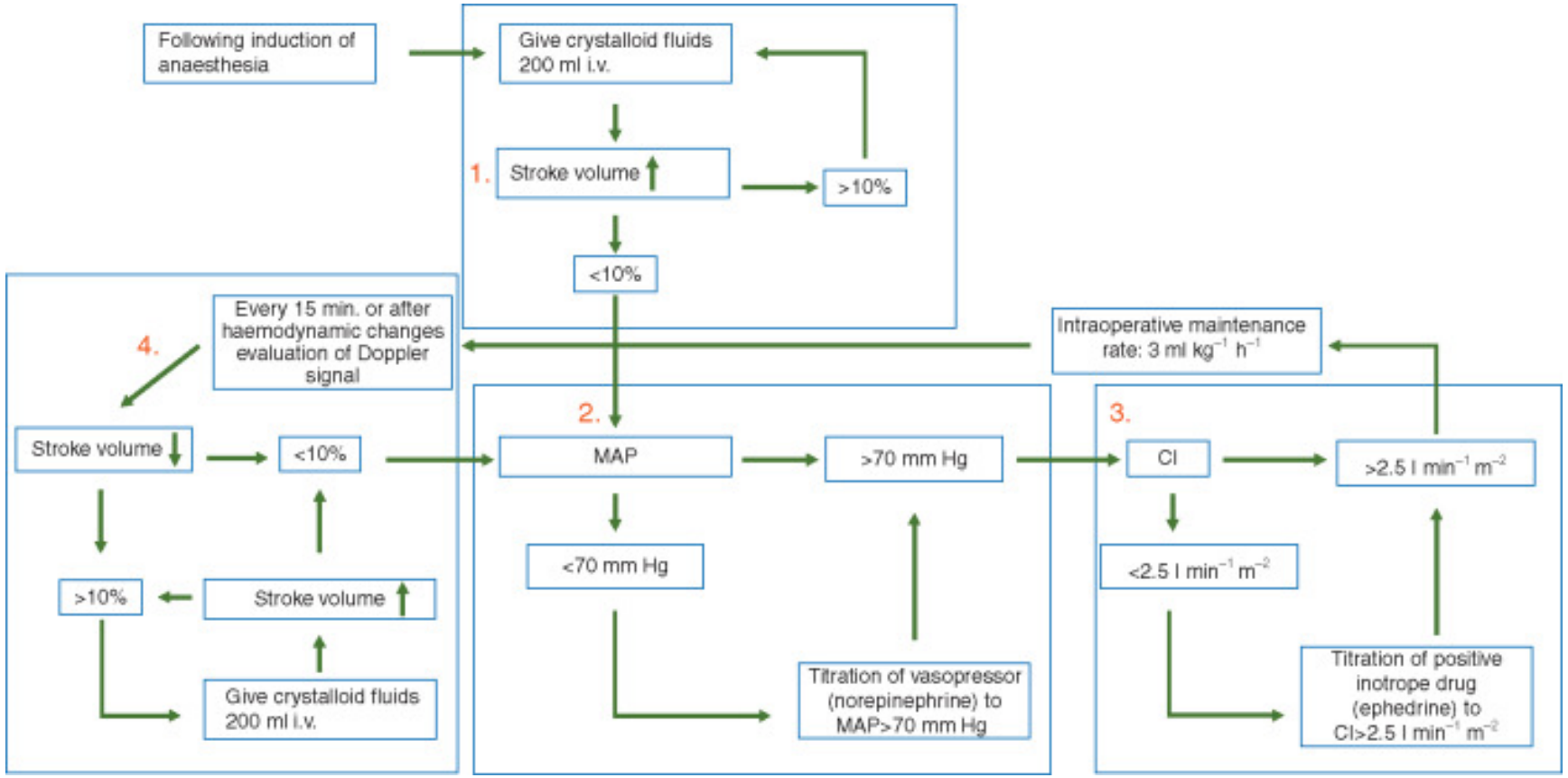
patients à risque, chirurgie lourde, association de vasopresseurs, moniteurs de DC mini-invasifs (analyse d'onde de pouls)

Subgroup	OR (95% CI)	NNTB or (NNTH)	*N* of studies	*P* value
Overall pooled; $I^2 = 0.0\%$	**0.66 (0.50 to 0.87)**	**59**	**52**	**0.004**
Patient risk				
High	**0.60 (0.42 to 0.85)**	**34**	**28**	**0.004**
Low	0.79 (0.50 to 1.24)	–	24	0.30
Surgical risk				
High	**0.69 (0.51 to 0.95)**	**75**	**43**	**0.02**
Intermediate	0.55 (0.30 to 1.02)	–	9	0.06
Industry ties				
Yes	0.83 (0.56 to 1.22)	–	23	0.34
No	**0.52 (0.35 to 0.77)**	**35**	**29**	**0.001**
Surgical type				
Noncardiac	**0.67 (0.50 to 0.91)**	**60**	**44**	**0.009**
Cardiac	0.59 (0.27 to 1.27)	–	8	0.18
Elective surgery				
Elective only	**0.66 (0.48 to 0.92)**	**73**	**45**	**0.01**
Includes emergency cases	0.66 (0.39 to 1.12)	–	7	0.13
Start of GDT				
Preoperative	–	–	1	–
Intraoperative	**0.65 (0.47 to 0.89)**	**59**	**45**	**0.007**
Postoperative	0.72 (0.38 to 1.33)	–	6	0.29
Use of vasopressors				
If required per protocol	**0.59 (0.40 to 0.89)**	**44**	**26**	**0.01**
Not per protocol (fluid-based intervention only)	0.65 (0.41 to 1.05)	–	23	0.08
Per protocol (mandatory)	–	–	2	0.85
Unclear	–	–	1	0.55
Technology				
Cardiac output monitors	**0.68 (0.49 to 0.95)**	**56**	**29**	**0.02**
Oesophageal Doppler	0.71 (0.39 to 1.28)	–	16	0.26
Pulse pressure variation	0.54 (0.14 to 2.05)	–	4	0.37
Oxygen delivery or extraction	–	–	2	–
Echocardiography	–	–	1	–
Study size				
Large trials ($n \geq 100$)	**0.69 (0.50 to 0.95)**	**59**	**24**	**0.02**
Small trials ($n < 100$)	0.59 (0.34 to 1.03)	–	28	0.06

DTO guided Goal directed hemodynamic therapy algorythm

chirurgie non cardiaque

Feldheiser, J Int Med Res 2012



The effects of goal-directed fluid therapy based on dynamic parameters on post-surgical outcome: a meta-analysis of randomized controlled trials

Benes, Crit Care 2014

14 études randomisées (chir abdominale lourde: 11 études), 960 patients

Study	Type of surgery	Risk	Number of participants*	Timing	GDFTdyn end point	Other optimization goals	Type of intervention	Mortality reported	Morbidity reported
Benes, 2010 [38] Europe	Major abdominal	High	120 (60/60)	Intra	SVV <10%	CI >2.5 l/min/m^2, MAP >65 mmHg, CVP <15 mmHg,	Fluids, inotropes	Y	CV, GI, infectious, renal, respiratory
Buettner, 2008 [11] Europe	Major abdominal	Moderate	80 (40/40)	Intra	SPV <10%	N/A	Fluids	Y	-
Forget, 2010 [37] Europe	Abdominal	Moderate	82 (41/41)	Intra	PVI <10%	MAP >65 mmHg	Fluids	Y	CV, GI, infectious, renal
Goepfert, 2013 [36] Europe	Elective cardiac	High	100 (50/50)	Intra, post	SVV <10%	CI >2.0 l/min/m^2, MAP >65 mmHg, HR 50-100 bpm, EVLWI ≤12 ml/kg	Fluids, inotropes	N	CV, infectious, respiratory, renal
Harten, 2008 [35] Europe	Emergency abdominal	High	29 (15/14)	Intra	PPV <10%	N/A	Fluids	Y	CV, GI, infectious, renal, respiratory
Kapoor, 2008 [39] India	Cardiac	High	27 (14/13)	Intra, post	SVV <10%	CI >2.5 mL/min/m^2, CVP >6 mmHg, $ScvO_2$ > 70%, SVI >30 ml/m^2, SVRI >1,500 dynes.s/cm^5/m^2, DO_2I >450 ml/min/m^2	Fluids, inotropes	Y	GI, CV, renal, respiratory
Lopes, 2007 [10] Brazil	Major abdominal	High	33 (16/17)	Intra	PPV <10%	N/A	Fluids	Y	CV, GI, infectious, renal, respiratory
Mayer, 2010 [40] Europe	Major abdominal	High	60 (30/30)	Intra	SVV <12%	CI >2.5 mL/min/m^2, MAP >65 mmHg, SVI >35 ml/m^2	Fluids, inotropes	Y	Renal, respiratory
Ramsingh, 2013 [34] USA	Major abdominal	High	38 (20/18)	Intra	SVV <13%	N/A	Fluids	N	-
Salzwedel, 2013 [30] Europe	Elective abdominal	Moderate	160 (81/79)	Intra	PPV <10%	CI >2.5 mL/min/m^2, MAP >65 mmHg	Fluids, inotropes	N	CV, GI, infectious, renal, respiratory
Sheeren, 2013 [33] Europe	Major abdominal	High	52 (26/26)	Intra	SVV <10%	SV increase >10%	Fluids	Y	CV, GI, infectious, renal, respiratory
Zhang Ju, 2012 [32] China	Major abdominal	Low	60 (20/40)	Intra	PPV <11%	N/A	Fluids	N	CV, GI, infectious, renal, respiratory
Zhang Ji, 2013 [31] China	Thoracic	Moderate	60 (30/30)	Intra	SVV <9%	CI >2.5 mL/min/m^2, MAP >65 mmHg	Fluids, inotropes	N	GI, infectious, renal, Respiratory
Zheng, 2013 [29] China	Elective abdominal	Moderate	60 (30/30)	Intra, post	SVV <12%	CI >2.5 mL/min/m^2, MAP >65 mmHg, SVI >35 ml/m^2	Fluids, inotropes	N	CV, GI

The effects of goal-directed fluid therapy based on dynamic parameters on post-surgical outcome: a meta-analysis of randomized controlled trials

Benes, Crit Care 2014

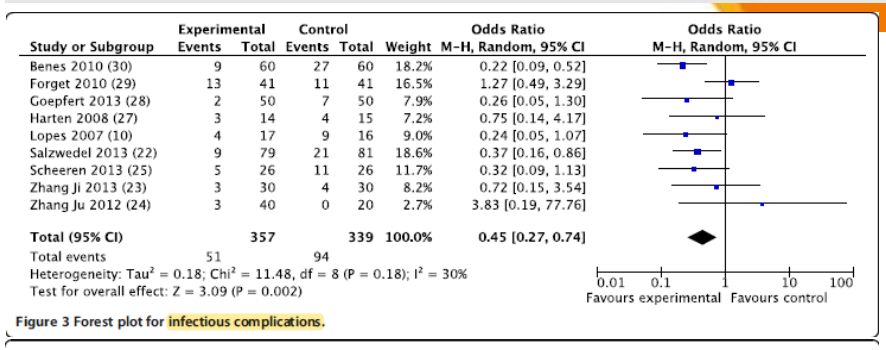
14 études randomisées (chir abdominale lourde: 11 études), 960 patients

7 études / 14 (SVV):
Flo-Trac (onde de PA)

			Number of participants*	Timing	GDFTdyn end point	Other optimization goals	Type of intervention	Mortality reported	Morbidity reported
Buettner, 2008 [11] Europe	Major abdominal	Moderate	120 (60/60)	Intra	SVV < 10%	CI >2.5 l/min/m^2, MAP >65 mmHg, CVP <15 mmHg,	Fluids, inotropes	Y	CV, GI, infectious, renal, respiratory
Forget, 2010 [37] Europe	Abdominal	Moderate	80 (40/40)	Intra	SPV < 10%	N/A	Fluids	Y	-
Goepfert, 2013 [36] Europe	Elective cardiac	High	82 (41/41)	Intra	PVI < 10%	MAP >65 mmHg	Fluids	Y	CV, GI, infectious, renal
Harten, 2008 [35] Europe	Emergency abdominal	High	100 (50/50)	Intra, post	SVV < 10%	CI >2.0 l/min/m^2, MAP >65 mmHg, HR 50-100 bpm, EVLWI ≤12 ml/kg	Fluids, inotropes	N	CV, infectious, respiratory, renal
Kapoor, 2008 [39] India	Cardiac	High	29 (15/14)	Intra	PPV <10%	N/A	Fluids	Y	CV, GI, infectious, renal, respiratory
Lopes, 2007 [10] Brazil	Major abdominal	High	27 (14/13)	Intra, post	SVV < 10%	CI >2.5 mL/min/m^2, CVP >6 mmHg, $ScvO_2$ > 70%, SVI >30 ml/m^2, SVRI >1,500 dynes.s/cm^5/m^2, DO_2I >450 ml/min/m^2	Fluids, inotropes	Y	GI, CV, renal, respiratory
Mayer, 2010 [40] Europe	Major abdominal	High	33 (16/17)	Intra	PPV <10%	N/A	Fluids	Y	CV, GI, infectious, renal, respiratory
Ramsingh, 2013 [34] USA	Major abdominal	High	60 (30/30)	Intra	SVV < 12%	CI >2.5 mL/min/m^2, MAP >65 mmHg, SVI >35 ml/m^2	Fluids, inotropes	Y	Renal, respiratory
Salzwedel, 2013 [30] Europe	Elective abdominal	Moderate	38 (20/18)	Intra	SVV < 13%	N/A	Fluids	N	-
Sheeren, 2013 [33] Europe	Major abdominal	High	160 (81/79)	Intra	PPV <10%	CI >2.5 mL/min/m^2, MAP >65 mmHg	Fluids, inotropes	N	CV, GI, infectious, renal, respiratory
Zhang Ju, 2012 [32] China	Major abdominal	Low	52 (26/26)	Intra	SVV < 10%	SV increase >10%	Fluids	Y	CV, GI, infectious, renal, respiratory
Zhang Ji, 2013 [31] China	Thoracic	Moderate	60 (30/30)	Intra	PPV <11%	N/A	Fluids	N	CV, GI, infectious, renal, respiratory
Zheng, 2013 [29] China	Elective abdominal	Moderate	60 (30/30)	Intra	SVV <9%	CI >2.5 mL/min/m^2, MAP >65 mmHg	Fluids, inotropes	N	GI, infectious, renal, Respiratory
			60 (30/30)	Intra, post	SVV < 12%	CI >2.5 mL/min/m^2, MAP >65 mmHg, SVI >35 ml/m^2	Fluids, inotropes	N	CV, GI

