Use of bedside ultrasound to assess fluid status: a literature review

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Use of Bedside Ultrasound to Assess Fluid Status: a literature review.

Short title - Bedside US in fluid status – review.

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Abstract

A review of the literature to determine the ability of the assessment of a patient’s body fluid status by ultrasound methods. Assessment of a patient’s body fluid status is a challenging task for modern clinicians. Ultrasonography has many advantages, the most important being the reproducibility of the examination and bedside monitoring of the patient. The examination is quick and of significant diagnostic value. The bibliography from the databases (Pubmed, Medline) has been fully reviewed up to February 2019. Data from published reports and clinical observations prove that the quick and noninvasive ultrasound examination facilitates the assessment of intravascular volume status, and the results correlate with other modalities, including invasive methods. Ultrasound allows physicians to determine the baseline status of hydration and to control the patient during fluid therapy. Additionally, asymptomatic patients can be assessed, as well as those patients well adapted to chronic oxygen deficiency, who develop pulmonary congestion secondary to congestive heart failure or chronic kidney disease. Progress in ultrasound techniques (blood vessels, heart, lungs) facilitates the assessment of intravascular volume status, the results of which correlate with those obtained through invasive methods. Designing the protocol for assessing volume status through the use of ultrasound would significantly facilitate the everyday practices of specialists in internal medicine.

Key words: carotid Doppler ultrasound, inferior vena cava/aorta index, point of care ultrasound, transthoracic lung ultrasound, volume status
Introduction

Despite rapid advancements in medicine, correct body fluid volume regulation still remains a key concern for modern clinicians. From the point of view of pathophysiology, it is most important to assess intracellular water volume (IWV), directly impacting on arterial and venous pressure, volume status, and consequently on the organism’s life functions. The spectrum of available modalities to assess IWV is considerable: from a clinical evaluation of basic life parameters to advanced invasive methods, i.e., pulmonary artery catheterisation [1].

Point of care (PoC) ultrasound presently serves as a tool assisting clinicians in solving problems at a patient’s bedside, and one of the challenges involved is the assessment of intravascular volume status. This method allows clinicians to assess the degree of hydration non-invasively in real time and – due to its reproducibility – to monitor the patient. The results of the ultrasound assessment of the degree of hydration correlate with those obtained with other referential methods [2]. Moreover, performing ultrasound examination is easy to learn even for those clinicians beginning their careers [3].

1. Ultrasound assessment of the inferior vena cava

1.1 Method (equipment, technique)

The ultrasound device to assess fluid status should be equipped with convex or phased array probe. The selection of an adequate probe depends on the patient’s body build. Convex and phased array probes are effective for in-depth examinations of tissues (about 25-30 cm). This allows for the assessment of the inferior vena cava (IVC) and aorta (Ao) when the probe is placed over the epigastric region and over the right lateral abdominal wall. The standard placement of the probe to visualize both vessels is in the arterior median line over the epigastrium (inferior to the xipoid process). In special cases when the assessment over the epigastrium is difficult (e.g., due to substantial amounts of intestinal gas, large dressings or
wounds in the median line), the probe should be placed over the lateral abdominal wall, in the right anterior axillary line. Assessment with the probe placed over the lateral abdominal wall can be very effective because the liver is a perfect acoustic window for the imaging of the major abdominal vessels. Color Doppler option is not required for the assessment of fluid status. The examination involves only the assessment of the vein diameter, and in the case of the IVC/Ao index additionally referring this ratio to the aorta diameter.

First, the IVC collapsibility is assessed. Maximal and minimal IVC diameters are measured, using M-mode, during the expiratory and inspiratory phases of the respiratory cycle, and obtained results are computed according to the following formula:

\[ d_{\text{IVC}} = \left( \frac{D_{\text{max}} - D_{\text{min}}}{D_{\text{max}}} \right) \times 100\% \]

\( d \) – distensibility

\( D_{\text{max}} \) – maximal diameter

\( D_{\text{min}} \) – minimal diameter

Fluid responsive patients present the value of the IVC collapsibility >40%. Patients who do not respond adequately to the administered fluid therapy have the IVC collapsibility index <15%. Moreover, the IVC index >50% is strongly associated with low values of the central venous pressure [4].

