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REVIEW ARTICLE

Effect of ultrasonography on the teaching-learning of anatomy compared to cadaveric prosections: systematic review

Efeito da ultrassonografia no ensino-aprendizagem da anatomia comparada a peças cadavéricas: revisão sistemática

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ABSTRACT

Introduction: With the new curricular determinations in medical education and the difficulties in obtaining corpses, the need to include new teaching-learning methodologies in anatomy was seen. Ultrasonography can be a viable alternative, as it provides a visual-spatial, dynamic, and real-time assessment of anatomical structures. **Objectives:** Evaluate the effect of ultrasound in teaching-learning anatomy compared to the use of cadaveric specimens through a systematic review. **Methods:** It is a systematic review, in which articles were collected from the PubMed, LILACS and SciELO databases. With the keywords used, 3,963 articles were obtained. After reading the titles and abstracts, 27 articles were selected for complete analysis. Four were included for use after eligibility analysis. **Results:** Among them, two studies showed equivalent learning between the conditions of cadaver and ultrasound teaching. Two studies evaluated the association of methodologies (ultrasound plus cadaver study) comparing students exposed only to cadaveric parts. In one of them, the ultrasound group obtained higher scores than the control group, but with a moderate to small effect size, and the other study showed lower values in the ultrasound group, however, without statistical significance. **Conclusion:** This review showed favorable results for the use of ultrasound in the teaching of anatomy; however, few comparative studies with the use of cadaveric parts were carried out, which prevents the generalization of these effects. Therefore, more research is needed in order to obtain greater confidence for its inclusion in the teaching and learning of anatomy in medical graduation.

Keywords: Anatomy; Ultrasonography; Medical Education; Ultrasound.

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RESUMO

Introdução: Com as novas determinações curriculares na educação médica e as dificuldades na obtenção de cadáveres, foi verificada a necessidade da inclusão de novas metodologias de ensino-aprendizagem na Anatomia. A ultrassonografia pode ser uma alternativa viável, pois oportuniza uma avaliação visual-espacial, dinâmica e em tempo real das estruturas anatômicas. **Objetivos:** Avaliar o efeito da ultrassonografia no ensino-aprendizagem da Anatomia comparada ao uso de peças cadavéricas por meio de uma revisão sistemática. **Métodos:** Trata-se de uma revisão sistemática, na qual foram coletados artigos das bases PubMed, LILACS e SciELO. Com os descritores utilizados foram obtidos 3.963 artigos. Após a leitura dos títulos e resumos foram selecionados 27 artigos para análise completa. Quatro artigos foram inclusos para serem utilizados após análise de elegibilidade. **Resultados:** Dois dos estudos demonstraram aprendizagem equivalente entre as condições de ensino cadáver e ultrassom. Duas pesquisas avaliaram a associação das metodologias (ultrassonografia mais estudo com cadáver) comparando com alunos expostos somente a peças cadavéricas. Em uma delas o grupo com ultrassonografia obteve pontuações maiores que o grupo controle, mas com tamanho de efeito moderado a pequeno e a outra pesquisa apresentou valores inferiores no grupo ultrassom, no entanto, sem significância estatística. **Conclusão:** Essa revisão evidenciou resultados favoráveis ao uso da ultrassonografia no ensino da anatomia, entretanto, poucos estudos comparativos com o uso de peças cadavéricas foram realizados o que impede a generalização desses efeitos. Portanto, mais pesquisas são necessárias, a fim de obter maior confiança para a sua inclusão no ensino-aprendizagem da anatomia na graduação médica.

Palavras-chave: Anatomia; Ultrassonografia; Educação Médica; Ultrassom.

Introduction

Medical education in Brazil has been undergoing transformations determined by the National Curriculum Guidelines (DCNs)[1] of the undergraduate Medical course and these resulted in the implementation of new teaching-learning methodologies. Thus, to keep up with these changes, the educational institutions doctor are replacing the traditional method of discipline based on active methodologies, in order to interdisciplinary, the assimilation of theory with practice, the placing of the student at the center of the process and the experience of new educational experiences[2,3].

Anatomy is seen as one of the most significant components of medical education and teaching it through the cadaver is considered an approach to introducing traditional and humanistic goals into the student curriculum. One of its main advantages is the ability to learn the three-dimensionality of human anatomy[4], however, the dissection and deterioration of pieces over time destroy and distort the real anatomy[5,6]. Its use is limited by difficulties in obtaining cadavers and financial issues for storage and maintenance[7]. These limitations, together with the fact of the adoption of curricula in which the basic disciplines coexist with clinical medicine, have led to the removal of its use by some medical education institutions[8-10].

