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Impact of bedside ultrasound teaching on deep vein thrombosis in medical education

Impacto do ensino de ultrassonografia à beira do leito sobre trombose venosa profunda na graduação médica

Graciliano José França[1] graciliano.franca@up.edu.br
Amanda Terres Fausto[1] amanda.faustoo@gmail.com
Giulia Ferreira Tonon[1] giuliaf.tonon@hotmail.com
Julia Agibert Rohnelt[1] juliaagibert@hotmail.com
Kaori Tavares Kihana[1] kaoritavares@hotmail.com
Maria Luisa Gobbi Longhi[1] maluluisa@icloud.com
Sabrina Barancelli Pereira[1] sabrinabarancelli@gmail.com

ABSTRACT

Introduction: Virchow's triad characterizes deep vein thrombosis (DVT) as hypercoagulability, stasis of blood flow and endothelial injury. Vascular ultrasound is a "gold standard" technique used to expedite the diagnosis of patients presenting this condition and several studies demonstrate the benefits of teaching ultrasound use to undergraduates.

Objectives: This study aims to analyze the contribution of ultrasound to medical education and the early diagnosis of deep vein thrombosis.

Methodology: A cross-sectional study involving medical students, training them to use point-of-care ultrasound, along with pre- and post-tests to assess the technique's contribution to deep vein thrombosis (DVT) diagnosis, approved by the Research Ethics Committee.

Results: it was observed that after the educational intervention on Point of Care ultrasonography (POCUS), students' knowledge increased significantly, as reflected in improved scores on questions specifically related to signs, symptoms, and key diagnostic areas of the condition. This improvement is demonstrated by the substantial increase in post-test average scores and the statistical significance of the results ($p<0.001$).

Conclusion: The study concluded that training students in the use of Point of Care Ultrasonography (POCUS) provided a significant improvement in knowledge related to the diagnosis of deep vein thrombosis (DVT), underscoring the importance of including this training in the medical curriculum as a valuable tool for enhancing the understanding of Deep Vein Thrombosis.

Keywords: ultrasound; deep vein thrombosis; medical education; bedside diagnoses.

RESUMO

Introdução: *A tríade de Virchow caracteriza a trombose venosa profunda (TVP) por hipercoagulabilidade, estase venosa e injúria endotelial. O ultrassom vascular é um método "padrão ouro" para o diagnóstico dos pacientes que apresentam essa condição, e vários estudos demonstram o benefício do ensino da utilização do ultrassom para a graduação.*

Objetivo: *O presente estudo teve como objetivo analisar a contribuição do ultrassom para o ensino médico e o diagnóstico precoce de TVP.*

Método: *Trata-se de um estudo transversal que envolve alunos de Medicina, com o propósito de capacitá-los a utilizar o ultrassom e realizar os pré e pós-testes para analisar a contribuição do método para o ensino nas suspeitas diagnósticas de TVP, após a aprovação do Comitê de Ética em Pesquisa.*

Resultado: *Observou-se que, após a intervenção educacional sobre ultrassonografia Point of Care (Pocus), o conhecimento dos estudantes aumentou significativamente, refletindo uma melhora nos acertos de questões específicas sobre sinais, sintomas e locais de pesquisa da condição. Essa evolução é evidenciada pelo aumento expressivo na média de acertos do pós-teste e pela significância estatística dos resultados ($p < 0,001$).*

Conclusão: *O estudo concluiu que a capacitação dos alunos a respeito da utilização da ultrassonografia Pocus proporcionou uma melhora significativa no conhecimento sobre o diagnóstico de TVP, ressaltando a importância de incluir esse treinamento no currículo médico como ferramenta de aprendizado sobre TVP.*

Palavras-chave: *Ultrassonografia; Trombose Venosa Profunda; Educação Médica; Diagnóstico à Beira do Leito.*

[1] Universidade Positivo, Curitiba, Paraná, Brasil.

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INTRODUCTION

Deep Vein Thrombosis (DVT) is characterised by Virchow's Triad – endothelial injury, stasis of blood flow and hypercoagulability. The formation of thrombi in the venous system usually occurs in areas of stasis, predominantly in the lower limbs, due to the loss of the calf muscle pump in situations of immobilisation[1]. Its aetiology is multifactorial, involving genetic and acquired factors such as neoplasms, obesity, chronic diseases, advanced age, pregnancy and trauma[2,3].

