

## Chest ultrasound integrated teaching of respiratory system physiology to medical students: a first experience

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ULTRASOUND IMAGING is a useful diagnostic technique that has spread among several different medical specialties within the last few years. Initially restricted to radiology, cardiology, obstetrics, and gynecology, today it is widely used by many specialists, especially in critical care. Technological improvements have led to the construction of high-definition and increasingly smaller devices and have enabled the creation of the so-called “bed-side ultrasound.”

New graduate physicians will need to be comfortable with ultrasound technologies and competent in the interpretation of ultrasound images for the well-being of patients(2), so the ultrasound technique has been included in current clinical teaching to medical students at university, but most of the time only by showing images or videos, without adding practical activities.

Hoppmann et al. (4), Bahner et al. (1), and Kessler and Bhandarkar (6), in contrast, have proposed year-long ultrasound practical activities with accompanying lectures. The aim was to provide a solid basis to newly graduated students, so that they will be able to use this technique by themselves.

Traditionally, the teachings of preclinical subjects, such as human anatomy or physiology, are based only on frontal lectures with slides, on cadaver dissections, and on personal study (1). However, in medical literature, several experiences of ultrasound-integrated anatomy teaching have been described with positive and convincing results (2, 3, 5, 7-10). The only experience of ultrasound-integrated teaching of physiology has been made by Hammoudi et al. (3) about the heart.

Our goals were to integrate chest ultrasound into the traditional teaching of the respiratory system physiology and to evaluate if it was possible, in terms of practicality and time spent, using this technique.

In November 2013, at the end of the course in human physiology, third-year medical students attended an ultrasound-integrated lecture at the Medical University of Padova (Padova, Italy). All students had previously passed the human anatomy exam, taken during the second academic year. They had never had ultrasound experiences before, because the ultrasound technique is taught after the preclinical subjects (in the fourth academic year).

The lectures were delivered by an expert sonographer physician (M. Paganini) supported by the professor (A. Rubini) of human physiology. Each lecture lasted ~45 min and was divided into three parts.

The first part, which lasted ~15 min, consisted of an introduction on specialized terms such as hyperechoic, hy-

poechoic, anechoic, acoustic bioimpedance, acoustic interface, and probe spatial orientation. The details of image formation and technical components of ultrasound physics were not discussed, because they are part of the radiology course. The introduction was followed by an explanation of the capacity of the ultrasound technique to show dynamically and in vivo the anatomy, physiology, and pathology of patients and by a comparison between ultrasound and static techniques, such as the standard chest radiograph technique. Students were given the basics to understand ultrasound images.

In the second part, which lasted ~20 min, a male student volunteered to undergo a real-time ultrasound scanning, which was commented and performed by the sonographer with a portable M-Turbo ultrasound device (Sonosite Fujifilm, Bothell, WA) and a Convex probe (2–5 MHz). The volunteer provided verbal consent. Images were projected on a big screen in standard definition, so that every student could see them from their seats. The sonographer was supported by the professor, who commented every image recalling physiology concepts he had previously explained in his lectures. Four anatomic sectors of particular interest and easy to understand for beginners were shown in B-mode. First, the students were shown movements of the visceral and parietal pleura during the respiratory cycle (pleural sliding), in lengthwise and crosswise projections on the anterior chest wall. Second, the diaphragm was visualized in long-axis and oblique views on the lateral chest wall, and its excursion was shown during normal breathing (curtain sign), after maximal inspiration and maximal expiration. Third, the inferior vena cava was displayed in long axis along the epigastric region, where the inferior vena cava joins the right atrium; its diameter reduction during normal and maximal inspiration was displayed. Finally, heart movement was shown in the apical four-chamber view.

In the third and final part, which lasted ~10 min, short videos about main pathologies detectable with chest ultrasound were projected with commentaries referring to physiology abnormalities and alterations. In particular, students were shown ultrasound reports of cardiogenic pulmonary edema, noncardiogenic pulmonary edema, pneumonia, and pneumothorax. By showing to the class a case of pulmonary embolism, right ventricular strain and overload were highlighted and compared with the normal contraction of the healthy heart (septal shift, right ventricular dilatation).

Ours is the first attempt to introduce chest ultrasound into traditional physiology teaching of the respiratory system as a tool that can help the professor show in vivo the function and anatomic relations among respiratory system components as well as the structures around them. Compared with a standard lesson, where the professor shows several static images and explains key concepts only relying on those, a ultrasound-based lesson could be more effective because the professor

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could show what is happening inside the human body right in that moment. If we think that the ultrasound is used to answer specific questions in the clinical setting, it could be used during a physiology lesson to answer students' questions as best as possible, directly showing and explaining what they want to know and see.

In particular, we chose a portable ultrasound device because of its feasibility and simplicity of use. We used only the Convex probe to show anatomy and physiology in wide panoramic views and zoomed in on details if necessary. A high-frequency linear probe, as commonly used in clinical chest ultrasound and visualization of the pleural line, would have shown only particulars and images would not have been so understandable to students such as panoramic views.

Students' general opinions seemed to be positive, according to an anonymous questionnaire delivered at the end of the lecture; they also verbally approved and widely confirmed the positive value of ultrasound as an educational tool, because they were particularly impressed by its being so simple and capable to represent anatomy, physiology, and pathology in real time.

This time they needed the help of the sonographer to correctly understand the images projected, but some other research in the literature has suggested that the use of ultrasound in many times could help students to get acquainted with this technique (1, 4, 6). For this reason, the integration of ultrasound into the whole physiology syllabus and traditional teaching should be investigated in the future and be compared with a single lecture experience.

The evaluation of ultrasound as a teaching tool in other systems, an objective analysis on exam performance, and long-term concept retention could be interesting as well.

In conclusion, in the modern era, where technology answers the physicians' clinical questions, ultrasound may also assist students in better understanding their foundational science: they could see anatomic sections or organs moving while the professor is talking about them. This experience suggests that ultrasound could also be a didactic tool, which students appreciated very much. In particular, chest ultrasound could support effectively the traditional teaching of respiratory physiology. According to the new concept of "ultrasound-based education," this experience is a spur to an even better integration of

ultrasound into preclinical subjects, so that students could become familiar as soon as possible with this new technique and have an earlier performance of it during clinical subjects.

#### DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the author(s).

#### AUTHOR CONTRIBUTIONS

Author contributions: M.P. and A.R. conception and design of research; M.P. and A.R. performed experiments; M.P. analyzed data; M.P. interpreted results of experiments; M.P. drafted manuscript; M.P. edited and revised manuscript; M.P. and A.R. approved final version of manuscript.

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