Ultrasound-based teaching of cardiac anatomy and physiology to undergraduate medical students

Utilisation des ultrasons pour l’enseignement de l’anatomie et de la physiologie cardiaque en premier cycle des études médicales

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Summary
Background. — Ultrasonography is a non-invasive imaging modality that offers the opportunity to teach living cardiac anatomy and physiology.
Aims. — The objectives of this study were to assess the feasibility of integrating an ultrasound-based course into the conventional undergraduate medical teaching programme and to analyse student and teacher feedback.
Methods. — An ultrasound-based teaching course was implemented and proposed to all second-year medical students (n = 348) at the end of the academic year, after all the conventional modules at our faculty. After a brief theoretical and practical demonstration, students were allowed to take the probe and use the ultrasound machine. Students and teachers were asked to complete a survey and were given the opportunity to provide open feedback.

KEYWORDS
Ultrasound; Anatomy; Undergraduate; Education; Physiology

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Results. — Two months were required to implement the entire module; 330 (95%) students (divided into 39 groups) and 37 teachers participated in the course. Student feedback was very positive: 98% of students agreed that the course was useful; 85% and 74% considered that their understanding of cardiac anatomy and physiology, respectively, was improved. The majority of the teachers (97%) felt that the students were interested, 81% agreed that the course was appropriate for second-year medical students and 84% were willing to participate to future sessions.

Conclusions. — Cardiac anatomy and physiology teaching using ultrasound is feasible for undergraduate medical students and enhances their motivation to improve their knowledge. Student and teacher feedback on the course was very positive.

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Résumé

Contexte. — L'échographie est une modalité d'imagerie non invasive qui peut servir à l'enseignement de l'anatomie et de la physiologie cardiaque.

Objectifs. — Étudier la faisabilité de l'intégration d'un module d'enseignement basé sur les ultrasons au programme pédagogique des études médicales et d'évaluer la perception de cet enseignement par les étudiants et les enseignants.

Méthodes. — Un programme d’enseignement basé sur les ultrasons a été proposé aux étudiants inscrits en deuxième année dans notre faculté (n = 348). Après un rappel théorique et une démonstration pratique, les étudiants ont utilisé les appareils d’échographie. La perception de l’enseignement a été évaluée à la fin de chaque session à l’aide d’un questionnaire électronique.

Résultats. — Deux mois ont été nécessaires pour mettre en place le module ; 330 (95 %) étudiants répartis en 39 groupes, ainsi que 37 enseignants ont participé à l’enseignement. Les appréciations des étudiants ont été positives : 98 % des étudiants ont estimé que l’enseignement a été utile ; respectivement 85 % et 74 % ont estimé que leur compréhension de l’anatomie et de la physiologie cardiaque a été améliorée. La majorité des enseignants (97%) a constaté que les étudiants ont été intéressés par les séances, 81 % ont estimé que le module était adapté au niveau des étudiants et 84 % se sont déclarés volontaires pour encadrer d’autres séances.

Conclusions. — L’instauration d’un module d’enseignement d’anatomie et de physiologie cardiaque basé sur les ultrasons au cours du premier cycle des études médicales est faisable et augmente la motivation des étudiants pour approfondir leurs connaissances. Les commentaires des étudiants et des enseignants ont été positifs.

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Background

Teaching of anatomy and physiology during medical studies relies mainly on textbooks, lectures and dissection of cadavers. Ultrasonography is routinely used in clinical practice and an increasing number of physicians are trained for its everyday use [1]. Modern ultrasound machines are less cumbersome and more user friendly than older machines [2]. In this context, encouraging ultrasound-based teaching experiences of anatomy have been reported [3–6], but to the best of our knowledge, none has studied the teaching of physiology using ultrasound and limited data are available on the practical aspects of integrating an echography course into the conventional teaching programme. Moreover, ultrasonography is particularly relevant for exploring the heart, which is a dynamic organ. Thus, we decided to initiate an ultrasound-based teaching module, with the educational goal of enhancing the comprehension of cardiac anatomy and physiology of second-year medical students. The objectives of this pilot study were to assess the feasibility of delivering an ultrasound-based course to undergraduates and to explore the students’ and teachers’ perceptions of this promising teaching modality.

Methods

During May and June 2011, the ultrasound course was proposed to all second-year medical students at the Pierre et Marie Curie Faculty—Paris 6 University, located in Paris, France. Prior to the intervention, students had received the usual anatomy and physiology teaching and had already attended the scheduled written and practical examinations. None of the students had previous practical ultrasound experience.

