THE GLOBAL ULTRASOUND CHECK FOR THE CRITICALLY ILL (GUCCI)

Proposal of a new systematized protocols for the purpose of integrating Point-of-Care Ultrasonography (POCUS) in the ICU

Ultrasound in the ICU is useful not only for procedures but as a diagnostic tool (see attached SCCM guidelines I and II). This diagnostic proposal (GUCCI) is organized based on three syndromes (see attached original publication):

- Acute respiratory failure
- Shock
- Cardiac arrest

ACUTE RESPIRATORY FAILURE

GUCCI proposes a two-step approach to integrate lung ultrasound with complementary cardiac and vascular ultrasound in a stepwise approach to exclude the most severe diagnoses and those with possible immediate intervention **(Figures 1A and 1B).**

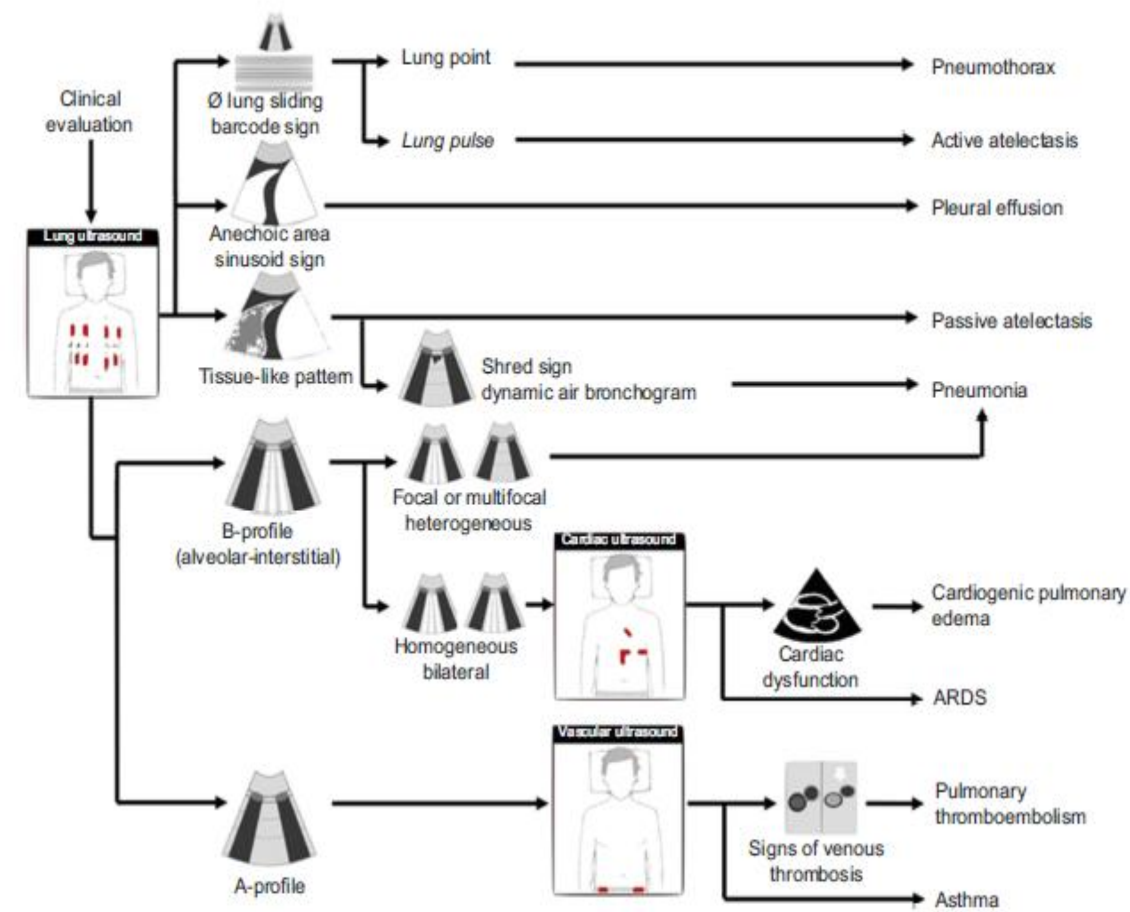

Figure 1A Acute respiratory failure – SOB algorithm

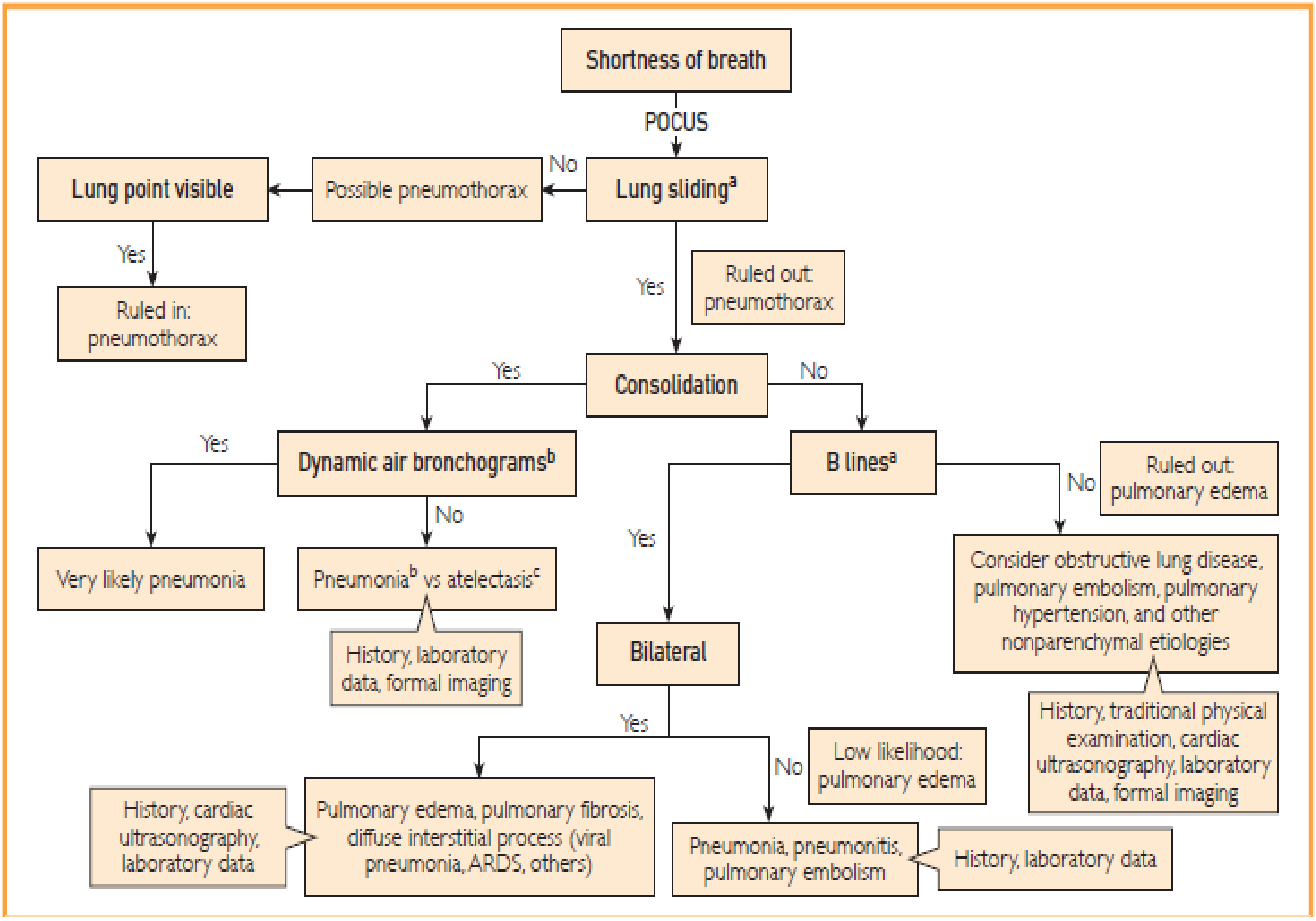

Figure 1B Acute respiratory failure – SOB algorithm

PROCEDURE

The ultrasound probe should be placed longitudinally and perpendicular to the ribs on the chest wall. A micro convex probe is preferred for lung assessment because it allows the probe to be positioned between the ribs to minimize shadows. However, other transducers such as linear (vascular), phased array (cardiac), convex (abdominal) probes may be used based on physician preferences and clinical settings. Low-frequency probes (3.5–5 MHz) to examine deeper structures (eg, heart, pleural effusion) and high-frequency probes (>5 MHz) to examine superficial structures (eg, pleural sliding) can be used.

