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and
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C03: Focus on POCUS: Assessment of Fluid Responsiveness, Hemodynamic Monitoring and Targets

The Assessment of Fluid Deficiency and Fluid Responsiveness in Children

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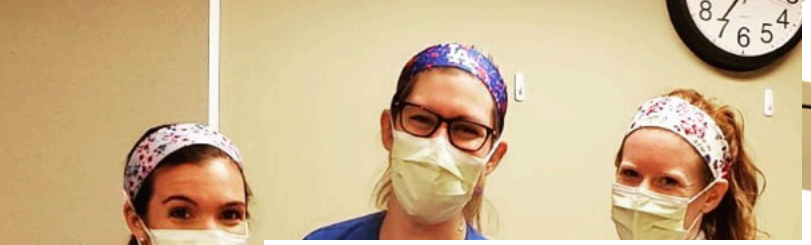
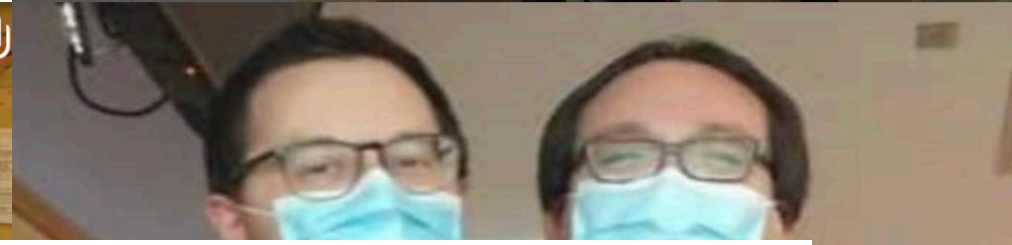




Although this is an innovative advancement in medical education, several subspecialties including nephrology will soon face a situation where incoming trainees are more skilled in POCUS than the supervising physicians, potentially leading to role reversal in the clinical decision-making process and confusion in medical documentation.


Review Article

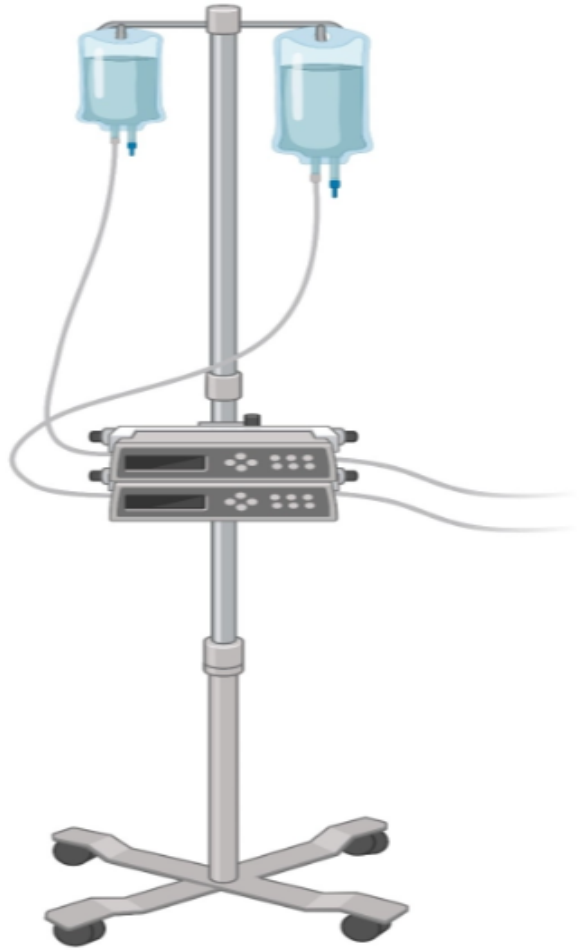
Kidney360

POCUS for Nephrologists: Basic Principles and a General Approach

Abhilash Koratala [1] *and Nathaniel Reisinger* [2]

Objectives

- Be familiar with the use of ultrasound for the assessment of fluid deficiency and fluid responsiveness in children with evolving critical illness.
- Understand the use of POCUS methods that show promise for accurately predicting fluid responsiveness in children.



POCUS: Game-changer at the bedside

- A systemati
- 501 boluses
- Investigated
- Defined flui

STATIC	
Clinical	Heart rate Systolic arterial blood pressure
Preload pressure	Central venous pressure Pulmonary artery occlusion pressure
Thermodilution	Global end diastolic volume index
Ultrasound dilution	Active circulation volume Central blood volume Total end diastolic volume Total ejection fraction
Echocardiography and Doppler	Left ventricular end diastolic area Stroke volume index Corrected flow time
DYNAMIC	
Arterial pressure	Systolic blood pressure variation Pulse pressure variation Stroke volume variation Difference between minimal SAP and SAP at end-expiratory pause Difference between maximal SAP and SAP at end-expiratory pause
Plethysmography	Pulse oximeter plethysmograph amplitude variation Plethysmograph variability index
Echocardiography and Doppler	Respiratory variation in aortic blood flow peak velocity Stroke distance variation Inferior vena cava diameter variation
PASSIVE LEG RAISING (PLR)	
Echocardiography and Doppler	PLR-induced change in cardiac index PLR-induced change in stroke volume

Predicting Fluid Responsiveness in Children

A Systematic Review

Gan, Heng MBBCh, MRCPCH, FRCA*†; Cannesson, Maxime MD, PhD‡; Chandler, John R. MBBCh, FCARCSI, FDSRDS§; Ansermino, J. Mark MBBCh, MSc (Inf), FFA (SA), FRCPC*†

	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]
Preload pressur	CVP		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]

Respiratory variation in aortic blood flow peak velocity was the only variable shown to predict fluid responsiveness in children across multiple studies

A Study to Compare Ultrasound-guided and Clinically-guided Fluid Management in Children with Septic Shock

Ryan Sohail Kaiser[1], Mihir Sarkar[2], Sumantra Kumar Raut[3], Manas Kumar Mahapatra[4], Mohammad Asraf Uz Zaman[5], Oishik Roy[6], Satyabrata Roy Chowdhoury[7], Mousumi Nandi[8]

Received on: 18 January 2023; *Accepted on:* 24 January 2023; *Published on:* 31 January 2023

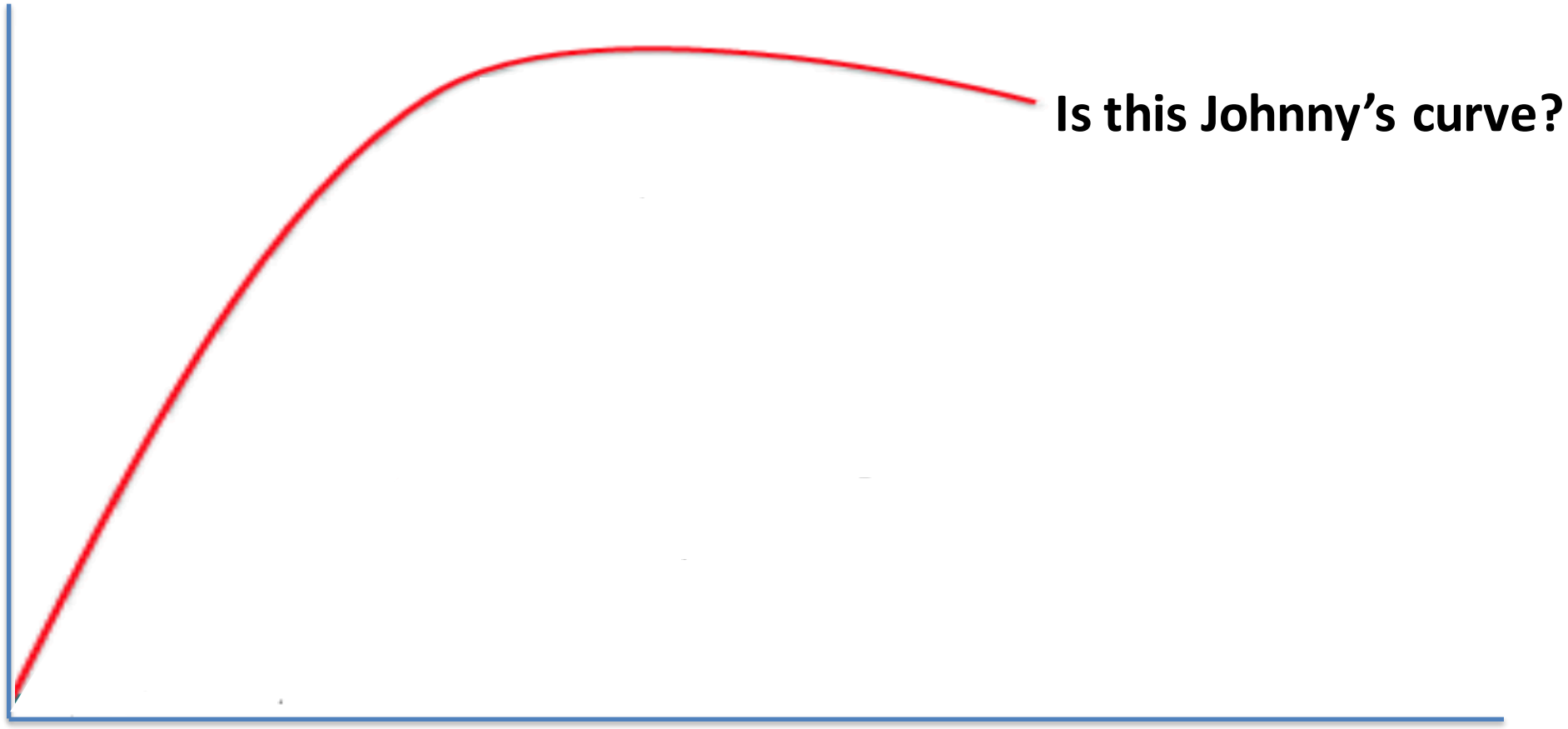
- 56 children with septic shock were randomized to ultrasound guided or clinically guided fluid boluses

