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POINT OF VIEW

Clinical ultrasound in the ICU: Changing a medical paradigm☆

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Abstract In recent decades there has been an evolution from the traditional paradigm of sporadic ultrasound performed by radiologists and cardiologists in the ICU to clinical ultrasound performed by intensivists as an extension of patient evaluation rather than as a complementary test. Such clinical ultrasound aims to diagnose and treat the patient directly. All ultrasound modalities could be interesting in the ICU, either helping in decision making or guiding procedures. Clinical ultrasound training should include all the possibilities of ultrasound, and the tutelage of other trained intensivists and other specialists with more experience should be available at all times. Training should be phased into basic, advanced and expert levels, with adjustment to the contents of the CoBaTrICE Project and the recommendations of the SEMICYUC.

PALABRAS CLAVE
Ultrasonografía;
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Ecografía clínica en la unidad de cuidados intensivos: cambiando un paradigma médico

Resumen En las últimas décadas se ha evolucionado desde el paradigma tradicional de la ecografía esporádica realizada en las UCI por radiólogos y cardiólogos hacia estudios ultrasonográficos realizados por intensivistas como extensión de la evaluación del paciente en lugar de como prueba de imagen complementaria. Esta ecografía clínica se orienta a diagnosticar y tratar directamente al paciente. Todas las modalidades de ultrasonografía pueden tener interés en la UCI, tanto para ayudar a tomar decisiones como para guiar la realización de procedimientos. La formación en ecografía clínica debería incluir todas las técnicas de ultrasonografía y

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debería contarse en todo momento con la tutela de otros intensivistas y otros especialistas con mayor experiencia. La formación debería escalonarse en niveles básico, avanzado y experto, y ajustarse a los contenidos del Proyecto CoBaTrICE y a las recomendaciones de la SEMICYUC.

Introduction

Major changes are sporadically experienced in medicine, including technological innovations and modifications in operating protocols and in the profiles of the specialists that apply them. One such major change has been ultrasound.

Clinical ultrasound in the intensive care unit

Intensive care units (ICUs) have evolved from the traditional paradigm comprising sporadic ultrasound explorations made by radiologists and cardiologists to a new concept of clinical ultrasound performed by intensivists as an extension of patient evaluation instead of a mere complementary imaging technique.[1] This new approach implies prompt execution resulting in rapid action, and reflects the needs of intensivists. An example of the change in paradigm is provided a study carried out in an ICU in Paris, in which the diagnostic precision was found to be similar in application to major thoracic and abdominal syndromes on comparing 8 experienced radiologists versus 8 residents in Intensive Care with training in ultrasound. However, while the residents completed the ultrasound explorations in 37 ± 39 min from the time of indication, the radiologists took 296 ± 487 min counting from the moment of request of the exploration ($p = 0.004$).[2]

The new paradigm

The initial ultrasound assessment of a critical patient performed by an intensivist includes the characterization of respiratory failure or shock, and orientation of the required treatment.[3,4] In this regard, we evaluate variations in the diameter of the inferior vena cava, the existence of pericardial effusion, right and left ventricular function, the presence of lung congestion and consolidation, pleural effusion, the presence of ascites, the condition of the gallbladder, kidney morphology, the integrity of the abdominal wall, and the presence or absence of deep venous thrombosis of the lower extremities. Ultrasound allows us to detect lung congestion, pneumonia, bronchopneumonia or acute respiratory distress syndrome associated to sepsis, and facilitates the early diagnosis of possible treatment complications such as pneumothorax secondary to central venous puncture or lung congestion following fluid infusion.[5] An adequately trained intensivist could perform this full initial ultrasound assessment in no more than 15 min.[6]

Clinical ultrasound is useful in intensive care, and all its modalities may be of interest in the ICU, both for decision making and providing guidance in performing procedures (Table 1). A prospective multicenter study conducted among 142 ICUs in France, Belgium and Switzerland recorded a daily prevalence of ultrasound explorations performed by intensivists of 55% (1073 explorations in 1954 patients). Ultrasound was used for diagnostic purposes in 87% of the cases, and afforded orientation on the procedures to be carried out in 13% of the cases. The use of the technique influenced the diagnostic and management strategies in 84% and 69% of the cases, respectively.[7] Non-published data from a survey conducted in 2015 in 20 ICUs in the Community of Madrid (Spain) yielded comparable results, with an annual prevalence of explorations of 58% (9649 explorations in 16,774 patients).

Clinical ultrasound performed by intensivists in the ICU has a bearing upon each of the 6 fundamental domains of the current concept of quality care: safety, effectiveness, efficiency, equity, opportunity and ''patient centrism''.[8] By using clinical ultrasound, patient management in the ICU can be safer, shortening the time to diagnosis, and reducing diagnostic errors, the time elapsed between diagnosis and treatment, and errors in performing treatment procedures. The effectiveness and efficiency of the interventions are favorably modified, with a cost/benefit ratio that is very hard to exceed with any other healthcare technology. Clinical ultrasound can be performed on an equity basis in the course of a single day among all the patients admitted to the ICU, and its opportune character (''I need it here and now; I have it here and now'') is evident. Lastly, the intensivist – critical patient relationship becomes even closer thanks to the direct intervention afforded by clinical ultrasound, with no need for moving the patient to some remote location unfamiliar to him or her, and without the need for intervention by other specialists unrelated to his or her care.

