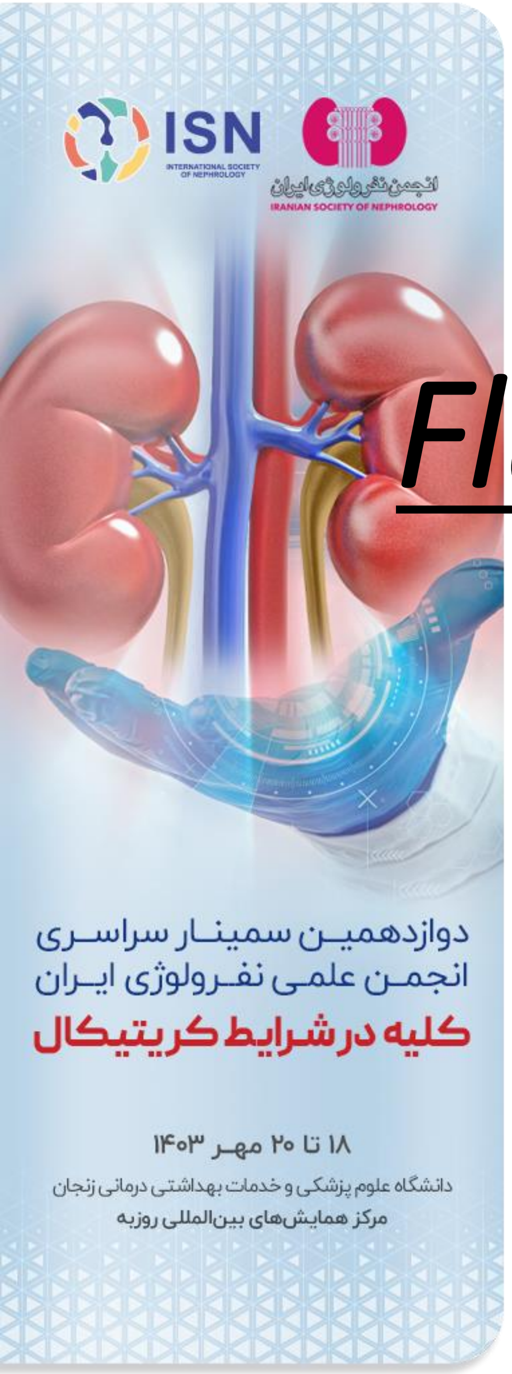

Fluid assessment in critically ill patients

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Introduction

- Volume status assessment is a critical but challenging clinical skill and is especially important for the management of patients in the emergency department, intensive care unit, and dialysis unit where accurate intravascular assessment is necessary to guide appropriate fluid management.

- Assessment of volume status is subjective and can vary from provider to provider, posing clinical dilemmas.
- Decisions on the administration of diuretics, initiation of renal replacement therapy, and ultrafiltration goals rely on proper intravascular assessment.

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Amount of fluid

- The amount of fluid required by any one patient depends on several factors, including the patient’s diagnosis and severity of disease.
- We need to find the ideal balance between too little and too much fluid in all patients, because both these conditions are associated with worse outcomes.

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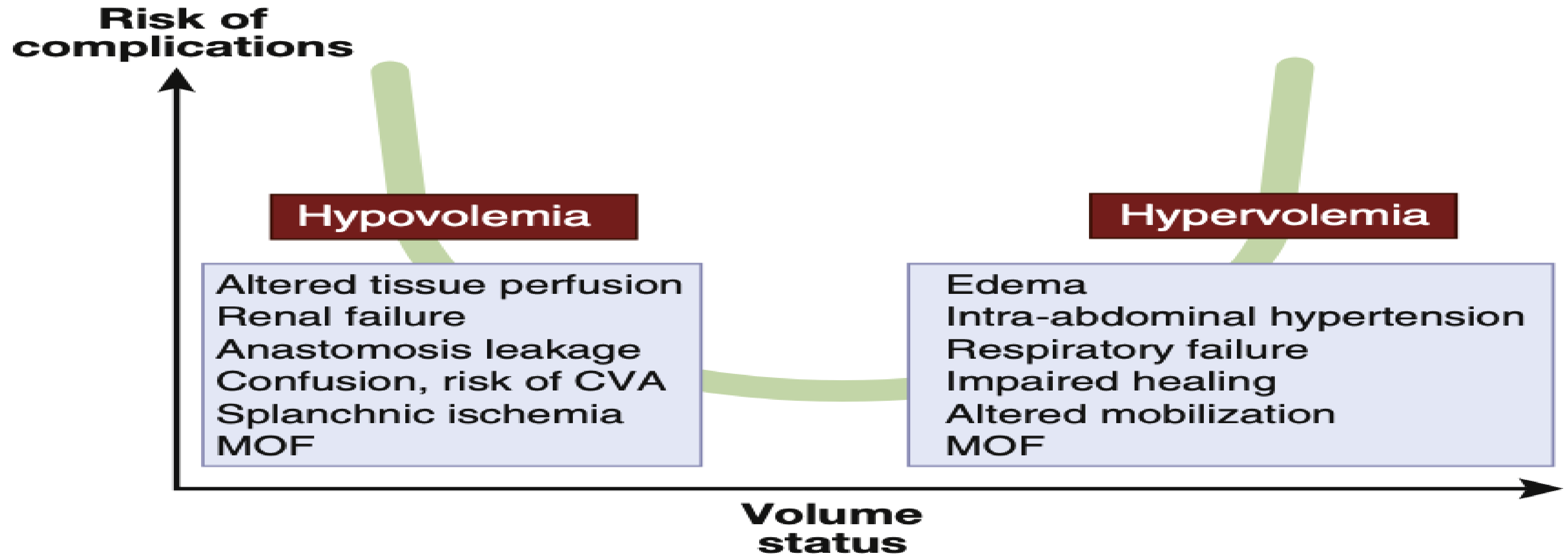