Point of Care Ultrasonography (POCUS) can be highlighted as an early and effective method for diagnosing DVT, which can develop into complications such as pulmonary embolism[4]. This occurs when the thrombus migrates to the pulmonary arteries, obstructing blood flow and compromising oxygenation. The clinical signs of DVT, however, are non-specific and require a detailed anamnesis and physical examination[5].

In medical practice, ultrasound has been widely used, from monitoring chronic diseases to guiding procedures. In an emergency context, POCUS enables quick and assertive decisions. Bedside Compression Ultrasonography (CUS), is considered the most accurate non-invasive test for diagnosing DVT, and the absence of venous compressibility suggests the presence of intravascular thrombi[6].

The diagnostic accuracy of POCUS is greater when performed by well-trained doctors. Practical and active teaching approaches, such as that offered by the Parallel Ultrasound Hands-on (PUSH) course, favour anatomical learning and follow trends in modern clinical practice, where ultrasound has become an essential tool[7].

In this context, training medical students in the use of POCUS for the investigation of DVT emerges as an innovative strategy[8]. Its integration into medical training contributes to the acquisition of a valuable tool for clinical practice, which can reduce diagnostic time and enable earlier interventions, with possible clinical benefits[8].

In addition, practical ultrasound teaching promotes active learning, strengthens technical skills and consolidates anatomical-clinical reasoning[9]. Investing in the training of future doctors in POCUS represents a step forward in the modernisation of teaching and professional qualification, with a promising impact on health care[9].

Justification

Deep vein thrombosis is a prevalent condition in the population and it is extremely important to train future doctors to identify it more quickly using Point of Care Ultrasonography (POCUS).

OBJECTIVES

General Objective

To evaluate the effectiveness of training in ultrasonography for suspected venous thrombosis in undergraduate medical courses and its importance in training future professionals.

Specific Objectives

To compare the knowledge acquired by medical students before and after a theoretical-practical class on deep vein thrombosis, using an electronic form developed by the authors, thus evaluating the evolution of medical students' learning in ultrasound in medical education.

METHODOLOGY

This is a paired, prospective longitudinal study based on medical education. The data collection period ran from August to September 2024. The research participants were volunteer medical students who agreed to take part after the study was publicised by the lead researcher. All the research participants signed an informed consent form. The study was approved by the Research Ethics Committee of Positivo University on 15 April 2024 under the Certificate of Presentation for Ethical Appraisal number 78534524.5.0000.0093 and substantiated opinion 6.765.508.

The inclusion criteria were participants of both sexes, aged 18 or over and regularly enrolled in the Medicine course at Positivo University, following the criteria for voluntariness. To guarantee the consistency and integrity of the collected data, avoiding unilateral data entry, participants who were unable to complete the pre- or post-test questionnaire were excluded.

A total of 31 students regularly enrolled in the Medicine course at Positivo University were included. All the participants signed the informed consent form. A theoretical-practical class was held focussing on the use of ultrasound to investigate deep vein thrombosis. The practical was conducted using portable Sonosite M-Turbo ultrasound equipment from Fujifilm Sonosite, by medical students from Positivo University, who performed the examination on their fellow students and research participants under the guidance of the research professor, optimising the students' experience with Point of Care ultrasound (POCUS).

Participants were asked to fill in a form with information about their student profile, such as age, gender and semester of the course, as well as to complete a self-assessment of their prior knowledge about deep vein thrombosis (DVT) (pre-test). The post-exposition questionnaire (post-test) covered the same questions as the pre-test, with important aspects about the

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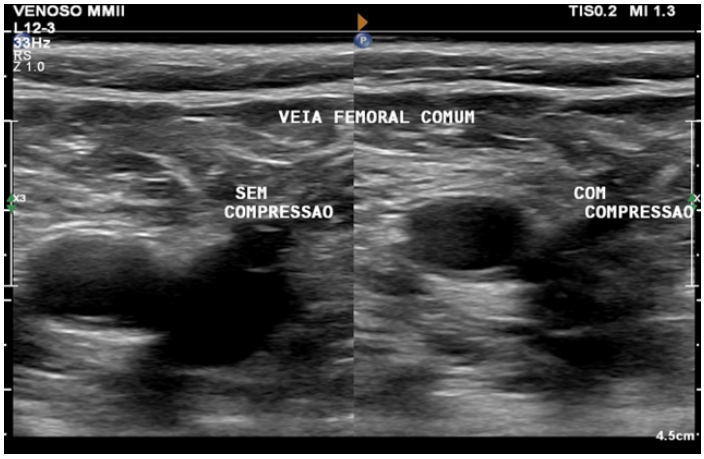
correct use of Point of Care ultrasound (POCUS) for diagnosing deep vein thrombosis in the clinical setting.

