Ultrasound to evaluate the patient's volume status

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- Why predicting the volume status is important?
- How can we predict the patient’s volume status?
- How can we use ultrasound to predict the patient’s volume status?
- We have estimated the volume status, is the game over?

Introduction

- Evaluation and management of intravascular volume are a central challenge in caring for the critically ill.
- Patients with hypotension are commonly resuscitated with intravenous crystalloid fluid, in keeping with recommendations for treatment of many shock states.

Dellinger RP, Levy MM, Rhodes A, et al. Surviving sepsis campaign: international guidelines for management of severe sepsis and septic shock: 2012. Crit Care Med. 2013;41:580–637

- The therapeutic goal of fluid administration is to increase preload and leading to an increased stroke volume and cardiac output.
- But, studies of hypotensive patients consistently demonstrate that approximately 50% of fluid boluses fail to achieve the intended effect of increasing cardiac output.

Osman D, Ridel C, Ray P, et al. Cardiac filling pressures are not appropriate to predict hemodynamic response to volume challenge. Crit Care Med. 2007;35:64–8.

Marik PE, Cavallazzi R, Vasu T, Hirani A. Dynamic changes in arterial waveform derived variables and fluid responsiveness in mechanically ventilated patients: a systematic review of the literature. Crit Care Med. 2009;37:2642–7.

- Moreover, there is increasing data to demonstrate that excess fluid administration may be harmful, and is associated with increased mortality.

Marik PE. Iatrogenic salt water drowning and the hazards of a high central venous pressure. Ann Intensive Care. 2014;4:21.

Wang CH, Hsieh WH, Chou HC, et al. Liberal versus restricted fluid resuscitation strategies in trauma patients: a systematic review and meta-analysis of randomized controlled trials and observational studies. Crit Care Med. 2014;42:954–61.

The ways of predicting fluid status
Physical Exam

- The earliest assessment of the patient is the history and physical examination
- Studies show that Physical exam have a poor performance to predict fluid status.

McGee S, Abernethy WB III, Simel DL. The rational clinical examination. Is this patient hypovolemic? JAMA 1999; 281: 1022–1029

Stephan F, Flahault A, Dieudonne N et al. Clinical evaluation of circulating blood volume in critically ill patients- contribution of a clinical scoring system. Br J Anaesth 2001; 86: 754–762.

Eisenberg PR, Jaffe AS, Schuster DP. Clinical evaluation compared to pulmonary artery catheterization in the hemodynamic assessment of critically ill patients. Crit Care Med 1984; 12: 549–553

The ways of predicting fluid status CVP

- CVP is the most commonly used parameter for guiding fluid management especially in ICUs.
- Intensivists and anesthesiologists more than 90% use CVP to guide fluid management.
- Guidelines have recommended the use of CVP in guiding fluid management in critically ill septic patients.

Dellinger RP, Carlet JM, Masur H et al. Surviving Sepsis Campaign guidelines for management of severe sepsis and septic shock. Crit Care Med 2004; 32: 858–873.

- But, the likelihood that CVP can accurately predict fluid responsiveness is only 56%!
- CVP is dependent on venous return to the heart, right ventricular compliance, peripheral venous tone, and posture,
- And the CVP is particularly unreliable in pulmonary vascular disease, right ventricular disease, patients with tense ascites, isolated left ventricular failure, and valvular heart disease.

*Marik PE, Baram M, Vahid B. Does central venous pressure predict fluid responsiveness? A systematic review of the literature and the tale of seven mares. Chest 2008; 134: 172–178.

Marik PE, Baram M. Non-invasive hemodynamic monitoring in the intensive care unit. Crit Care Clin 2007; 23: 383–400.

The ways of predicting fluid status PCWP

- The vast majority of studies have demonstrated a poor correlation between PCWP, volume status, and responsiveness to fluid resuscitation.
- Even combining CVP with PCWP does not change the result

Michard F, Teboul JL. Predicting fluid responsiveness in ICU patients: a critical analysis of the evidence. Chest 2002; 121: 2000–2008.