Figure 1 | The relationship between blood volume and the risk of complications. Both hypo- and hypervolemia should be avoided because these 2 extremes are associated with a greater risk of complications. CVA, cerebrovascular accident; MOF, multiple organ failure. Modified from Vincent JL, Pelosi P, Pearse R, et al. Perioperative cardiovascular monitoring of high-risk patients: a consensus of 12. *Crit Care*. 2015;19:224.[4] Copyright © 2015 Vincent *et al.*; licensee BioMed Central. 2015. This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly credited.

How much fluid a patient requires

- Unfortunately one cannot use global formulas to decide how much fluid a patient requires; this process requires individualization guided by hemodynamic monitoring.
- Moreover, the time factor is of great importance and varies according to the phase of resuscitation.

- Four phases can be recognized:

-salvage,

-optimization,

-stabilization, and

-deescalation.

Kidney International (2019) 96, 52–57 / Fluid management in the critically ill

Salvage

- Salvage is the initial phase during which a **patient needs rapid resuscitation** for profound alterations in tissue perfusion as a result of multiple conditions, including sepsis, hemorrhage, and profound dehydration.
- During this very early phase, a plentiful amount of fluids must be administered rapidly to facilitate effective resuscitation.
- Often the need to **act quickly** means there is no time to position complex monitoring systems to guide fluid administration.

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Salvage

- **Vasopressin** (and vasopressin derivatives), **interferon-b**, and **thrombomodulin** are potential candidates for endothelial cell protection.
- When vasopressors are used, **norepinephrine** is the vasopressor of choice in critically ill patients.
- Kidney International (2019) 96, 52–57 / Fluid management in the critically ill

Optimization.

- As soon as is possible, in addition to performing a reliable assessment of heart rate and arterial pressure, an **echocardiogram** should be obtained to assess the degree of filling and function of the cardiac chambers.
- **Echography should be repeated periodically to monitor the response to treatment.**
- **Every physician involved** in the management of acutely ill patients should be able to perform an echocardiogram.
- **Blood lactate levels**, which are increased in patients with shock and reflect tissue oxygenation, should be measured serially (at least every hour) as an indicator of the effectiveness of therapy and resolution of shock.

- Kidney International (2019) 96, 52–57 / Fluid management in the critically ill

Stabilization.

- Once the patient is stable, or when the patient no longer responds to fluid, aggressive fluid administration must be stopped, and only minimal, if any, maintenance fluid is required.
- **Persisting positive fluid balance** is associated with worse outcomes, more so than a positive fluid balance early during resuscitation.

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De-escalation.

- When the patient is well stabilized, he or she enters the de-escalation phase and should not receive much fluid; rather, excess fluids should be eliminated to remove any edema that has formed.
- During this phase, **diuretics** can be administered if a negative fluid balance is not achieved spontaneously.
- **Loop diuretics**, such as furosemide, are most widely used but can lead to hypernatremia if sodium excretion is not adequate.
- In patients with renal dysfunction, diuretics are less effective and renal replacement therapy (RRT) will likely be necessary.
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Fluid assessment in critically ill patients

- **history and physical examination are the clinicians' first steps in assessing volume status:**
- **Dynamic tests to assess the response to fluids**
- **Biomarkers**
- **Invasive Methods**

Conventional Methods of Volume Assessment and Pitfalls

- **history and physical examination are the clinicians' first steps in assessing volume status:**