The effects of goal-directed fluid therapy based on dynamic parameters on post-surgical outcome: a meta-analysis of randomized controlled trials

Benes, Crit Care 2014

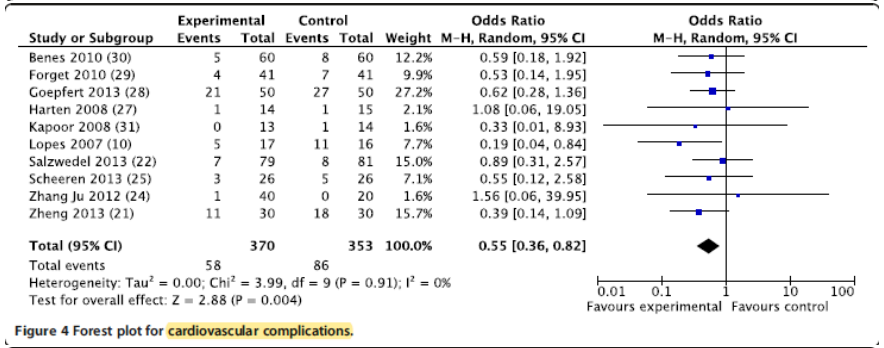


Study or Subgroup	Experimental Events	Experimental Total	Control Events	Control Total	Weight	Odds Ratio M-H, Random, 95% CI
Benes 2010 (30)	9	60	27	60	18.2%	0.22 [0.09, 0.52]
Forget 2010 (29)	13	41	11	41	16.5%	1.27 [0.49, 3.29]
Goepfert 2013 (28)	2	50	7	50	7.9%	0.26 [0.05, 1.30]
Harten 2008 (27)	3	14	4	15	7.2%	0.75 [0.14, 4.17]
Lopes 2007 (10)	4	17	9	16	9.0%	0.24 [0.05, 1.07]
Salzwedel 2013 (22)	9	79	21	81	18.6%	0.37 [0.16, 0.86]
Scheeren 2013 (25)	5	26	11	26	11.7%	0.32 [0.09, 1.13]
Zhang Ji 2013 (23)	3	30	4	30	8.2%	0.72 [0.15, 3.54]
Zhang Ju 2012 (24)	3	40	0	20	2.7%	3.83 [0.19, 77.76]
Total (95% CI)		**357**		**339**	**100.0%**	**0.45 [0.27, 0.74]**
Total events	51		94			

Heterogeneity: Tau² = 0.18; Chi² = 11.48, df = 8 (P = 0.18); I² = 30%
Test for overall effect: Z = 3.09 (P = 0.002)

0.01 0.1 1 10 100
Favours experimental Favours control

Figure 3 Forest plot for infectious complications.

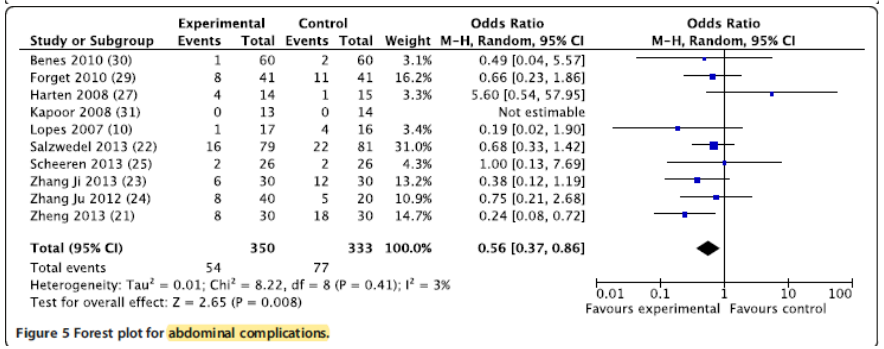


Study or Subgroup	Experimental Events	Experimental Total	Control Events	Control Total	Weight	Odds Ratio M-H, Random, 95% CI
Benes 2010 (30)	5	60	8	60	12.2%	0.59 [0.18, 1.92]
Forget 2010 (29)	4	41	7	41	9.9%	0.53 [0.14, 1.95]
Goepfert 2013 (28)	21	50	27	50	27.2%	0.62 [0.28, 1.36]
Harten 2008 (27)	1	14	1	15	2.1%	1.08 [0.06, 19.05]
Kapoor 2008 (31)	0	13	1	14	1.6%	0.33 [0.01, 8.93]
Lopes 2007 (10)	5	17	11	16	7.7%	0.19 [0.04, 0.84]
Salzwedel 2013 (22)	7	79	8	81	15.0%	0.89 [0.31, 2.57]
Scheeren 2013 (25)	3	26	5	26	7.1%	0.55 [0.12, 2.58]
Zhang Ju 2012 (24)	1	40	0	20	1.6%	1.56 [0.06, 39.95]
Zheng 2013 (21)	11	30	18	30	15.7%	0.39 [0.14, 1.09]
Total (95% CI)		**370**		**353**	**100.0%**	**0.55 [0.36, 0.82]**
Total events	58		86			

Heterogeneity: Tau² = 0.00; Chi² = 3.99, df = 9 (P = 0.91); I² = 0%
Test for overall effect: Z = 2.88 (P = 0.004)

0.01 0.1 1 10 100
Favours experimental Favours control

Figure 4 Forest plot for cardiovascular complications.

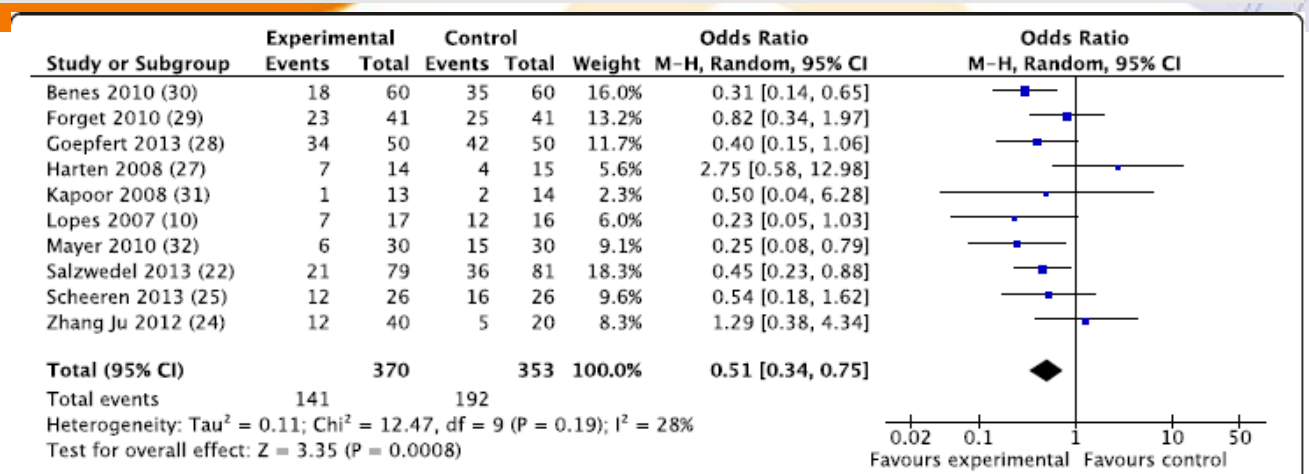


Study or Subgroup	Experimental Events	Experimental Total	Control Events	Control Total	Weight	Odds Ratio M-H, Random, 95% CI
Benes 2010 (30)	1	60	2	60	3.1%	0.49 [0.04, 5.57]
Forget 2010 (29)	8	41	11	41	16.2%	0.66 [0.23, 1.86]
Harten 2008 (27)	4	14	1	15	3.3%	5.60 [0.54, 57.95]
Kapoor 2008 (31)	0	13	0	14		Not estimable
Lopes 2007 (10)	1	17	4	16	3.4%	0.19 [0.02, 1.90]
Salzwedel 2013 (22)	16	79	22	81	31.0%	0.68 [0.33, 1.42]
Scheeren 2013 (25)	2	26	2	26	4.3%	1.00 [0.13, 7.69]
Zhang Ji 2013 (23)	6	30	12	30	13.2%	0.38 [0.12, 1.19]
Zhang Ju 2012 (24)	8	40	5	20	10.9%	0.75 [0.21, 2.68]
Zheng 2013 (21)	8	30	18	30	14.7%	0.24 [0.08, 0.72]
Total (95% CI)		**350**		**333**	**100.0%**	**0.56 [0.37, 0.86]**
Total events	54		77			

Heterogeneity: Tau² = 0.01; Chi² = 8.22, df = 8 (P = 0.41); I² = 3%
Test for overall effect: Z = 2.65 (P = 0.008)

0.01 0.1 1 10 100
Favours experimental Favours control

Figure 5 Forest plot for abdominal complications.

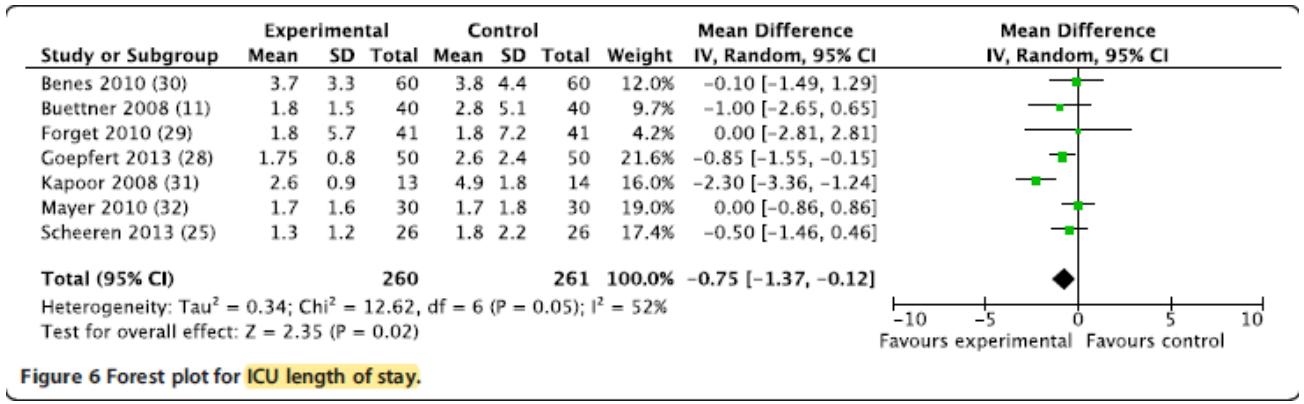


Study or Subgroup	Experimental Events	Experimental Total	Control Events	Control Total	Weight	Odds Ratio M-H, Random, 95% CI
Benes 2010 (30)	18	60	35	60	16.0%	0.31 [0.14, 0.65]
Forget 2010 (29)	23	41	25	41	13.2%	0.82 [0.34, 1.97]
Goepfert 2013 (28)	34	50	42	50	11.7%	0.40 [0.15, 1.06]
Harten 2008 (27)	7	14	4	15	5.6%	2.75 [0.58, 12.98]
Kapoor 2008 (31)	1	13	2	14	2.3%	0.50 [0.04, 6.28]
Lopes 2007 (10)	7	17	12	16	6.0%	0.23 [0.05, 1.03]
Mayer 2010 (32)	6	30	15	30	9.1%	0.25 [0.08, 0.79]
Salzwedel 2013 (22)	21	79	36	81	18.3%	0.45 [0.23, 0.88]
Scheeren 2013 (25)	12	26	16	26	9.6%	0.54 [0.18, 1.62]
Zhang Ju 2012 (24)	12	40	5	20	8.3%	1.29 [0.38, 4.34]
Total (95% CI)		**370**		**353**	**100.0%**	**0.51 [0.34, 0.75]**
Total events	141		192			

Heterogeneity: Tau² = 0.11; Chi² = 12.47, df = 9 (P = 0.19); I² = 28%
Test for overall effect: Z = 3.35 (P = 0.0008)

0.02 0.1 1 10 50
Favours experimental Favours control

Figure 2 Forest plot for post-surgical morbidity.



Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Random, 95% CI
Benes 2010 (30)	3.7	3.3	60	3.8	4.4	60	12.0%	-0.10 [-1.49, 1.29]
Buettner 2008 (11)	1.8	1.5	40	2.8	5.1	40	9.7%	-1.00 [-2.65, 0.65]
Forget 2010 (29)	1.8	5.7	41	1.8	7.2	41	4.2%	0.00 [-2.81, 2.81]
Goepfert 2013 (28)	1.75	0.8	50	2.6	2.4	50	21.6%	-0.85 [-1.55, -0.15]
Kapoor 2008 (31)	2.6	0.9	13	4.9	1.8	14	16.0%	-2.30 [-3.36, -1.24]
Mayer 2010 (32)	1.7	1.6	30	1.7	1.8	30	19.0%	0.00 [-0.86, 0.86]
Scheeren 2013 (25)	1.3	1.2	26	1.8	2.2	26	17.4%	-0.50 [-1.46, 0.46]
Total (95% CI)			**260**			**261**	**100.0%**	**-0.75 [-1.37, -0.12]**

Heterogeneity: Tau² = 0.34; Chi² = 12.62, df = 6 (P = 0.05); I² = 52%
Test for overall effect: Z = 2.35 (P = 0.02)

-10 -5 0 5 10
Favours experimental Favours control

Figure 6 Forest plot for ICU length of stay.