Diebel LN, Wilson RF, Tagett MG et al. End-diastolic volume: a better indicator of pre-load in the critically ill. Arch Surg 1992; 127: 817–822

Wagner JG, Leatherman JW. Right ventricular end-diastolic volume as a predictor of the hemodynamic response to a fluid challenge. Chest 1998; 113: 1048–1054

Osman D, Ridel C, Ray P et al. Cardiac Filling Pressures are not appropriate to predict hemodynamic response to volume challenges. Crit Care Med 2007; 35: 64–68

Sonographic methods to estimate the patient’s volume status

- Point-of-care ultrasound has been proven to improve patient outcomes and experiences. PoCUS allows:
- Providing faster diagnosis of time-sensitive critical conditions
- Minimizing delays in care
- Diminishing procedural complications
- Guiding to make better treatment plans

IVC measurements

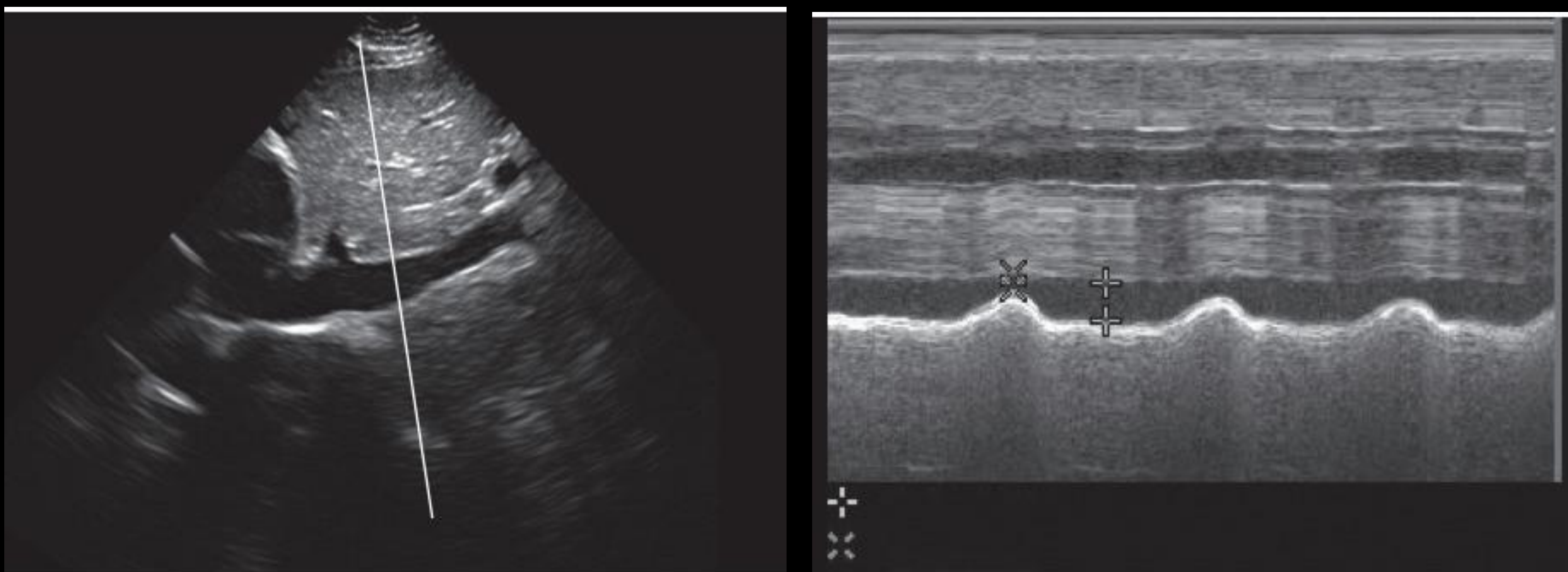
- Ultrasound measurements of the inferior vena cava (IVC) have been proposed as a tool to help guide fluid management.
- Well-established correlations exist between respiratory cycle-induced changes in IVC diameter and CVP.
- IVC ultrasound is non-invasive and relatively easy to perform, and has been used extensively in the ED.

Prekker ME, Scott NL, Hart D, Sprenkle MD, Leatherman JW. Point-of-care ultrasound to estimate central venous pressure: a comparison of three techniques. Crit Care Med 2013;41:833-41.

Nagdev AD, Merchant RC, Tirado-Gonzalez A, Sisson CA, Murphy MC. Emergency department bedside ultrasonographic measurement of the caval index for noninvasive determination of low central venous pressure. Ann Emerg Med 2010; 55:290-5.