Patients in the ICU are usually examined in a supine or semi recumbent position with arms abducted to facilitate examination of the lateral chest wall. The chest is scanned bilaterally in four different areas, which are defined by the anterior axillary line and fifth intercostal space line, AS, LS, AI, LI **(Figure 2).** The diaphragm should be carefully identified. In some cases, to allow better pleural effusion and consolidation pattern recognition, the patient is placed in the lateral decubitus position.

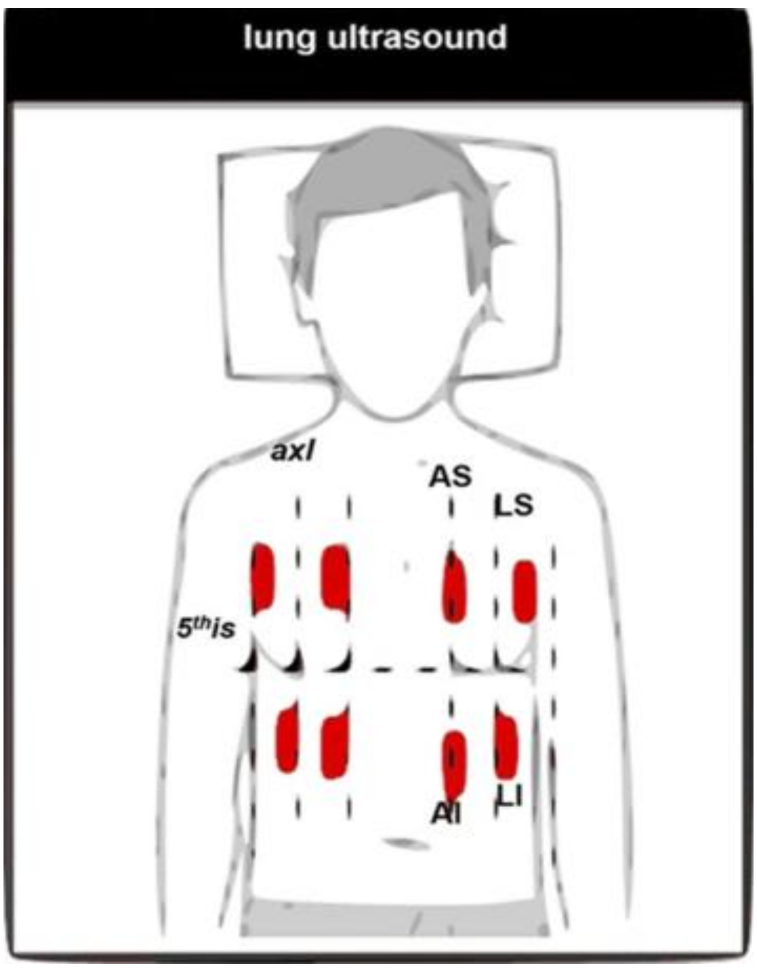

Figure 2 Areas to be scanned

NORMAL FINDIGS

Ribs and pleural line

With the probe placed between two rib spaces in the craniocaudal direction, the typical lung pattern **(Figure 3)** consists of two echogenic interfaces: the acoustic shadows (produced by the two adjacent ribs), and a hyperechoic horizontal line (produced by the visceral and parietal pleural surfaces) that represents the interface between the chest wall and aerated lung.

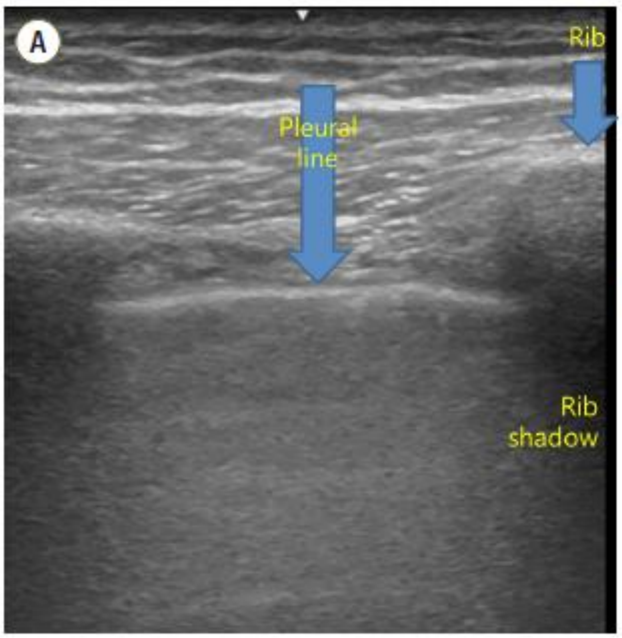

Figure 3 Normal findings of lung ultrasound. (A) Characteristic pleural-line and rib shadow that should be identified before starting the exam.

A-lines

The reverberation of ultrasound waves between the pleura and the probe produces horizontal artifact lines that are equidistant from each other; they are referred to as A-lines (Figure 4).

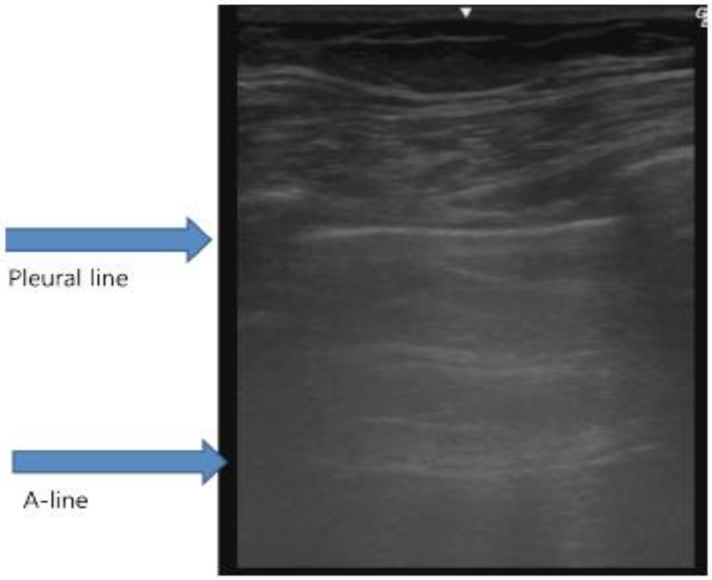

Figure 4 Normal findings of lung ultrasound: A-lines are horizontal hyperechoic lines parallel to the pleural line and are basic artifacts of a normally aerated lung.

B-lines

Hyperechoic lines perpendicular to the pleural lines extending to the bottom of the screen without fading and moving synchronously with lung sliding. One or two B-lines can be seen in normally aerated lungs, more than two are abnormal (Figure 5).