Therefore, the need for the introduction of new Anatomy teaching-learning methodologies was verified, such as the use of synthetic anatomical parts, virtual reality, body painting, ultrasonography (USG), and others[11]. USG is a form effective to visualize structures and has been used by doctors for over half a century as a tool to assist the diagnosis and guidance procedures. It has made a great and lasting impact on modern medicine and its applicability continues to expand[8].

Over the past two decades, ultrasound (US) equipment has become more portable and has higher image quality. Such developments have provided an increasing popularization of USG and its use in medical schools has become a tool in the teaching-learning process of anatomy, allowing a virtual dissection of the human body in a lively and dynamic way. Thus, it is a method that provides a visual-spatial and real-time assessment of anatomical structures and their relationships[12,13], in addition to not offering radiation, being accessible, repetitive and devoid of degradation[11,14,15]. Still, there are obstacles to its use as a specialized instruction, the basic ultrasound knowledge and limitations in the view of some organs due to the fact that gases and bones are bad conductors of sound waves[5,8,16].

Thus, considering ultrasonography as an important teaching-learning tool, the present study aimed to evaluate the effect of ultrasonography in the teaching-learning of anatomy compared to the use of cadaveric specimens through a systematic review.

Methods

This is a systematic literature review, carried out between March and August 2020, on ultrasound in the study of anatomy, in which articles were collected, without date restriction, in the Scientific Electronic Library Online (SciELO) databases, Public Medline (PubMed) and Latin-American and Caribbean Literature in Health Sciences (LILACS), using as search terms, in the PubMed and LILACS databases: "anatomy" and "education, medical" and "ultrassonography", and in SciELO the descriptors: "anatomy" and "medical education" and "ultrasonography" or "ultrasound".

The inclusion criteria were articles with controlled studies that had an intervention group with the application of US in the teaching-learning of anatomy and a control group with the use of cadaveric prosections, articles with an established focus on the study of Anatomy through US and students of the medical school as research participants. Duplicate studies in the analyzed databases that did not respect any point of the aforementioned criteria were excluded.

For data extraction was realized to primarily a screening of articles analyzing their titles and abstracts. Was evaluated after this, the eligibility of articles selected by reading the full text according to criteria inclusion and exclusion. The entire study selection process was carried out by a pair of reviewers independently and then discussed together.

The articles included were identified according to the study design approached according to Boet et al. (2012)17, who classifies the types of studies used in medical education, with two articles of the randomized clinical trial type and two post course-controlled studies.

Results

After searching the databases, 3,963 articles were obtained and after reading titles and abstracts, 27 articles were identified compatible with the theme of the review. Among them, four were selected to be used after eligibility analysis (Figure 1).