Outcome	Ultrasound-Guided Group	Clinically-Guided Group
Cumulative Fluid Balance >10%	25%	62%

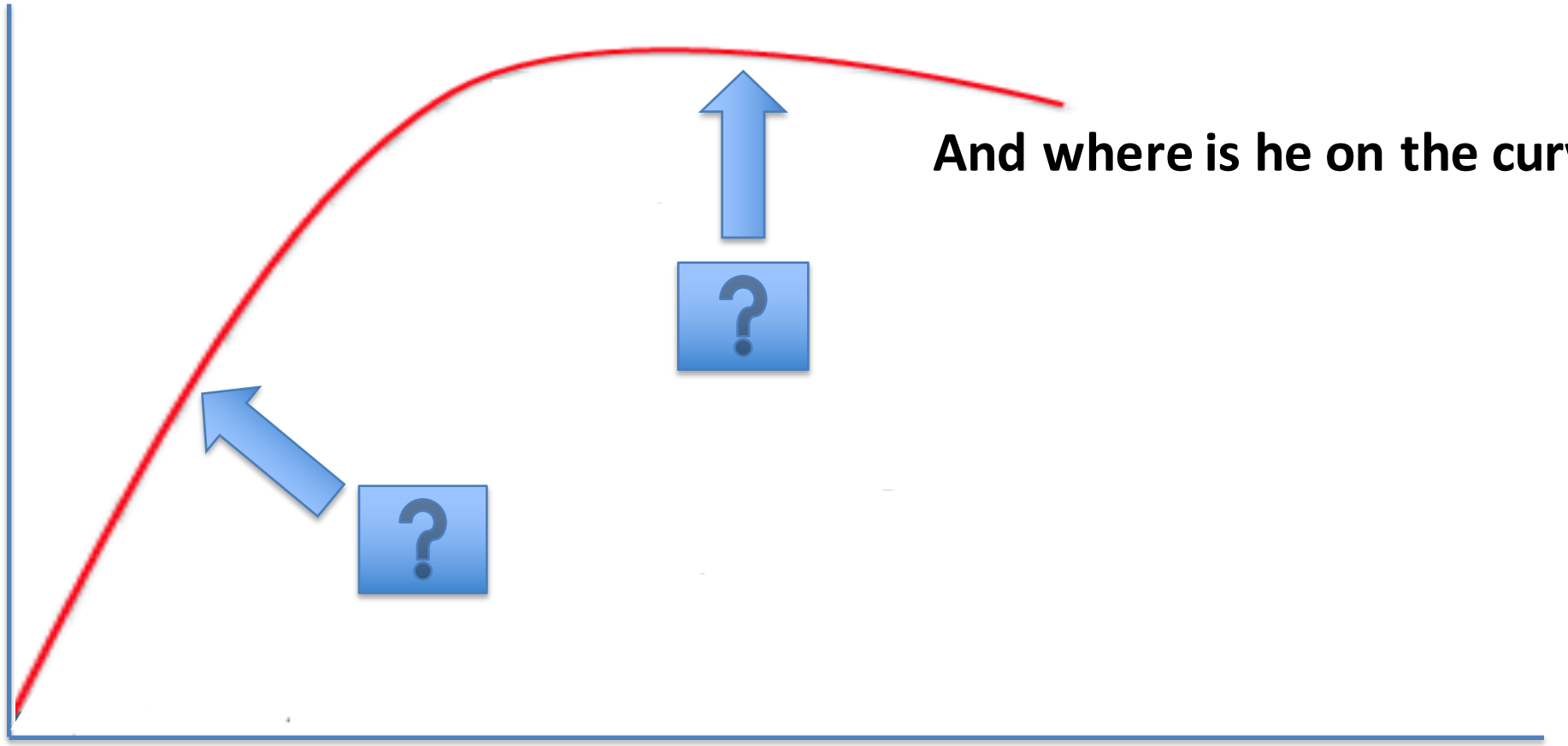
Case 1: Johnny Nopee

- 12-year-old male with influenza in septic shock
- Resuscitated with 2 liters of isotonic fluids
- Remains tachycardic and mildly hypotensi
- SpO2=94% on 2 L NC
- Lactate=2.2 mmol/L
- Should you give more fluid???

The Physiology of a Fluid Challenge



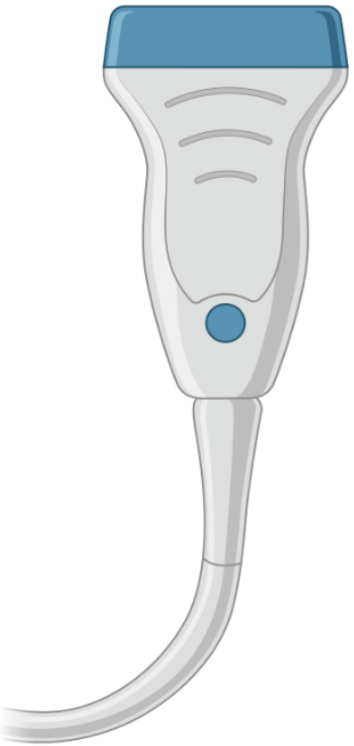
The Physiology of a Fluid Challenge



And where is he on the curve right now?

Will Johnny be fluid responsive??

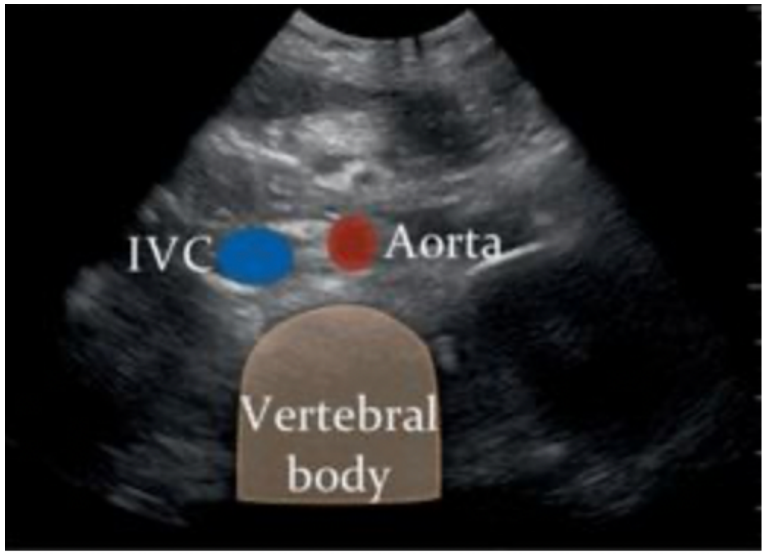
- Static measures:
  - Do not account for physiologic interactions
  - Can determine volume status, not fluid responsiveness