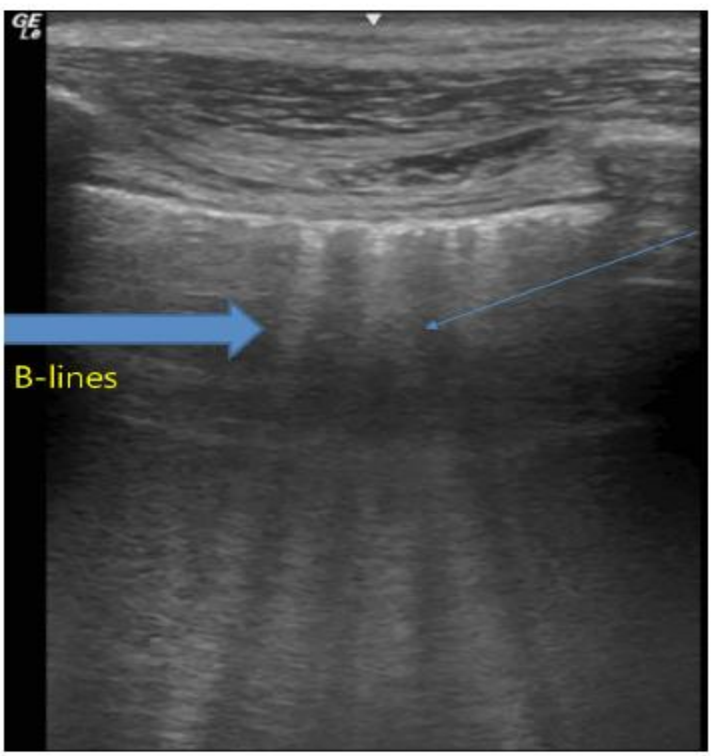

Figure 5 B-lines

Lung sliding sign
Respiratory movements generate the lung sliding sign that represents the sliding of the visceral pleura against the parietal pleura. Sonographically, lung sliding is seen as a hyperechoic line that moves with respiration. This is a dynamic sign observed on B-mode - real time **(To see video click here).**

Seashore Sign
The dynamic lung sliding sign can be recorded as a static sign on M-mode, generating the characteristic seashore sign with the static chest wall as waves and the normal lung parenchyma as a beach. The pleural surface is the boundary between the waves - chest wall and the beach - normal lung **(Figure 6).**

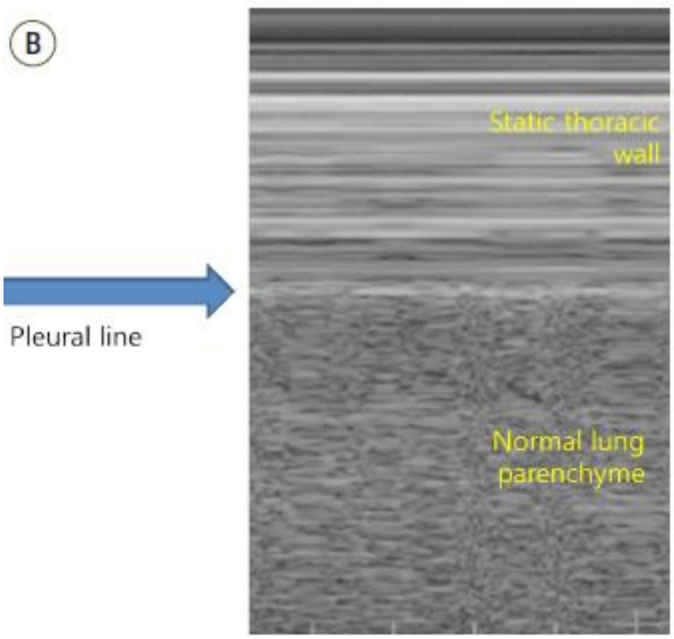

Figure 6 Normal findings of lung ultrasound (B). Normal lung pattern on M-mode: seashore sign. Motionless chest wall generates horizontal lines and lung sliding makes the sandy pattern.

Normal lung pattern - A profile

The pattern of the predominant A-lines along with lung sliding and seashore signs represents the normal lung pattern-A profile **(Figure 7).**

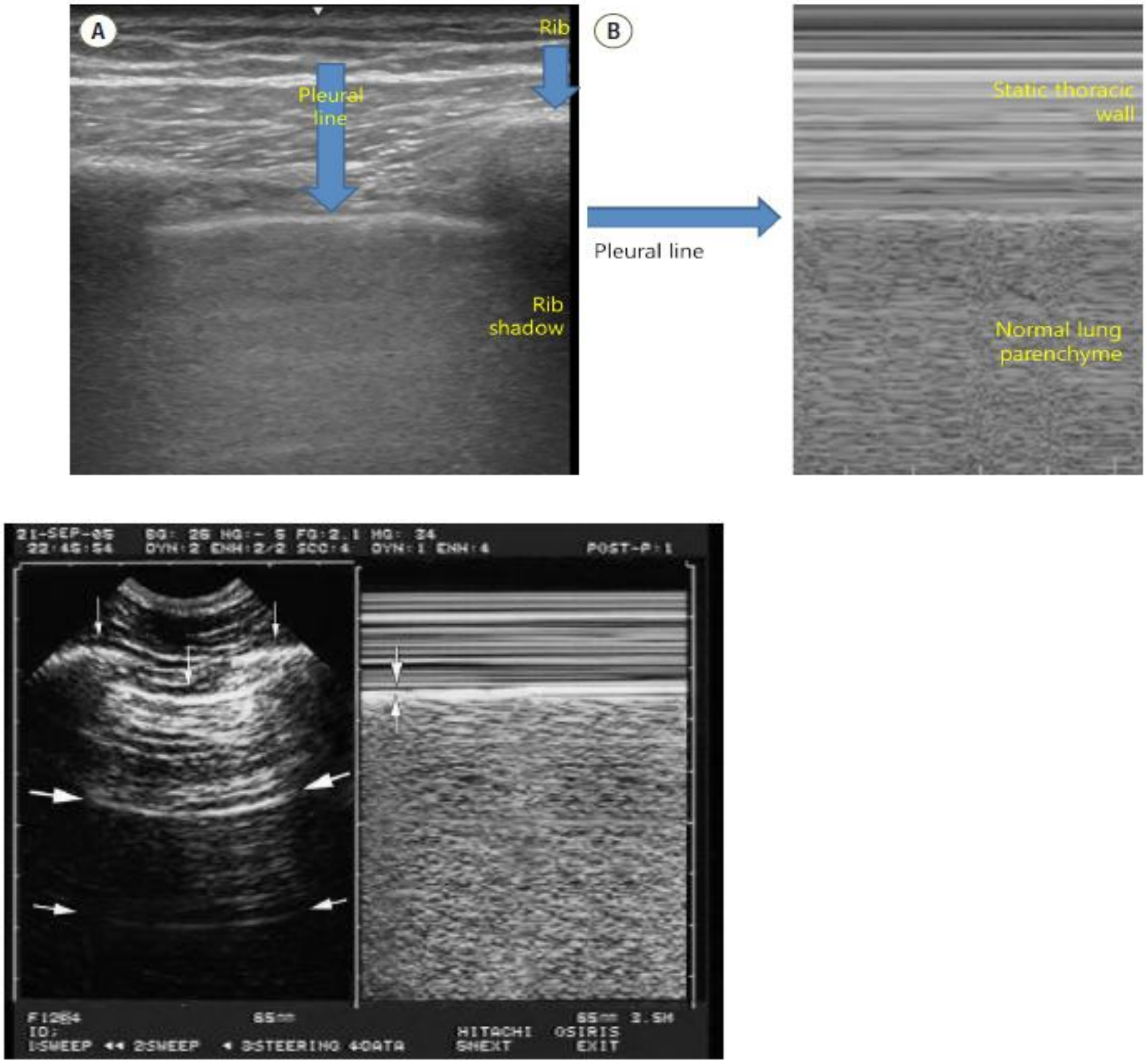

Figure 7 Normal findings of lung ultrasound. In the left bottom figure, the vertical arrows represent the pleural line and the horizontal arrows the A-lines. On the right of both upper and lower figures the seashore sign is noted on M mode.