It is essential for intensivists performing clinical ultrasound in the ICU to be aware of their limitations and of the need to resort to specialists with greater expertise in specific ultrasound techniques when the exploration findings can lead to decisions that might have important consequences for the patient in the event of diagnostic or treatment error. The ultrasound findings should never be the only information taken into account in making decisions: it is essential to integrate the data afforded by the technique with the clinical condition of the patient and the rest of the monitoring and complementary test information obtained.

Training requirements

Nothing of what has been commented above would make sense without adequate training of the intensivist. A training program in clinical ultrasound should contemplate a balance of all the ultrasound techniques (Table 2). The CoBaTriCe capacitation program, based on competences in Intensive Care Medicine in Europe, and which has been led by the European Society of Intensive Care Medicine with the active participation of the Spanish Society of Intensive Care Medicine and Coronary Units (*Sociedad Española*

Table 1 Application of ultrasound in the intensive care unit.

Body location	Ultrasound diagnosis	Ultrasound-guided interventions
Head	Diameter of the optic nerve sheath Position of the midline, hydrocephalia and hematomas Transcranial Doppler ultrasound	
Neck	Condition of the airway Carotid artery disease Vertebral artery disease Jugular vein thrombosis Presence of adenopathies	Catheterization of the internal jugular vein Endotracheal intubation Percutaneous tracheotomy
Thorax	Position of the endotracheal tube Detection of atelectasis Detection of pneumothorax Diagnosis of pneumonia Monitoring of lung recruitment Diagnosis of lung edema Quantification and classification of pleural effusion Study of the diaphragm Basic and advanced echocardiography Chest trauma ultrasound (contusions, fractures, hemothorax, etc.)	Pneumothorax drainage Thoracocentesis Pericardiocentesis Catheterization of the axillary and subclavian veins
Abdomen	Detection of hydronephrosis Detection urinary retention FAST Free intraperitoneal fluid Abdominal wall hematomas Acute cholecystitis Acute aortic syndrome Detection of liver disease, its complications and signs of portal hypertension Detection of embolic intestinal ischemia (edema of loops and obstruction of the superior mesenteric artery)	Paracentesis
Extremities	Femoral and popliteal venous thrombosis Presence of arterial flow in distal zones when ischemia is suspected Detection of complications of vascular access techniques (pseudoaneurysms, fistulas)	Catheterization of the femoral artery and vein Peripherally inserted central catheters and peripheral lines Sampling for blood cultures
General	Hematomas and foreign bodies Edema, myositis and cellulitis Evaluation of polyneuropathy/myopathy in the critical patient	Hematoma puncture

de Medicina Intensiva, Crítica y Unidades Coronarias [SEMICYUC]), includes training in different ultrasound modalities among its 12 domains and 102 competences, and the current approach to clinical ultrasound in the ICU would extend it to practically all of them.[9]

As in the rest of areas of Intensive Care Medicine, training in clinical ultrasound should be structured into basic, advanced and expert levels. The Working Group in Cardiological Intensive Care and CPR of the SEMICYUC (GTCIC-RCP) has published a consensus document defining the certification requirements referred to ultrasound use in critical patients and acquisition of the necessary skills.[10] However, authorship of the guidelines by a cardiological working group (with possible bias in the distribution of topics and time periods), and recognition of the prior experience of those intensivists who already perform ultrasound in the ICU, could delay and complicate implementation.

A number of barriers face the development of clinical ultrasound in the ICU – the most important undoubtedly being the lack of official certifications.[11] In Spain there are a series of university titles, but their contents are not adapted to the recommendations of the CoBaTriCe project or the GTCIC-RCP consensus document. The basic or advanced nature of the training activities in clinical ultrasound should be unequivocally specified. In this regard, the expert level should be reserved for activities with the homogeneity, official character and curricular value afforded for example by the creation of a specific interdisciplinary capacitation area set within the context of the national specialist training system.[12]

Table 2 Training contents of a basic upgrading course in clinical ultrasound in the intensive care unit (www.somiama.org) for intensivists.

Area	Contents
1. Physical principles and equipment	1.1. Physical principles 1.2. Ultrasound systems
2. Ultrasound by systems	2.1. Respiratory apparatus 2.2. Cardiac ultrasound 2.3. Vascular ultrasound 2.4. Abdominal ultrasound 2.5. Genitourinary system 2.6. Musculoskeletal ultrasound 2.7. Brain ultrasound
3. Ultrasound by syndromes	3.1. Cardiac arrest 3.2. Shock 3.3. Respiratory failure 3.4. Trauma 3.5. Sepsis 3.6. Acute renal failure 3.7. Stroke 3.8. Intracranial hypertension
4. Ultrasound-guided interventions	4.1. Artificial airway 4.2. Thoracocentesis 4.3. Pericardiocentesis 4.4. Paracentesis 4.5. Vascular accesses 4.6. Fluid drainage 4.7. Other interventions (e.g., temporary or permanent pacemakers)

Conclusions

The technological developments of the last few decades have facilitated implantation of the concept of clinical ultrasound in the ICU. The change in the traditional paradigm includes application of the full range of ultrasound studies in all the phases of critical patient care. Clinical ultrasound performed by intensivists in the ICU influences the quality of care, with an impact upon safety, effectiveness, efficiency, equity, opportunity and ''patient centrism''. Evolution toward this new paradigm implies a series of initial and ongoing training requirements, structured into basic, advanced and expert levels, and adapted to the contents of the CoBaTriCe project and recommendations of the SEMICYUC.

Conflicts of interest

The authors declare that they have no conflicts of interest.

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