Caval Index

- Caval index, or percentage collapsibility of the IVC (cIVC), is used as a predictor of preload reserve.
- The cIVC is measured from the long axis view of the IVC, distal to the entry of the hepatic veins.
- For mechanically ventilated patients, a distensibility index (dIVC) is measured.
- Changes in size over the respiratory cycle are identified with the machine in M-mode.
- The cut-off values for Caval index and distensibility index are 50% and 12%, respectively.



Inferior vena cava size (cm)	Percent of collapsibility (%)	mm of Hg CVP
<1.5	>50	0–5
1.5–2.5	>50	6–10
1.5–2.5	<50	11–15
>2.5	<50	16–20

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Flow time

- Flow time is the time required for systole in the cardiac cycle.
- The time is corrected for heart rate (FTc) and is calculated as FTc=systole time/the square root of cardiac cycle time.
- Singer et al. developed the concept of measuring aortic flow time with an esophageal Doppler monitor.

Singer M, Clarke J, Bennett ED. Continuous hemodynamic monitoring by esophageal Doppler. Crit Care Med 1989;17:447-52.

- Initial results culminated in the publication of a trial demonstrating improved patient-oriented outcomes in patients undergoing hip surgery with intraoperative fluid management guided by FTc.
- Subsequent efforts to validate the use of FTc as a predictor of preload reserve have not been consistently successful.

Sinclair S, James S, Singer M. Intraoperative intravascular volume optimisation and length of hospital stay after repair of proximal femoral fracture: randomised controlled trial. BMJ 1997;315:909-12.

Monnet X, Rienzo M, Osman D, et al. Esophageal Doppler monitoring predicts fluid responsiveness in critically ill ventilated patients. Intensive Care Med 2005;31:1195-201.

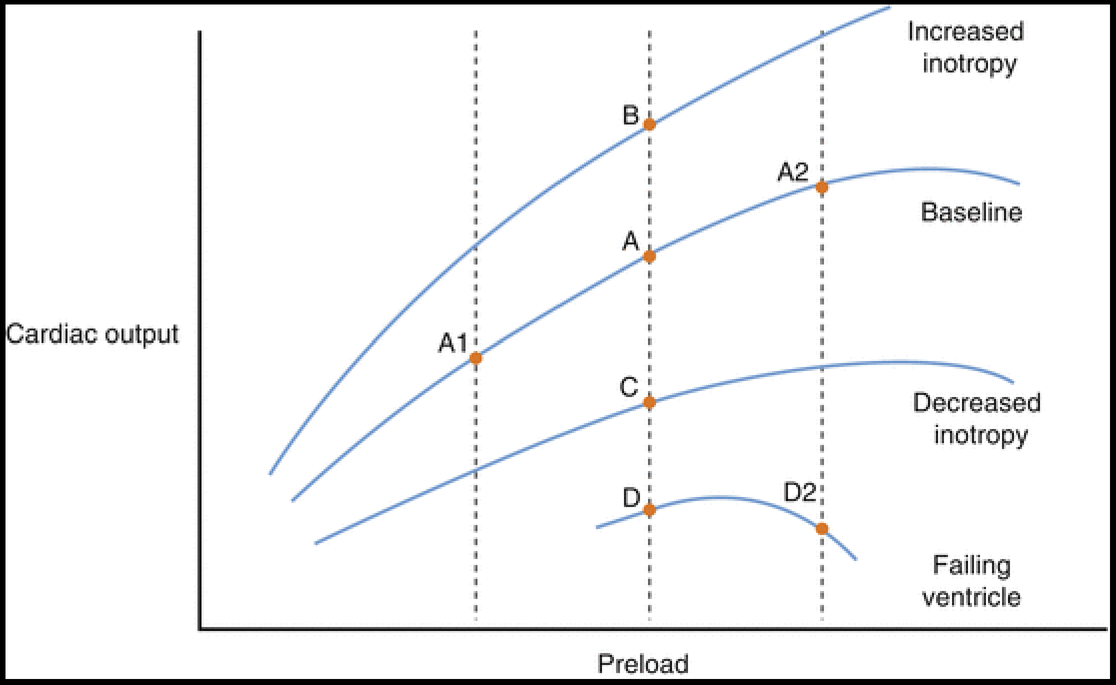
Guinot PG, de Broca B, Abou Arab O, et al. Ability of stroke volume variation measured by oesophageal Doppler monitoring to predict fluid responsiveness during surgery. Br J Anaesth 2013;110:28-33.