PATHOLOGIC FINDINGS

Barcode sign (indicate absent lung sliding)

The absence of the lung sliding sign generates the characteristic barcode sign on M-mode (the normal sandy beach-like pattern below the pleural line is replaced by horizontal lines), signifies no lung movement **(Figure 8).**

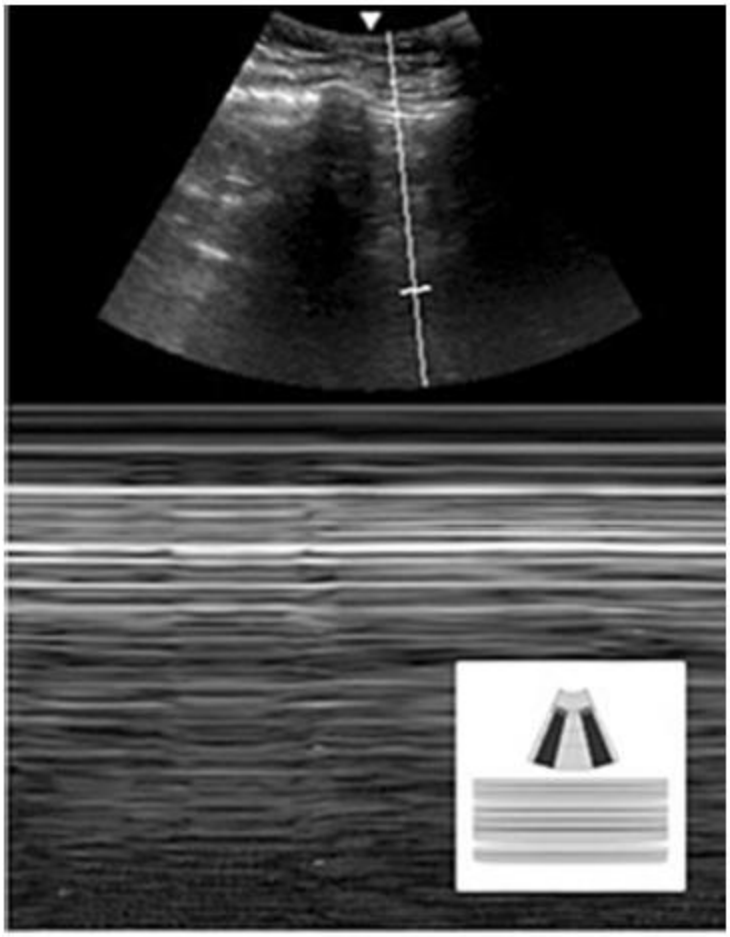

Figure 8 Ultrasound image of abnormal lung presentation with the absence of lung sliding (M-mode): barcode sign.

Lung point sign
Point of transition which represents the boundaries of the pneumothorax: alternating seashore sign, indicating lung sliding, and barcode sign indicating absent lung sliding, in the same intercostal space.

Lung pulse sign
Heart activity perception at the pleural line (small movement of the visceral on the parietal pleura induced by heartbeat indicating intact pleural interface

- The two most common conditions that generate the absence of lung sliding with the barcode sign are atelectasis and pneumothorax. They can be differentiated by the lung point and lung pulse signs. The presence of a lung pulse sign aids in identifying lung atelectasis, whereas the presence of a lung point sign aids in identifying pneumothorax

More than two B-lines – B profile
The number of B-lines depends on the degree of lung aeration loss. Their number increases with decreasing air content. A positive region is defined by the presence of more than two B-lines in a

longitudinal plane between two ribs **(Figure 9. To see video, click here).** Fewer than two B-lines can be detected in dependent lung regions even in normally aerated lungs.

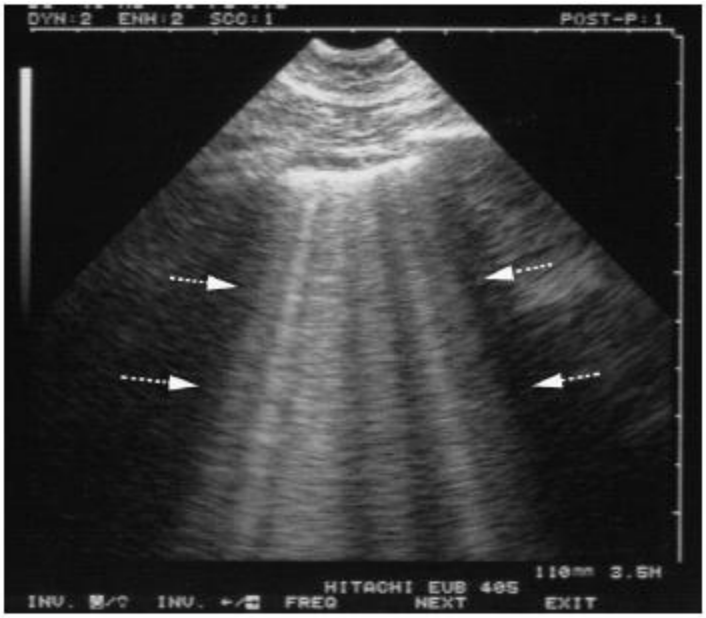

Figure 9 B-profile with more than 2 B-lines in the same intercostal space

ABNORMAL LUNG PATTERNS

Pneumothorax
To diagnose pneumothorax by US, there must be absent lung sliding and presence of lung point sign. B-lines and lung pulse sign should not be observed **(Figure 10).**

- Absence of lung sliding on B-mode, presence of barcode on M-mode and lung point sign
- The presence of lung sliding effectively rules out pneumothorax with a negative predictive value of 99.2% to 100%.
- However, the absence of lung sliding is not specific for pneumothorax. In addition to atelectasis, absence of lung sliding can be seen in other conditions such as ARDS, pleural adhesions, pulmonary fibrosis and single-lung intubation.
- The lung point sign allows confirmation of pneumothorax with a positive predictive value of 100%.
- Although A-lines constitute a basic artifact of the normally aerated lung, they are also seen in pneumothorax without lung sliding.