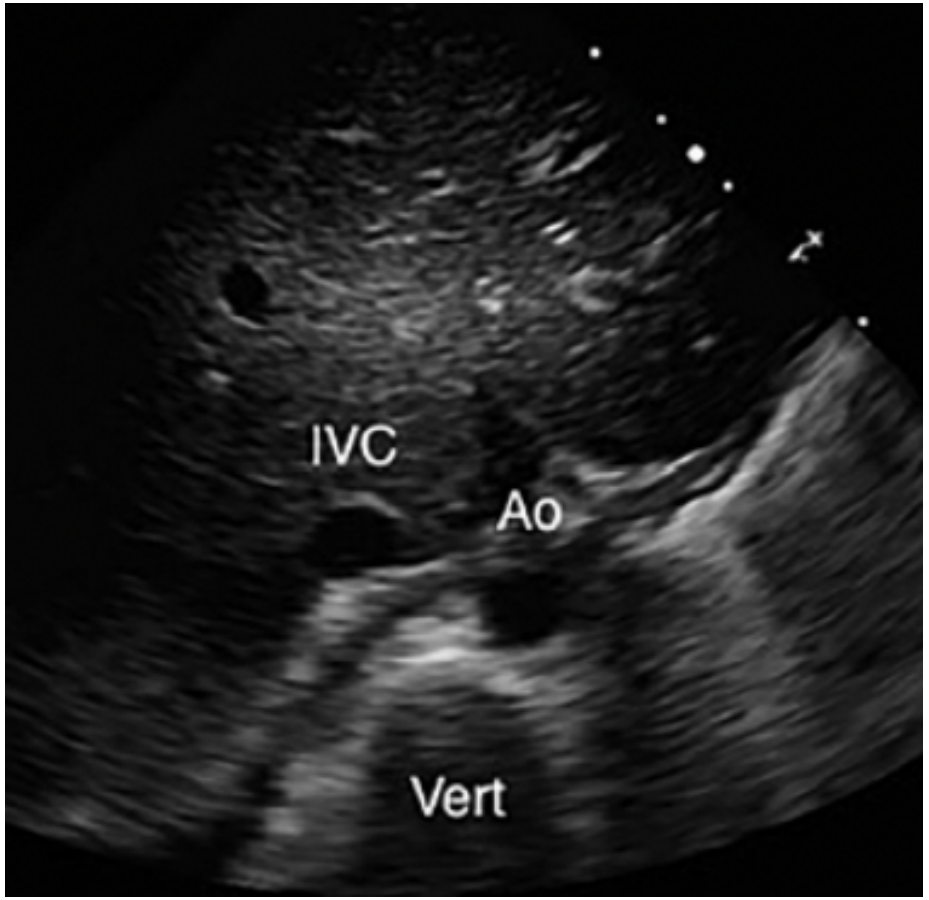
- Dynamic measures:
  - Use or induce a change in preload and see if it changes stroke volume

A Static Measure : The Inferior Vena Cava to Aorta Ratio

- Correlates with fluid status with a cutoff of < 0.8
- Has been mainly studied in relation to fluid status, but not fluid responsiveness
- Its correlation with dehydration has not been reproducible over multiple studies
- Not useful in patients < 5 years of age

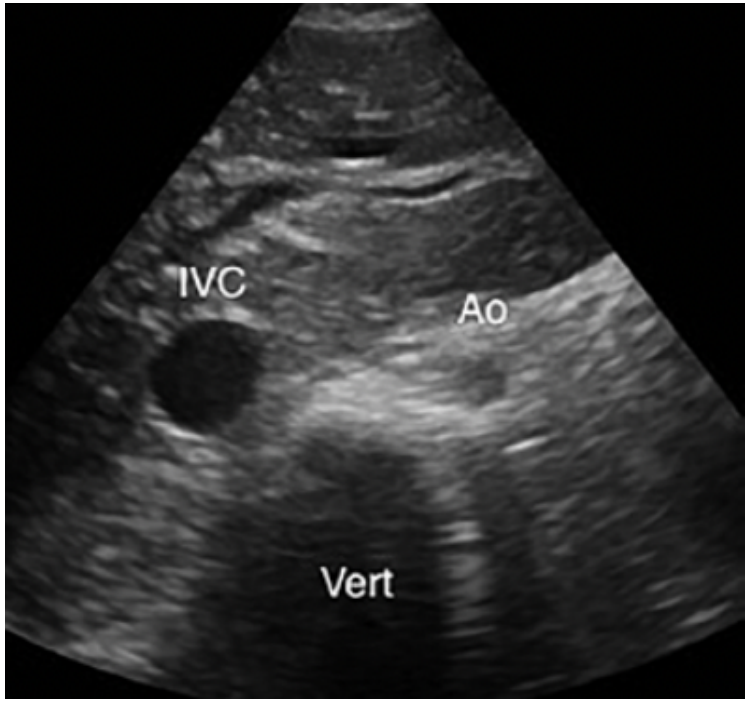


The Inferior Vena Cava to Aorta Ratio

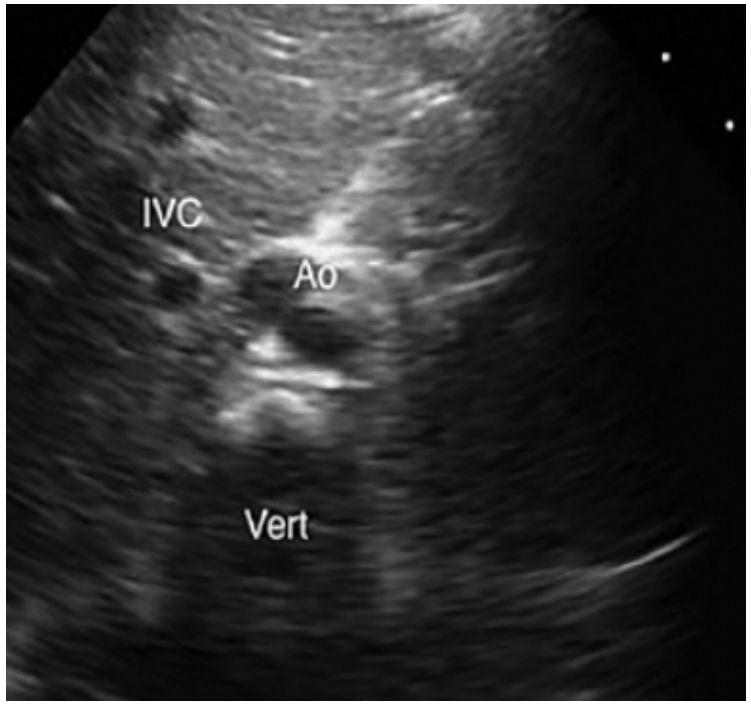


Jauregui et al. *Crit Ultrasound Journal* 2014

The Inferior Vena Cava to Aorta Ratio

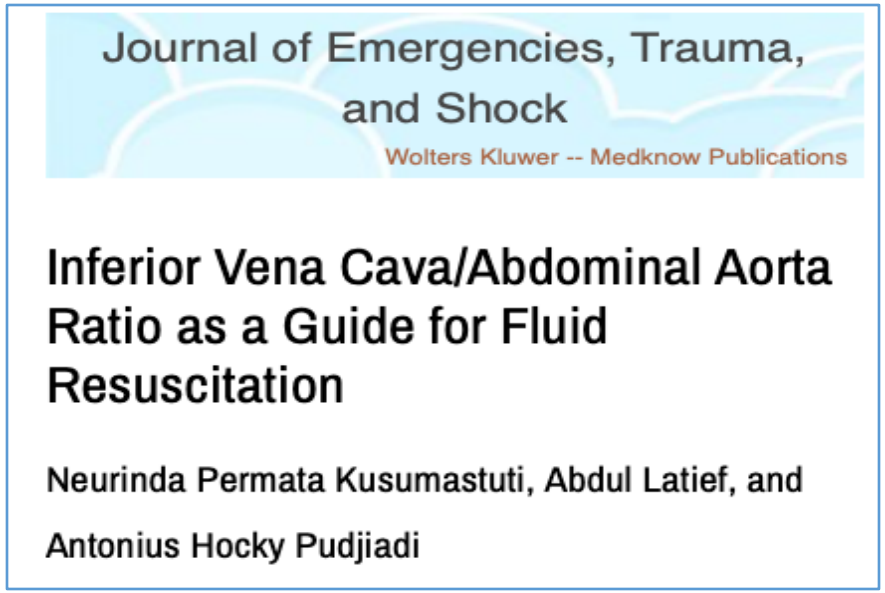


Hypervolemic: >1.4



Hypovolemic: <0.8

Some studies have examined IVC/Aorta as a dynamic measure…



- 58 Critically ill children 1 month to 18 years with shock (52.6% receiving mechanical ventilation)
- Measurements of IVC to Aorta Ratio and stroke volume before and after a fluid challenge (10 mL/kg of Lactated Ringer's)
- Measured stroke volume using an ultrasound cardiac output monitor (USCOM): fluid responder=increase in stroke volume >10%