Paramètres dynamiques sont de très bons prédicteurs de la réponse au remplissage (>> paramètres statiques)

Cherpanath, Neth Heart J 2013

	Parameter	AUROC
Static		
	CVP	0.55 (0.48–0.62)
	LVEDA	0.64 (0.53–0.74)
Dynamic		
	SVV	0.84 (0.78–0.88)
	PPV	0.94 (0.93–0.95)

SVV: mesurée par moniteurs mini invasifs de DC par analyse onde de PA

Paramètres dynamiques sont de très bons prédicteurs de la réponse au remplissage (>> paramètres statiques)

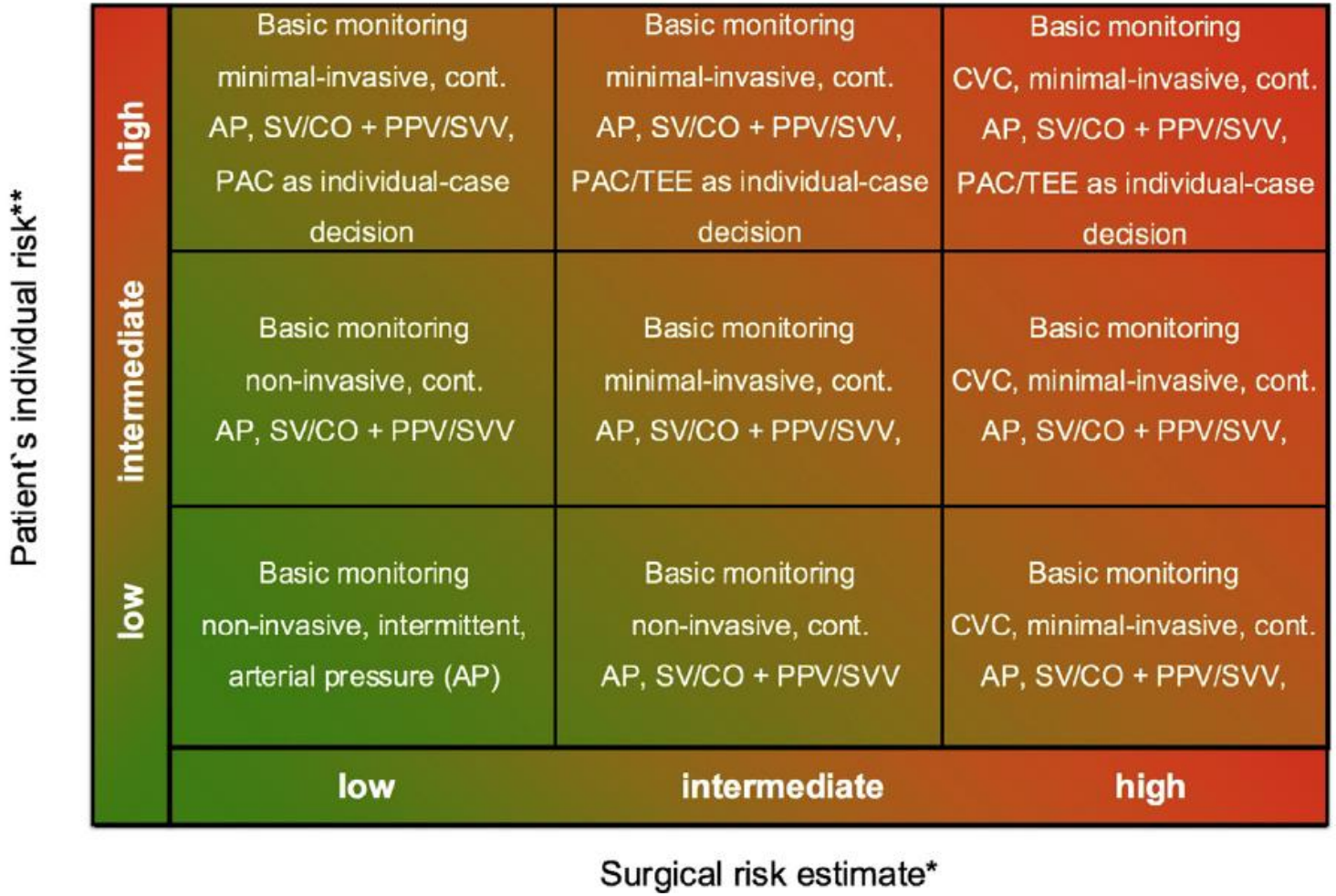
Cherpanath, Neth Heart J 2013

	Parameter	AUROC
Static		
	CVP	0.55 (0.48–0.62)
	LVEDA	0.64 (0.53–0.74)
Dynamic		
	SVV	0.84 (0.78–0.88)
	PPV	0.94 (0.93–0.95)

LIMITES: VS (faux +), Vt ↘ (faux -), peep ↗, compliance pulmonaire ↘, thorax ouvert, arythmies (faux +), HTAP, pneumopéritoine (faux +), position non décubitus

Stratégie de choix du monitorage

Renner, Best Prac Res Clin Anaesthesiol 2016



Recommandations SFAR

- **Réhabilitation améliorée après lobectomie pulmonaire (2019)**
  - Il est probablement recommandé de titrer le remplissage vasculaire peropératoire à l'aide d'un monitorage hémodynamique, en privilégiant le ***Doppler oesophagien***, pour diminuer la survenue de complications respiratoires postopératoires. GRADE 2+ (accord fort)
- **Réhabilitation rapide après une chirurgie colorectale programmée (2014)**
  - L'optimisation des apports liquidiens peropératoires, basée sur la mesure d'un paramètre hémodynamique reflétant la volémie, est recommandée lors de la chirurgie colorectale programmée. GRADE 1+ (accord fort)
    - Trois méta-analyses [26–28], dont une exclusivement dédiée à la chirurgie colorectale [27], s'intéressent à l'impact d'une stratégie de guidage des apports liquidiens peropératoires par des épreuves de remplissage sur la durée de séjour. Toutes retrouvent un bénéfice d'environ 2 jours en faveur du groupe bénéficiant de la stratégie d'optimisation. Les modalités techniques de surveillance du remplissage sont variées mais le ***Doppler oesophagien*** représente la technique la moins invasive et qui a fait l'objet d'un plus grand nombre de publications. Cette recommandation repose sur des études randomisées de bonne qualité et plusieurs méta-analyses et est similaire à celle proposée dans la RFE de la Sfar sur la stratégie du remplissage vasculaire périopératoire (2012).

A systematic review and meta-analysis of intraoperative goal directed fluid and haemodynamic therapy *in children* and postoperative outcome

Kumba, Orliaguet, J Emerg Med Critical Care 2019

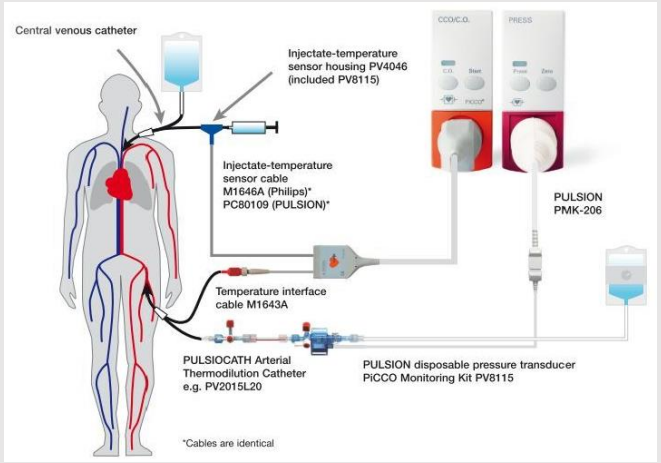
- 23 études, 3 400 enfants
- 21/23 études, 90% patients: chirurgie cardiaque
- Rétrospectives ou prospectives observationnelles (20/23): recherche d'association entre un (des) paramètre(s) et la morbi-mortalité postopératoire
- Hétérogénité: DC (PiCCO, DTO), Saturation tissulaire O_2 (NIRS), lactates, $SvcO_2$, DAV CO_2
- Pas d'étude bien conduite prospective randomisée GDT
- ***Optimisation des paramètres hémodynamiques associée à une ↓morbi-mortalité postopératoire (dysfonction d'organe & complications infectieuses) & durée H***
- Faible niveau de preuve

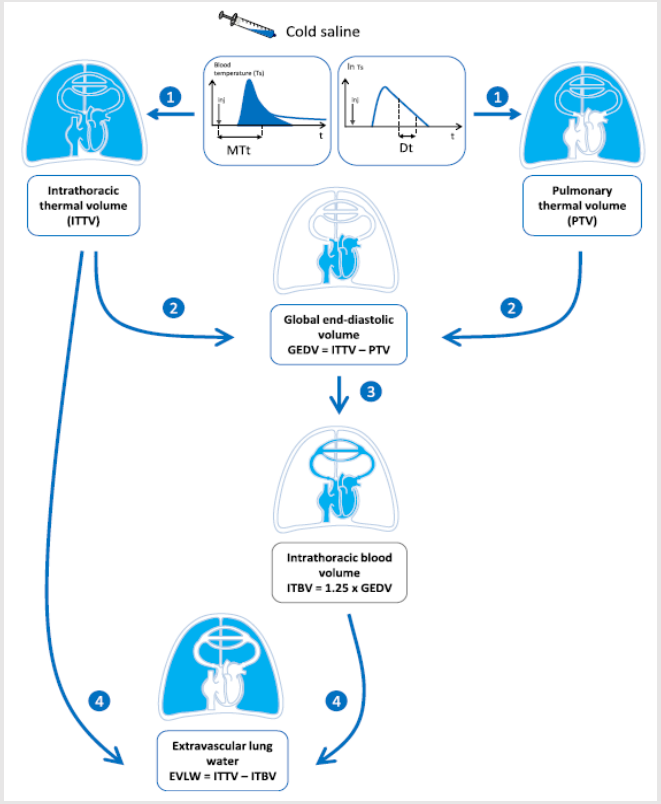
Thermodilution trans-pulmonaire

PiCCO® Pulse index Continuous Cardiac output (Pulsion Medical Systems, Allemagne), VolumeView® (Edwards, USA)

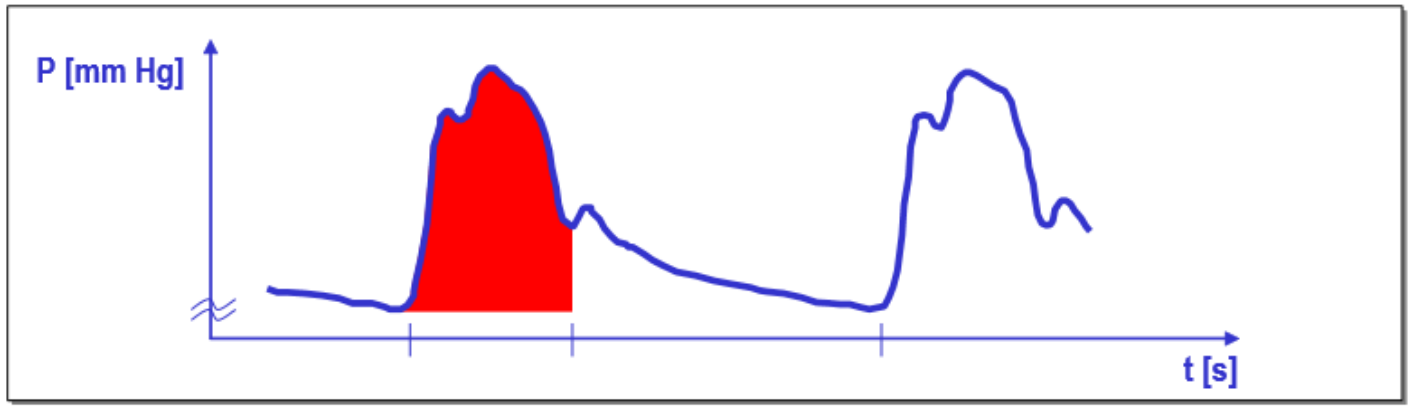
Monet &Teboul, Crit Care 2017

- Précision comparable à Swan Ganz (gold standard) # 12%
  - Discontinu
- VVC cave supérieur + KTA fémoral (thermistance) (3F: nourrisson)
- Couplé à technique d'analyse de l'onde de PA
  - Analyse géométrique, algorithme « privé » avec calculs de compliance, résistance & impédance
  - Monitorage continu du DC
  - Calibration initiale / mesure ThD
  - Précision acceptable (y compris traitement vasoP) et > techniques sans calibration
  - Recalibration régulière (modification importante du tonus vasculaire : vasopresseur)
  - Indices dynamiques de précharge dépendance: VVE, VPP
- Index de précharge
  - Global End Diastolic Volume GEDV (680-800 ml/m^2), Volume Sanguin Intra thoracique VSIT (850-1000 ml/m^2)
  - Mieux corrélés au VES que PVC/PAPO *Mahajan, AA2003*
  - Bénéfice clinique GDHDT basée sur GEDV *Goepfert, ICM 2007, Anesthesiology 2013*
  - Par contre moins bons marqueurs d'OAP hydrostatique
  - Cavités *droites* & gauches (dilatation VD)
- Index de ft systolique
  - Cardiac Function Index (DC/GEDV = 4,5-6,5 /min), Global Ejection Fraction (4 x VES/GEDV = 25-35%)
  - Corrélation correcte avec FEVG (écho)
  - ↓ si dilatation VD
- Eau Pulmonaire Extra-Vasculaire EPEV (3-7 ml/kg)
  - Index fiable d'œdème pulmonaire (gravimétrie, dilution de colorant)
  - Facteur indépendant de mortalité en réanimation, diagnostic et suivi des SDRA (↓ durée VM & H)





PiCCO: calcul du DC par « pulse contour »