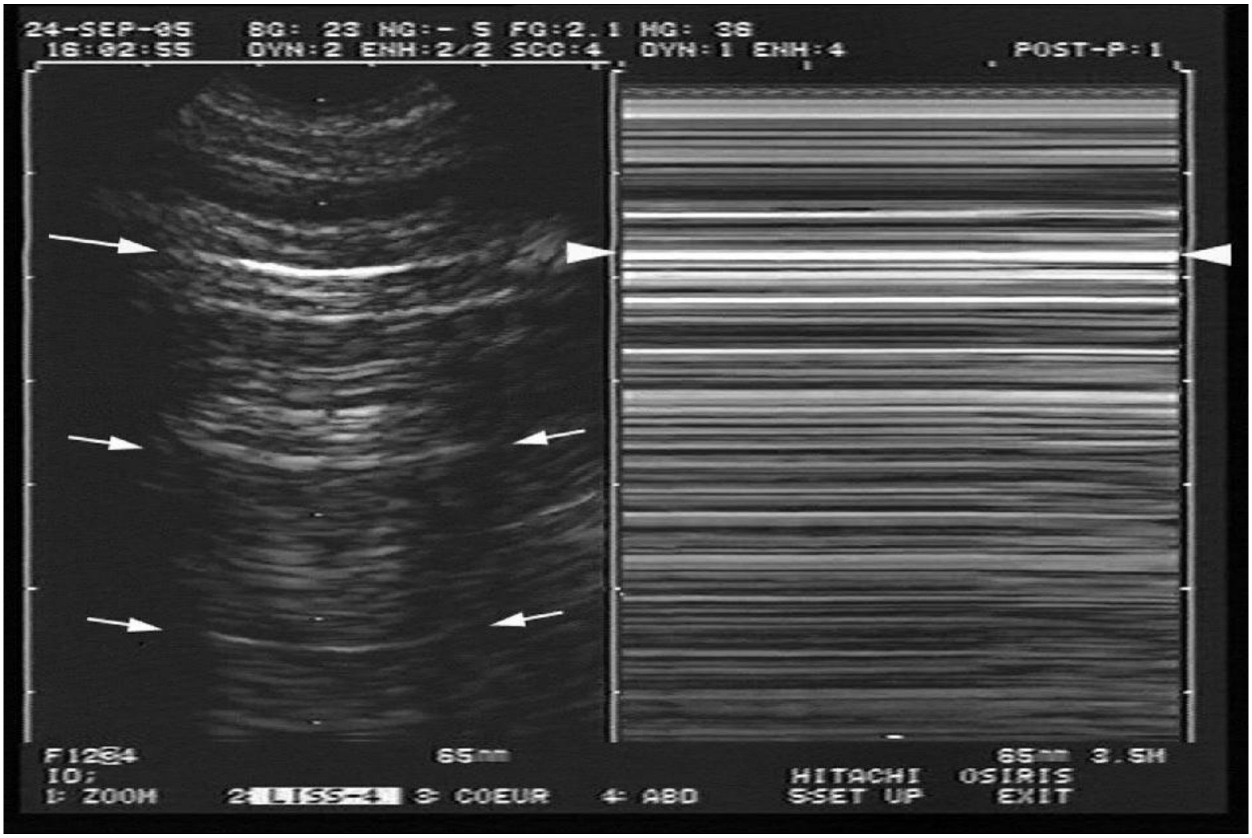

Figure 10 Pneumothorax *Left panel* (real-time) shows the complete absence of the B lines, the pleural line (upper arrow) and A lines (lower arrows). *Right panel* (M mode): this succession of horizontal lines indicates complete absence of lung. The arrowheads represent the pleural line. This pattern is called the stratosphere sign. The lung point (not featured here) confidently rules in the diagnosis.

Atelectasis

- Recognized by the absence of lung sliding on B-mode and presence of barcode on M-mode. The presence of lung pulse sign indicates active atelectasis and its absence passive atelectasis.

Pneumonia

- Lung consolidation is sonographically observed as an area of tissue density **(Figure 11).** Within the consolidation, hyperechoic foci might be seen that represent air bronchograms.
- Dynamic air bronchogram, which is the respiratory movement of gas bubbles within the bronchus, aids in identifying pneumonia and helps with differentiation from atelectasis.

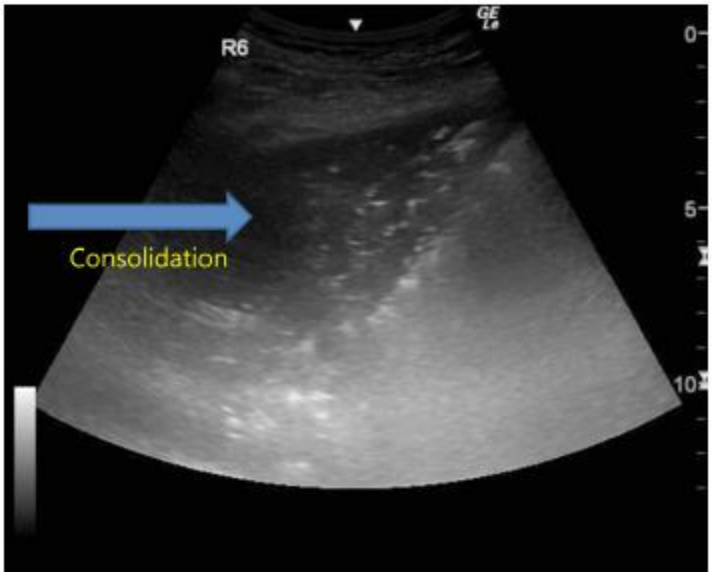

Figure 11 Tissue-like pattern characteristic of pneumonia.

Interstitial Syndrome

In interstitial syndrome, aeration is impaired due to an increase in interstitial fluid, while some lung aeration is preserved. Sonographically it is defined as more than two B lines between two ribs.

- Multiple, homogeneous and bilateral diffuse B-lines are suggestive of hydrostatic-cardiogenic or permeability pulmonary edema, which can be distinguished both clinically and by evaluating the cardiac function (see Shock).
- Multiple heterogeneous focal or multifocal B-lines are suggestive of pneumonia/ pneumonitis, atelectasis, pulmonary contusion, pulmonary infarction, or neoplasm.

Pleural effusion

Pleural effusion is sonographically seen as an anechoic or hypoechoic space between the visceral and parietal pleura. In supine patients, the optimal site for evaluation is at the posterior axillary line above the diaphragm.

PE, Asthma-COPD

If respiratory failure is detected along with a normal A profile, then two conditions must be considered: obstructive pulmonary disease (asthma or COPD) and PE.

SHOCK

Although the type and etiology of shock may be apparent from the medical history, physical examination, or clinical investigations, the diagnosis can be refined by conducting a Point of Care Ultrasound (POCUS) evaluation.

For cardiac ultrasound, low-frequency probes (3.5–5 MHz) are used, and an organized approach is recommended **(Figure 12).** More frequently the heart is scanned in the decubitus position, and three different views (parasternal long axis, apical four-chamber, and subxiphoid window) are obtained.

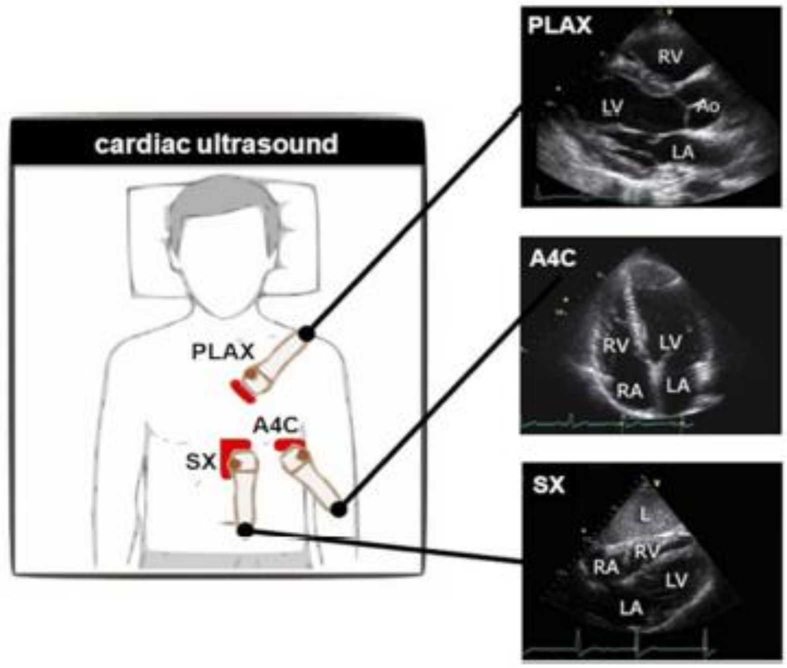

Figure 12 Systematic approach for cardiac ultrasound placement locations. PLAX, parasternal long axis; A4C, apical four chambers; SX, subxiphoid.

This approach permits the evaluation of the crucial elements of the cardiac ultrasound examination (chamber size and shape, LV systolic function, IVC) size, and collapsibility and pericardial effusion) and other gross morphological abnormalities (eg, mass in the heart chambers).

GUCCI proposes a stepwise approach for diagnosing shock, integrating cardiac, lung, vascular, and abdominal ultrasound, and guiding directed immediate therapeutic management (Figure 13).