Hemodynamic Characteristics before fluid administration between fluid responsive and nonfluid responsive subjects

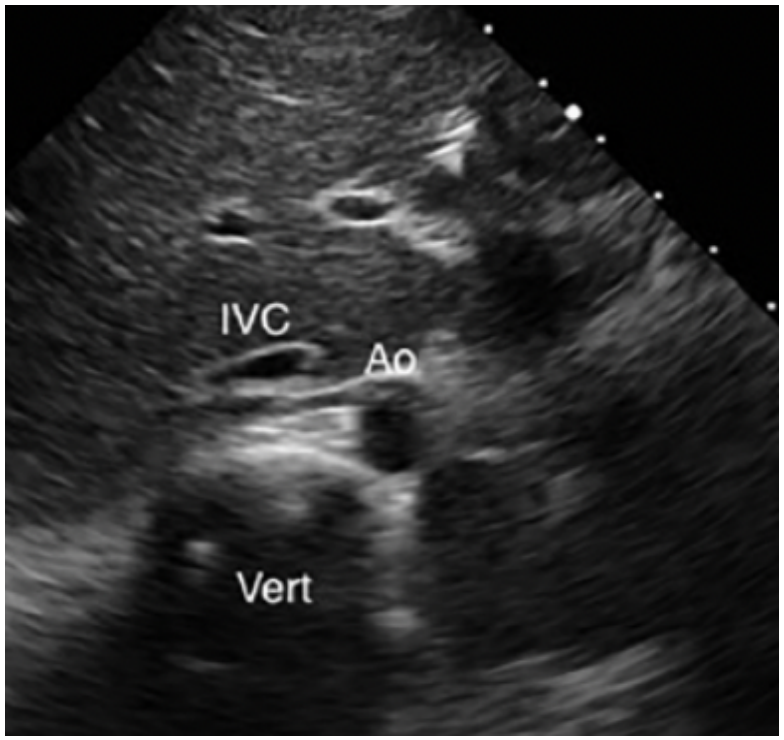
Parameter	Fluid responsive (n=37)	Nonfluid responsive (n=21)	P
Heart rate (beats/min), mean±SD	157.4±25.2	158.1±29.2	0.200
MAP (mmHg), mean±SD	61.9±18.47	65.7±13.07	0.200

Sensitivity and specificity of the IVC/Ao before the fluid challenge

Variable	Value	Fluid responsiveness		Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
		Yes	No				
Ratio diameter IVC/Ao before fluid challenge	≤0.675	28	8	75.7	61.9	77.8	59.1
	>0.675	9	13				

Kusumastutiet al. *J Emerg Trauma Shock* 2021

Back to Johnny Nopee: 14 year old male with influenza with septic shock



- Flattened or elliptical-shaped transverse IVC, IVC:Ao <0.8

Case 2: Dayna Reesus

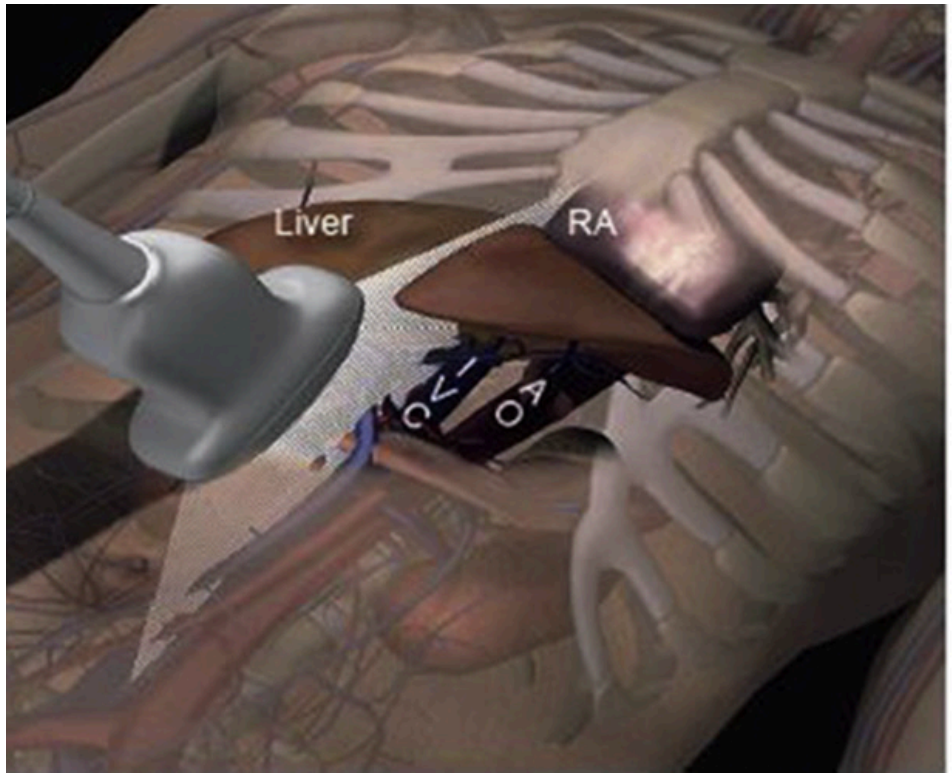
- 2-year-old female intubated with rhinovirus, metapneumovirus and Streptococcus pneumoniae
- Received 20 mL/kg of isotonic fluids in the emergency room
- She has had no urine output in the last 8 hours
- Remains tachycardic and hypotensive (HR=190, BP=70/42)
- On low ventilator settings
- Lactate=1.8 mmol/L
- Should you give more fluid??

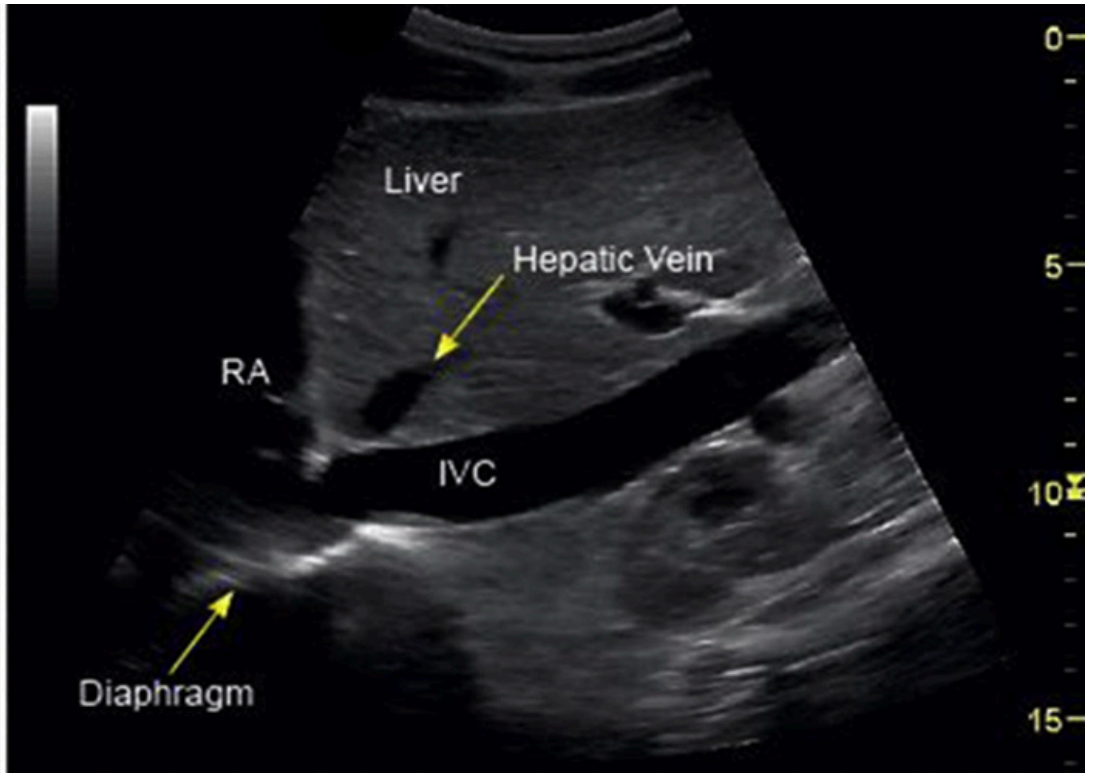
A Dynamic Measure: Respiratory Variation of the IVC Diameter During PPV

- IVC diameter depends on the pressure gradient between the abdominal IVC and right atrium
- What happens in a patient with preload recruitable cardiac output??