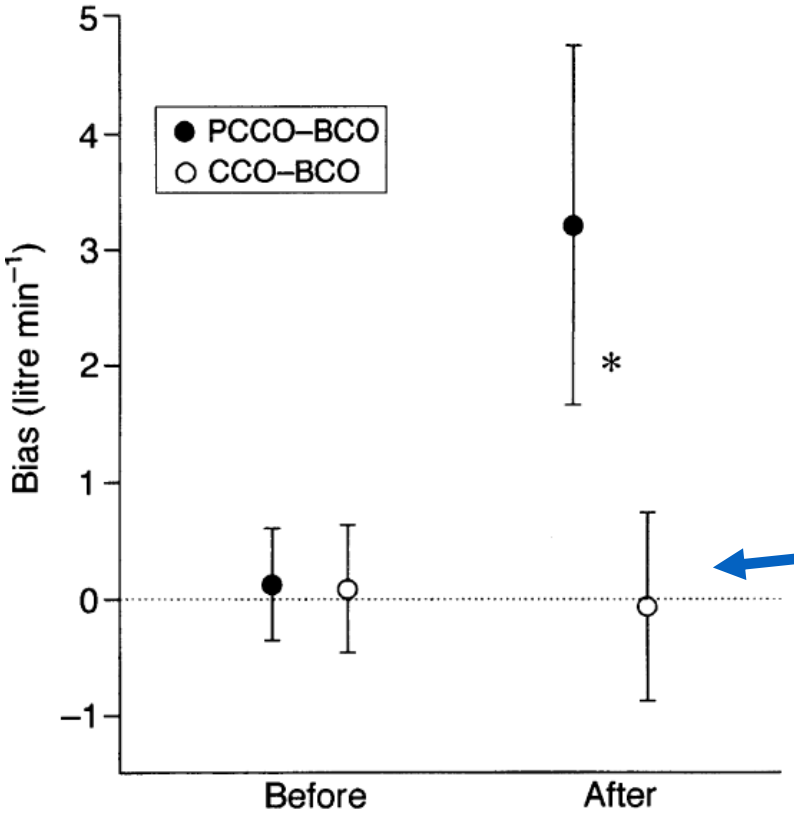


$$PCCO = cal \cdot HR \cdot \int_{Systole} \left(\frac{P(t)}{SVR} + C(p) \cdot \frac{dP}{dt} \right) dt$$

- Patient-specific calibration factor (determined with thermodilution)
- Heart rate
- Area of pressure curve
- Compliance
- Shape of pressure curve

Modèle de Windkessel: impédance A°, compliance A^{elle} & RVS

PiCCO: monitorage du DC par pulse contour
influence des RVS



PCCO: Pulse contour
BCO: Bolus froid
CCO: PAC continu

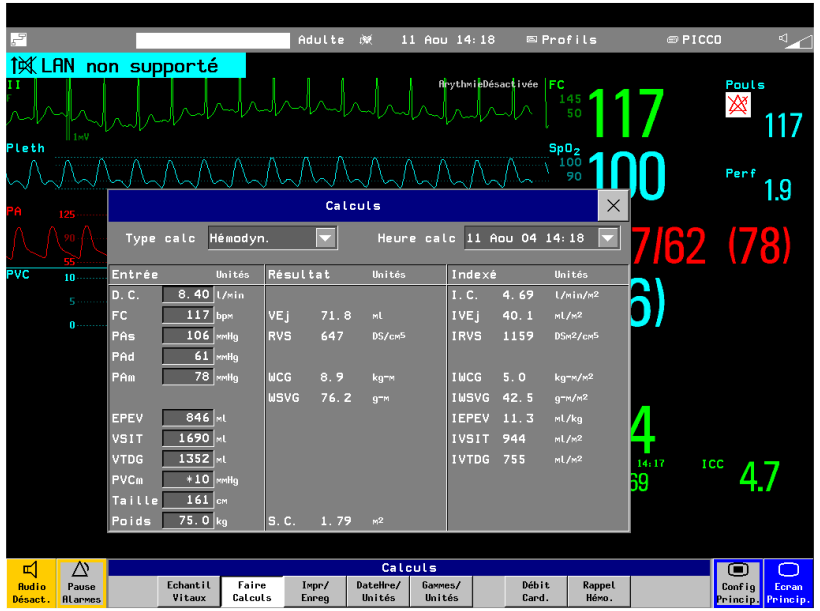
phenylephrine

Rodig, Br J Anesth, 1998

PiCCO

3 injections successives de sérum froid (8°) → moyenne







PiCCO chez l'enfant

Proulx, Pediatr Crit Care 2011

- Cathéter artériel fémoral (thermistance) ∅ 3F (nourrisson)
  - 💣 Cathétérisme fémoral (A terminale): risque de thrombose, spasme ☹
- Gold standard mesure du DC chez l'enfant *Lemson, Pediatrics 2011*
  - Reproductibilité = 5%, pourcentage d'erreur = 15% (⇔ swan-ganz)
- Ok shunts G-D *Nusmeier, BJA 2011*
- Valeurs normales (indexées) ≠ adultes *Grindheim, Ped Anesth 2015*
  - GEDVi & VSITi = -50%
  - EPEVi = +100%
  - Variabilité importante (interindividuelle)

Accuracy and precision of minimally-invasive cardiac output monitoring in children: a systematic review and meta-analysis

Suehiro, J Clin Monit Comput 2016

References	Device type	Device name	Sample size	Patient characteristics	Setting	Age, mean (SD) or median [IQR* or range]	Gender M/F	Reference method	Bias ± SD (l min^{-1})	PE (%)
Linton et al. [4]	Pulse contour analysis	LiDCO	17	ICU patients	ICU	1.3 [3 weeks–9 years]	N.A.	PICCO	0.1 ± 0.31	31.8
Botte et al. [5]	Partial CO_2 rebreathing	NICO	21	ICU patients	ICU	7.89 years [2.9–16.8 years]	12/9	2D echo Doppler method	0.61 ± 0.94	43.1
Calamandrei et al. [6]	Pulse contour analysis	Mostcare	48	ICU patients	ICU	19 months [1–204 months]	29/19	2D echo Doppler method	0.12 ± 0.27	20.4
Knirsch et al. [48]	Ultrasound Doppler flow	USCOM	24	Cardiac catheterization	CR	7.6 years [0.1–16.7 years]	N.A.	PAC	−0.13 ± 0.67	36.4
Knirsch et al. [49]	Ultrasound Doppler flow	CardioQ	40	Cardiac catheterization	CR	8.2 years [0.5–16.7 years]	18/22	PAC	0.66 ± 0.91	54.3
Norozi et al. [50]	Electrical cardiometry	AESCULON	32	Cardiac catheterization	CR	0.675 year [0.03–17.8 years]	N.A.	Fick principle	−0.01 ± 0.23	33.1
Schubert et al. [51]	Ultrasound Doppler flow	CardioQ	26	Post-cardiac surgery	ICU	3.5 years [1–17.5 years]	13/14	2D echo Doppler method	0.36 ± 0.85	78.0
Tomaske et al. [52]	Electrical cardiometry	AESCULON	50	Cardiac catheterization	OR	7.5 years [0.5–16.5 years]	22/28	PAC	0.66 ± 0.76	44.7
Teng et al. [53]	Pulse contour analysis	FloTrac	31	Cardiac catheterization	OR	9 [0.66–16 years]	19/12	PAC	2.7 ± 2.8	84.2
Crittendon et al. [54]	Ultrasound dilution	COstatus	28	Cardiac catheterization	CR	8 years [1–17 years]	14/14	PAC	−0.004 ± 0.4	25.4
Noori et al. [55]	Electrical cardiometry	AESCULON	20	Healthy neonates	GW	1 day	10/10	2D echo Doppler method	0.004 ± 0.12	43.7
Weisz et al. [56]	Electrical cardiometry	NICOM	10	NICU patients	NICU	Neonates	3/7	2D echo Doppler method	0.15 ± 0.06	25.8
Floh et al. [57]	Ultrasound dilution	COstatus	35	Post-cardiac surgery	ICU	147 days [11–216 days]*	N.A.	Fick principle	0 ± 0.38	97
Rauch et al. [58]	Electrical cardiometry	ICON	64	Obese children	GW	12.5 years [7.9–17.6 years]	28/36	2D echo Doppler method	−0.15 ± 0.53	20.3
Boehne et al. [59]	Ultrasound dilution	COstatus	26	Cardiac catheterization	CR	6.2 years [8 months–17 years 4 months]	18/8	Fick principle	0.26 ± 0.47	25.9
Lindberg et al. [60]	Ultrasound dilution	COstatus	21	Cardiac surgery	OR/ ICU	8.1 months [6 days–27 months]	N.A.	TTU	−0.02 ± 0.15	29.7
Sun et al. [61]	Electrical cardiometry	NICOM	28	General surgery	OR	24.0 months [6.5–36.0 months]*	17/11	2D echo Doppler method	0.03 ± 0.20	22.4
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Terada et al. [62]	Pulse contour analysis	esCCO	7	Kidney transplant surgery	OR	9.4 years (3.1 years)	4/3	Dye dilution	−0.27 ± 0.91	37.5
Vergnaud et al. [63]	Electrical cardiometry	NICOM	30	Neurosurgery	OR	50.0 months (43.0 months)	N.A.	2D echo Doppler method	−0.11 ± 0.67	56.9
Wongsirimetheekul et al. [64]	Ultrasound Doppler flow	USCOM	34	ICU patients	ICU	7.86 years (5.78 years)	15/19	2D echo Doppler method	−0.53 ± 1.23	59.3

Accuracy and precision of minimally-invasive cardiac output monitoring in children: a systematic review and meta-analysis

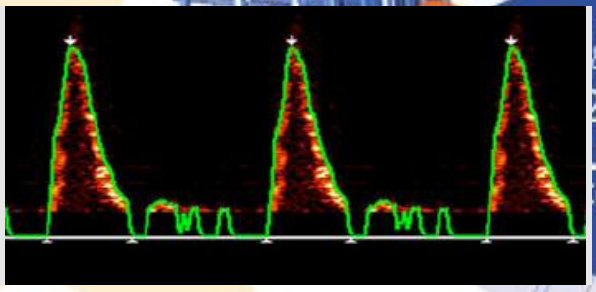
Suehiro, J Clin Monit Comput 2016

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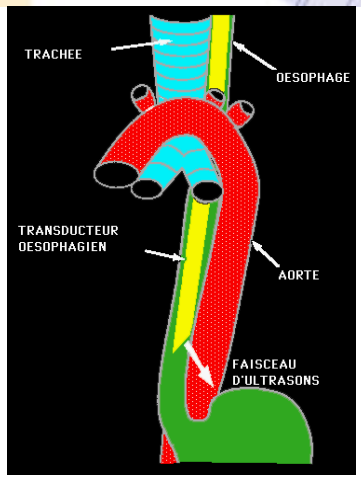
Pourcentage d'erreur # 30%: « zone grise de l'applicabilité clinique »

DTO Doppler trans oesophagien

ODM+® (Œsophageal Doppler monitor, Deltex, UK)



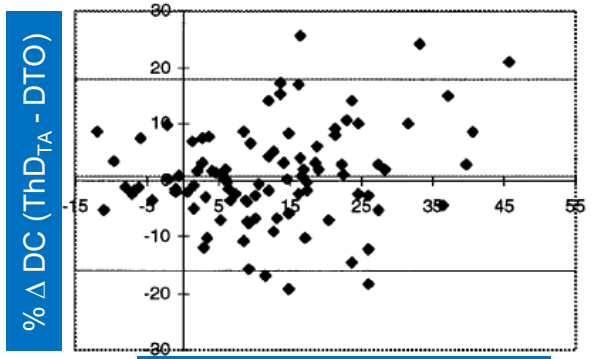
- Peu invasif
- Vélocité sanguine A° descendante: **ITV** (distance d'éjection)
  - DC = **ITV** x *SA°* x FC
  - *Angle d'insonation* = 45° (Cos)
  - *Ratio débit A° descendante / DC* = 70%
- Détermination SA°
  - Mesure écho DA°
    - Principale cause d'erreur (au carré)
    - ↑ ∅ sonde œsophagienne
  - Valeur fixe (abaques / taille, âge, poids)
    - Erreur neutralisée lors des mesures répétées chez un même patient (monitorage de tendance)
    - Sous-estimation des variations de DC ?
- Fiabilité établie chez adulte (ODM)
  - TENDANCES (pas de biais systématique)
  - Insuffisante pour les valeurs absolues
  - Recherche du meilleur signal à chaque mesure (# mesure discontinue)
  - Apprentissage rapide (# 10 patients)
- GDFT / GDHDT: ↓ morbidité postop (ODM)
- Indices dynamiques de précharge dépendance
  - VVES, variation Pic Vélocité A°
- Couplage avec technique d'analyse d'onde de PA invasive
  - Calibration initiale / mesure Doppler
  - Mesure continue DC & indices dynamiques sans repositionnement sonde DTO



Dark & Singer, ICM 2004

Krishnamurthy, Anaesthesia 1997
Lefrant, ICM 1998

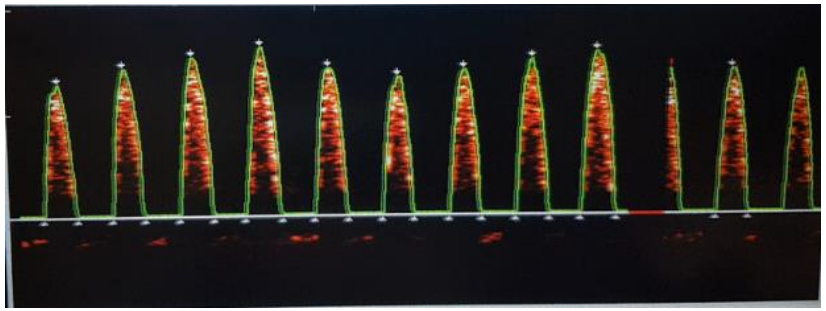
Hamilton, AA 2011



Tibby, Crit Care Med 2000

DTO chez l'enfant

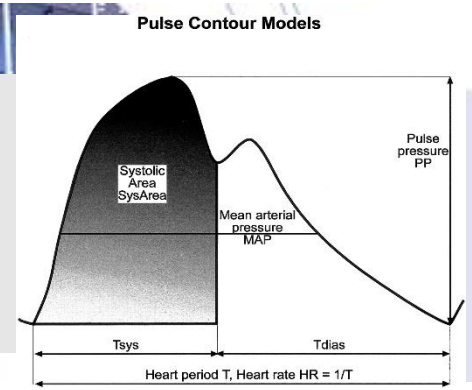
- Fiabilité idem adulte:
  - Tendances > valeurs absolues *Chew, ICM 2003*
- Sondes de taille adaptée & abaques de SA° à partir de 3 kg
- Valeurs normales:
  - IC 3,5 – 5 l/min.m^2
  - VESi 30-60 ml/m^2
  - TEc 330-360 msec (corrélation positive avec pré-charge & négative avec post-charge)
- Delta pic vélocité A°
  - Indice le plus fiable de RR chez l'enfant
- CI: atrésie de l'œsophage
- Interférences avec bistouri é^{ique} ☹