Lee JH, Kim JT, Yoon SZ, et al. Evaluation of corrected flow time in oesophageal Doppler as a predictor of fluid responsiveness. Br J Anaesth 2007;99:343-8.

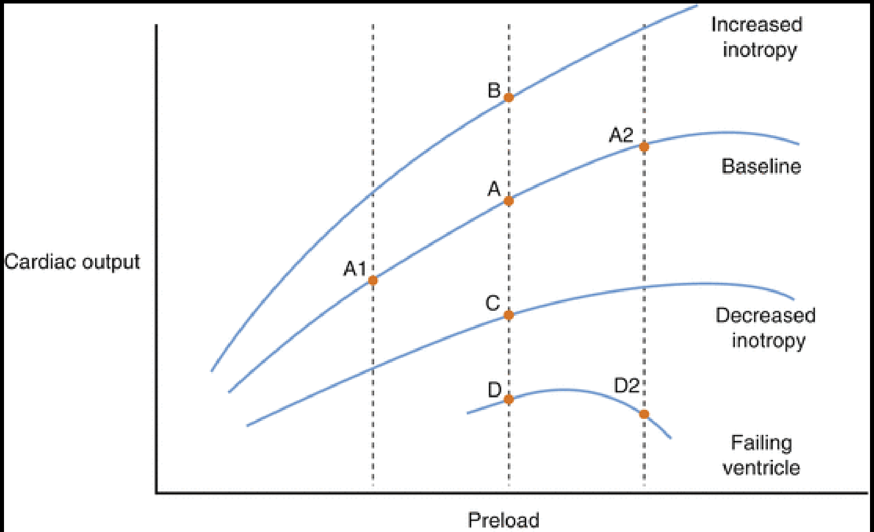
- Aortic flow time measurement requires an invasive oesophageal ultrasound imaging.
- A novel non-invasive method is applying the same approach to carotid artery (Carotid flow time).
- There is limited data about Carotid flow time to estimate patient’s volume status.

We have estimated the volume status, is the game over?

- If a patient is not overhydrated does not mean he/she will respond to fluid therapy.
- Volume expansion does not always increase cardiac output as one expects.


Increased
inotropy
B
A2
Baseline
A
Cardiac output
A1
C
Decreased
inotropy
D
D2
Failing
ventricle
Preload

- The current topic is not ‘fluid satus’, but a step further, ‘fluid responsiveness’ about fluid therapy for critically ill patients…
- Only 50% of the hypotensive patients are fluid responsive!

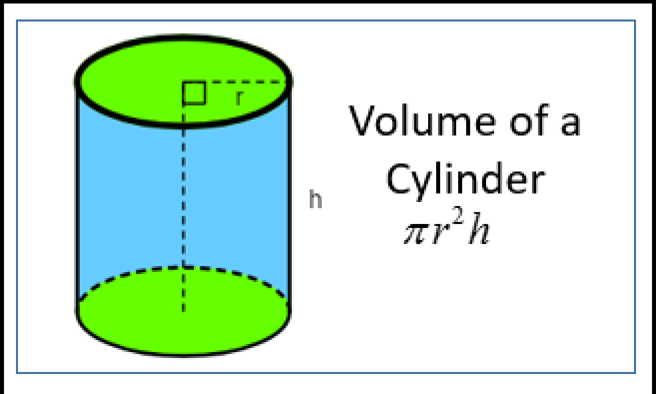


- Traditional methods just like vital signs, CVP or Caval index fail to predict fluid responsiveness…
- So, we need more sophisticated methods.