All students were divided into small groups to allow better interaction between students and teachers and to facilitate access to the echocardiography machines. The objective was to include, in each group, at least two male volunteer students who had given prior informed consent to act as live models. In order to recruit teachers, e-mails explaining the project were sent through the university intranet to colleagues, including cardiologists and intensivists, who were familiar with the use of ultrasound and the interpretation of images and used echocardiography in their routine clinical practice. Teachers’ participation was on a voluntary basis.
The module was integrated into the regular programme, at the end of the academic year. Students’ participation was highly advised, but no written or oral examinations were conducted after the session. The course included a 3-hour single session divided into three parts. First, a brief theoretical introduction to the basics of ultrasound physics applied to medicine and a reminder of cardiac physiology and anatomy were performed by the teacher for 30 minutes using a standardized slideshow presentation. Teachers were asked to clearly explain to all students that the module was dedicated to the teaching of cardiac anatomy and physiology and certainly not to the use of ultrasound machines. Students were also told that ultrasound techniques must not be used instead of the clinical examination but in addition to it even though the applications of echocardiography to clinical practice were not addressed during the module.

Second, an explanation of the use of the ultrasound machine was carried out, followed by an ultrasound practical demonstration on a volunteer student for 30 minutes, including a description of the different echocardiographic windows, two-dimensional views and Doppler modes. During the third part, the students were given the opportunity to take the probe and use the ultrasound machine for 2 hours, with the objective of identifying the anatomical cardiac structures and interpreting the physiological phenomena that were described during the previous parts of the session.

All students were actively engaged through each phase, as they were constantly questioned on relevant cardiac anatomy and physiology during the course.

A classroom with a dedicated ultrasound laboratory and a computer were provided by the Pitié-Salpêtrière Hospital. The ultrasound equipment consisted of two Vivid 3 ultrasound units (GE Healthcare, Horten, Norway).

Using the two-dimensional mode, parasternal long-axis, parasternal short-axis, apical four-chamber, apical two-chamber and subcostal views were performed. Anatomical description and dynamic functioning of the great vessels and the heart’s structures, including ventricles, atria, valves and subvalvular mitral apparatus, were studied using these views. Colour Doppler-ultrasound was then performed to study arterial, venous and intracardiac blood flow. Pulsed-wave Doppler was used to display transaortic and transmitral blood flow patterns.

This approach allowed students to understand the cardiac cycle, including the systolic and diastolic phases. The blood flow through the four cardiac chambers, the filling and ejection periods, the co-ordination between the right pulmonary and left systemic circuits and the synchronized movements of heart valves were visualized.

The value and effectiveness of the course was evaluated through self-report anonymous questionnaires using a web-based instrument at the end of each session. This exit survey was also used to assess the students’ and teachers’ opinions and impressions. The survey consisted of four questions addressing student satisfaction, based on a ranking from 1 to 4 (totally agree, somewhat agree, somewhat disagree, totally disagree) and a free response area for listing the most and least useful elements of the project and suggestions for improvement. A specific survey was designed for teachers, following the same pattern.

The feasibility evaluation was based on the time required to implement the course and on the participation rates of students and teachers.

### Results

A period of 2 months was required to implement the course, including educational programme design, integration into the main syllabus, organization of teaching staff and students and obtaining the computer and ultrasound machines.

An initial 348 students were divided into 39 groups, of whom 330 (95%) effectively attended the course. The mean number of students per group was nine. Unfortunately, only one male student could be included in two groups. A total number of 37 teachers, including 21 intensivists and 16 cardiologists, participated on a voluntary basis. All demonstrators were fulltime doctors or professors working in teaching hospitals affiliated to the Paris 6 University.

The survey was completed by 301/330 (91%) students, with overall very positive feedback (Table 1). The course was considered useful by 98% of participants. Moreover, 85% and 74% of students considered that their understandings of cardiac anatomy and physiology, respectively, were improved. Enhanced motivation to learn cardiac anatomy and physiology was highlighted by 83% of students. A majority (66%) preferred the last part of the session, when they had the opportunity to use the ultrasound machine. Free text comments were made by 70 students (23%). They mostly emphasized the ‘entertaining’, ‘interactive’ and ‘practical aspects’ of the course that appeared to be ‘complementary to the lectures and dissection sessions’ and ‘very helpful to further enhance knowledge of anatomy and physiology’. Some participants suggested further

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Student feedback on the course (n=301).</th>
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<tbody>
<tr>
<td></td>
<td>Totally disagree</td>
</tr>
<tr>
<td>Useful</td>
<td>0</td>
</tr>
<tr>
<td>Improved understanding of cardiac anatomy</td>
<td>7 (2)</td>
</tr>
<tr>
<td>Improved understanding of cardiac physiology</td>
<td>11 (4)</td>
</tr>
<tr>
<td>Enhanced motivation to learn cardiac anatomy and physiology</td>
<td>2 (1)</td>
</tr>
</tbody>
</table>

Data are expressed as number (percentage).

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* a n = 300.
expansion of the ultrasound-based teaching approach to other organs.

All demonstrators completed the survey and results are shown in Table 2. The educational objectives were considered as reached at the end of the session in 95% of cases. Moreover, 97% of demonstrators considered that the students were interested and 81% agreed that the course was appropriate for second-year medical students. The third part of the course was considered to be the most relevant part by 60% of teachers. The majority (84%) of teachers were willing to participate in future sessions.