Inspiration	Expiration
IVC drainage to the right heart is reduced	IVC drainage to the right heart is increased
IVC Diameter Increases	**IVC Diameter Decreases**

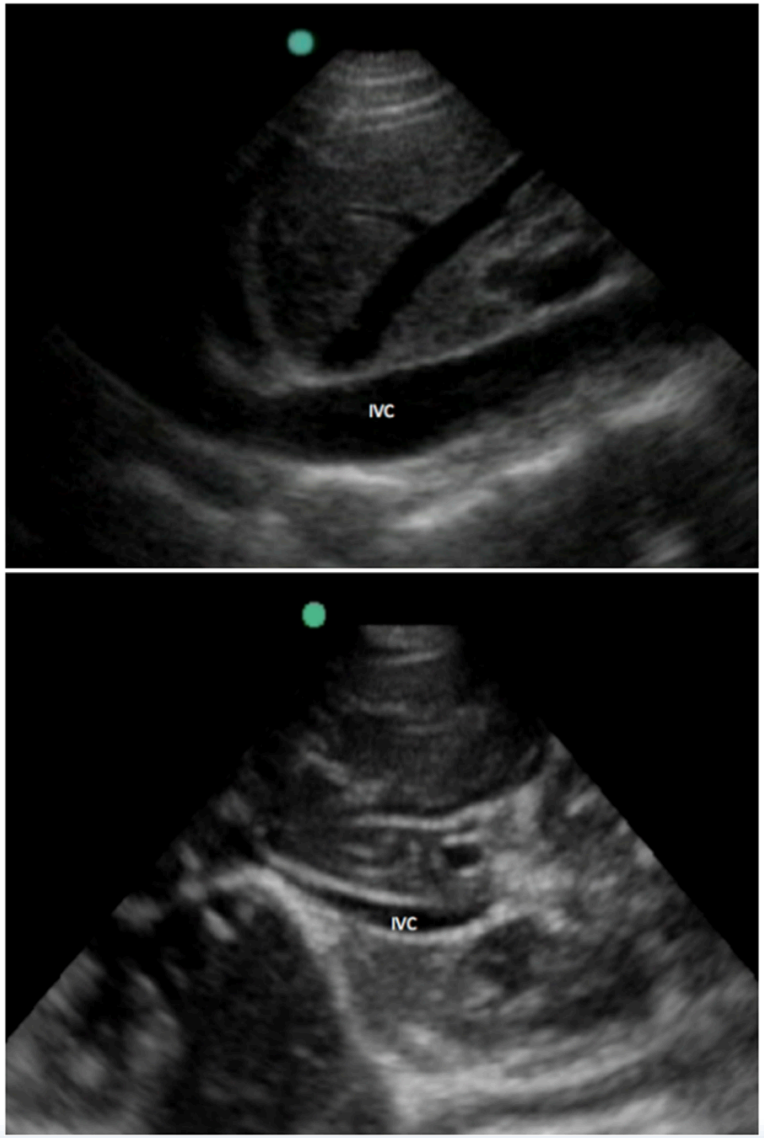
Respiratory Variation of the IVC Diameter





Kaptein MJ, Kaptein EM *ACKD* 2021

IVC in Our Patient Dayna



Inspiration

Expiration

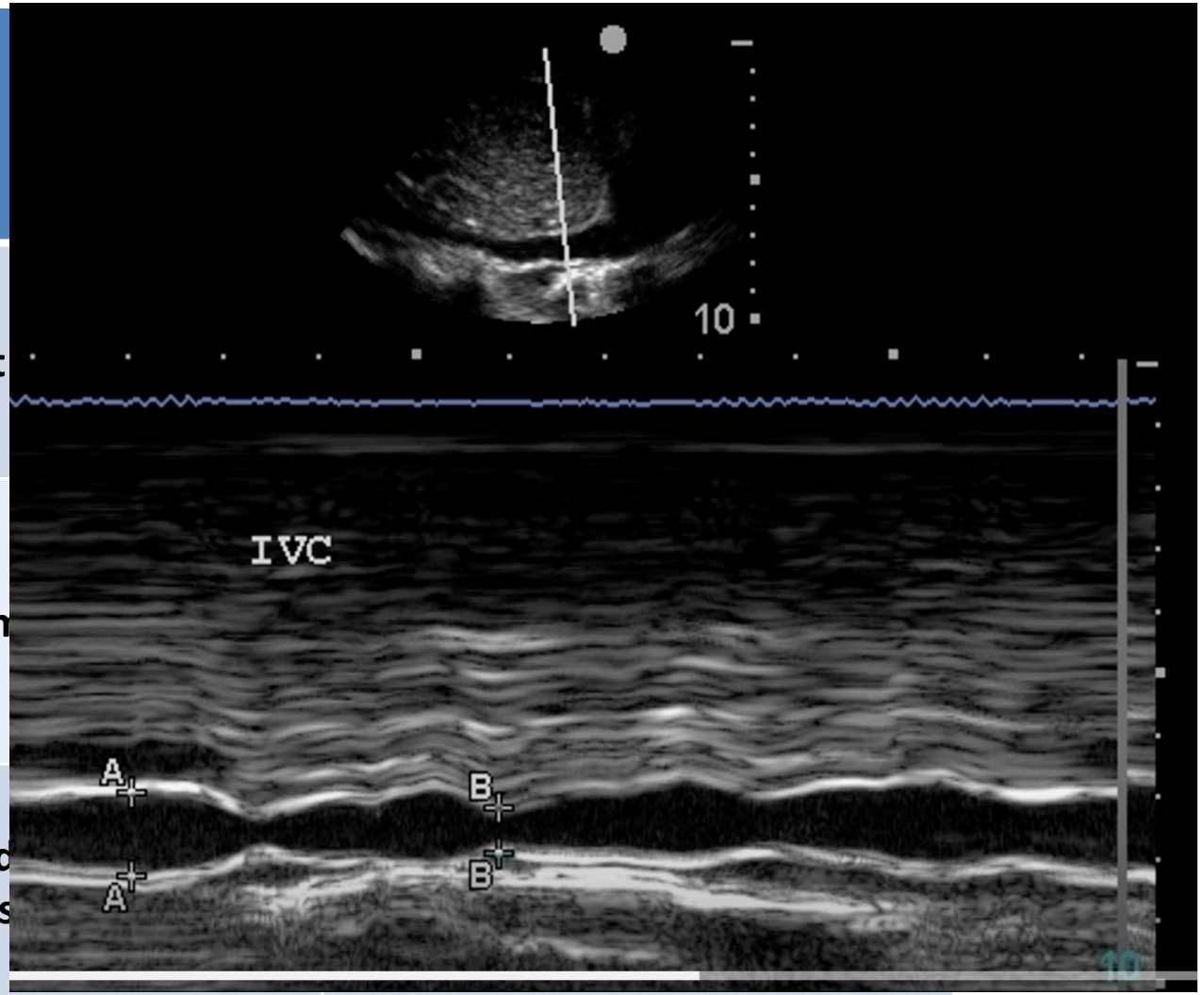
Jaureguiet al. *Crit Ultrasound Journal* 2014