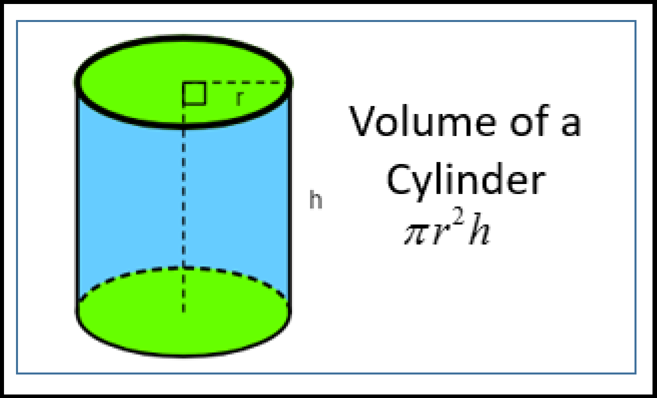
- If we can achieve an increase in ‘cardiac output’ with fluid therapy, our patient is ‘fluid responsive’…
- CO= Stroke volume (SV) x Heart rate
- So, if we measure SV using usg, we can estimate CO.
- Increase in CO ≈ increase in SV

- Volume of a cylinder is;

  area of the base X height

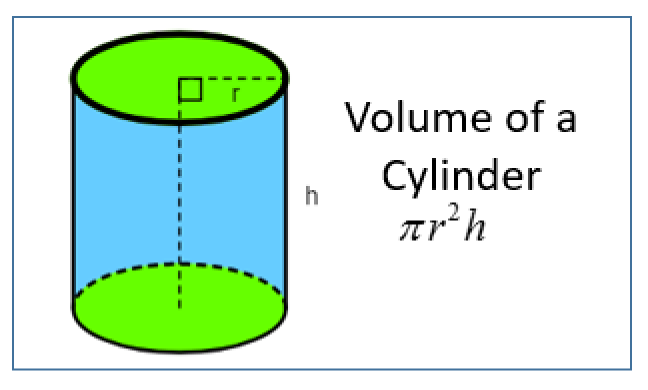


- If we think aorta as a base for a cylinder
- The distance of travel of the erytrocyt at the aortic root during cystole is 'height'



- Distance = Velocity X Time
- We take integral, because the blood flow can differ at the areas of aortic root

(center ≠ periphere)



- So;
- SV = Aortic root area X Distance

SV = Aortic root area X Aortic VTI

CO = SV x Heart rate

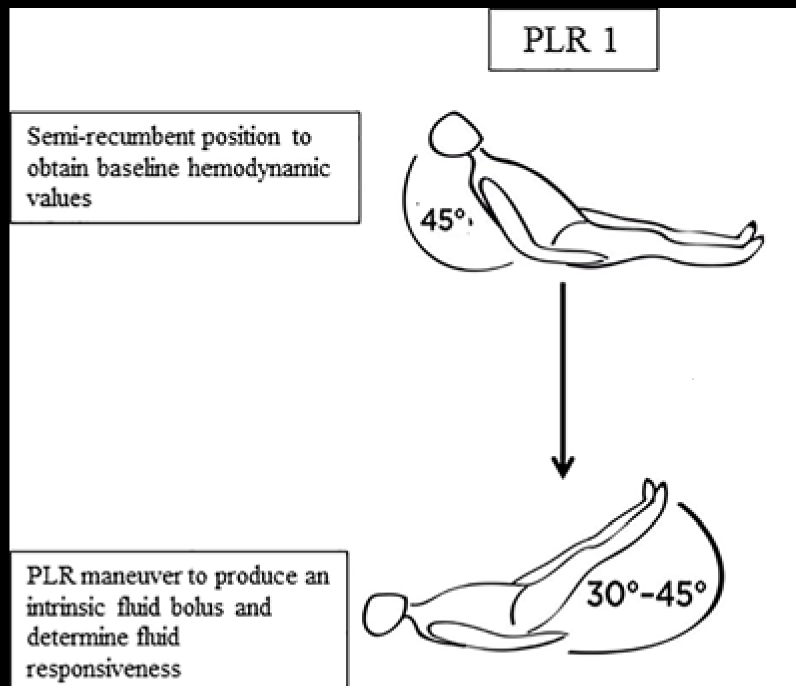
- If we measure CO before and after a fluid bolus and show a significant increase in CO;
- That means our patient is <u>fluid responsive</u>!
- As the base of the Aorta is constant in the same patient;
- <u>Increase in CO ≈ Increase in SV ≈ Increase in Aortic VTI</u>

- It is shown that, 15% increase in SV with 500 ml IV fluid given in 10 minutes means that our patient is fluid responsive.