The value of the IVC/Ao index is obtained by calculating the ratio of the diameters of both vessels. The IVC is assessed in its intrahepatic fragment, about 3 cm below the diaphragm, during the expiration phase of the respiratory cycle. The Ao is measured at the same level, moving the probe with a swinging motion to the left (of the patient’s body). A normal value of the IVC/Ao index ranges approximately from 0.8 to 1.2. The value of the IVC/Ao index
<0.8 indicates that the patient requires fluid therapy, and the value >1.2 indicates that the patient is most likely overhydrated.

For patients undergoing respiratory therapy, the assessment of the IVC compressibility is helpful. Technically, the examination is analogous to the assessment of the IVC index. The IVC is measured analogously (minimal and maximal diameters are measured in the M-mode). However, to assess the volume status the so-called IVC collapsibility index is calculated, expressed as a ratio according to the following formula:

$$\text{IVCCI} = \frac{(D_{\text{max}} - D_{\text{min}})}{D_{\text{min}}} \times 100\%$$

The threshold of the IVCCI is 18%. With the use of this formula patients may be discriminated among those potentially responsive (>18%) and non-responsive (<18%) to fluid therapy [5,6].

1.2 Clinical usefulness of the IVC/Ao index and the IVC index

The calculation of the IVC index and the IVC/Ao index are auxiliary modalities in determining the degree of the patient’s hydration. The usefulness of these indexes is particularly appreciated when the clinical assessment is difficult and may fail to provide adequate results. In order to assess body fluid status in adults with the use of ultrasound, initially the IVC collapsibility was evaluated [7,8]. The evaluation of the IVC on expiration and inspiration and its collapsibility ratio leads to the assessment of the so-called IVC index. The usefulness of the IVC/Ao index was initially well documented in the pediatric population [3,9]. Presently, both the IVC index and the IVC/Ao index are well documented as useful measurements in assessing body fluid status in adult patients [10,11,12]. One of the basic differences between the two methods is the impact of the patient’s individual characteristics in terms of: age, gender, height, body surface, body mass, and, for instance, waist circumference. The IVC/Ao index is more susceptible to patient characteristics than the IVC
Rahman et al. and Lyon et al. proved the efficacy of the IVC index and the IVC/Ao index and demonstrated that these indexes can be used as parameters for detecting an early phase of hypovolemic shock [13,14]. However, the sensitivity of the IVC index in detecting early loss of blood does not exceed 80% [15]. Additionally, the IVC/Ao index has been found very useful for the evaluation of preoperative and intraoperative volume status, especially in major surgeries with marked fluid shift or blood loss [16].

Other target groups for the application of ultrasonography in the assessment of body fluid status are patients with cardiovascular diseases, e.g., patients with exacerbated congestive heart failure (CHF), with kidney diseases, i.e., acute kidney injury (AKI) and exacerbation of chronic kidney disease (CKD), and patients who receive dialysis therapy. In these patient groups it is essential that the initial body fluid status be assessed, but more importantly that the patient be carefully monitored during fluid therapy or fluid removal.

1.3 Limitations of the IVC/Ao index and the IVC index

The usefulness of ultrasound in the assessment of the IVC index and the IVC/Ao index is limited by its high dependence on the experience of the operator and the presence of specific clinical conditions that prevent a reliable calculation of these indexes. Such conditions and situations include: pulmonary hypertension, elevated intraabdominal pressure, cardiac tamponade and mechanical ventilation. Pathological obesity can be an obstacle in assessing IVC diameter. When hypervolemia is detected, falsely positive results should be considered due to pulmonary hypertension, high intraabdominal pressure or cardiac tamponade. The experience of the operator and obtaining optimal views are of key significance in a correct assessment of body fluid status. As in the case of any examination, training and gaining experience through practice are essential. Due to the high reproducibility of performing
ultrasound examinations, especially when monitoring the patient, it is advisable that the examination be conducted by a clinician – the treating physician.

2. **Lung ultrasound in the assessment of body fluid status**

2.1 Method (equipment, technique)

For a lung ultrasound examination, a convex probe is most often employed for the preliminary assessment and a linear probe for the visualization of small subpleural lesions and the pleural line [17]. A linear probe helps to differentiate B-line artifacts, e.g., irregularities, fragmentation and the blurring of the pleural line can be visualized in pulmonary fibrosis. In emergency situations phased array probes are used as an extension of echocardiography (additionally, a small probe head facilitates intercoastal access) as well as microconvex probes [18,19]. The assessment of body fluid status is based on the analysis of artifacts. Consequently, it is necessary to switch off additional options improving visualization such as: compound imaging, algorithms that reduce speckle, haze, and clutter artifacts, harmonic imaging.