Analyse onde de PA sans calibration

Flo-Trac/vigileo® (Edwards, USA), ProAQT/Pulsioflex® (Pulsion Medical System, Allemagne), LiDCOrapid® (UK), MostCare®/PRAM (Pressure Recording Analytical Method) (Vygon, Italie)

Jozwiak AA 2018, Slagt BJA 2014



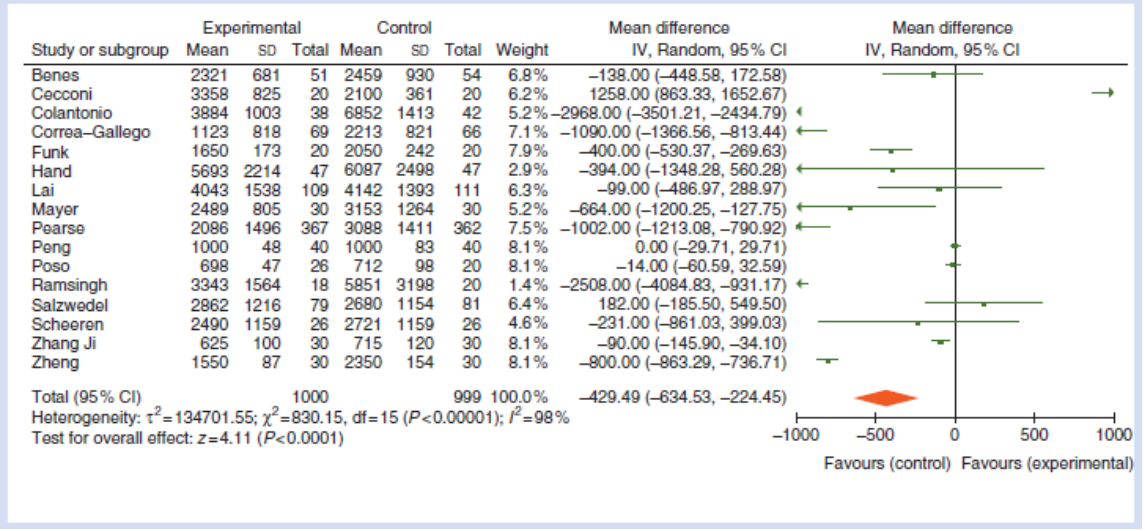
- Mini-invasif: PA invasive
  - KTA (non spécifique) ➔ échographie ++
- Lien mathématique entre onde de PA et VES
  - Amplitude de la partie **systolique** de la courbe de PA proportionnelle au VES & (inversement) compliance artérielle
  - Identification nœud dicrotique essentielle
- Point clé = compliance & résistance (impédance A°) artérielle
  - Chaque appareil utilise un procédé propre (et secret)
  - Perte de fiabilité en cas de modification significative RVS (états « hyperdynamiques » - sepsis & vasopresseurs)
  - Perte de l'amplification de pression / arbre artériel → ss estimation DC + ↑ pourcentage d'erreur > 30%
  - Inadapté à la réanimation *Monnet BJA 2012*
- Continu & temps réel, simplicité (« plug and play »)
- Monitorage peropératoire
  - Sauf: chirurgie (greffe) hépatique, post CEC, modifications du tonus vasculaire (vasopresseur) *Biais AA 2008, Monnet Crit Care 2010*
  - Pourcentage d'erreur 25-30%, bonne reproductibilité (mesures répétées)
  - Monitorage de tendance, suivi du remplissage
  - 💣 arythmie ☹
- Enfant:
  - compliance & tonus vasculaire ≠ adulte (facteur de variation → x2)
- Paramètres dynamiques: VVES (= VVE, SVV)
  - Pourcentage d'erreur # 45% (vs VVES / analyse d'onde de PA avec calibration [PiCCO] ou VPP)
  - Capacité de prédiction de la réponse au remplissage # VPP (« redondance »)
  - Seuil # 10%

Perioperative goal-directed therapy with uncalibrated pulse contour methods: impact on fluid management and postoperative outcome

Michard, BJA 2017

Méta-analyse: 19 études, 2160 patients

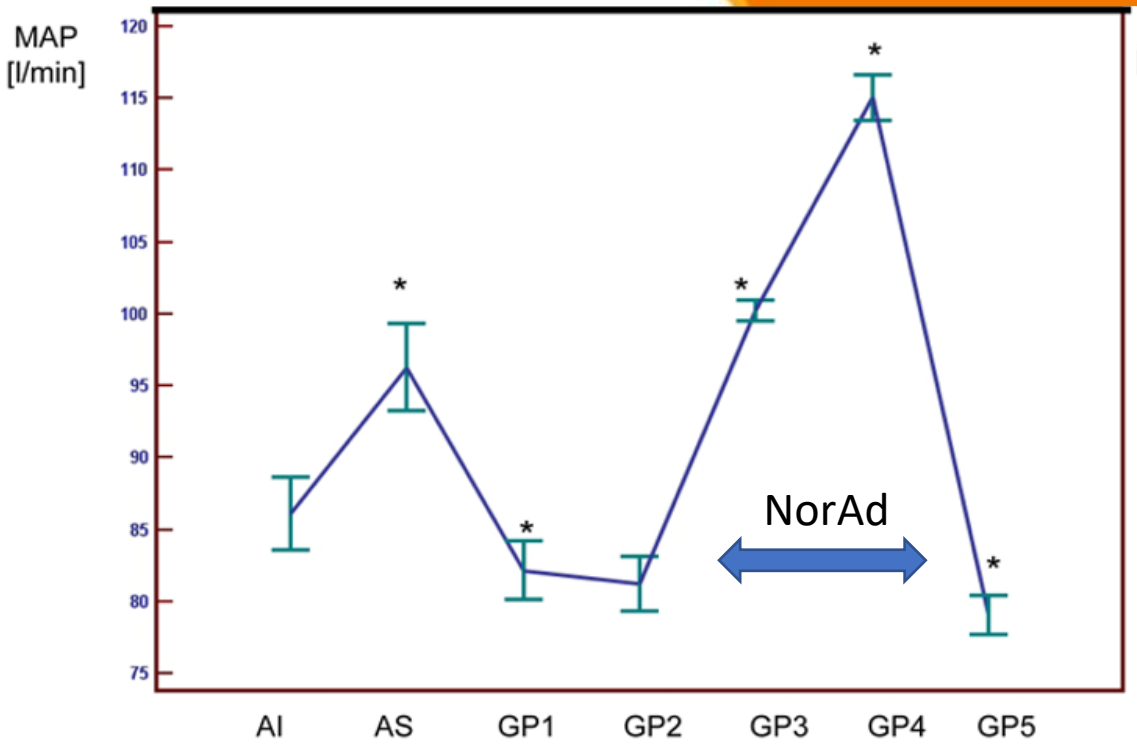
First author (ref)	Surgery, *n*	uPC method	Haemodynamic goals
Benes[32]	Abdominal and vascular, 120	FloTrac	SVV<10, CI>2.5
Cecconi[33]	Hip, 40	FloTrac	SVplateau, DO_2I>600
Colantonio[34]	HIPEC, 80	FloTrac	SVV<15, SVI>35, CI>2.5
Correa-Gallego[35]	Liver, 135	FloTrac	SVV<15
Funk[36]	AAA, 40	FloTrac	SVV<13, CI>2.2
Hand[37]	Head and neck, 94	FloTrac	SVV<13, CI>3, SVR>800
Kapoor[38]	Cardiac, 27	FloTrac	SVV<10, SVI>30, CI>2.5, $ScvO_2$>70, DO_2I>450
Lai[39]	Abdominal, 220	LiDCOr	SVV<10
Mayer[40]	Abdominal, 60	FloTrac	SVV<12, SVI>35, CI>2.5
Pearse[2]	Abdominal, 734	LiDCOr	SVplateau
Peng[41]	Orthopaedic, 80	FloTrac	SVV<10 (supine) or <14 (prone)
Poso[42]	Bariatric, 50	FloTrac	SVV<12, SV and CO>70% of baseline
Ramsingh[43]	Abdominal, 38	FloTrac	SVV<12
Salzwedel[44]	Abdominal, 160	ProAQT	PPV<10, CI>2.5
Scheeren[45]	Abdominal, 64	FloTrac	SVV<10
Van der Linden[46]	Vascular, 37	FloTrac	CI>2.5
Zeng[47]	Abdominal, 60	FloTrac	8<SVV<13
Zhang[48]	Thoracic, 60	FloTrac	SVV<11, CI>2.5
Zheng[49]	Abdominal, 60	FloTrac	SVV<12, SVI>35, CI>2.5

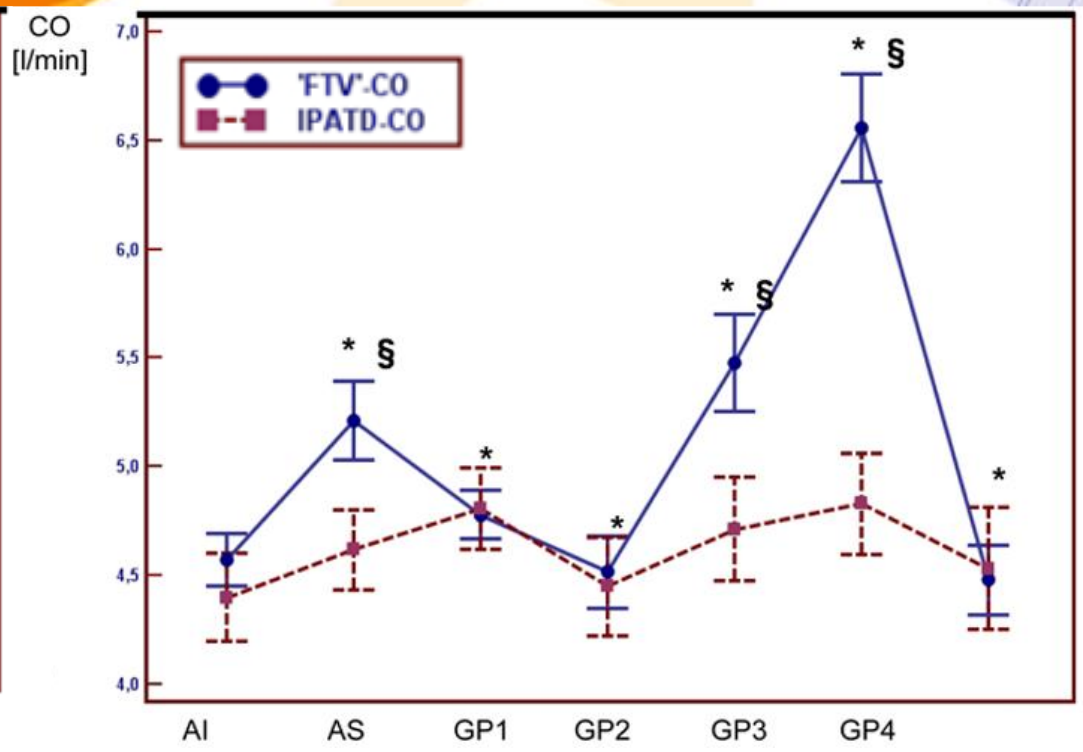


- Essentiellement:
  - FloTrac
  - SVV (+/- limite minimale d'IC)
- ↓ complications cardiaques, abdominales et infectieuses
- Volume de perfusion n'est pas supérieur dans le groupe GDT
  - Au bon moment, au bon patient: personnalisation
  - Limitation des apports / GDHDT basée sur les indices dynamiques

Variations in arterial blood pressure are associated with parallel changes in FlowTrac/Vigileo®-derived cardiac output measurements: a prospective comparison study

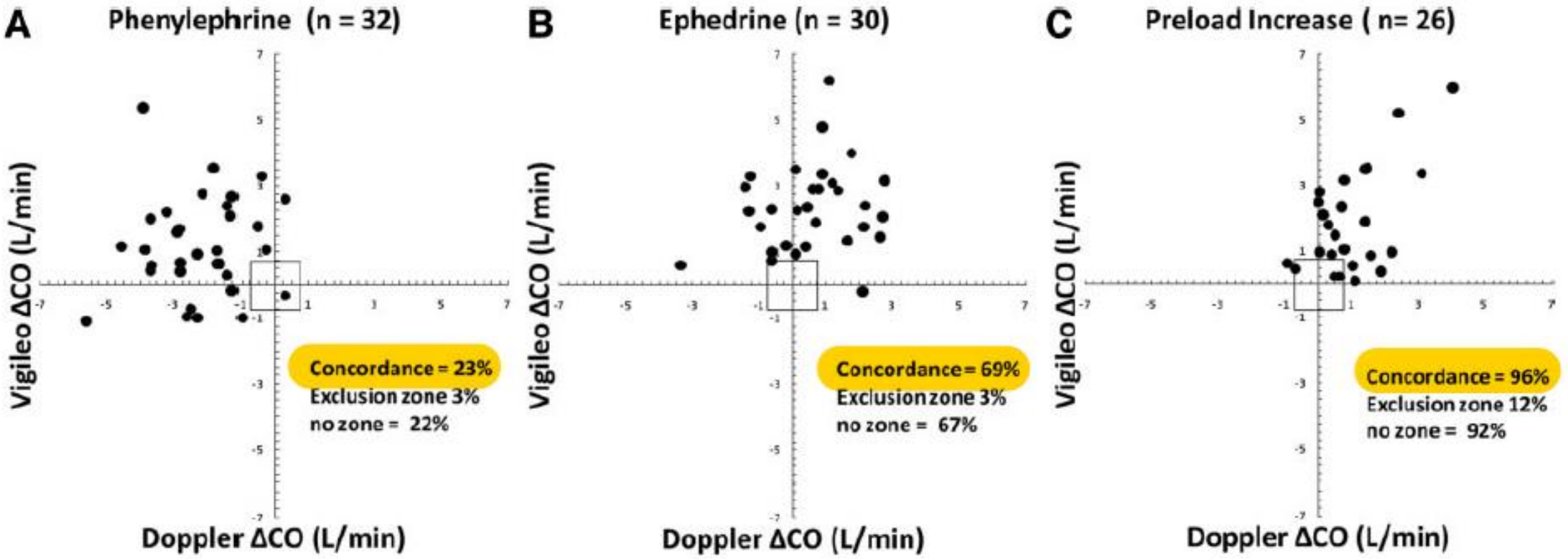
Eleftheriaids, Crit Care 2009





The impact of phenylephrine, ephedrine, and increased preload on third-generation Vigileo-FloTrac and esophageal Doppler cardiac output measurements

Meng, AA 2011



Chez l'enfant

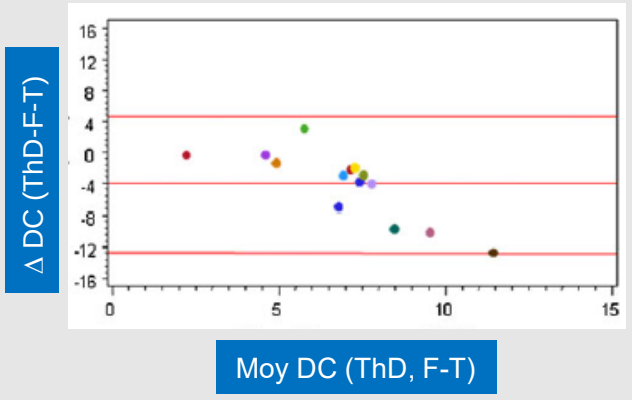
Flo-Trac





Compliance: Analyse complexe de la géométrie de la courbe de PA & données biométriques (comparaison à une banque de données humaines: pédiatrique ???)

