Ultrasonography in the Intensive Care Unit

Looking at the World through Colored Glasses

"*That's why I'm looking at the world through rose-colored glasses, everything is rosy now. Yes, everything is rosy now.*"

"*Looking at the World thru Rose Colored Glasses,*" *1962 recording by Frank Sinatra with Count Basie, written by Tommy Malie and Jimmy Steiger.*

"… ultrasonography has become an invaluable tool in the management of critically ill and injured patients, which makes it imperative for critical care physicians to stay up to date with this advanced modality."

IN this issue of ANESTHESIOLOGY, Manno *et al.*[1] present an evaluation of the clinical impact of an ultrasound protocol in intensive care unit (ICU) protocol. The study suggests that bedside ultrasound examination by the attending physician at ICU admission can detect significant, unsuspected abnormalities, with a major impact on diagnosis and treatment plans, thus obviating the need to transport patients to other facilities and improving healthcare quality. These data confirm that routine clinical examination, electrocardiography, and chest x-ray may not suffice to identify all significant underlying diseases. The study is interesting because there are few prospective evaluations of ultrasound in ICU.

Manno *et al.*[1] used a fixed protocol examining by means of ultrasound: 1) optic nerve sheath diameter in comatose or deeply sedated patients to detect intracranial hypertension; 2) chest in different ventral-to-dorsal longitudinal and axial scans to detect pneumothorax, lung consolidation, interstitial syndrome, and alveolar edema; 3) heart by means of transthoracic echocardiography to detect valvular disease, left and right ventricle performance, and pericardial effusion; 4) abdomen in different abdominal areas, from epigastrium to right iliac fossa, to detect peritoneal effusion, cholecystitis, hydronephrosis, and parenchymal abnormalities; and 5) venous system of lower and upper limbs and neck with a mild compression maneuver to detect deep venous thrombosis.

Manno *et al.* focused on the number and type of ultrasound abnormalities and the role of ultrasound to confirm or modify diagnosis as well as to induce further investigations or perform a new procedure.

A population of 125 consecutive critically ill patients admitted in a general ICU were included within 12 h from admission. Ultrasound findings modified initial diagnosis in 26% of patients and confirmed initial diagnosis in 58% of patients, whereas it was not effective in confirming or modifying the diagnosis in 14% of patients and missed the diagnosis in 2% of patients. The findings of ultrasound examinations induced further investigations in 18% of patients and modification of medical therapy in 39% of patients including invasive procedures. No correlation was found between number of ultrasonographic findings, mortality, Simplified Acute Physiology Score II, and length of ICU stay. Patient- and environment-related sonography limitations had little influence on the majority of examinations.

Interestingly, the ultrasound examination revealed a high prevalence of unsuspected clinical abnormalities in acute heart failure, such as valvular disease and lower ejection fraction in septic shock lung consolidation. However, because the study relied only on transthoracic echocardiography, the true prevalence of cardiac ultrasound abnormalities may have been underestimated. New unexpected findings in the abdominal and venous system or neurologic abnormalities were rare.

There are several applications of ultrasonography in the critically ill patients at the bedside, including evaluation of alveolar recruitment and positive end-expiratory pressure-induced lung reaeration, during mechanical ventilation, in more severe hypoxemic patients;[2] evaluating volume load

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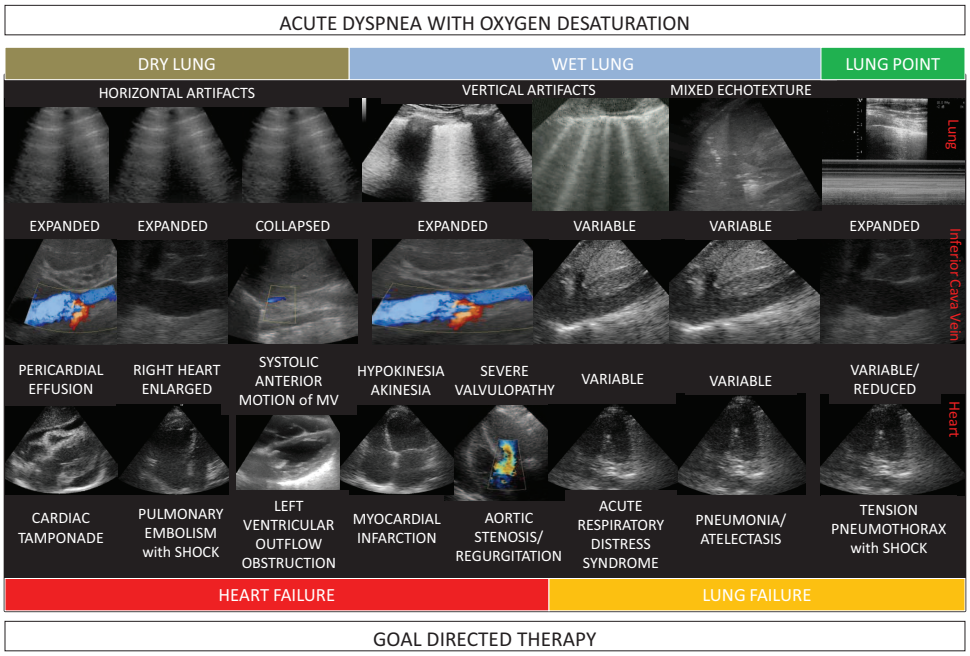