The ultrasound examination was conducted on healthy volunteer participants who had no suspicion of deep vein thrombosis. They were positioned in the supine position, with the lower limb flexed and in external rotation, following a specific compression protocol at three different venous points: the common femoral vein (FIgure 1), the femoral vein (Figure 2) and the popliteal vein (Figure 3). Venous compressibility was assessed by compressing the transducer over the areas mentioned, and the absence of luminal compressibility would indicate the presence of deep vein thrombosis.

The data collected was used exclusively for the purposes of this study, with the researchers fully committed to ensuring confidentiality and respect for the information obtained during the research. Data was collected using the Google Forms platform, which facilitated the virtual storage of information from the pre-test and post-test questionnaires answered by the volunteers.

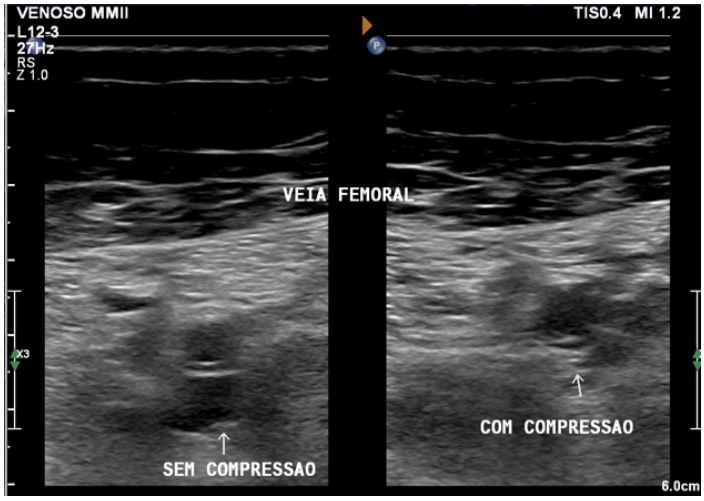
Means, medians and standard deviations were used to describe normal or non-normal distributions, depending on the normality of the data. The proportion was used for categorical variables. Associations between categorical variables were assessed using the chi-squared test, while differences in the means of continuous variables were compared using the paired t-test. The sample size (n) was calculated using the G-Power v. 3.1 software for a two-tailed paired t-test, considering a significance level of 5% and a statistical power of 80%; resulting in an n = 34. This survey reached 91% of the planned sample. The post-hoc analysis revealed a test power of 99%, as calculated by the same software. The statistical analysis was conducted using JAMOVI 2.6.2.0 for iOS.

Figure 1. PHOTOGRAPH OF THE COMMON FEMORAL VEIN – Cross-sectional ultrasound images of the common femoral vein at two different times: on the left, without compression, showing preserved vascular structure; on the right, with compression by the transducer, showing complete collapse of the venous lumen, evidence of a patent vein and absence of DVT.



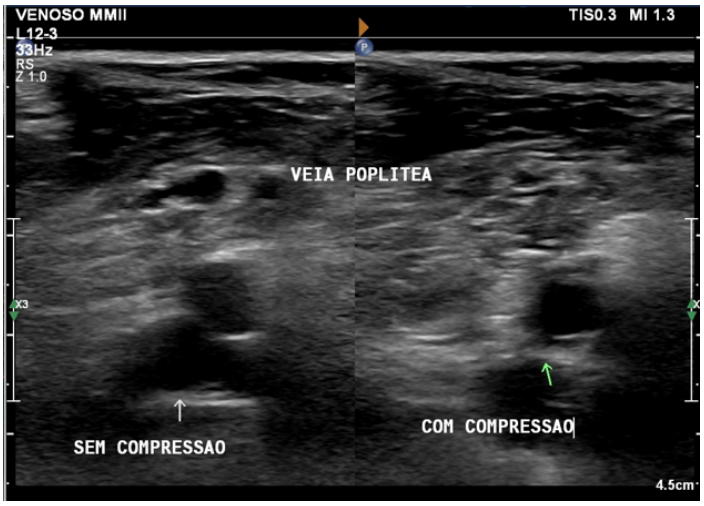
(SOURCE: the authors, 2024).