Features of the ultrasound device that facilitate bedside examination include: a small size, a few-seconds switching time, and an easily cleaned transducer. Additionally, Doppler options are not required. Modern pocket-size imaging devices seem to be useful tools for assessing the lungs [20].

In recumbent patients, when searching for B-line artifacts the region along the middle and posterior axillary lines is mainly assessed. In the case of patients mainly in the erect position, in order to search for interstitial and alveolar-interstitial syndromes first the lower lung fields are assessed. Then the level to which B-line artifacts are present is analyzed moving the probe up to the middle and upper lung fields. This examination technique is correlative to the gravitation-dependent presence of air and fluid. There are many protocols that can be used to
image the lungs. The best-known protocol is the evaluation of eight region. Anterior two-region scan may be sufficient to rule out interstitial syndrome in cardiogenic acute pulmonary edema. Two-region protocol may be sufficient to rule out interstitial syndrome in cardiogenic acute pulmonary edema [21].

Lung ultrasound (LUS) facilitates the assessment of extravascular lung water (EVLW) [22]. It has been proved that the degree of lung aeration, dependent on the fluid volume in the interstitial and interalveolar spaces, directly correlates with the ultrasound image [23]. ELVW assessment can be reliable and effective irrespective of the operator’s experience in performing LUS [24].

Another important feature of EVLW is the symmetric bilateral localization of the lesions. B-line artifacts detected unilaterally may correspond to different processes within pulmonary interstitial spaces (e.g., inflammation), and the presence of fluid in the interstitial and interalveolar spaces usually produces a symmetrical image on both sides of the chest.

2.2 Artifact analysis

Ultrasound assessment of body fluid status involves the analysis of artifacts visualized on the ultrasound image.

A-line artifacts: In a normal aerated lung, ultrasound images show A-line artifacts. These are horizontal regularly spaced lines. A-lines are a type of reverberation artifacts which appear between two bordering surfaces: the probe/body surface and the pleura/air in the alveoli. The distance between A lines is equal [25]. When fluid status is assessed such an image is interpreted as the so-called dry lung [26]. The image presenting A-line artifacts may be also present in pneumothorax; however, the pleural sliding sign is then absent (Image 1).
B-line artifacts: The major reason for B-line artifacts is the presence of fluid in the interstitial or interalveolar spaces. These artifacts can also be found in pneumonia and fibrosis [27]. B-line artifacts are caused by a reverberation phenomenon. The area where reverberation occurs covers a small space – interlobular septa or pulmonary alveoli, consequently the obtained image yields an apparent effect of a vertical line consisting of numerous small horizontal lines [28]. B-line artifacts are defined as follows: laser-like vertical hyperechoic reverberation artifacts that arise from the pleural line, which extend to the bottom of the screen (without fading irrespective of the programmed depth of penetration), and move synchronously with the respiratory cycle [29] (Image 2).

Depending on the fluid volume in the lung, B-line artifacts produce:

- the interstitial syndrome – corresponding to the presence of fluid in the interstitial spaces – B-line artifacts of ≥ 3 are present within one intercostal window with a longitudinal probe position. The distance between them is larger than 7 mm, which results from the anatomical structure and equates the thickness of interlobular septa. B-lines artifacts move synchronously with the respiratory cycle and pleural sliding, and remain separated [26].

- the alveolar-interstitial syndrome – corresponding to the presence of fluid both in interstitial and interalveolar spaces – the distance between artifacts is 3 mm, and B-line artifacts “overlap” synchronously with the respiratory cycle [25].

- the “white lung” sign – a completely white image of the lung, without visible single artifacts – corresponding to large fluid volumes within alveolar-interstitial spaces, the next stage being airless consolidation[29].