Roger C, Zieleskiewicz L, Demattei C, et al. Time course of fluid responsiveness in sepsis: the fluid challenge revisiting (FCREV) study. Crit Care. 2019 May 16;23(1):179. doi: 10.1186/s13054-019-2448-z. PMID: 31097012; PMCID: PMC6524325.

- But, what if your patient is not fluid responsive?
- How will you take back the fluid that you have given?

- As we all know, leg veins consist about 500 ml. of blood
- So, if we riase the legs, this blood will pass trough the heart... We can turn the situation back easily.


PLR 1
Semi-recumbent position to obtain baseline hemodynamic values
45°
PLR maneuver to produce an intrinsic fluid bolus and determine fluid responsiveness
30°-45°

- If we measure SV or CO before and after leg raising and achieve a meaningful increase,
- This means our patient is fluid responsive…
- This technique is named as Passive Leg Raising (PLR)
- An achievement of 12% increase in SV is meaningful.

Monnet X, Rienzo M, Osman D, Anguel N, Richard C, Pinsky MR, Teboul JL. Passive leg raising predicts fluid responsiveness in the critically ill. Crit Care Med. 2006 May;34(5):1402-7.

- As we remember from Caval index; intrathoracic pressure gets lower with every inspirium and higher with every expirium
- This means that, blood turning to RV from the venous system is more in inspiratory phase of respiration than the expiratory phase..
- = Preload is more in inspirium than expirium

- If we measure SV in inspirium and expirium, and if;
- There is no change in SV between inspirium and expirium => the heart is at the limit. We can not increase the SV by giving fluid.
- There is a meaningful difference in SV between inspirium and expirium => Our patient is fluid responsive!

- CO ≈ SV ≈ Aortic VTI
- So, >10% difference in Aortic VTI between inspirium and expirium means that our patient is fluid responsive!

- Circulatory system is nearly a closed loop,
- Output of the LV (CO) is equal to the output of RV, and,
- Tricuspid annulus systolic velocities derived from Doppler tissue imaging (DTI) with TAPSE is an accurate way of estimating RV function.

Saxena N, Rajagopalan N, Edelman K, López-Candales A. Tricuspid annular systolic velocity: a useful measurement in determining right ventricular systolic function regardless of pulmonary artery pressures. Echocardiography. 2006 Oct;23(9):750-5.

- So, we can use the variation of Tricuspid annulus systolic velocities with PLR derived from DTI to estimate fluid responsiveness, also.

Ünlüer EE, Karagöz A, Bayata S, Çatalkaya S, Bozdemir H. A novel prediction of simulated fluid responsiveness by echocardiography assessment of tricuspid annulus tissue velocity with passive leg raising. Hong Kong Journal of Emergency Medicine. 2020;27(5):270-276.

- I am a novice sonographer and can not take sophisticated CO, VTI… measurements with ultrasound…
- What can I do???

- Why do we afraid to give excess fluid to patient??
- What happens if we give inappropiate fluid to patient with his/her status?
- Why the mortality increases with inappropiate fluid boluses???

=> PULMONARY EDEMA!

- We can easily diagnose pulmonary edema with PoCUS!
- If we combine this information with our other basic ultrasound knowledge…

- Fluid administration limited by lung sonography: the place of lung ultrasound in assessment of acute circulatory failure (the FALLS-protocol) by Lichtenstein.

The FALLS-protocol

1) Ruling out obstructive shock

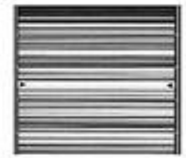
Simple emergency cardiac sonography:

Pericardial tamponade

Right ventricle dilatation [1]

BLUE-protocol: Pneumothorax

(A'-profile)



2) Ruling out (left) cardiogenic shock [2]

BLUE-protocol: Pulmonary edema

(B-profile)

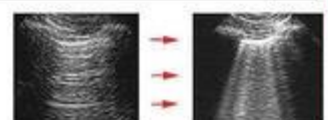
3) Ruling out hypovolemic shock

(A-profile)

Correction of clinical signs of shock under fluid administration

4) Detecting distributive shock (septic shock usually)

Fluid therapy not able to improve circulation - eventually generating a B-profile



THANKS…