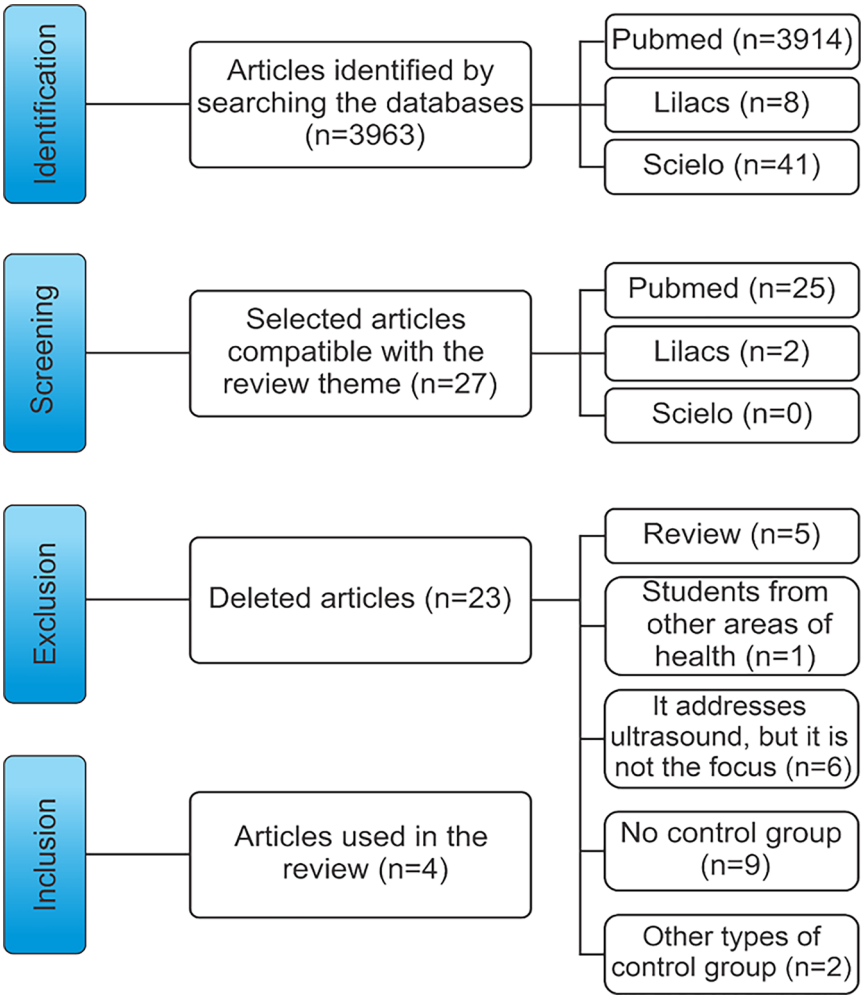

Figure 1. Flowchart of the article selection process.
Source: Prepared by the authors according to the PRISM Diagram.

The articles included evaluated the effect of ultrasound on the teaching-learning of anatomy by comparing it with control groups that used a cadaver and for data extraction were identified in each of them: authors, year, country, population, tests, anatomy addressed, statistical analysis, results, and conclusions. To illustrate the main quantitative results, a table was created in which the scores of the students in the post-test, the percentage of increase in the pre-test score after intervention and statistical analysis were described (in all studies, $p<0.05$ was considered statistically significant) (Table 1).

Griksaitis et al. (2012)[18] carried out a randomized clinical trial that evaluated 108 first-year medical students teaching and learning cardiac anatomy in a 30-minute session, randomized into two groups, one of which experimented with teaching using cadaveric heart prostheses and the another was instructed on the same anatomy through US. A pre-test was applied two weeks prior to assess the prior knowledge and test immediately after the end of the study, which resulted in 85% yield for the cadaver group and 85.1% for ultrasound group (Table 1). Digitization of ultrasound images was performed on a volunteer by a clinical professor.

In another randomized clinical trial, carried out by Canty et al. (2015)[5], 39 second-year students were evaluated after a lecture on cardiac anatomy, they were divided into two groups, one using an ultrasound simulator and the other using cadaveric specimens and models synthetic, lasting for three hours in each group. Participants were given learning objectives for a self-directed study. In the simulator group, the students themselves manipulated the portable transthoracic probe and, to assess the performance, pre and post-tests were performed. In the post-test, the control group had 64% as a result and the ultrasound had 68% (Table 1).

In both articles mentioned, student pretest scores were similar. In the study by Griksaitis et al. (2012)18 the cadaver group reached 53.8% vs. 53.6% of the ultrasound group, with p-value = 0.947 while in the study by Canty et al. (2015)5, the cadaver group had 47.8% vs. 48.3% of the ultrasound group, with p-value = 0.9. These results indicate equivalent basic knowledge in cardiac anatomy between the two groups. Students improved significantly from pre-test to post-test evaluation in both groups, with a significance level of less than 0.05 (Table 1). When comparing the gain of the two, there was no difference in the scores between them, thus demonstrating that the two teaching conditions were equivalent for teaching-learning in cardiac anatomy in these two analyzed studies.

The two other articles included are controlled post-course studies, however, the study by Jamniczky et al. (2017)[12], was not randomized because it had a historical control group.