2.3 Clinical usefulness of LUS in heart failure (HF)
In everyday practice, the assessment of HF exacerbation is based on a clinical examination, evaluation of the chest radiography, N-terminal pro-B-type natriuretic peptide (NT-proBNP) level, and echocardiography (ECHO) [30,31]. Physical examination still remains the initial diagnostic modality. However, it does not yield reliable results in asymptomatic patients and does not allow for a precise assessment of the degree of HF exacerbation [32]. In asymptomatic patients LUS facilitates the detection of pulmonary congestion, which at the early stage does not present any signs on auscultation. Crackles over lung fields appear only when the fluid volume is large enough to be present in the interalveolar space. Additionally, the number of B-line artifacts in HF increases synchronously with the increase of the New York Heart Association (NYHA) class and is directly dependent on the ejection fraction and degree of diastolic dysfunction [19]. Moreover, a stable number of B-line artifacts was observed in patients who, despite their heart disease, retained a stable level of physical efficiency [19]. In HF exacerbation LUS is employed to monitor the resolution of pulmonary congestion and treatment efficiency, and the results correlate directly with NT-proBNP levels and radiologic examinations [33]. LUS is also useful in monitoring patients with pulmonary congestion who undergo intensive diuretic therapy or hemodialysis [34,35]. Meta-analysis of 7 large-scale studies indicated that LUS differentiates cardiogenic and non-cardiogenic dyspnea with the sensitivity of 94% and the specificity of 92% in emergency department patients [36]. Moreover, a multicenter study revealed that the analysis of B-line artifacts is more accurate in detecting acute decompensated HF than a clinical workup, chest radiography or NT-proBNP levels [37].

2.4 Clinical usefulness of LUS in renal failure and dialysis therapy

Fluid overload is one of the most important prognostic factors in patients with CKD. Hypervolemia results in left ventricular (LV) hypertrophy. More than 1/3 of patients undergoing dialysis die due to cardiovascular (CV) incidents (arrhythmia, myocardial
The most common causes of CV incidents include LV hypertrophy and arterial hypertension [38,39,40]. A successful control of extracellular volume in chronically dialyzed patients allows for monitoring arterial blood pressure, largely reducing the intake of hypotensive drugs or actually eliminating them [41].

Controlling fluid balance in patients who undergo dialysis is still based on the physical examination, assessment of the so-called “dry weight” and the measurement of arterial blood pressure [42]. Such an evaluation involves parameters that depend on too many factors to be reliable, considering, for instance, the amount of fluid volume change necessary to obtain alteration in arterial pressure values, peripheral edema and cardiac function.

The number of B-line artifacts before and after dialysis in patients who receive hemodialysis (HD) correlates directly with the measurements of the IVC and bioelectrical impedance analysis. This correlation was revealed in both asymptomatic and symptomatic patients in all NYHA classes [43,44]. Additionally, LUS appears to be an effective tool for monitoring and detecting patients with HF and CKD who develop pulmonary congestion despite the absence of symptoms. Monitoring with the use of LUS may diminish the risk of decompensated HF, that being the most frequent cause of death in dialysis patients [43]. The use of B-line score defined as the percentage of regions where B-lines are present also correlates with the EVLW before and after HD [45,46]. In the case of patients undergoing peritoneal dialysis LUS allows for determining EVLW, especially in asymptomatic patients [47].

2.5 LUS limitations

LUS is a relatively new modality for the assessment of body fluid status; it is easy to use, but has some limitations [48]. Patients who have undergone pneumonectomy may prove to be problematic. B-line artifacts are found in many different clinical conditions: cardiogenic pulmonary edema, noncardiogenic pulmonary edema, pneumonia, interstitial lung disease,
and lymphangitis carcinomatosa. It is extremely important for the operator (clinician who performs LUS) to differentiate between these conditions. In order to determine whether the problem is cardiogenic or lung-related, the following features are helpful: lesions distribution, localization, regularity of B-line artifacts distribution, assessment of the pleural line and associated lesions [18,19,49,50]. It should be noted that in the population of hemodialysed patients who are suffering from heart failure, assessment may be limited. [51]. Designing guidelines and an algorithm for the assessment of body fluid status with LUS allowing physicians to refer the examination to the general population will be an important step.

3. **Usefulness of echocardiography in assessing body fluid status**

3.1 Method (equipment, technique) and clinical significance

To assess the heart a phased array probe is necessary. The ultrasound device must be equipped with a color Doppler option. Portable and pocket-size devices are ever more frequently used at present. A phased array probe allows for the optimal visualization of a single intercostal window due to the small surface of the probe head. During the examination the patient is placed in the left lateral decubitus (LLD) position, with the left arm abducted to widen intercostal spaces. The assessment is performed in the following views: parasternal long axis (the probe is placed at the 3rd or 4th intercostal space, just lateral to the left sternal border); parasternal short axis view (the probe is placed as above, rotated by 90 degrees), apical views (the probe is placed over the expected apex of the heart).