2 ans, 30 cm (!), 1 kg



Teng, ICM 2011

8 mois-16 ans, cardiomyopathie, HTAP, postop greffe ♥ (∅ shunt)
Biais -4 l/min, limites de concordance +/- 8,5 l/min, PE # 100%

MostCare

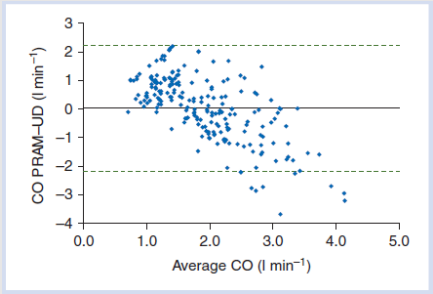
Théorie des perturbations (un système tend à s'opposer aux perturbations qui lui sont imposées)

Analyse h^{te} résolution de l'onde de PA (1 000 points /sec): identification de points d' «instabilité » → impédance

Algorithme pédiatrique

Saxena, BJA 2013

Enf^{ts} 5-15 kg, postop chir ♥ (∅ shunt) vs ThD- TP
Mauvaise concordance
Biais # 0, Limites d'agrément +/- 2,2 l/min
PE 116%
Mauvaise capacité à suivre les modif^{tions} de DC



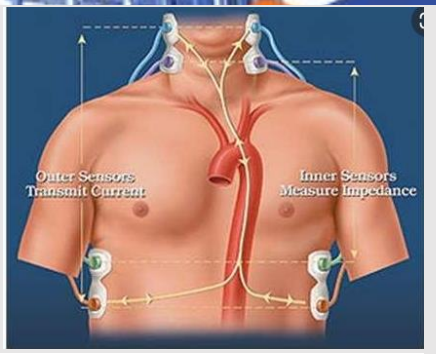
Alonso-Inigo, Ped Anesth 2016: Enfants 3-70 kg, KT cardiaque vs Fick
Bonne concordance, Biais # 0, Limites d'agréments +/- 0,5 l/min, PE 17%
Exclusion: shunts, arythmies, défaut d'identification noeud dicrotique, mauvais tracés PA, instabilité HD
Conflit d'intérêt

Mesures isolées: pas d'analyse de la capacité à suivre les modif de DC

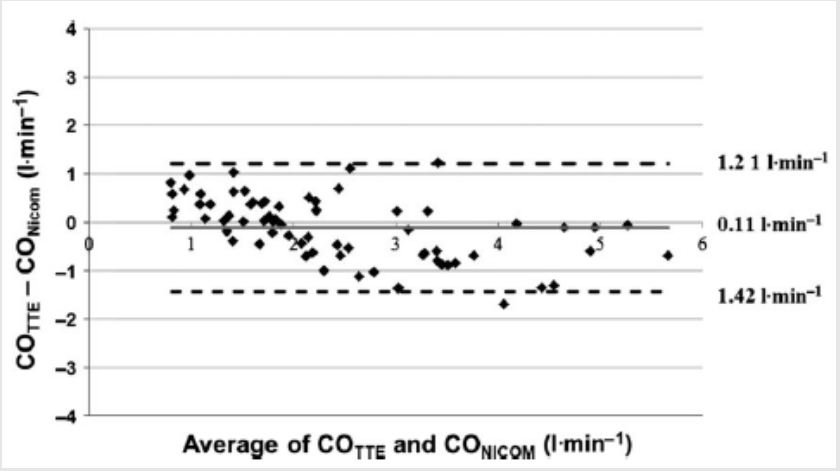
Bioréactance / vélocimétrie électrique

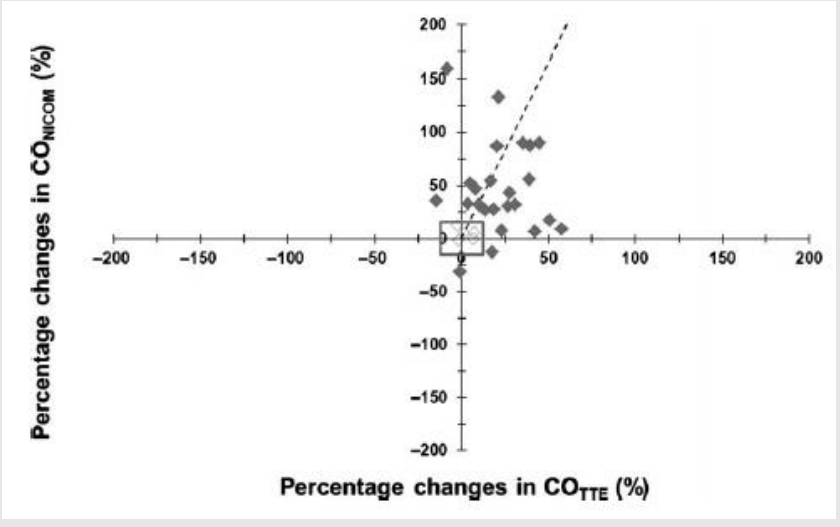
NICOM® (Cheetah Medical, Israël)

Vergnaud, Orliaguet, Ped Anesth 2014



- Non invasif
- Mesure des variations de voltage induites par VES ds le thorax (décalage de phase)
  - Facteur de calibration lié aux caractéristique anthropométriques
- Fiabilité ↓: pathologie pulmonaire (surcharge, atélectasie, condensation, épanchements), arythmie, mouvements, interférences e^{-iques}
- Comparaison avec ETT (postop N°chir, 4 (0-16)ans):
  - Manque de précision / valeurs absolues
    - Limites de concordance = -1,4 à 1,2 l/min
    - pourcentage erreur 55% (45% après ajustement / PE de l'ETT # 30%)
  - Capacité satisfaisante à suivre les changements > 15% après remplissage (moniteur de « tendance »): 84% de concordance





Predicting Fluid Responsiveness in Children: A Systematic Review

Gan, AA 2013

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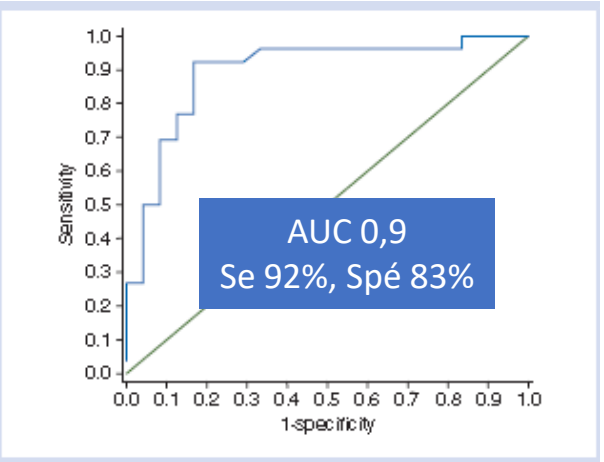
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Raux, BJA 2012

DTO

Chir ***néonatale*** non cardiaque

Seuil = 25 ml/min.m^2



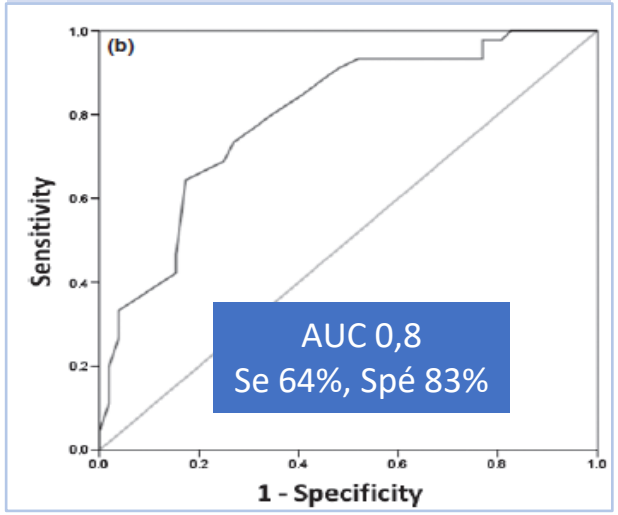
Julien, Ped Anesth 2013

DTO

2-7 ans

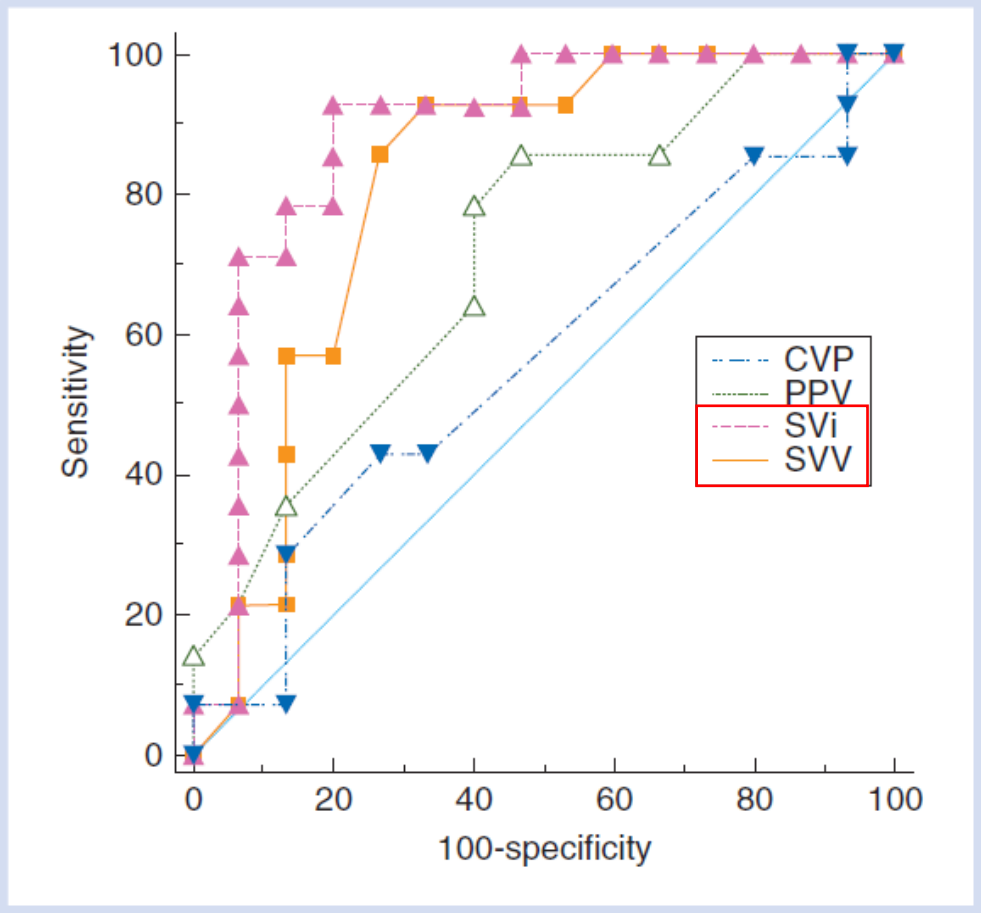
Chir non cardiaque

Seuil = 28 ml/min.m^2



Prédiction de la réponse au remplissage: bioréactance

Vergnaud, Orliaguet, BJA 2015



- SVi: cutoff 29ml.m^{-2} (zone grise: 27-29)
- SVV: cutoff 10% (zone grise: 9-15)

	Cut-off value	AUC (95% CI)	Sensitivity (%)	Specificity (%)	Positive predictive value (%)	Negative predictive value (%)	Grey zone
Children <3 yr (*n*=17, *R*=12, NR=5)							
CVP	6 mm Hg	0.74 (0.38–0.95)	100	43	34	100	3–5 mm Hg
PPV	12%	0.60 (0.33–0.83)	28	100	37	100	9–11%
SVi	26 ml m^{-2}	0.92 (0.68–0.99)	75	100	100	63	27–28 ml m^{-2}
SVV	9%	0.57 (0.31–0.81)	91	40	80	100	7–17%
Children >3 yr (*n*=13, *R*=3, NR=10)							
CVP	5 mm Hg	0.76 (0.41–0.96)	100	43	44	100	8–9 mm Hg
PPV	8%	0.81 (0.48–0.97)	67	100	100	87	6–6%
SVi	33 ml m^{-2}	0.81 (0.49–0.96)	100	60	52	100	28–32 ml m^{-2}
SVV	10%	0.97 (0.70–1.00)	100	90	81	100	10–11%