IVC Indices in Pediatrics

Patient

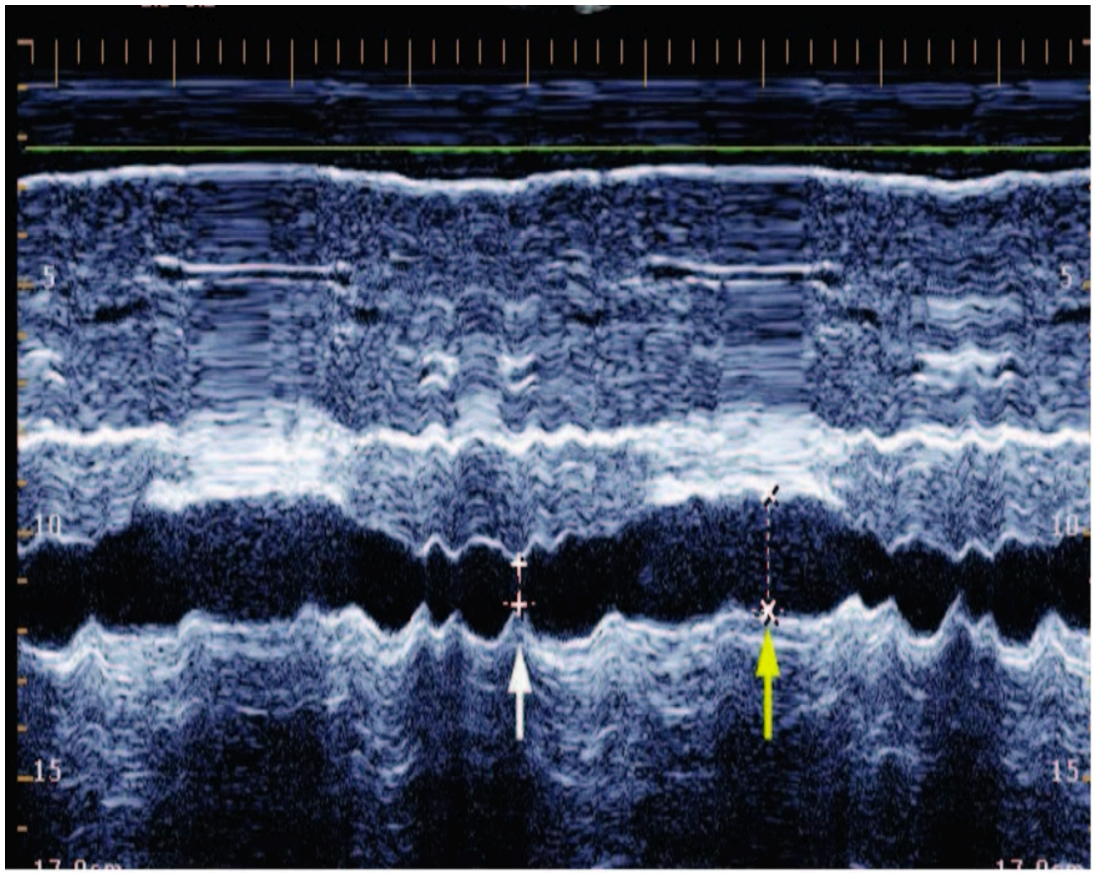
Form

Threshold
Respons

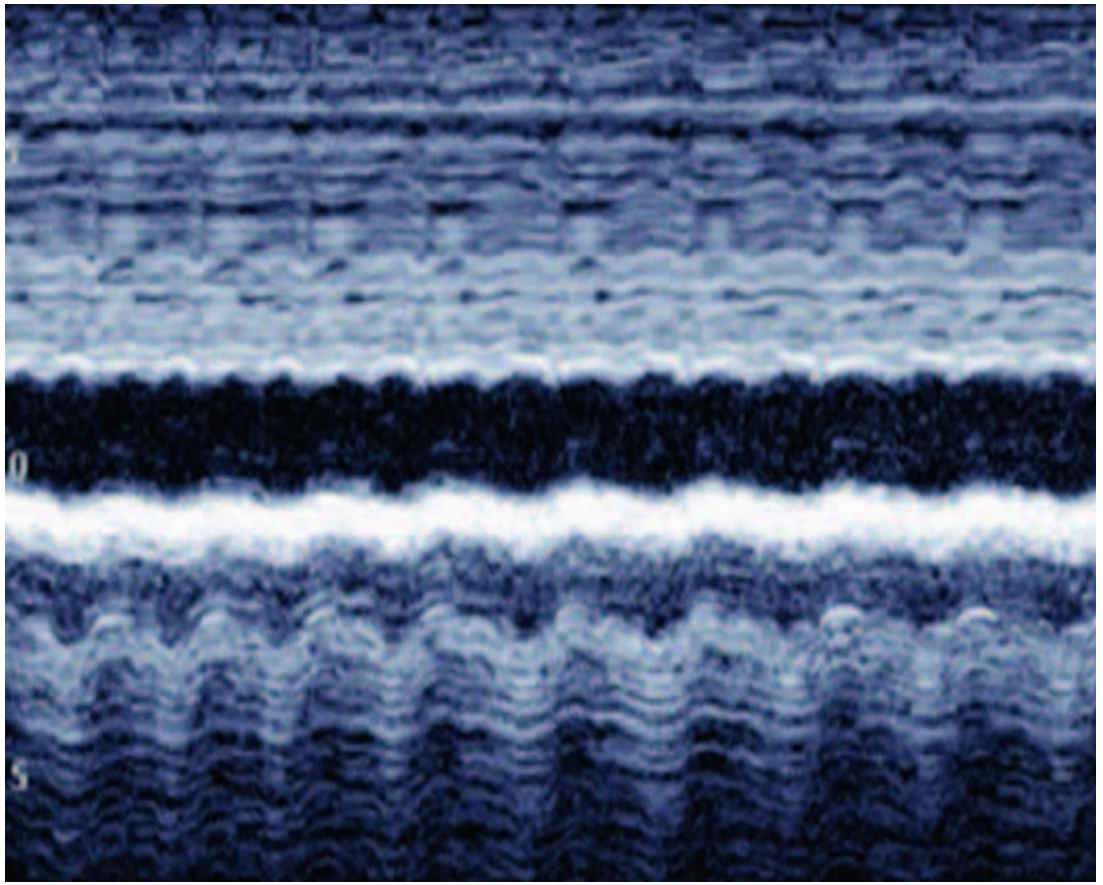


Motion-Mode

IVC Distensiblity Index~80%



IVC Distensiblity Index <15%



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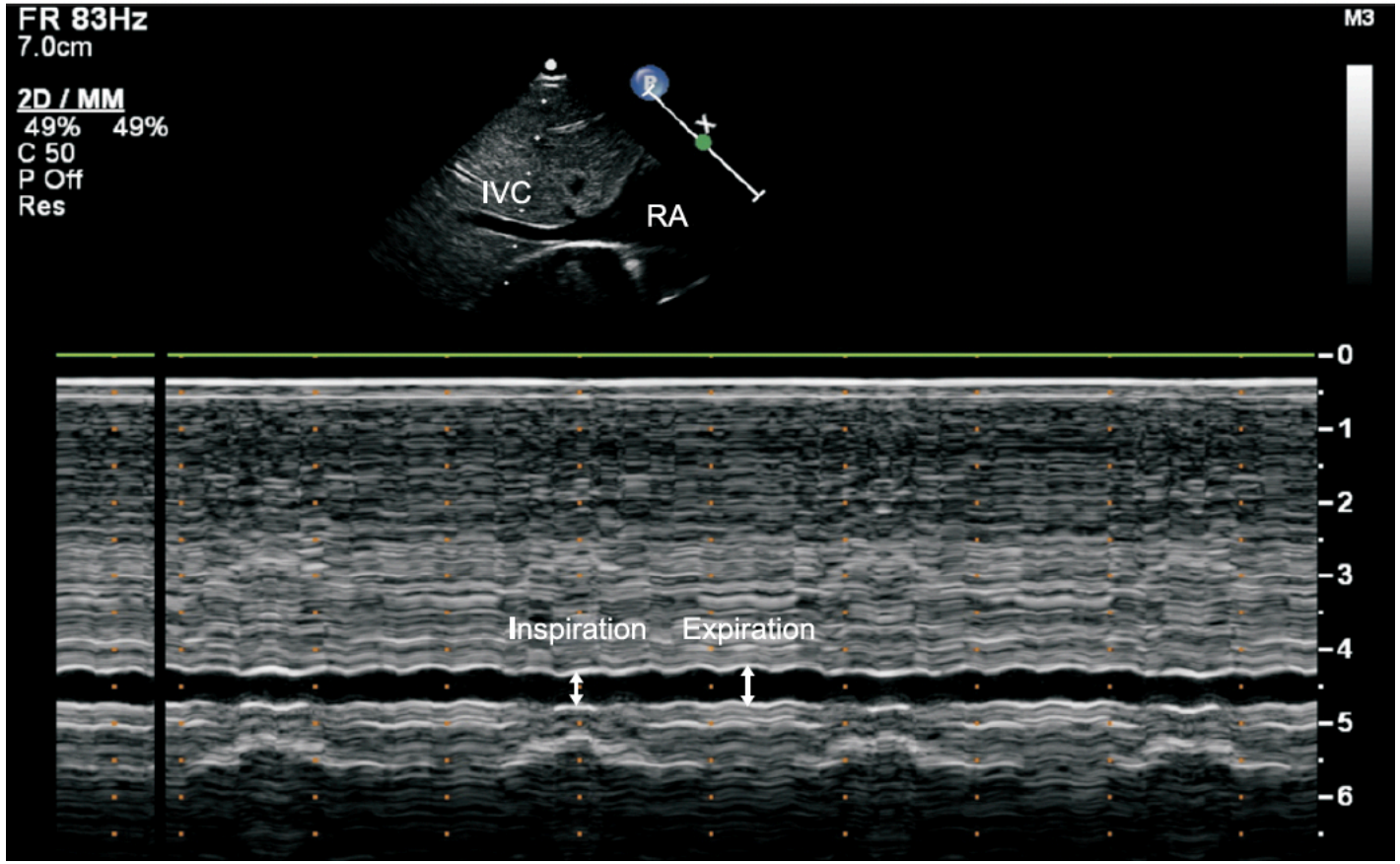
Real World Notes