- Mucus Membrane Examination

-Capillary Refill Time

-Skin Turgor and Axillary Sweat Examination

-Orthostatic Vital Signs

-Jugular Venous Pressure Measurements

-Edema

-Lung Examination and Chest Radiograph

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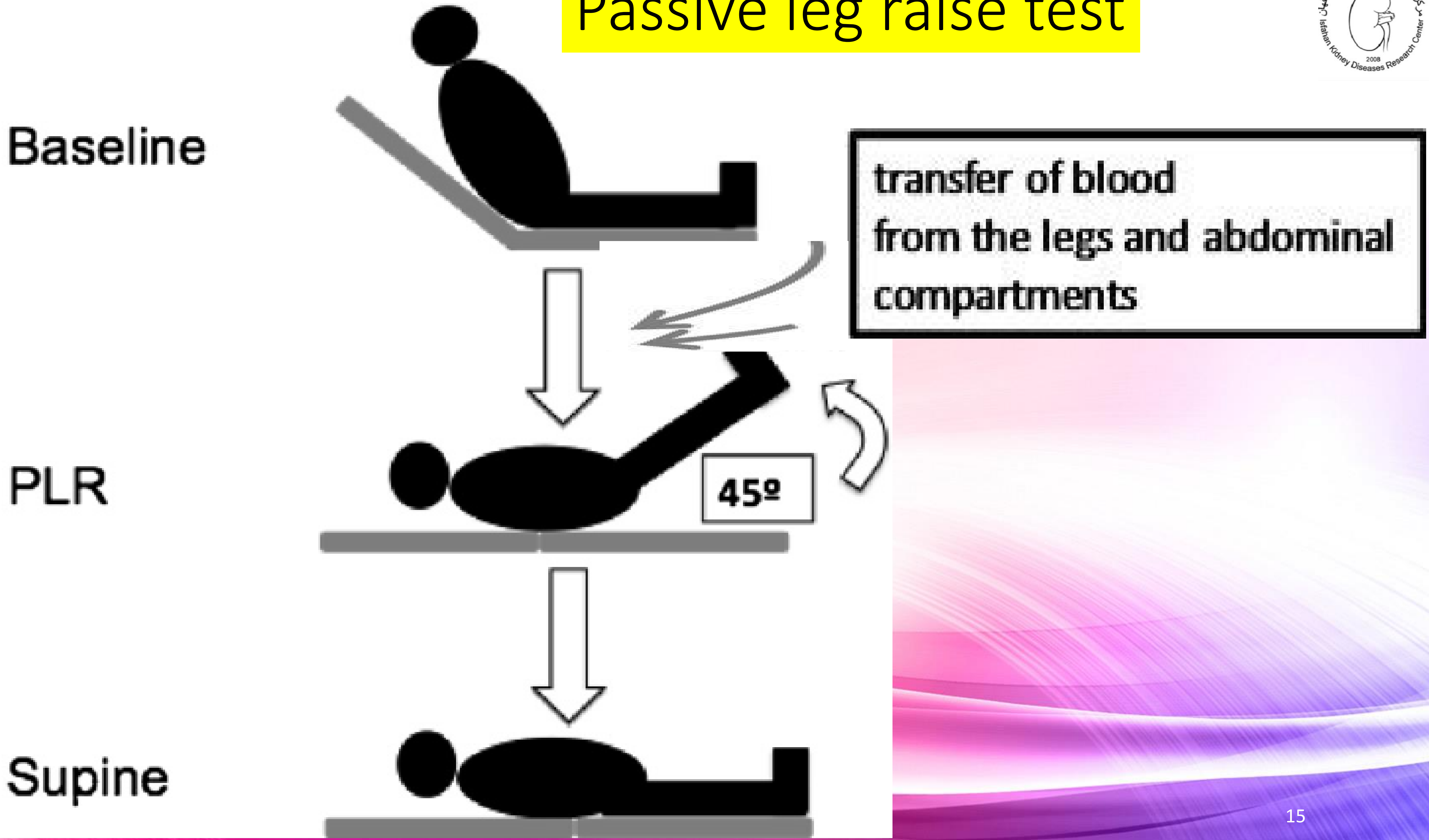
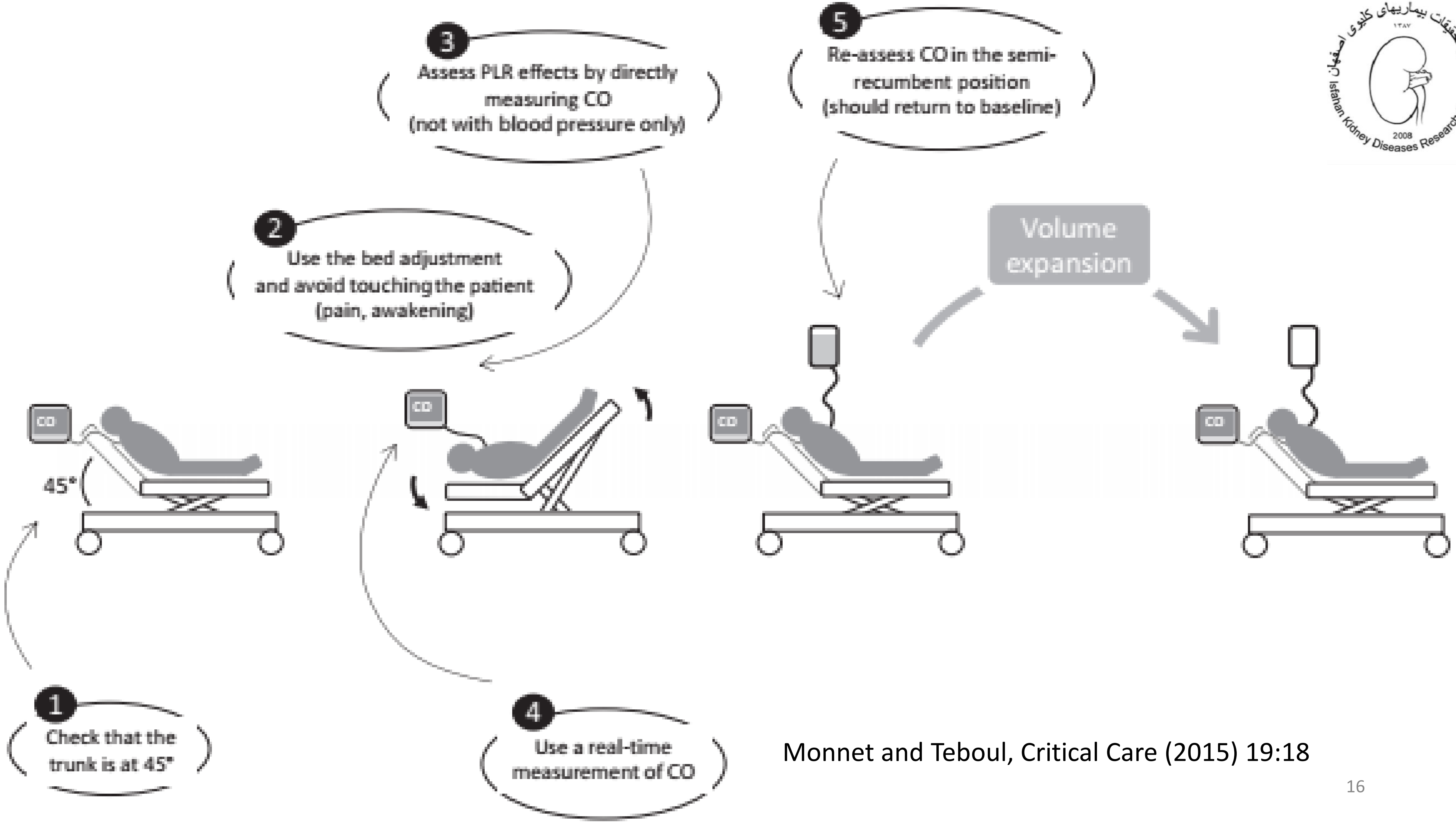
Dynamic tests to assess the response to fluids