Fig. 1. A flowchart explaining the possible applications of ultrasonography in critically ill patients through a quick sequential qualitative analysis of the lung, vena cava, and heart (from top to bottom). The lung can be dry (normal) or wet (pathologic), with normal (lung sliding) or impaired (lung point: pathognomonic of pneumothorax) movement of the pleural surface. The inferior cava vein may be small, normal, or increased (expression of hypovolemia, normovolemia, or fluid overload, respectively) with normal or abnormal movement (collapsible or fixed as an expression of hindered flow). The heart cavities can be normal, reduced, or increased in size, with normal or impaired movement. By simple and rapid sequence analysis of the three main anatomical structures of lung, inferior cava vein, and heart, a differential diagnosis of the main causes of acute dyspnea with oxygen desaturation can be obtained.

and occult hemorrhagic shock by renal and splenic Doppler;[3] and guiding percutaneous tracheostomy.[4] Moreover, ultrasound imaging allows the physician to obtain central venous and peripheral arterial access; place vena cava filters and treat iatrogenic arterial pseudo aneurysms with a great degree of safety, patient comfort, and overall success;[5] and detect postprocedural complication, such as catheter misplacement and pneumothorax.[6]

Collecting such ultrasound data on ICU admission could have a significant therapeutic impact in the optimal setting of mechanical ventilation in acute lung injury/acute respiratory distress syndrome patients at the bedside, avoiding unnecessary computed tomography scans and risky transfers out of the ICU. The use of lung ultrasound could also have a great impact out of the ICU – in the emergency department, as well as in the ward when rapid diagnosis of respiratory failure is required – and could optimize the implementation of noninvasive respiratory support by continuous positive airway pressure or positive pressure ventilation, particularly in patients with acute cardiogenic edema, those experiencing exacerbation of chronic obstructive disease, or hematologic patients with progressive acute respiratory failure.

There are two main limitations for the use of ultrasound in ICU. First, patient-related conditions like obesity, subcutaneous emphysema, bandages, and digestive gas could strongly hamper the examination in some areas, so that the protocol could not be performed entirely. In fact, these cases were excluded from the study. Second, the subjective interpretation of the images. In the future, every effort should be made to develop ultrasound quantitative methods of analysis because this technique is potentially more objective than visual scoring, depends less on experience of the examiner, is more sensitive to subtle changes in anatomical structure, and allows comprehensive statistical analysis. It could also the physician in the correct interpretation of the sono-anatomy.

It is our opinion that using ultrasonography can accommodate differentiation between the majority of clinical emergencies, mainly heart and/or lung failure, allowing an "early goal-directed therapy" as well as obtaining information on the volemic status noninvasively at the bedside. A flowchart explaining the possible applications of ultrasound in critically ill patients is shown in figure 1. The main characteristics considered for the lung, inferior vena cava, and heart are normal, wet, dry, or consolidated/atelectatic lungs. At ultrasonography: the normal lung is characterized by horizontal lines; the wet lung is characterized by vertical lines (narrow lines indicate interstitial edema, whereas larger lines indicate alveolar edema); and the consolidated/atelectatic lung is characterized by "tissue-like sign" with regular trabeculations reminiscent of a liver. Consolidation can be discriminated from atelectasis because it is not modified by increasing transpulmonary pressure at end inspiration or expiration. Pneumothorax is suspected when the pleural sliding is absent, *i.e.*, lung point; by normal, decreased, or increased dis-

tension of the inferior vena cava; or by normal or impaired heart function. In emergency conditions, it is essential to limit the examination to only these sonographic signs: the size (normal, enlarged, reduced) and the motion (normal or impaired) of the anatomical structures; the color code interpretation of black, gray, and white (liquid, tissue parenchyma, or air, respectively), to better define normal or abnormal localization and extent; and the flow analysis based on immediate display of colors (red and blue).

The dry lung might be associated with heart failure in presence of expanded vena cava or hindered flow in presence of collapsed vena cava. The wet lung might be associated with heart failure, in presence of expanded vena cava, or lung failure, *i.e.*, acute respiratory distress syndrome in presence of variable dimension of vena cava. The consolidated lung is associated with atelectasis or pneumonia. The lung point, or the absence of pleural sliding, indicates air in the pleural space, such as pneumothorax.

In conclusion, ultrasonography has become an invaluable tool in the management of critically ill and injured patients, which makes it imperative for critical care physicians to stay up-to-date with this advanced modality.

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