Table 1. Quantitative results of studies

Authors, year, country.	Test score after intervention (post-test)		Pre-test score gain after intervention		Statistical analysis
Griksaitis et al. (2012)[18], England.	Cadaver Group	Ultrasound Group	Cadaver Group	Ultrasound Group	-Test t ($p<0.05$); -ANOVA: difference between groups; -T here was no statistical difference between groups.
	85.0% (SD±15.7%)	85.1% (SD±13.5%)	31.66%	31.63%	
Canty et al. (2015)[5], Australia.	64.0% (SD±9.9%)	68.0% (SD±9.6%)	16.4% (SD±10.2%)	19.8% (SD±12%)	
Jamniczky et al. (2017)[12], Canada.	**Theoretical-practical test:** 78.8% (SD±8.5%) **Global theoretical test:** 80. 0% (SD±7.7%)	**Theoretical-practical test:** 82.4% (SD±8.6%) **Global theoretical test:** 82.0% (SD±7.1%)	———	———	-Test t ($p<0.05$); -Cohen's test: effect size; -The ultrasound plus cadaver group had higher scores, with small to moderate effect size.
Knobe et al. (2012)[19], Germany.	**Theoretical test** (15 points): 11.3 **OSCE** (80 points): 70.8	**Theoretical test** (15 points): 11.1 **OSCE** (80 points): 67.0	———	———	-Test t ($p<0.05$); -ANOVA: difference between groups; -Fisher's exact test: evaluating the theoretical exam; -There were no significant differences between groups.

Legend: SD: Standard deviation; OSCE: Objective structured clinical examination; p: Level of significance; ANOVA: Analysis of variance.
Source: Prepared by the authors.

Unlike the two studies previously reported, Jamniczky et al. (2017)[12] and Knob et al. (2012)[19] evaluated the additional effect of USG, presenting the two teaching conditions in the intervention group (cadaver and US) compared to a control group that was taught only by cadaveric prosections. Jamniczky et al. (2017)[12] compared first-year academics who had studied through traditional anatomy (historical control - 348 students) with those who were taught with the inclusion of ultrasound in the academic curriculum (161 students). The gastrointestinal system was approached with a training duration of around one hour. The students themselves generated the ultrasound images supervised by a preceptor. Learning was assessed by a theoretical-practical test and a general exam four weeks after the intervention. Students exposed to ultrasound-facilitated teaching scored significantly higher (p=0.001), with 82.4% on the theoretical-practical test and 82% on the overall theory test. The historical group obtained 78.8% in the theoretical-practical test and 80% in the global theoretical test with small to moderate effect sizes.

The research by Knob et al. (2012)[19] evaluated second-year students regarding the learning of musculoskeletal anatomy (shoulder and knee) in a 75-minute session for each group, divided into three: a control who studied anatomy only through cadaveric prostheses (88 students); another who received additional ultrasound training (84 students) after a cadaver study; and the third group that had an additional study with arthroscopy, but for this review only the comparative data of the control group with the US group were used. They were evaluated by a theoretical test of 15 points after one week and an objective structured clinical examination (OSCE) of 80 points after three weeks. In the first exam, students exposed to ultrasound scored 11.1 points and the control group 11.3; in the OSCE, the ultrasound group scored 67 points versus 70.8 in the control. There was no significant difference between them, with p-value greater than 0.05.

Discussion

The results show that there are a large number of studies involving the use of ultrasonography in anatomy, however, few researches proposed to compare the effect of ultrasound versus cadaver in the teaching-learning of anatomy.

The first two articles described, Griksaitis et al. (2012)[18] and Canty et al. (2015)[5], that compared the teaching-learning of cardiac anatomy through US and cadaver, showed favorable results for the use of US, as they demonstrated equivalent effects in teaching. It was then observed that, even though methodologies with different resources were used, ultrasound provided, as well as the cadaver, the ability to identify structures, have contact with a real anatomy of the heart and learning in groups[8,13].

Although they had this positive outcome, only two articles were carried out with the purpose of evaluating the effect of the USG in isolation when comparing it with cadaveric prosections, despite the extensive search carried out for this systematic review.

The other articles compared the learning of the association of ultrasound and cadaver with the use of cadavers only. However, Knob et al. (2012)[19] highlighted in their study the fact that US did not have a significant effect on the learning of musculoskeletal anatomy. On the other hand, the study Jamniczky et al. (2017)[12] obtained higher scores for the group exposed to ultrasound despite the small to moderate effect size. In this study, the inclusion of US in the anatomy of the liver, kidney, spleen and the relationship between the inferior vena cava, abdominal aorta and spine improved student performance[12]. This gain in learning can be mainly related to the ability of the US to demonstrate the relationship between the organs and interpret their dynamics[8,20].