Passive leg raising (PLR)

- PLR is a bedside maneuver that involves elevating the patient❼s legs to 30ଓ45◦ while supine, which results in the transfer of roughly 300 mL of venous blood from the lower extremities to the central circulation.
- In this way, PLR increases cardiac preload, consequently inducing a significant rise of the mean systemic pressure .
- **In fluid responders**, **this rise is accompanied by an increase in venous return and thus in cardiac output.**
- On the contrary, in fluid non-responders, the increase in the right atrial pressure balances the increase in mean systemic pressure, such that the pressure gradient of venous return (and cardiac output) does not change .
- This maneuver has the advantage of being **reversible** ,and it can be **repeated** as frequently as required without infusing a drop of fluid.
- Also, PLR has been proven to be accurate in spontaneously breathing patients and with cardiac arrhythmias, low tidal volume ventilation and low lung compliance .
- **A PLR-induced increase in cardiac output greater than 10% is generally considered to predict fluid responsiveness with high sensitivity and specificity (85 and 91%, respectively) .**
- In fact, PLR is recommended by the Surviving Sepsis Campaign for the hemodynamic management of septic shock patients .
- https://doi.org/10.1016/j.tacc.2023.101316 /Prediction of fluid responsiveness in critical care: Current evidence and future perspective

Passive leg raise test





Monnet and Teboul, Critical Care (2015) 19:18

Mini-fluid challenge

- Administering a fluid challenge, with the infusion of **250–500 mL of fluids**, and measure its effect on cardiac output, has long been used as a method to assess fluid responsiveness.
- However, this test cannot be considered as a ❽challenge❾, but as the treatment itself.
- Moreover, this test **is not reversible**.
- In fact, in case of no preload responsiveness, which occurs in half of the cases, it is not possible to withdraw the fluid administered in excess, leading to fluid overload.
- For this reason, some authors have suggested the idea of administering only a ❽mini-fluid challenge❾, consisting in infusing **100–150 mL of fluids** over one or **2 min** and measuring the response of cardiac output or one of its surrogates .

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Serum lactate

- Serum lactate is a more objective metabolic surrogate to guide fluid resuscitation.
- Irrespectively of the source, **increased lactate levels are associated with worse outcomes** ,and lactate-guided resuscitation significantly reduced mortality as compared to resuscitation without lactate monitoring .
- Recent published data showed **that lactate levels > 4 mmol/l combined with hypotension** are associated with a mortality rate of 44.5% in ICU patients with severe sepsis or septic shock .

- https://doi.org/10.1016/j.tacc.2023.101316 /Prediction of fluid responsiveness in critical care: Current evidence and future perspective

Biomarkers

Biomarkers

- B-type natriuretic peptide **(BNP)** and N-terminal prohormone of BNP (**NT-proBNP) h**as been traditionally used as biomarkers for volume overload or heart failure.
- Elevated BNP does not always indicate volume overload.
- Heart failure patients with renal impairment and patients on dialysis have higher concentrations of BNP and NT-proBNP .
- Recent studies have shown serum **carbohydrate antigen 125 (CA-125) levels** have been associated with state of volume overload and heart failure independently and in combination with NT-proBNP .
- https://doi.org/10.1016/j.tacc.2023.101316 /Prediction of fluid responsiveness in critical care: Current evidence and future perspective

Invasive Methods

Central Venous Pressure (CVP) Measurement

- Assessment of CVP is widely available in the intensive care units and is feasible.
- However, the CVP alone has poor predictive value for fluid responsiveness.
- A systematic review demonstrated a poor relationship between CVP and blood volume (pooled correlation coefficient 0.16, 95% CI 0.03 - 0.28) and was unable to predict the hemodynamic response to a fluid challenge .