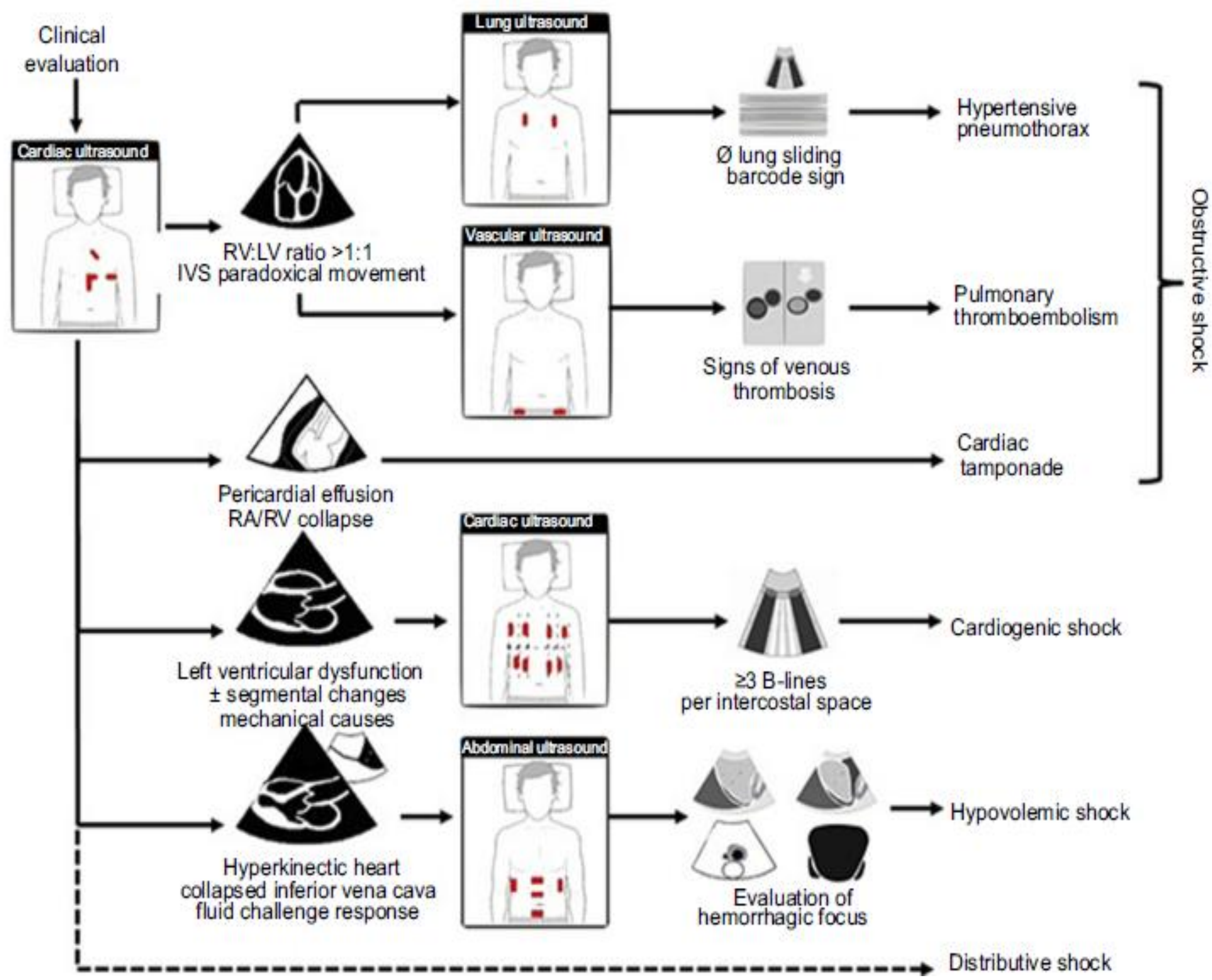

Figure 13 Shock algorithm.

Pulmonary embolism (PE)

- PE should be suspected in the adequate clinical context if right heart chamber dilatation (right/left ventricular ratio >0.6 in the apical four chamber view **(Figure 14)** is detected.
- McConnell sign **(to see video, click here)**
- Documentation of DVT **(Figure 15)** supports the diagnosis of PE

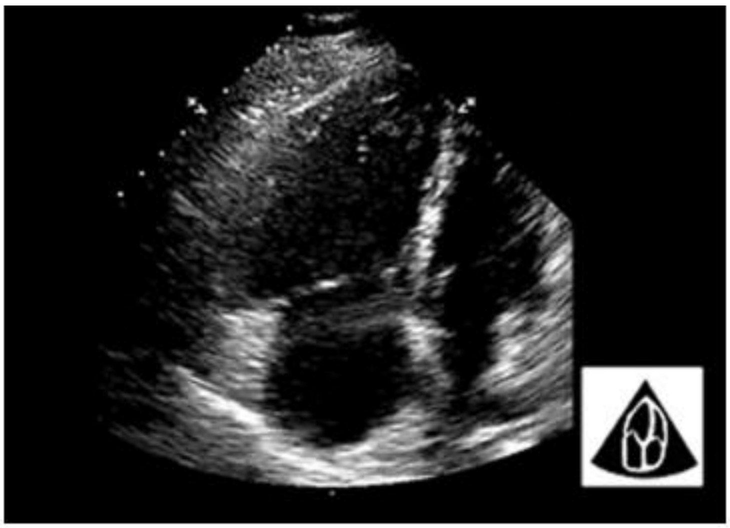

Figure 14 PE with RV dilatation

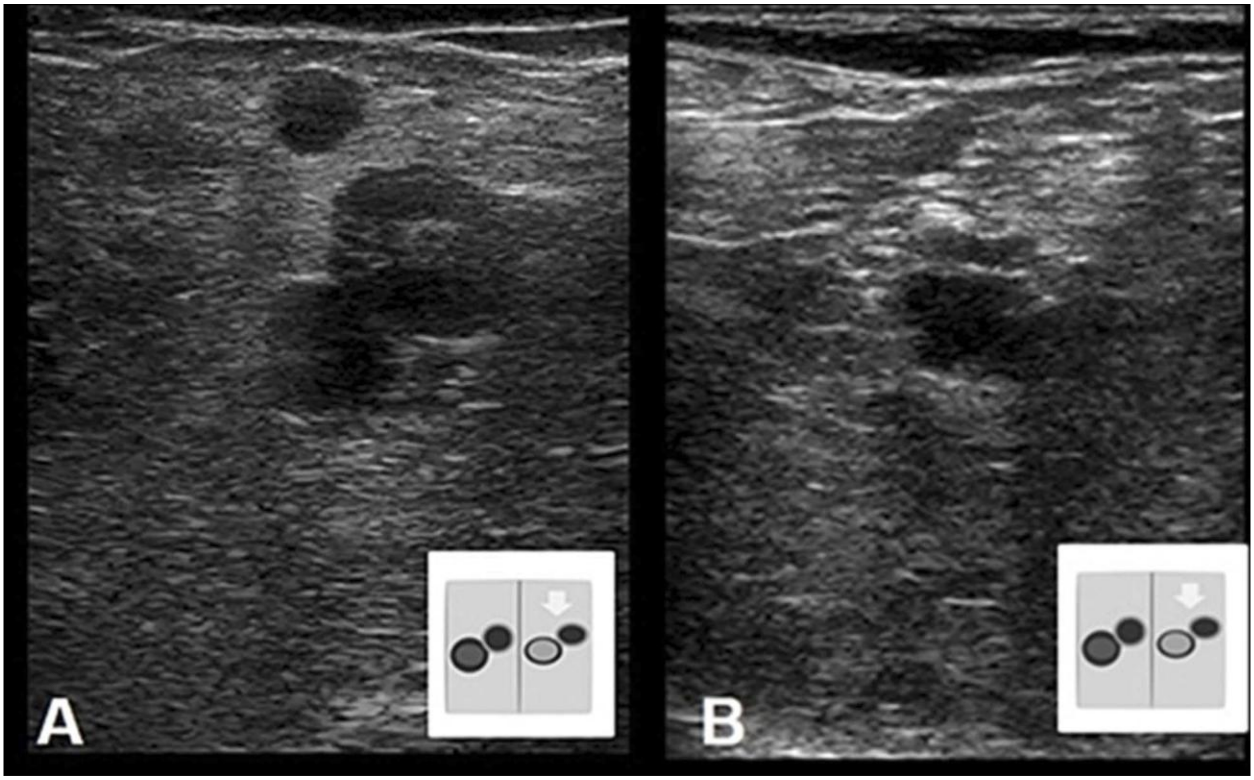

Figure DVT 15: (A) Left femoral vein-non-compressible thrombus; (B) Normal, compressible popliteal vein.