Figure 2. PHOTOGRAPH OF THE FEMORAL VEIN – Cross-sectional ultrasound images of the superficial femoral vein. On the left, the vein is seen uncompressed. On the right, total compression of the vein indicates no intraluminal material, characterising a patent vein.



(SOURCE: the authors, 2024).

Figure 3. PHOTOGRAPH OF THE POPLITEAL VEIN – Cross-section ultrasound images of the popliteal vein. The image on the left shows the vein without compression, while the image on the right shows the vein completely collapsed after compression of the transducer, excluding the presence of venous thrombosis.



(SOURCE: the authors, 2024).

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4. RESULTS

For the study, 31 answers were collected in the pre-test and post-test. The participants are 8th and 9th year undergraduate medical students at Positivo University, 27 of whom are female (87.1%) and 4 male (12.9%). In addition, the age of the volunteers ranged from 21 to 39.

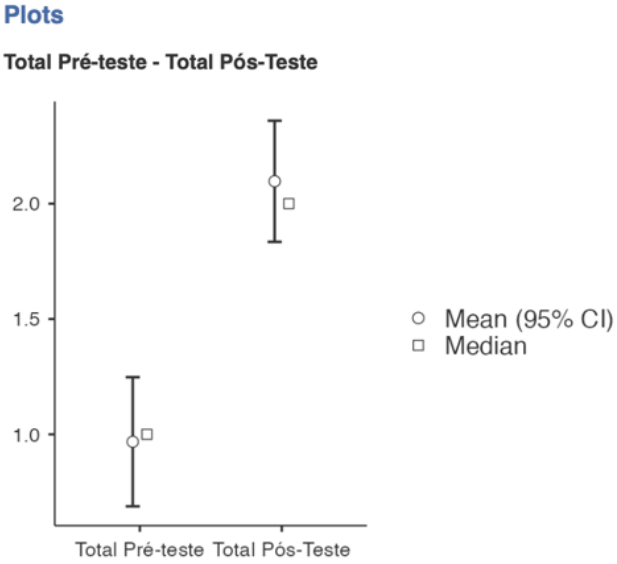
The questionnaire analysed the students' knowledge of the diagnosis of deep vein thrombosis, both in the pre-test and post-test. The questions covered suspicious signs or symptoms of deep vein thrombosis (DVT) (question 1), the main ultrasound sign for diagnosing deep vein thrombosis (DVT) (question 2) and the three main points for bedside investigation of deep vein thrombosis (DVT) (question 3).

Graph 1 shows that the mean and median increased after the test, indicating a significant increase in correct answers after the lesson. The average pre-test score was 0.968, with a standard deviation (SD) of 0.795. In the post-test, the average rose to 2.097, with a standard deviation of less than 0.746. The growth demonstrates the improvement in the participants' overall performance after the intervention, reinforced by the significant difference with $p<0.001$ and a rank by serial correlation of -0.908.

Graph 2 illustrates the growth in the number of correct answers given by the participants in the post-test, which is evident in all three questions, with the greatest emphasis and statistical relevance in questions 2 and 3. The results of the paired t-test showed an average difference of 1.1 points between the pre- and post-test scores ($t(30) = -5.95$, $p < .001$), indicating a significant improvement in the participants' knowledge. The effect size, measured by Cohen's $d = -1.06$, suggests that the educational intervention had a substantial impact, highlighting the effectiveness of Point of Care Ultrasound (POCUS) training for the diagnosis of deep vein thrombosis.