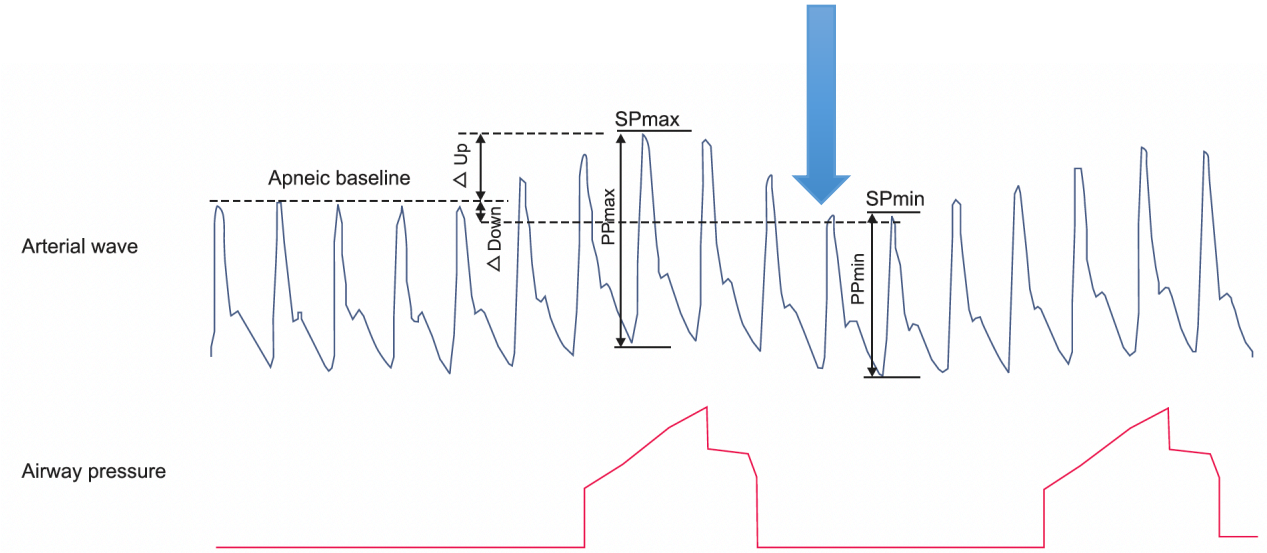
- The performance of respiratory variation of the IVC is mixed in children
- △IVC decreases with PPV in children
- Changes in M-mode of the IVC during mechanical ventilation in a 5-month-old infant:



Lee et al. KJA 2019

Another Dynamic Measure: Respiratory Variation in Aortic Flow Peak Velocity

- Mechanical ventilation transiently increases intrathoracic pressure during inspiration
- This results in a phasic drop in venous return to the RA over the respiratory cycle
- There is a corresponding cyclical drop in stroke volume 3-5 heart beats after a mechanical breath



Lee et al. *KJA* 2019

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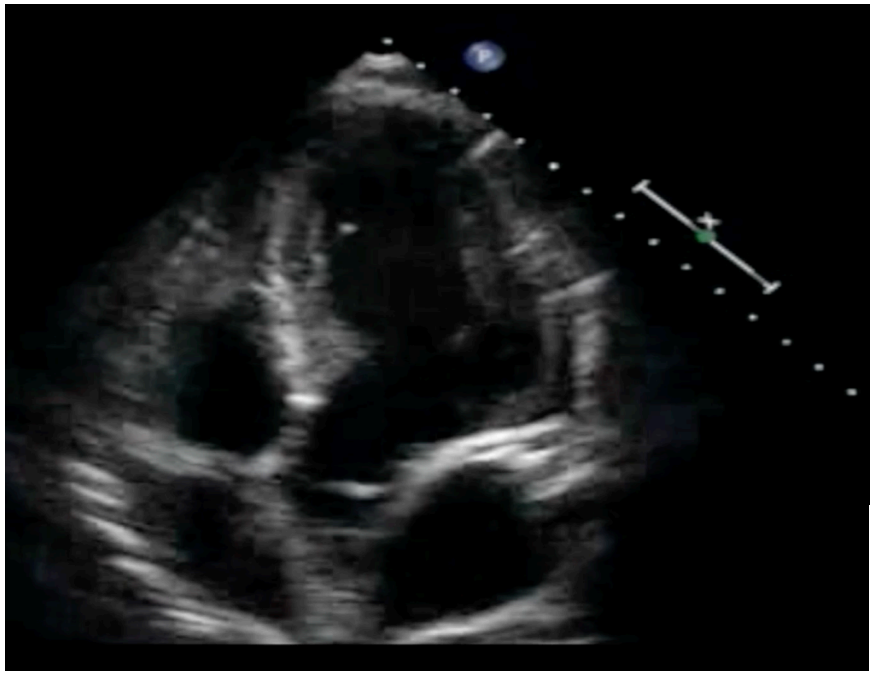
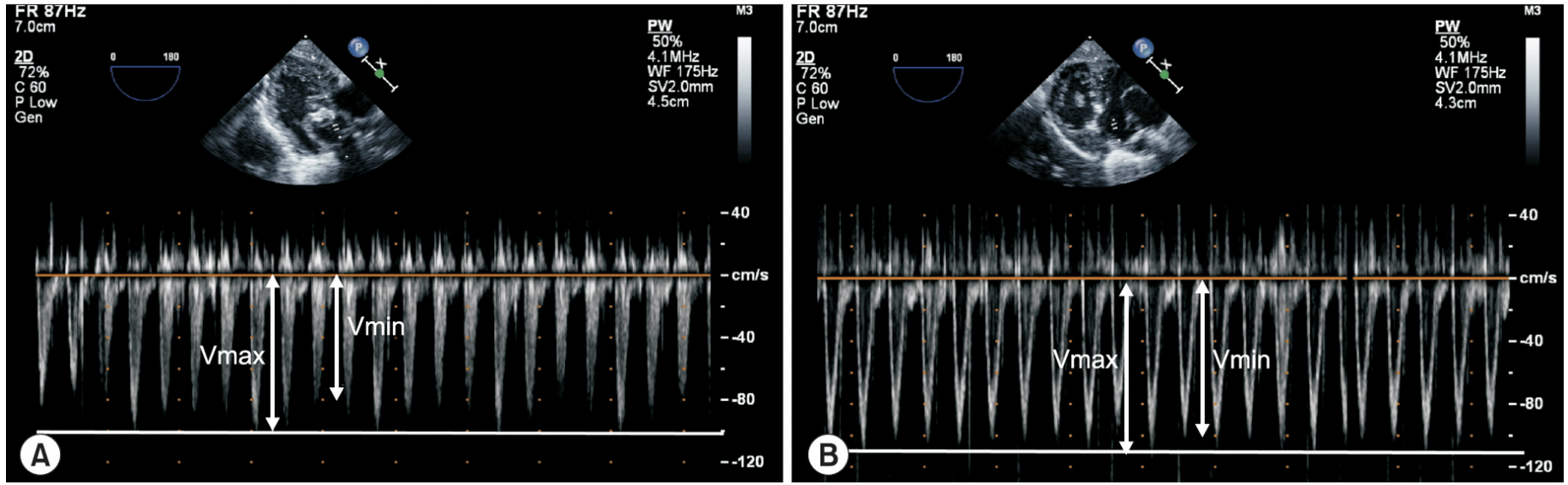
Another Dynamic Measure: Respiratory Variation in Aortic Flow Peak Velocity