Left ventricular stroke volume (SV) correlates closely with the right ventricular filling pressure. The volume parameter – LV end-diastolic volume (LVEDV) – represents well the amount of lost intravascular volume. The calculation of LVEDV is, however, time-consuming, so a different parameter – LV end-diastolic area (LVEDA) – has been applied
instead. Additionally, the analysis of LV outflow tract (LVOT) velocity time integer (VTI) has proved very useful for the assessment of fluid responsiveness [50,52].

The LVEDA is measured at the level of mid-papillary level in the left parasternal short axis view. It is important that the measurement be done in the plane perpendicular to the LV axis. LVEDA values <10 cm² indicate hypovolemia, and values > 20 cm² suggest hypervolemia [53,54]. In extreme hypovolemia the obliteration of the LV cavity can be observed, known as “kissing ventricles”. Then the LVOT in apical 3- and 5-chamber views is assessed. The sample gate should be placed about 10mm from the level of the aortic valve (towards the LV lumen), in the center of the outflow tract.

The obtained outflow tract should be outlined, thus automatically providing the value of LVOT VTI.

The LVOT VTI is a good predictor of a potential fluid responsiveness. An increase in LVSV >12% is considered a positive response [54]. An increase < 10% is seen as a weak response to fluid therapy [55].

Additionally, an increase of the LVOT VTI >12.5% after a passive leg raise (PLR) maneuver (elevation to 45°, measurement taken after 1 min) is diagnostic of fluid-responsive state.

3.2 Limitations of heart assessment

When measuring the LVOT the patient must have sinus rhythm. The administered volume of fluid must be adequate in order not to obtain falsely negative results and it should amount to about 8ml/kg. In the case of obese individuals, patients with breast implants, and with severe emphysema it may prove difficult to obtain views with standard placements of the probe. ECHO examination is largely dependent on the operator’s skills and obtaining diagnostic views requires much experience.
4. Ultrasound of carotid arteries in the assessment of body fluid status

4.1 Method (equipment, technique)

Corrected carotid flow time (cCFT) refers to the time length of blood flow through the common carotid arteries (CCA) during systole, corrected for heart rate: time/√cycle time [56]. This time is measured from the beginning of the systole to the beginning of diastolic flow. The measurement is taken with a linear probe placed at the level of the lower lobe of the thyroid, visualizing CCA in the longitudinal plane (Image 3). The Doppler gate is placed analogously to the regimen appropriate for other vessels. Hooman et al. proved that no significant difference exists between measurements taken on the right and left CCA, which additionally increases diagnostic possibilities, for instance in patients who have a central venous catheter or neck injuries [57].

4.2 Clinical usefulness of the CCA assessment

Blehar et al. demonstrated that cCFT increases in dehydrated patients who received fluid intravenously [58]. Additionally, corrected flow time (FTc) changed in patients undergoing dialysis therapy. FTc measured in milliseconds was significantly shortened as compared to the values obtained before the administration of HD. Moreover, Hooman et al. demonstrated that this difference correlated with the volume of fluid removed by HD [56]. Researchers also attempted to determine the reference values of FTc and cutoff points [57]. Their studies revealed that FTc changes even with relatively small alterations in the intravascular volume status.

4.3 Limitations of vascular assessment

In the case of patients with arrhythmias it is necessary to assess several heart cycles [59]. Further studies are required to determine normal reference values for large populations. Studies conducted thus far have demonstrated that the differences are dependent on, for
instance, gender [57]. No data is available for FTc in the case of anomalies and pathologies within CCA.