- https://doi.org/10.1016/j.tacc.2023.101316 /Prediction of fluid responsiveness in critical care: Current evidence and future perspective

Pulmonary Artery Catheter Pressures (PAC)

- While routine use of pulmonary artery catheter (PAC) has fallen out of favor in the intensive care units (ICU), it is still useful in understanding a patient's hemodynamics.

- Based on the ESCAPE trial, PACs are **not routinely indicated** to adjust therapy during hospitalization for decompensation of chronic heart failure .

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Transpulmonary Thermodilution and Pulse Contour Analysis (TPTD)

- Transpulmonary thermodilution (TPTD) and pulse contour analysis are invasive and advanced hemodynamic monitoring techniques used for measurement of cardiac index (CI) and the assessment of cardiac preload by measuring dynamic cardiac preload variable volume variation (SVV) which helps in assessing responsiveness to fluid and pulmonary vascular status.
- These can be measured accurately only in sinus rhythm and controlled ventilation .
- The TPTD technique provides the variable extravascular lung water index (EVLWI) for the assessment of **pulmonary hydration .**
- These methods are invasive, expensive, and not widely available.

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point of care ultrasound (POCUS)

- More recently, point of care ultrasound (POCUS) examination at bedside has come into widespread practice and has become a fifth pillar of clinical medicine

POCUS

- 1. Internal Jugular Vein Assessment
- 2. Inferior Vena Cava Assessment
- 3. Lung Ultrasound
- 4. Focused Cardiac Ultrasound
- 5. Doppler Ultrasonography

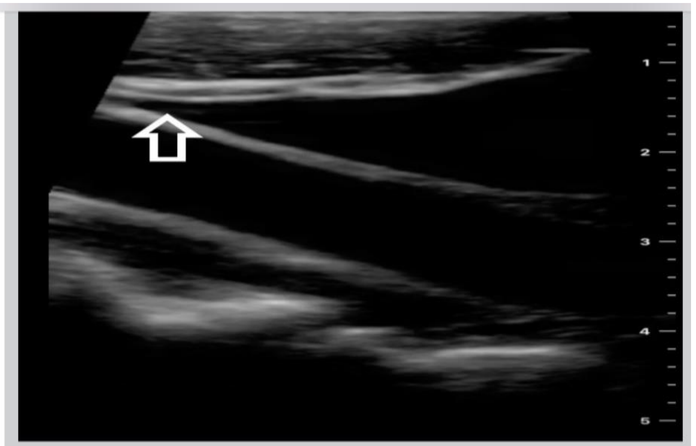

Figure 1. Internal jugular vein showing paint brush sign (arrow).

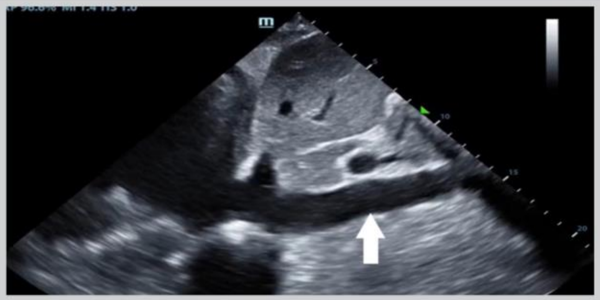

Figure 2. Inferior vena cava. This is subxiphoid view obtained with a linear probe placed below the xiphoid process (white arrow indicating dilated IVC).

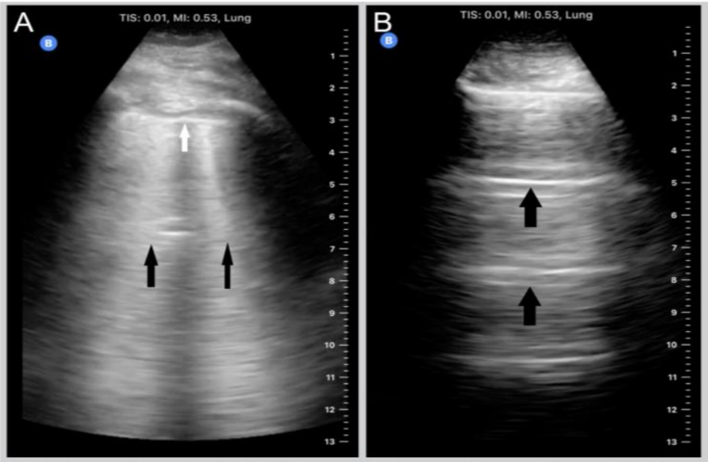

Figure 3. Lung US. A) demonstrating B lines (black arrows) and pleural line (white arrow). B) demonstrating A lines (black arrows)