Predicting Fluid Responsiveness in Chi

Gan, AA 2013

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		0.79	26	Cardiac OR, ASD/VSD	Renner 2012[7]
		0.86	26	Cardiac OR, closed ASD/VSD	Renner 2012[7]
		0.61	65	Mixed PICU	Saxena[9]
	SPV	0.58	33	Neuro OR	Byon[24]
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Echocardiography & Doppler	ΔV_{peak}	0.80	33	Neuro OR, TTE	Byon[24]
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	ΔVTI	0.84	27	Cardiac OR, TEE	Renner 2011[8]
	ΔIVCD	0.37	33	Neuro OR, TTE	Byon[1]
		0.85	21	Cardiac PICU, TTE	Choi[2]
PLR	ΔCI_{PLR}	0.71	40	General PICU, TTE	Lukito[4]
	ΔSV_{PLR}	0.75	40	General PICU, TTE	Lukito[4]

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Plethysmography	ΔPOP	0.56	19	Cardiac cath	Chandler[5]
		0.51	19	Neuro OR, 0-6 yrs	Pereira de Souza Neto[6]
		0.57	11	Neuro OR, 6-14 yrs	Pereira de Souza Neto[6]
	PVI	0.77	33	Neuro OR	Byon[24]
		0.54	19	Cardiac cath	Chandler[5]
		0.63	19	Neuro OR, 0-6 yrs	Pereira de Souza Neto[6]
		0.54	11	Neuro OR, 6-14 yrs	Pereira de Souza Neto[6]
		0.78	27	Cardiac OR	Renner 2011[8]
Echocardiography & Doppler	ΔV_{peak}	0.80	33	Neuro OR, TTE	Byon[24]
		0.83	21	Cardiac PICU, TTE	Choi[2]
		0.85	26	General PICU, TTE	Durand[1]
		1.00	19	Neuro OR, 0-6 yrs, TTE	Pereira de Souza Neto[6]
		1.00	11	Neuro OR, 6-14 yrs, TTE	Pereira de Souza Neto[6]
		0.92	27	Cardiac OR, TEE	Renner 2011[8]
	ΔVTI	0.84	27	Cardiac OR, TEE	Renner 2011[8]
	ΔIVCD	0.37	33	Neuro OR, TTE	Byon[1]
		0.85	21	Cardiac PICU, TTE	Choi[2]
PLR	ΔCI_{PLR}	0.71	40	General PICU, TTE	Lukito[4]
	ΔSV_{PLR}	0.75	40	General PICU, TTE	Lukito[4]

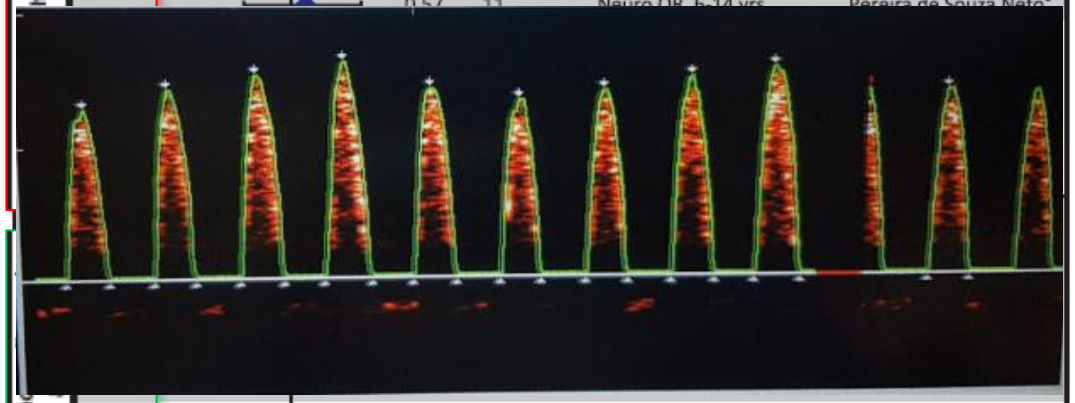
Compliance thoracique ↑
Compliance cardiaque ↓
Compliance vascu ↑
Fréquence respiratoire ↑

Predicting Fluid Responsiveness in Chi

Gan, AA 2013

	Potential predictor	Area under ROC with 95% CI (numerical value on right, vertical line is 0.5)	Fluid bolus, *n*	Setting	Study
Clinical	HR	0.55	33	Neuro OR	Byon[24]
		0.62	19	Neuro OR, 0-6 yrs	Pereira de Souza Neto[6]
		0.66	11	Neuro OR, 6-14 yrs	Pereira de Souza Neto[6]
		0.53	27	Cardiac OR	Renner 2011[8]
	SAP	0.67	33	Neuro OR	Byon[24]
Preload pressure	CVP	0.47	33	Neuro OR	Byon[24]
		0.61	19	Cardiac cath	Chandler[5]
		0.48	21	Cardiac PICU	Choi[2]
		0.61	26	Cardiac OR, ASD/VSD	Renner 2012[7]
		0.69	26	Cardiac OR, closed ASD/VSD	Renner 2012[7]
		0.57	27	Cardiac OR	Renner 2011[8]
		0.41	65	Mixed PICU	Saxena[9]
		0.60	58	Cardiac PICU	Tibby[25]
		0.51	36	General PICU	Tibby[25]
		0.58	44	Cardiac OR	Tran[26]
	PAOP	0.67	19	Cardiac cath	Chandler[5]
Thermodilution & US dilution	GEDVI	0.59	26	Cardiac OR, ASD/VSD	Renner 2012[7]
		0.77	26	Cardiac OR, closed ASD/VSD	Renner 2012[7]
	ACV	0.47	65	Mixed PICU	Saxena[9]
	CBV	0.53	65		
	TEDV	0.44	65		
	TEF	0.45	65		
Echocardiography & Doppler	LVEDA	0.59	19	Neuro OR, 0-6 yrs, TTE	Pereira de Souza Neto[6]
		0.71	11	Neuro OR, 6-14 yrs, TTE	Pereira de Souza Neto[6]
	SVI	0.90	50	General OR, TED	Raux[3]
	FTc	0.54	58	Cardiac PICU, TED	Tibby[25]
		0.76	36	General PICU, TED	Tibby[25]

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Arterial pressure	PPV	0.54	33	Neuro OR	Byon[24]
		0.60	19	Cardiac cath	Chandler[5]
		0.59	26	General PICU	Durand[1]
		0.52	19	Neuro OR, auto PPV, 0-6 yrs	Pereira de Souza Neto[6]
		0.60	11	Neuro OR, auto PPV, 6-14 yrs	Pereira de Souza Neto[6]
		0.71	19	Neuro OR, manual PPV, 6-14 yrs	Pereira de Souza Neto[6]
		0.60	11	Neuro OR, manual PPV, 6-14 yrs	Pereira de Souza Neto[6]
		0.79	26	Cardiac OR, ASD/VSD	Renner 2012[7]
		0.86	26	Cardiac OR, closed ASD/VSD	Renner 2012[7]
		0.61	65	Mixed PICU	Saxena[9]
	SPV	0.58	33	Neuro OR	Byon[24]
		0.65	26	General PICU	Durand[1]
		0.58	65	Mixed PICU	Saxena[9]
		0.74	44	Cardiac OR	Tran[26]
	SVV	0.70	26	Cardiac OR, ASD/VSD	Renner 2012[7]
		0.78	26	Cardiac OR, closed ASD/VSD	Renner 2012[7]
		0.61	65	Mixed PICU	Saxena[9]
		0.74	44	Cardiac OR	Tran[26]
	ΔDown	0.62	33	Neuro OR	Byon[24]
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		0.85	21	Cardiac PICU, TTE	Choi[2]
PLR	ΔCI_{PLR}	0.71	40	General PICU, TTE	Lukito[4]
	ΔSV_{PLR}	0.75	40	General PICU, TTE	Lukito[4]

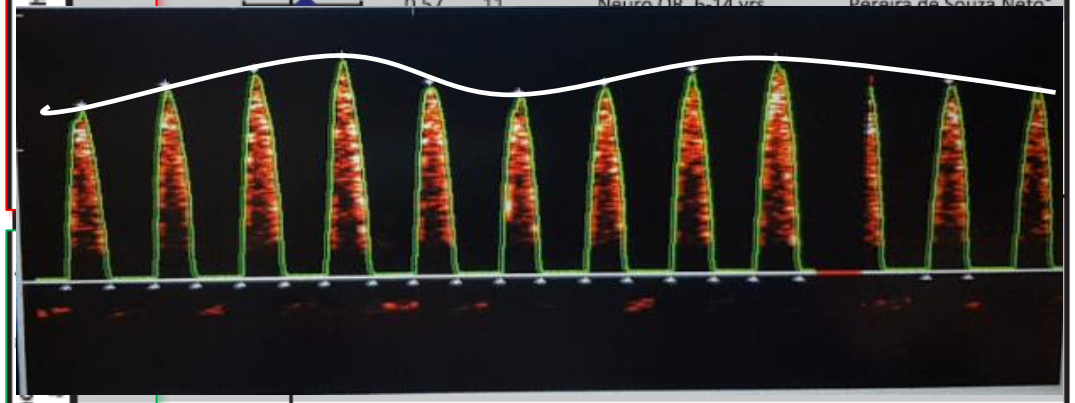


Predicting Fluid Responsiveness in Chi

Gan, AA 2013

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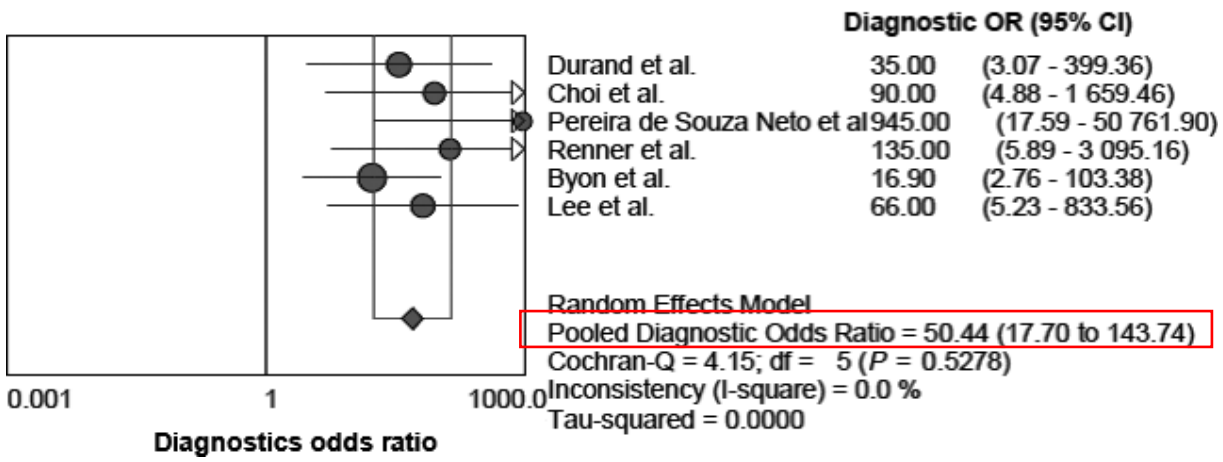
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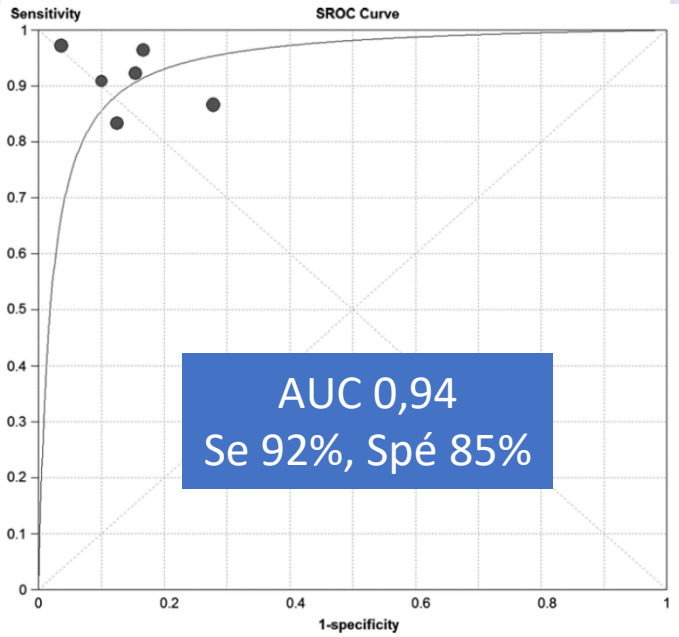


Respiratory variation in aortic blood flow peak velocity to predict fluid responsiveness in mechanically ventilated children: a systematic review and meta-analysis

Desgranges, Ped Anesth 2016

References	Sample size (*n*)	Setting	Type of patients	Age (months)	Fluid challenge	Use of inotropes/ vasopressors	Tidal volume ($ml \cdot kg^{-1}$)	Definition of fluid responsiveness	Measurement of ΔVPeak
Durand *et al.* (17)	26	ICU	Shock, various etiologies	Median = 28.5	20 $ml \cdot kg^{-1}$ Colloids (*n* = 23)/Crystalloids (*n* = 3)	Yes (*n* = 11)	Median = 7.4	ΔSVI > 15%	TTE
Choi *et al.* (18)	21	ICU	Postoperative, cardiac surgery	Mean = 30	10 $ml \cdot kg^{-1}$ Colloids	Yes (*n* = 10)	10	ΔSV > 15%	TTE
Pereira de Souza Neto *et al.* (19)	30	OR	Neurosurgery	Mean = 28	20 $ml \cdot kg^{-1}$ Crystalloids	No	10	ΔVTI > 15%	TTE
Renner *et al.* (20)	27	OR	Cardiac surgery	Mean = 17	10 $ml \cdot kg^{-1}$ Colloids	No	10	ΔSVI > 15%	TEE
Byon *et al.* (21)	33	OR	Neurosurgery	Median = 74.1 in R and 70.4 in NR	10 $ml \cdot kg^{-1}$ Colloids	No	10	ΔSVI > 10%	TTE
Lee *et al.* (22)	26	ICU	Postoperative, cardiac surgery	Mean = 28	10 $ml \cdot kg^{-1}$ Colloids	Yes (*n* = 14)	10	ΔSVI > 15%	TTE