Cardiac tamponade

The observable features in cardiac tamponade includes **(Figure 16).**

- RA collapse (RA inversion during ventricular end-diastole).
- RV diastolic collapse (absence of RV free wall expansion during early diastole).
- Dilated IVC.

Figure 16 Pericardial effusion with tamponade.

Left ventricular dysfunction ± regional wall motion abnormalities

Visually LV EF estimation ("eyeball") is a feasible and accurate method to evaluate LV systolic function. With focused training on eyeball cardiac function evaluation, even non experienced physicians can achieve good agreement with cardiologists **(to see video of severely decreased LV function click here).**

Hypovolemic shock

In patients who experience hypovolemic shock, the LV becomes small (the lumen may even become obliterated with "kissing" ventricular walls), and the IVC collapses **(Figure 17. To see video of kissing sign and IVC less than 1 cm in diameter with 100% collapse except during expiration, click here)**

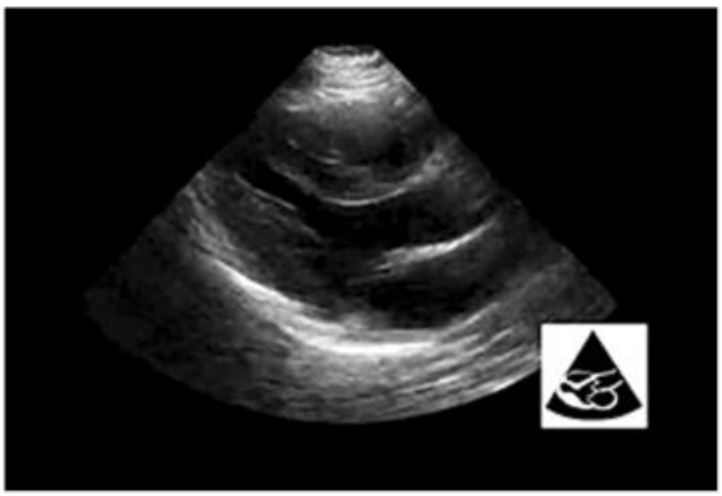

Figure 17 Kissing" ventricular walls in hypovolemic shock

In this setting, it is mandatory to conduct an abdominal ultrasound to check for hemorrhage, aortic aneurysm rupture, or other organ lesions. A global abdominal ultrasound, employing the three focused assessment with sonography for trauma views (right flank, left flank, and pelvis), should be performed when no obvious sources of bleeding can be identified in the context of hypovolemic shock to allow the detection of other arterial catastrophes (eg, rupture of splenic artery aneurysm). The proximal section of the abdominal aorta lies along the mid-line of the abdomen on the left side of the IVC and should be screened to detect aortic aneurysm (aortic diameter >3 cm) **(Figure 18)** which, in the adequate clinical context, makes aneurysmal rupture probable.

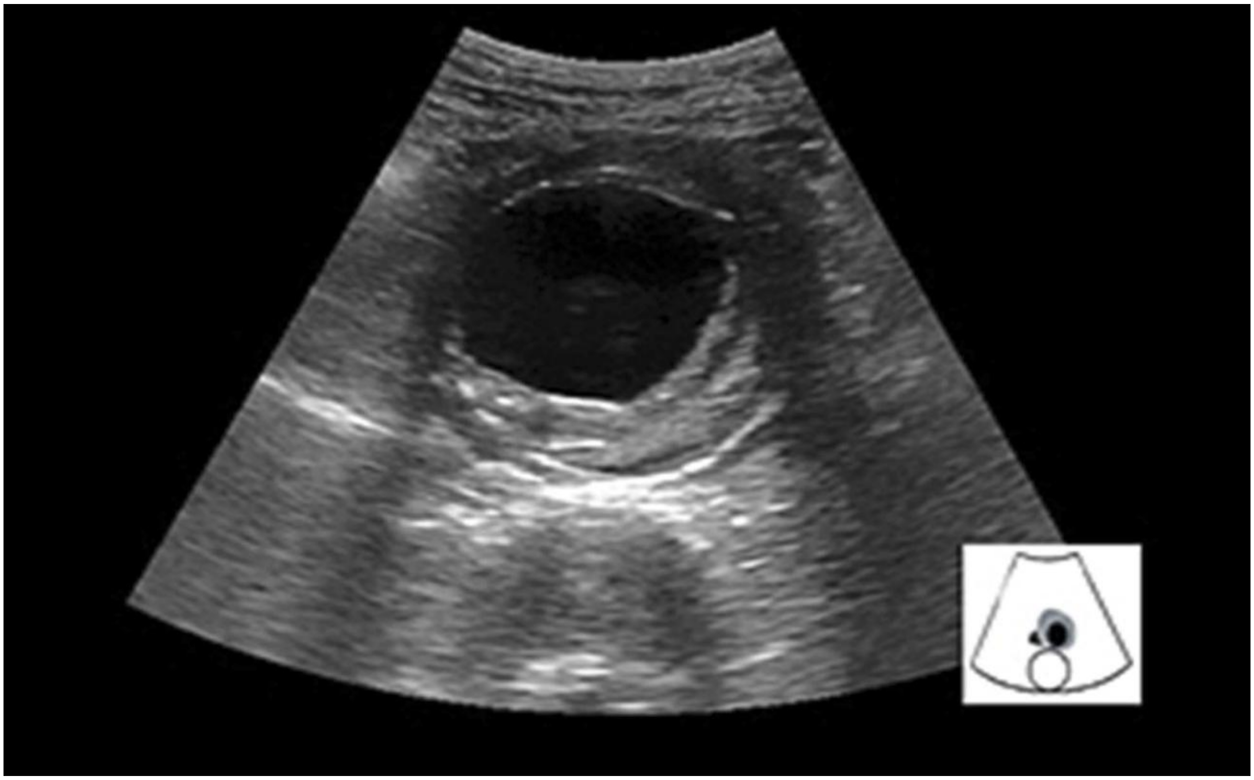

Figure 18 Aortic aneurysm using FAST views.