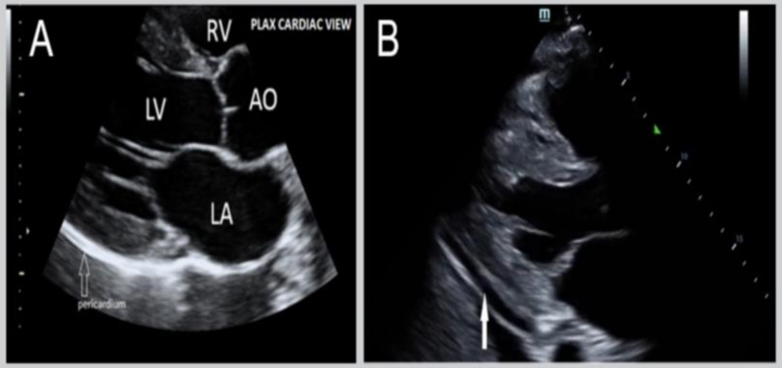

Figure 4. A) Focused cardiac ultrasound (FoCUS). Parasternal long axis view (PLAX) showing different chambers and aorta. B) Focused Cardiac Ultrasound. PLAX view showing pericardial effusion (white arrow).


CONCLUSION

Table 1. Sensitivity/specificity in assessment of intravascular volume (volume overload)

Method of volume assessment	Sensitivity	Specificity	Positive predictive value	Negative predictive value	Diagnostic accuracy
Tachycardia [4]	17%	94%			
Orthostatic hypotension [9]	29%	81%			
Dry oral mucosa [4]	49%	87.8%			
Jugular Venous Pressure >8 cm [12,13]	47-92%	93-96%			
Axillary sweat [4]	50%	82%		84%	
Abnormal skin turgor (sub clavicular) [4]	73.3%	79%			
Abnormal skin turgor (forearm) [4]	68.3%	67.8%			
Auscultation for crackles [22]	51% (43-60%)	79 % (73–84%)			
Crackles for severe congestion [55]	9%	98%	100%	78%	
Crackles and edema for severe congestion [55]	13%	97%	90%	33%	
Chest X-ray [91]	46%	80%	Not available	Not available	58%
CVP [32]	76%	62%			
IVC assessment (Respiratory variation) [48]	63%	73%	Not available	Not available	
Lung US [52]	88%	90%	Not available	Not available	
Carotid blood flow with Passive leg raise [39,84]	94%	86%			

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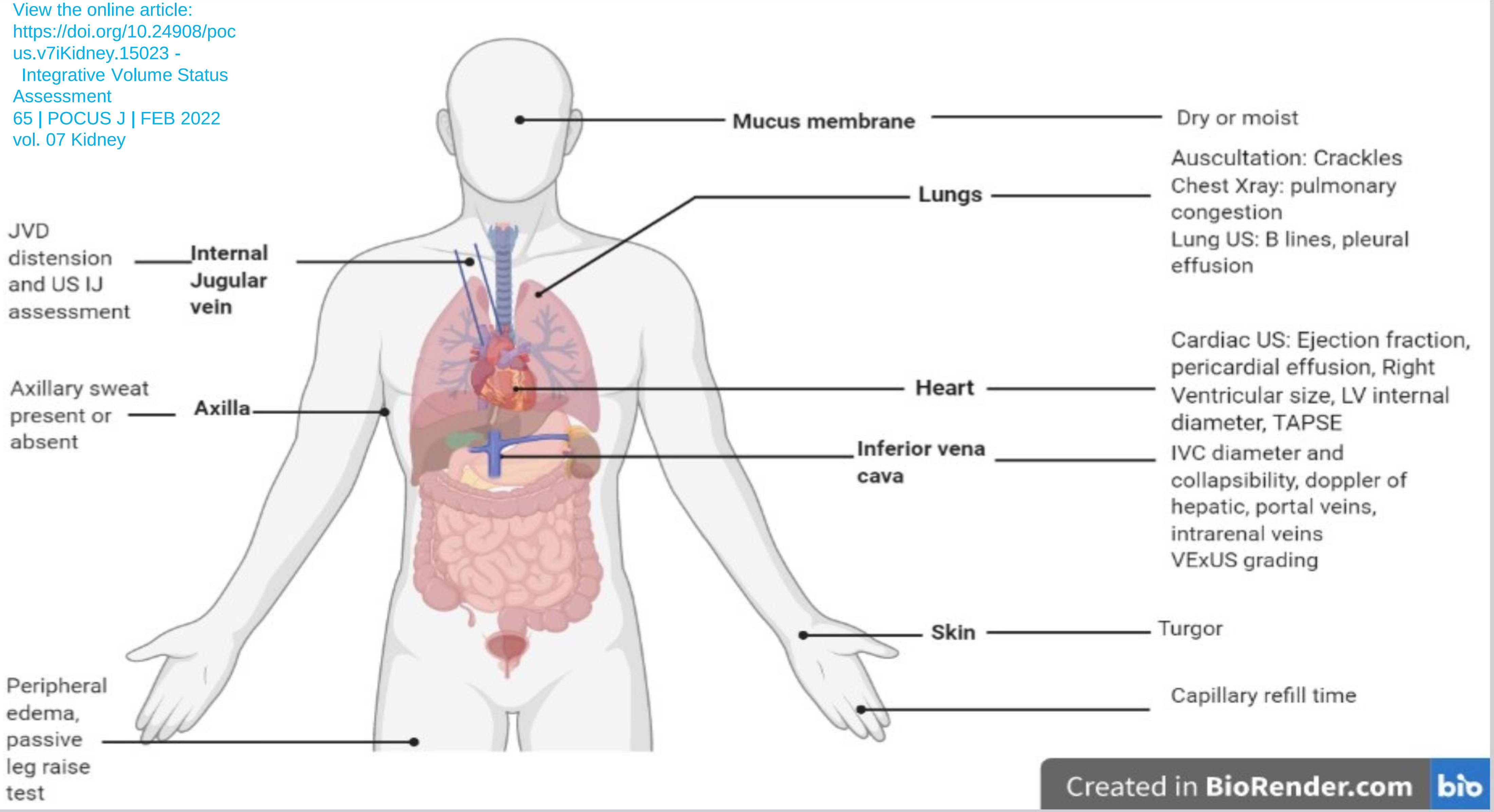