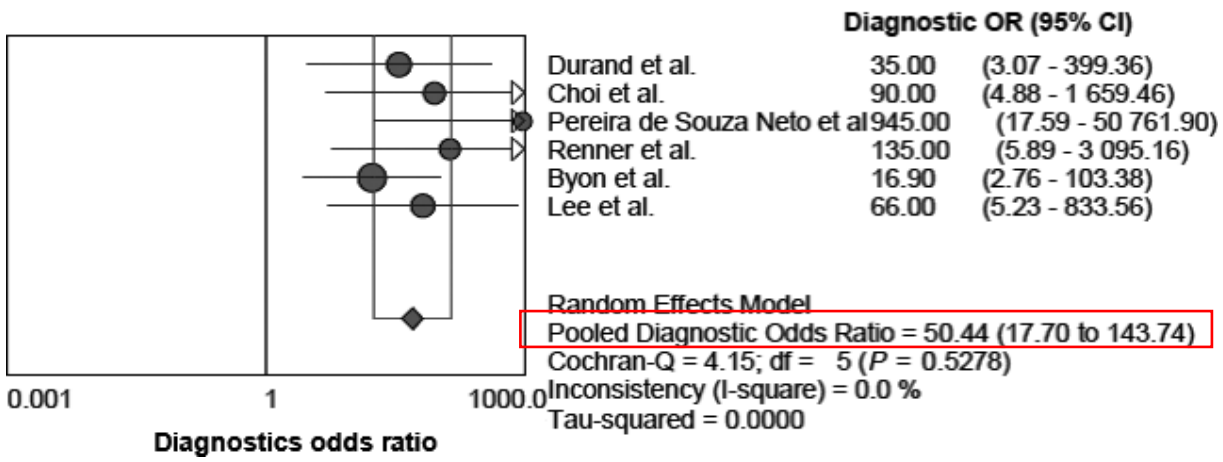
AUC 0,94
Se 92%, Spé 85%

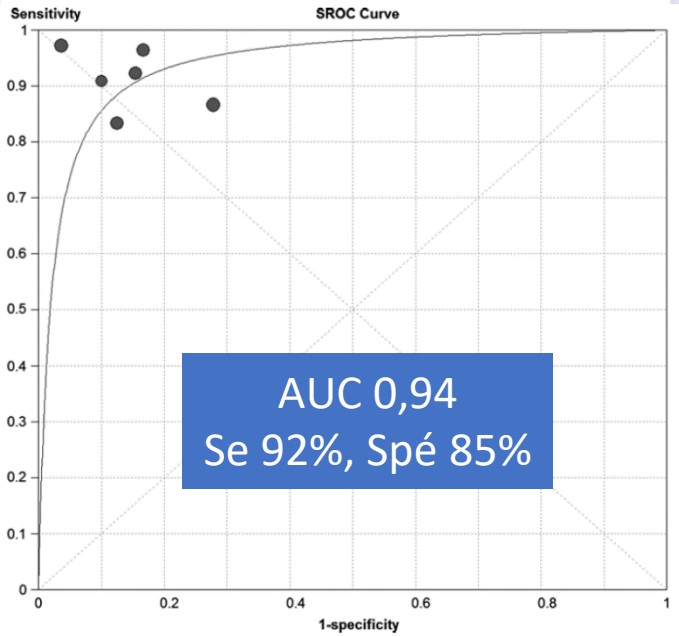
Cut-off = 12-13% (8% Nné)

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AUC 0,94
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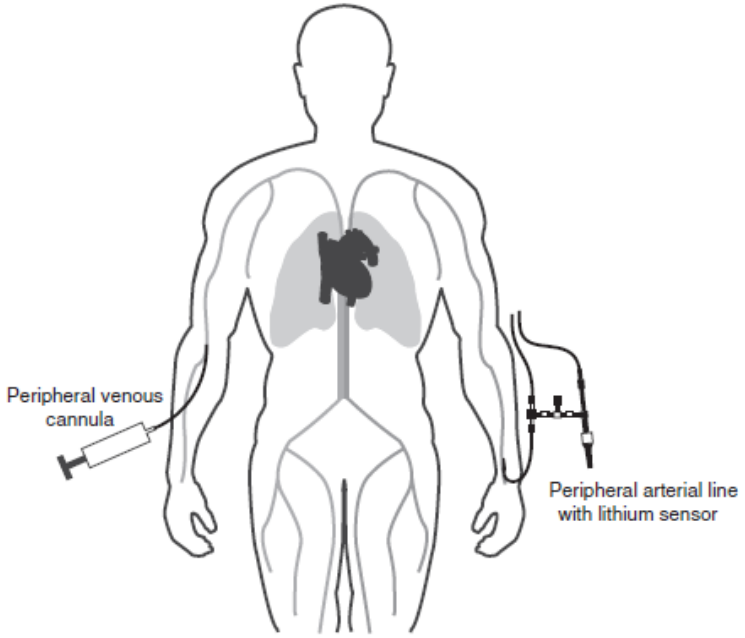
	< 2ans	> 2 ans
AUC	0,80	0,96

Wang, Crit Care 2019

Conclusion

- Monitorage peropératoire DC chez l'enfant:
  - Possible
  - Y compris (et surtout) mini/non-invasif: DTO, bio-réactance
  - Probablement utile: chirurgies & patients (?) à risque (néonat)
  - DTO: repositionnement sonde à chaque mesure → signal optimal
  - Analyse onde de PA: recalibration en cas de modification HD importante, modification spontanée ou thérapeutique RVS (vasopresseur)
- Monitorage de tendances plus pertinent que valeurs absolues
  - Précocité de mise en place
- Objectif: guider le remplissage (courbe en U: ni trop ni trop peu)
- Paramètres:
  - VESi (seuil # 25-30 ml/m^2) (↗ âge)
  - Paramètres dynamiques: Δ pic VA° (DTO) (seuil 12-13 # %), Δ VES DTO (# Δ ITV)
- Couplage & confrontation à d'autres paramètres:
  - Hémodynamiques (cliniques, FC, PA, diurèse, NIRS…)
  - Profondeur d'anesthésie

LiDCO®



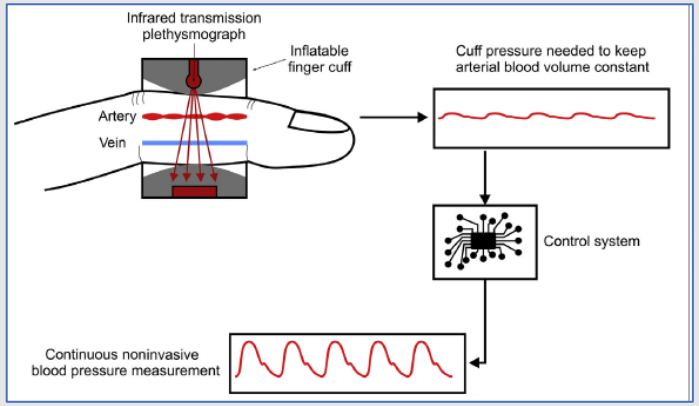
- Dilution trans-pulmonaire au Lithium
  - Fiabilité établie vs ThD trans-P adulte / enfant
    Linton, ICM 2000
  - Invasivité moindre que ThD-TP
  - Risque d'accumulation Lithium, coût élevé
  - Incompatibilité avec myorelaxants
- VVP, KTA (radial)
  - KTA: robinet 3 voies + pompe péristaltique
  - connexion d'une électrode sensible au Li → courbe de dilution (Stewart Hamilton)
- Analyse onde PA:
  - Principe de conservation de masse et de puissance
  - Calcul compliance A^{elle} / données biométriques
  - Calibration initiale / mesure DC par dilution Li

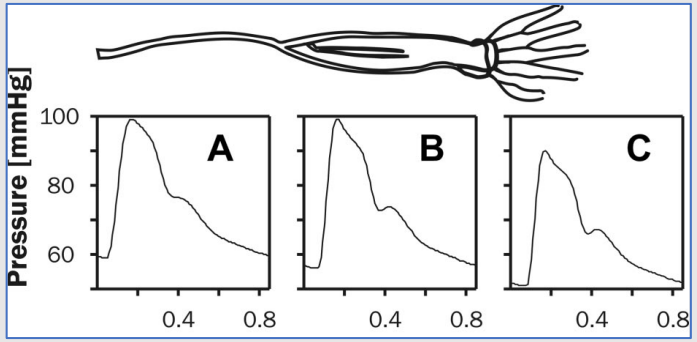
Analyse onde de PA continue non invasive (manchon digital)

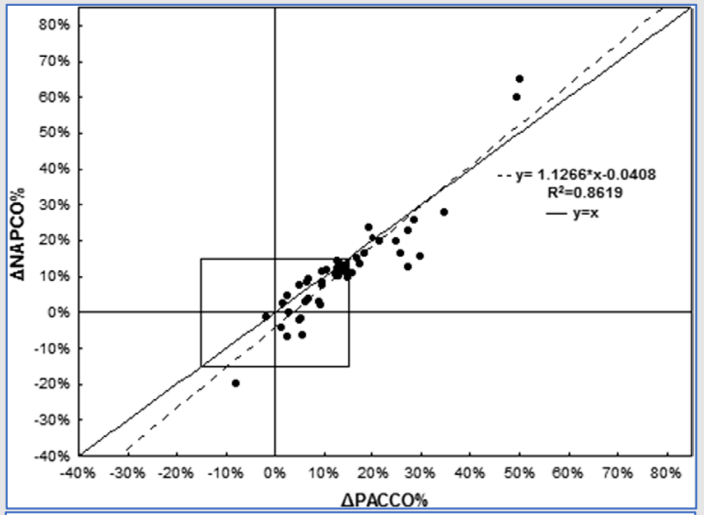
Clearsight® (Edwards, USA) (ex-Nexfin® (Bmeye, Pays-Bas))
CNAP (CNSystems, Autriche)

- **Non invasif**
- Manchon autour d'un doigt + capteur pléthysmographie
- Méthode de « volume clamp »: Gonflage / dégonflage pour maintenir volume artères constant
  - PA doigt # pression brassard
  - Traitem^{ts} mathématiques complexes (factrs correctifs / analyse de population…..)

  -> PA brachiale *Martina, Anesthesio 2012*
  - **Mesure continue** → VPP
  - Analyse de l'onde de PA (modèle de Windkessel) → DC
- « Acceptable » au bloc (patients « stables »)
  - Pourcentages d'erreur DC # 30-40%
  - Moniteur de tendance (imprécision des valeurs absolues): T^{x} de concordance > 90%
- Trop imprécis / états de choc (vasoconstriction, œdème)
  - Amplification de pression (↗ PP) (ft compliance & résistance) le long de l'arbre A^{el}
  - Altération (↘): athérosclérose (âge), traitement vasopresseur, sepsis
- **Uniquement taille de brassard adulte**







Épreuve de remplissage / levée de jambes Post CEC (vs ThD) *Bubenek-Turconi, AA 2013* (conflit d'intérêt)

Non-invasive continuous arterial pressure and pulse pressure variation measured with Nexfin in patients following major upper abdominal surgery: a comparative study

De Wilde, Anaesthesia 2016

- Mesure de PA:
  - Acceptable au bloc
  - Inacceptable en réanimation
- Mesure de PP & VPP:
  - « sommation des erreurs »
  - ↑ pourcentage d'erreur
- Capacité de prédiction de réponse au remplissage:
  - ⇔ VPP invasive *Monnet, BJA 2012*
  - Imprécision VPP = valeurs < 15%
- Bénéfice Clinique (↓ complications postop) avec GDFT guidée par VPP non invasive

  Benes, BMC 2015

	n		Accepted	(inv + ni)/2 Mean mmHg	Difference (ni − inv) Mean (SD) mmHg	COV	Limits of agreement Lower mmHg	Limits of agreement Upper mmHg	Patients
Stover et al. (2009)	10	MAP	No	78.5	−2.0 (8.0)	10.2%	−18.0	14.0	Critically ill
Martina et al. (2012)	50	SAP	Yes	99.0	−0.5 (6.7)	6.8%	−13.9	12.9	Cardiothoracic surgery
		DAP		57.5	2.8 (6.4)	11.1%	−10.0	15.6	
		MAP		71.5	2.2 (6.4)	9.0%	−10.6	15.0	
Weiss et al. (2014)	31	SAP	No	113.0	−2.0 (25.0)	22.1%	−51.0	47.0	General anaesthesia
		DAP		63.5	−9.0 (12.0)	18.9%	−33.0	14.0	
		MAP		82.5	−7.0 (16.0)	19.4%	−38.0	24.0	
Fischer et al. (2012)	50	SAP	Yes	107.0	5.7 (14.4)	13.5%	−22.5	34.0	Post cardiac surgery
		DAP		59.5	−8.9 (7.0)	11.7%	−22.6	4.7	
		MAP		76.0	−4.6 (6.5)	8.5%	−17.3	8.1	
Hofhuizen et al. (2014)	20	SAP	Yes	113.7	−2.7 (11.1)	9.8%	−24.9	19.5	Post cardiac surgery
		DAP		61.2	−4.9 (6.8)	11.1%	−18.5	8.7	
		MAP		78.0	−4.2 (6.9)	8.8%	−17.9	9.5	
Monnet et al. (2012)	45	MAP	No	75.0*	2.0 (10.3)	13.7%	−18.0	23.0	Critically ill
Hohn et al. (2013)	25	SAP	No	116.0*	−9.0 (25.0)	21.6%	−58.0	41.0	Critically ill
		MAP		76.	6.0 (12.0)	15.8%	−18.0	30.0	
Present study	19	SAP	Yes	108.8	−3.8 (7.8)	7.2%	−20.6	13.0	Post major abdominal surgery
		DAP		57.3	2.4 (4.2)	7.3%	−5.8	10.7	
		MAP		75.9	0.8 (5.0)	6.6%	−9.0	10.7	