In addition, in Italy, universities developed and implemented an anatomy educational project through the USG, which includes the musculoskeletal system, larger vessels, neck visceral spaces, most of the viscera contained in the thorax, abdomen, and pelvis. Thus, they concluded that this teaching model improved matching skills between palpation anatomy and ultrasound windows. However, the deeper structures were more laborious. As the students themselves used the US equipment, it was possible for them to compare results, learn from mistakes and improve their skills. They reported their experience with this equipment as an innovative, exciting, and engaging method[13].

One of the contributions of the USG to meaningful learning is that it enables an active methodology in which the student himself, when manipulating the probe and acquiring its images, can facilitate the development of skills and clinical reasoning, in addition to providing a context that helps the strengthening your professional identity[15,18]. By using something of medical practice in the early college years, uniting the basic to clinical, this method can possibly contribute, with a long-term retention, core competencies anatomy in clinical practice of medical student.

In addition, US plays a central role in medical diagnosis and therapy in primary, secondary and tertiary healthcare facilities and can also be a great teaching tool because of its advantages and accessibility. In addition, many US players are small and portable making them ideal for the purpose of teaching with academic[21]. McLachlan and Patten (2006)[14] report that physicians will likely encounter anatomy in their professional environment as live anatomy or imaging, and that these anatomical aspects should be taught during medical graduation. In this way, ultrasound provides a window into the "real practice" of the doctor's clinical anatomy.

Two of the articles, Griksaitis et al. (2012)[18] and Canty et al. (2015)[5], to be randomized clinical trials, provides a more robust understanding of the changing nature associated with an intervention that projects controlled post-stroke, as performed in the study Jamniczky et al. (2017)[12] and Knob et al. (2012)[19], as there is no baseline data collection, it is difficult to convincingly consider the reported changes[17,22].

Despite these types of studies described make possible the assessment of knowledge acquired after the application of an intervention and the comparison with the control group, there is still the difficulty in evaluating whether the reported results will be maintained over the time[17].

The articles reviewed in this study showed variations on the format of the application of the US in the teaching of anatomy, as a previous study (lectures), subject handler from the US and student teachers, but is so not influence the results of studies because there were not significant differences observed. Furthermore, medical students reacted favorably to the use of ultrasound in undergraduate studies with perceptions of improvements in their confidence in anatomical identifications and, in particular, in the relationships between organs[8,23,24].

Research by Royer (2019)[20] showed that teachers also have positive interpretations of the beneficial aspects of the US for teaching anatomy, and agreeing that it can enhance the anatomical knowledge. However, the same study showed that 65% of surveyed anatomists have little or no experience with ultrasound. If there is a minimal training, a non-practitioner, as an anatomist, can learn basic techniques of the US enough to use it as a teaching tool to view the anatomy alive[8,25].

The main limitation found was the small number of articles compatible with the proposal of the review, which compromises a more comprehensive conclusion, even if a vast search was carried out in the available literature. Another point is the fact that only two of the studies evaluated the use of US in isolation and, in addition, they were restricted to the cardiac area, which makes it difficult to extrapolate the positive results for the teaching of anatomy in general.

Thus, we suggest the development of research with a larger sample size and with methodologies that are similar to those described in this review, in particular, those carried out in the studies by Griksaitis et al. (2012)[18] and Canty et al. (2015)[5], as they are randomized clinical trials. A question for future studies is how the USG would best contribute to the teaching-learning process of anatomy: in isolation or in addition to cadaveric pieces?

Conclusion

The results of this systematic review showed data favorable to the use of ultrasound in teaching-learning anatomy. It is noteworthy that, only four articles were identified in order to compare the effect of using ultrasound versus corpse in the teaching of anatomy, which affects the comprehensiveness of these effects in this review.

The comparison of the two methodologies in isolation obtained similar results in anatomical learning, but research is limited to cardiac anatomy. Thus, the teaching-learning of anatomy through ultrasonography is not sufficiently scientifically based to be able to replace the cadaveric prosections in the teaching of cardiac anatomy.

Based on the articles analyzed on the association of US and cadaver or use of cadaveric parts in isolation, it is possible to verify that they favor the inclusion of the association in anatomical teaching. However, there is a need for more studies focused on this topic in order to prove the effectiveness of ultrasound in order to obtain greater confidence for its inclusion in the teaching and learning of anatomy in medical graduation.

Author's Contribution

Use CRediT – Contributor Roles Taxonomy as a reference (https://casrai.org/credit/).

Leonam Costa Oliveira: Conceptualization, Data curation, Formal analysis, Research, Methodology, Supervision, Validation, Original draft, Review and Editing.

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