Figure 5. Schematic of Integrated Volume Assessment (Created with BioRender.com).

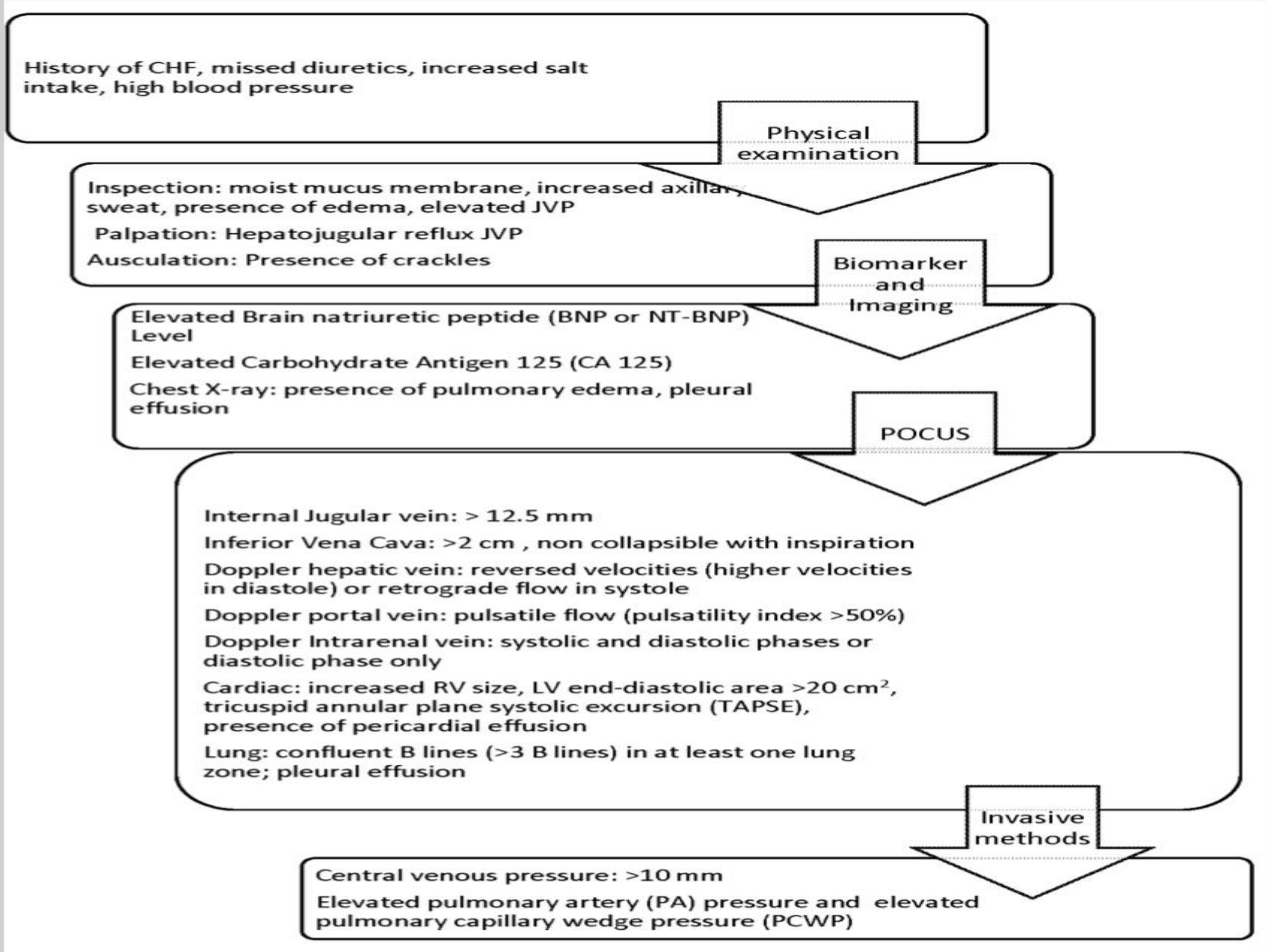

Figure 6. Algorithm for Systemic Approach to Volume Assessment: This is an algorithm that we propose will help with systematic approach to integrative volume assessment for diagnosing hypervolemia. Assigning a score system to each of the findings with higher scores to cardiac, lung and vascular ultrasound for volume assessment would be very useful tool to precisely diagnose volume status. Such tool needs to be studied and validated before widespread use. This approach will integrate POCUS to conventional methods and eliminate the shortcomings of individual methods.