- The phasic variation in the stroke volume can be approximated by measuring how the speed of blood through the left ventricular outflow tract varies over the respiratory cycle
- Obtain an apical 5-chamber view:



Respiratory Variation in Aortic Flow Peak Velocity

- Delta aortic velocity = [(max aortic velocity -min aortic velocity)/mean aortic velocity] x 100
- Obtain pulsed doppler at the level of the aortic annulus
- Quantify before and after a fluid challenge:



Lee et al. *KJAnesth* 2019

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6 studies in 163 Children

Pediatric Anesthesia

Pediatric Anesthesia ISSN 1155-5645

SYSTEMATIC REVIEW

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

François-Pierrick Desgranges[1], Olivier Desebbe[2], Edmundo Pereira de Souza Neto[3,4,5], Darren Raphael[6] & Dominique Chassard[1]

Table 3 Results of the studies included in the systematic review

References	Sample size (*n*)	Percentage of responders (%)	Best threshold value (%)	Sensitivity (%)	Specificity (%)	Area under ROC curve (95% CI)
Durand *et al.* (17)	26	69.2	12	81.2	85.7	0.82 (0.99–1.8)
Choi *et al.* (18)	21	52.4	20	91	90	0.83 (0.61–1.00)
Pereira de Souza Neto *et al.* (19)	30	56.7	10	100	100	1.00 (0.88–1.00)
Renner *et al.* (20)	27	48.1	7	100	85	0.92
Byon *et al.* (21)	33	45.5	11	86.7	72.2	0.80 (0.64–0.96)
Lee *et al.* (22)	26	50.0	14	92	85	0.96 (0.88–1.00)

ROC, receiver operating characteristic; CI, confidence interval.

- Typically >15% is thought to predict volume responsiveness in children

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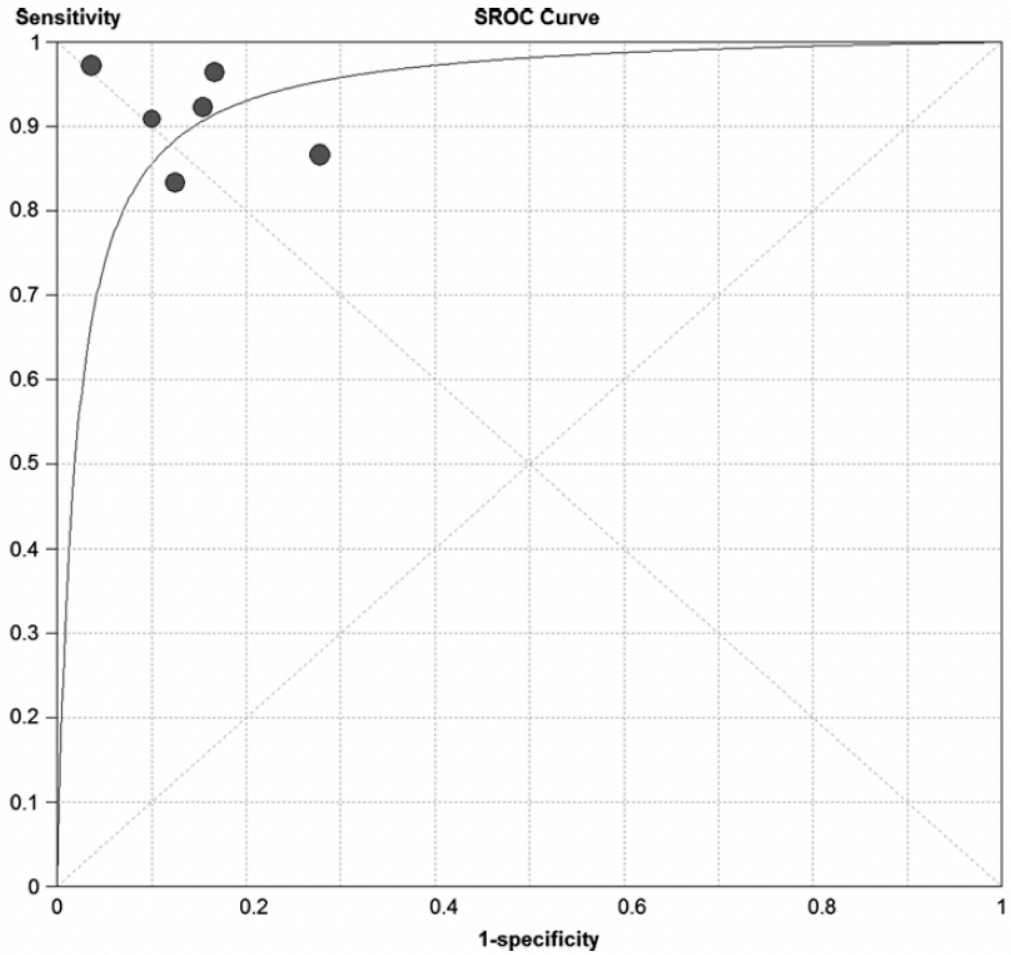
Aortic Flow Peak Velocity

- This is the only method that has consistently been shown to have predictive ability in pediatrics



Summary ROC: 0.9417

Desgranges et al. *Pediatr Anes* 2015

Respiratory Variation in Aortic Flow Peak Velocity: Limitations

- Must be in sinus rhythm
- Best with passive ventilation
- Best with larger tidal volumes (10-12 mL/kg)
- Increased abdominal pressure can lead to false positives
- Isolated right heart failure can lead to false positives

Lee et al. *KJAnesth* 2019

Singh et al. Critical Care (2020) 24:65
https://doi.org/10.1186/s13054-020-2787-9

Critical Care

RESEARCH Open Access

International evidence-based guidelines on Point of Care Ultrasound (POCUS) for critically ill neonates and children issued by the POCUS Working Group of the European Society of Paediatric and Neonatal Intensive Care (ESPNIC)

Yogen Singh[1,2*†], Cecile Tissot[3†], María V. Fraga[4], Nadya Yousef[5], Rafael Gonzalez Cortes[6], Jorge Lopez[6], Joan Sanchez-de-Toledo[7], Joe Brierley[8], Juan Mayordomo Colunga[9], Dusan Raffaj[10], Eduardo Da Cruz[11], Philippe Durand[12], Peter Kenderessy[13], Hans-Joerg Lang[14], Akira Nishisaki[15], Martin C. Kneyber[16], Pierre Tissieres[12], Thomas W. Conlon[15] and Daniele De Luca[5,17]

- Provided the first evidence-based guidelines for the use of POCUS in critically ill children
- Help to standardize and disseminate POCUS training programs

POCUS may be helpful to assess fluid responsiveness in neonates and children—*strong agreement (quality of evidence D)*. The variation of velocity-time integrals (VTIs) measured at the left ventricular outflow tract (LVOT), using pulse wave Doppler (PWD) in apical 5-chamber view, during inspiration and expiration has been reported to predict volume responsiveness. A variation of > 15% has been reported to have a high predictive value with a sensitivity and specificity exceeding 90%

Singh et al. *Crit Care* 2020

Conclusions

We need to move beyond measures such as CVP and blood pressure to determine if a child is fluid deplete or fluid responsive

Respiratory variation in aortic blood flow peak velocity has been shown to an accurate predictor of fluid responsiveness in children receiving mechanical ventilation

None of these tools should be used alone for determining fluid status/fluid responsiveness

POCUS should be part of our "tool box" for evaluating fluid status in children