Free text comments were made by 21 teachers (57%). The 'great interest shown by the students for the course and especially the third part' was frequently highlighted. The 'limited number of male students' who could potentially act as live models was often reported. Some demonstrators considered that a 2-hour session would be sufficient and suggested that providing the slideshow to the students before the course, in order to shorten or suppress the first part of the session, would be beneficial. They also suggested the expansion of the course to include exploration of other organs. One teacher was 'doubtful about the long-term educational benefits of a single session'.

Discussion

We report our first experience of a comprehensive cardiac anatomy and physiology teaching programme based on ultrasound for undergraduate medical students. Despite the large number of students in our faculty, the implementation of the course was feasible in a relatively short period of time. Feedback from teachers and students was very positive overall.

The fact that students valued the use of ultrasound highly consistent with data found in the literature. In a recent study, which assessed the use of ultrasound for teaching anatomy to undergraduates, more than 75% of students were satisfied, although they did not have the opportunity to use the ultrasound machine [3]. Our experience revealed that teachers and students found more relevance in the practical phase of the session, which combined education and entertainment. This part appeared to best stimulate the interest of students and encourage their desire to deepen their knowledge of anatomy. This result was previously described in a study assessing the usefulness of ultrasound-based technology to teach the anatomy of the thyroid, the forearm and intra-abdominal organs [7]. To the best of our knowledge, ours is the first study to also evaluate teacher feedback. Overall, teachers were enthusiastic, satisfied by the sessions and highlighted the curiosity and implication of students. A vast majority of teachers would volunteer to participate in this programme in the future.

In addition to lectures and anatomy textbooks, dissection is the traditional method of teaching anatomy [8]. Despite the emergence of innovative teaching methods, including interactive multimedia resources, students' perception of the importance of dissection remains intact [9]. A recent study that compared cardiac anatomy teaching using live ultrasound imaging and dissection showed similar substantial improvement of students' knowledge [10], underlining the fact that ultrasonography is not only an entertaining approach, but also an effective tool in terms of educational benefits. We believe that anatomy teaching using ultrasound should not replace dissection sessions, but should be part of an integrated approach in association with traditional methods. It has previously been described that combining imaging and traditional methods significantly improves short- and medium-term knowledge of anatomical structures [11,12]. Dissection remains irreplaceable to identify certain anatomical structures, such as nerves, and allows three-dimensional perspective and tactile perception. Moreover, dissection sessions constitute, for many students, the first confrontation with death [12].

Graphical simulation software to teach basic physiological principles of heart mechanics and a system based on the concept of simulating cardiovascular phenomena with equivalent electronic circuits have previously been proposed [13,14]. However, to the best of our knowledge, no studies have assessed the contribution of cardiovascular imaging to the teaching of physiology to undergraduates. Besides the possibility to analyse the cardiac morphology in two-dimensional echocardiography, the Doppler-ultrasound mode allows the study of haemodynamic variables [15], thus making this tool relevant for the teaching of living physiology. In our preliminary study, only basic principles of cardiac physiology were taught and the ultrasound technology appeared to really improve students' understanding.

Another point to emphasize is that the use of ultrasound technology is becoming more and more important in the everyday practice of many clinicians, especially in the diagnostic process, but also to guide procedures [1], and early exposure of medical students to this technique can only be beneficial [16].

Considering the high participation rate of students and teachers on a voluntary basis, the very positive feedback, the short period of time that was required to implement the course and the limited amount of equipment required, we conclude that integrating an ultrasound-based teaching
programme into the conventional curriculum is feasible. As we were convinced by this positive experience, we decided to further develop this new teaching method in 2012 by expanding the course to the teaching of the anatomy of intra-abdominal organs. Furthermore, we plan to use ultrasound to teach physical examination and pathology in the near future.

This study deserves several comments. First, knowledge of anatomy and physiology was not evaluated and only subjective elements were measured, such as confidence in knowledge, usefulness of the course and interest shown by students. Second, the long-term benefit of the course was not evaluated in this study. Third, two groups only included one male student, who therefore could not use the ultrasound machine during the third part of the session as he was acting as the live model. This is partly explained by the fact that 60% of students in our medical faculty are women. In the future, this problem should be solved with a better distribution of male students. Finally, the relatively high cost of ultrasound machines, the potentially limited access of educational institutions to these machines and the necessity to dedicate a non-negligible amount of time to this module in already heavy schedules may constitute limitations to the generalization of this teaching method.

Conclusions
Cardiac anatomy and physiology teaching using ultrasound imaging is feasible for undergraduate medical students and enhances their motivation to improve their knowledge. Student and teacher feedback was very positive. Ultrasound technology appears to be a complementary approach to conventional teaching methods, including dissection sessions, lectures and textbooks. Further studies, including students’ knowledge evaluation, are required to confirm the benefits of this method.

Disclosure of interest
The authors declare that they have no conflicts of interest concerning this article.

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