**Summary**

Ultrasonography appears to be a useful tool for the assessment of a patient’s body fluid status. Data from published reports and clinical observations prove that the quick and noninvasive ultrasound examination facilitates the assessment of intravascular volume status, and the results correlate with other modalities, including invasive methods [60]. Miniaturization of ultrasound devices diminish the obstacles as regards bedside assessment, allowing for the reproducibility of the examination in order to monitor, for instance, fluid responsiveness. Some issues associated with ultrasound assessment still require further studies, for instance establishing the examination protocol and the range of reference values. It seems that the near future will witness a breakthrough in ultrasound diagnostics of hypervolemia and hypovolemia, equipping clinicians with an invaluable tool for conducting and monitoring fluid therapy safely as well as controlling fluid deficiency.
Commentary

Available literature reports indicate that ultrasound assessment is a reliable source of information concerning body fluid status. A large number of information can be obtained by collecting data from various areas assessed by performing ultrasound examinations. A convex probe is necessary to assess IVC/Ao index, IVC collapsibility index and the lungs. In ambiguous cases phased array and linear probes should be used to assess the heart and vessels. This, however, requires access to a set of three probes and expertise in performing echocardiography. It is important that the examination be performed by a clinician, who is the patient’s diagnostician and treating physician, and the interpretation of the images should be based on information obtained from the assessment of the patient’s general condition and results of additional examinations and tests. Conducted studies confirm a positive correlation between the assessment of IVC/Ao index, IVC index and the lungs with referential methods [11,12,31]. Assessment involving echocardiography requires that the operator be skilled in performing the examination correctly. Normally, to assess the heart a phased array probe is used. However, due to the frequent need to examine a patient at bedside, especially in the case of critically ill patients, it is necessary to perform the examination with the use of one universal probe, e.g., a convex probe [61]. Lichtenstein argues for the efficacy of a microconvex probe to assess individuals with dyspnea or critically ill patients [62]. Due to its small head an optimal visualization of intercostal spaces can be obtained. Additionally, its penetration depth allows for the assessment of vessels in the retroperitoneal space. From a technical point of view, a portable/pocket-size device with a convex/microconvex probe seems optimal for a quick examination and continuous monitoring. In clinical evaluation, we use single heading without performing complete procedures. The time needed to determine the patient’s hydration status should not exceed two minutes.
Monitoring fluid responsiveness in patients who require bedside diagnostics is based on multi-organ assessment: the IVC, heart and lungs. First, IVC/Ao index or IVC index are calculated. The values of the IVC/Ao index < 0.8 and/or IVC index >40% indicate too small intravascular volume status and consequently a patient requires fluid therapy. The values of the IVC/Ao index > 1.2 and/or IVC index < 15% are usually indicative of an intravascular volume overload. The IVC assessment is diagnostic of the necessity for the introduction of fluid therapy.

It is also possible to assess the heart based on a convex probe. The LVEDA can be measured: values <10 cm² indicate hypovolemia, and values > 20 cm² hypervolemia [53,54]. In the case of severe hypovolemia, ventricular walls are clearly touching each other – the kissing ventricles can be observed. Additionally, the right/left ventricular end-diastolic diameter ratio >0.6 is indicative of the right ventricular overload [63]. With access to a phased array probe, LVOT VTI analysis before and after fluid therapy demonstrates fluid responsiveness [50,52].

When assessing the lungs it is especially important to visualize A and B-line artifacts during fluid therapy. If A-line artifacts are present bilaterally, the resulting image presents the so-called “dry lung”. Fluid therapy may be administered, although such an image is not an indication for requiring fluid therapy, but functions only as “the green light” for its administration when there are other indications for providing the patient with fluid. When B-line artifacts are present bilaterally the so-called “wet lung” is visible, corresponding to pulmonary congestion. In this case fluid therapy may only worsen a patient’s condition [20]. It is recommended not to introduce fluid therapy in such cases.

Finally, measurement of the carotid blood flow seems to be a promising parameter for the assessment of body fluid status; however, the range of reference values needs to be established first (Table 1).
References:


[45] Liu ZP, Zhang Y, Bian H et al. Clinical application of rapid B-line score with lung ultrasononography in differentiating between pulmonary infection and pulmonary


Image 1. Probe placed perpendicularly to the rib surface at the chest apex. Asterisks – ribs with visible shadows at the bottom of the screen. Arrows – A-line artifacts regularly spaced and extending towards the bottom of the screen.
Image 2. Probe placed parallel to intercostal spaces. B-line artifact visible (marked with an arrow) – hyperechoic, arising from the pleural line, extending to the bottom of the screen.
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Table 1. Advantages and disadvantages of ultrasound methods to assess fluid status.

Abbreviations: ARDS, Acute Respiratory Distress Syndrome