SHOCK TREATMENT

GUCCI proposes a three-step approach **(Figure 19).**

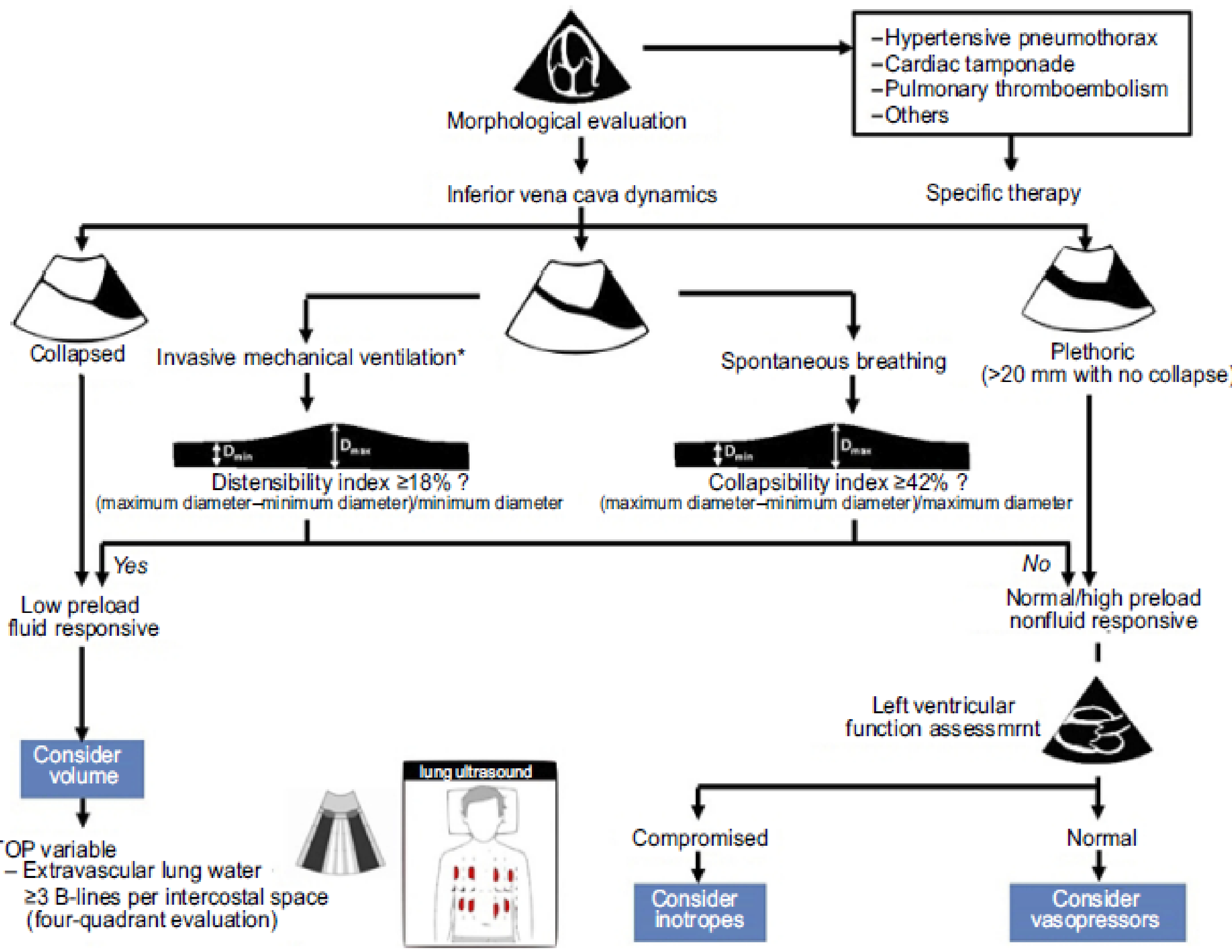

Figure 19 Shock treatment algorithm.

The first step in the shock treatment algorithm includes treating shock-reversible etiologies by following the shock diagnosis protocol (eg, thoracic drainage in tension pneumothorax, pericardiocentesis in cardiac tamponade, fibrinolysis in PE).

The second step includes assessing preload and fluid responsiveness using IVC dynamics. The evaluation of the IVC can begin at the subcostal classical view, moving slightly off the midline to the right of the abdominal aorta on the transverse view.

- The IVC size should be measured in the longitudinal view-2 cm caudal to the point where the IVC joins the RA. In patients with spontaneous breathing effort, due to a change in intrathoracic pressure, the IVC collapses on inspiration and distends on expiration, whereas the reverse occurs in patients on mechanical ventilation.

- A totally collapsed IVC implies low preload and fluid responsiveness; on the other hand, a plethoric IVC (dilated with no collapse) implies high preload and no fluid responsiveness **(Figure 16. To see video of IVC with less than 50% collapse on inspiration, click here).**

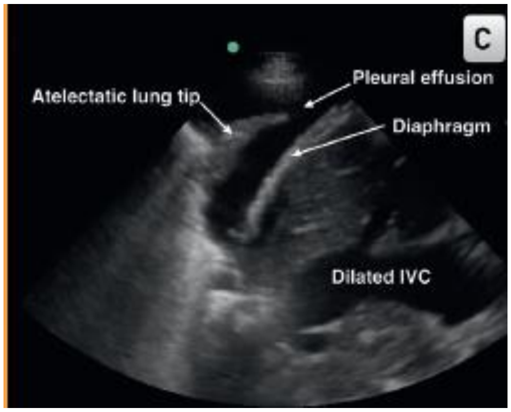

Figure 16 Dilated SVC

- For patients with IVC dynamics that stand between these opposite scenarios, the collapsibility index should be used [(maximum IVC diameter—minimum IVC diameter)/ maximum IVC diameter] if spontaneously breathing, and the distensibility index should be used [(maximum IVC diameter-minimum IVC diameter)/ minimum IVC diameter] if mechanically ventilated.
    - *A collapsibility index superior to 0.40 or a distensibility index superior to 0.18 translates into potential fluid responsiveness.*

The endpoint of fluid administration entails the appearance of B-lines, indicating iatrogenic interstitial edema (which is often clinically silent but precedes alveolar edema and worsens respiratory failure).

The third and final step includes evaluating the left ventricular systolic function. With focused training on eyeball cardiac function evaluation, even non experienced physicians can achieve good agreement with cardiologists.

The treatment protocol should be repeated after each intervention or if clinical changes are noted.

CARDIAC ARREST

POCUS included in the advanced life support algorithm can help to diagnose/exclude some of the potentially treatable causes of cardiac arrest, such as cardiac tamponade, severe LV failure, and hypovolemia. Moreover, it can help distinguish “pseudo-pulseless PEA (coordinated PEA with no palpable pulse, but with coordinated cardiac activity) from “true-PEA” (coordinated electrical activity with no palpable pulse nor detectable cardiac motion). This differentiation has a significant outcome implication.

GUCCI proposes a three-step approach using an ultrasound cardiac low-frequency (3.5–5 MHz) probe in a subcostal view in non-shockable rhythms (and selected cases of shockable rhythms), which are eventually complemented by thoracic, abdominal, and vascular ultrasound. A unique probe type and a single window are used to minimize the time spent acquiring the appropriate cardiac window (maximum 10-s interval).

The first step includes seeking one out of four patterns (subcostal window during pulse check):

- Myopathic pattern which includes
  - Ineffective myocardial contraction – epinephrine is not effective.
  - Disorganized myocardial contraction which implies probable ventricular fibrillation - delivery of a shock should be considered (after optimization of myocardial perfusion).
  - Standstill - refers to a situation where a patient is in asystole or “true-PEA”. Implies worse prognosis.
- Pericardial effusion/Cardiac tamponade – urgent pericardiocentesis indicated.
- RV dilatation – generally, when the RV is bigger than the LV, there is a likelihood of a PE or pneumothorax.
- Hyperdynamic heart, the “kissing ventricle” sign – prompts rapid fluid therapy.

The second step includes conducting a noncardiac ultrasound evaluation to complement the pattern found in the first step. This can be accomplished during chest compressions to avoid further delay in the diagnosis.

- In the case of RV dilatation, pneumothorax must be excluded with lung ultrasound (see “Acute respiratory failure” and “Shock”). To establish the absence of lung sliding, ventilation is mandatory. The absence of pneumothorax signs with RV dilatation increases the possibility of PE. Further echocardiography and vascular ultrasound can reveal an intracavitary thrombus or DVT to corroborate the diagnosis.

- In the case of a hyperdynamic heart, a hemorrhagic focus should be sought (see “Shock”).

The third step embodies three main goals:

- Confirm the previous findings.
- Conduct reevaluation after therapy (e.g., thrombolysis).
- Determine prognosis (e.g., persistent standstill implies poor prognosis.