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Future perspective in predicting fluid responsiveness

- Several other methods to predict fluid responsiveness have been proposed, including **end-expiratory occlusion test (EEOT)**, **carotid flow time (CFT)**, bioreactance-based **non-invasive cardiac output monitoring (NICOM)** and **machine learning approaches** applied to transthoracic echocardiography.
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Review

Integrative Volume Status Assessment

David Kearney, MD; Nathaniel Reisinger, MD; Sadichhya Lohani, MBBS

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Abstract

Volume status assessment is a critical but challenging clinical skill and is especially important for the management of patients in the emergency department, intensive care unit, and dialysis unit where accurate intravascular assessment is necessary to guide appropriate fluid management. Assessment of volume status is subjective and can vary from provider to provider, posing clinical dilemmas. Traditional non-invasive methods of volume assessment include assessment of skin turgor, axillary sweat, peripheral edema, pulmonary crackles, orthostatic vital signs, and jugular venous distension. Invasive assessments of volume status include direct measurement of central venous pressure and pulmonary artery pressures. Each of these has their own limitations, challenges, and pitfalls and were often validated based on small cohorts with questionable comparators. In the past 30 years, the increased availability, progressive miniaturization, and falling price of ultrasound devices has made point of care ultrasound (POCUS) widely available. Emerging evidence base and increased uptake across multiple subspecialities has facilitated the adoption of this technology. POCUS is now widely available, relatively inexpensive, free of ionizing radiation, and can help providers make medical decisions with more precision. POCUS is not intended to replace the physical exam, but rather to complement clinical assessment, guiding providers to give thorough and accurate clinical care to their patients. We should be mindful of the nascent literature supporting the use of POCUS and other limitations as uptake increases among providers and be wary not to use POCUS to substitute clinical judgement, but integrate ultrasonographic findings carefully with history and clinical examination.

Introduction

care ultrasound tools for accurate volume assessment

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Prediction of fluid responsiveness in critical care: Current evidence and future perspective

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A R T I C L E I N F O

Keywords:
Intensive care
Fluids
Echocardiograpy
Hemodynamic monitoring
Preload

A B S T R A C T

Background: Fluid responsiveness is a crucial concept in the management of critically ill patients, guiding fluid resuscitation to optimize hemodynamics while avoiding fluid overload. Various methods have been proposed to predict fluid responsiveness, but their applicability and accuracy vary.
Objectives: To provide a comprehensive review of the different methods used to assess fluid responsiveness in critically ill patients, including their principles, clinical applications, and limitations.

Messina *et al.*
Intensive Care Medicine Experimental (2022) 10:46
https://doi.org/10.1186/s40635-022-00473-4

Intensive Care Medicine
Experimental

REVIEWS **Open Access**

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Pathophysiology of fluid administration in critically ill patients

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Abstract

Fluid administration is a cornerstone of treatment of critically ill patients. The aim of this review is to reappraise the pathophysiology of fluid therapy, considering the mechanisms related to the interplay of flow and pressure variables, the systemic response to the shock syndrome, the effects of different types of fluids administered and the con-

Fluid management in the critically ill

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Fluid therapy, which is provided to restore and maintain tissue perfusion, is part of routine management for almost all critically ill patients. However, because either too much or too little fluid can have a negative impact on patient outcomes, fluid administration must be titrated carefully for each patient. The "salvage, optimization, stabilization, de-escalation" (SOSD) mnemonic should be used as a general guide to fluid resuscitation, and fluid administration should be adapted according to the course of the disease. In the initial salvage phase, lifesaving fluid should be administered generously. Once hemodynamic monitoring is available, fluid administration should be optimized by determining the patient's fluid status and the need for further fluid. This determination can be difficult, however; clinical indicators of hypovolemia, such as heart rate, blood pressure, and urine output, may not detect early hypovolemia, and edema is a late sign of fluid overload. Dynamic tests of fluid responsiveness such as pulse pressure or stroke volume variation can be used in

Fluid management in critically ill patients is both a simple and a complex process. It can be considered "simple" because inserting a catheter and allowing a solution to run into a vein is really not a very sophisticated procedure. Fluid administration represents one of the core interventions in the management of acutely ill patients, with about one third of patients in the intensive care unit (ICU) receiving resuscitation fluids on a specific day[1] and many more receiving maintenance fluids. However, although administering fluids in critically ill patients is a common intervention, it is far from simple if it is performed correctly. Determining the optimal type and amount of fluid for each patient at any specific moment in his or her ICU course is actually rather complex. Because colloid fluids can be administered in smaller amounts than can crystalloid fluids to produce the same effect, the amount and type of fluid are related. However, for the sake of simplicity we will consider these 2 aspects separately.[2]

Thanks for Attention