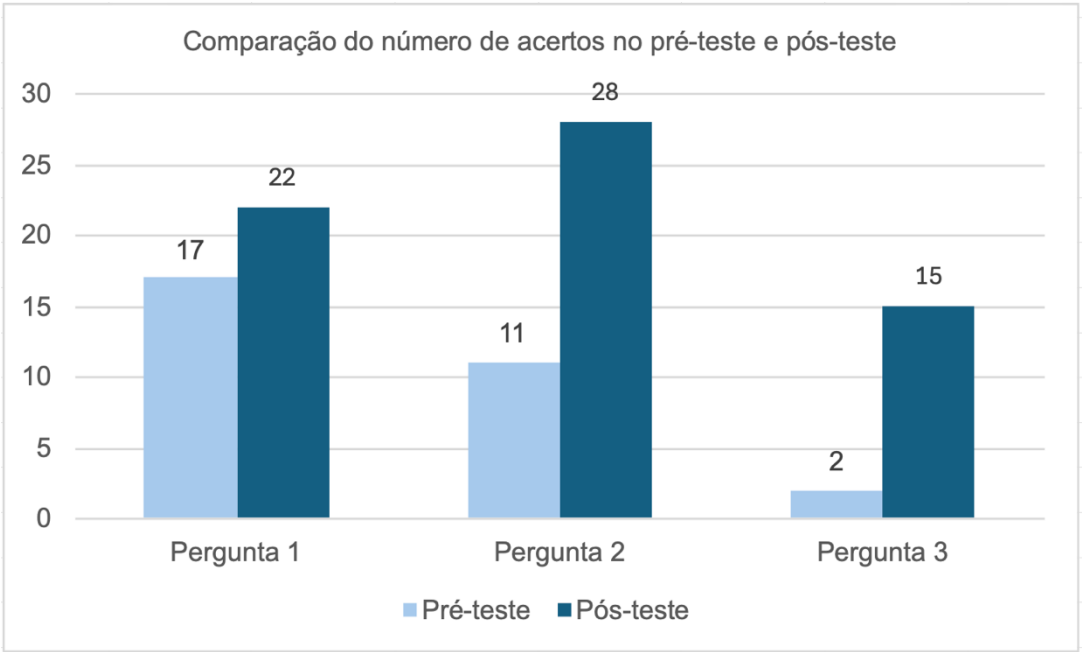
As regards the questions, question 1 assessed the students' knowledge of suspected deep vein thrombosis. Among the options, the correct answer was the alternative that listed unilateral oedema and calf impingement as signs of suspected diagnosis. In the pre-test, 54.8% of the students

Graph 1. Boxplot.



(SOURCE: the authors, 2024).

Graph 2. Comparison of correct answers in the pre-test and post-test.



(SOURCE: the authors, 2024).

marked this alternative as correct, while in the post-test, the percentage was 71%.

The second question discussed the main ultrasound sign for diagnosing deep vein thrombosis (DVT). The correct answer was "incapacity for venous compression". In the pre-test, 35.5% of the students chose this option as correct; in the post-test, this percentage increased significantly to 90.3%.

Finally, in the third question, the volunteers were asked about the three main places to look for deep vein thrombosis (DVT) at the bedside. The correct option was "common femoral vein, femoral vein and popliteal vein". In the pre-test, only 6.5% of the students correctly identified these locations, while in the post-test the percentage increased to 48.4%.

5. DISCUSSION

The use of Point-of-Care Ultrasound (POCUS) in undergraduate medical programmes began to be explored internationally in the 1990s and early 2000s. Already at that time, some medical schools in Europe were incorporating ultrasound into anatomy teaching, using the technology as a complementary tool to help students better understand anatomical structures[9]. In Brazil, the number of papers published on the use of Point of Care Ultrasound (POCUS) in undergraduate courses is still limited, and the incorporation of this resource into medical curricula also remains limited. At Positivo University we have been using ultrasound in our Surgical Clinic I practical classes since 2022. There are various methods of teaching ultrasound, including practical lessons with the students themselves, volunteer patients, simulators, standardised patients, cadavers and live models[9]. Our study taught about the use of ultrasound through the participation of the volunteer students themselves. An American study carried out with first to fourth year medical students at Wake Forest School of Medicine taught ultrasound through practical sessions with volunteer patients and recorded lectures. A total of 141 students learnt about the physics, applicability and technique of ultrasound. The academics were also assessed using multiple-choice tests, as in our study. After 10 days of follow-up, the research concluded that test scores improved significantly during the course. A total representing 91% of the participants agreed at the end of the sessions that they had received effective teaching[10]. Another study, conducted at the Warsaw University of Medical Sciences, provided Point of Care Ultrasound (POCUS) training for 57 sixth-year medical students. The aim was to teach students the visualisation windows for transthoracic, pulmonary and vascular cannulation echocardiography in an emergency room setting. The teachings consisted of a single day of classes, involving four lectures, seven practical skills training sessions on models and a computer with an ultrasound interpretation session. The assessment method consisted of multiple-choice tests and student self-assessment. The study showed that with just one day of training there was a significant improvement in the students' confidence scores and performance after the classes[11]. In our study we also only had one day of training and the mean and median scores were significantly higher in the post-test compared to the pre-test.

In one article, the Juiz de Fora Medical School in Minas Gerais presented its experience with the implementation of ultrasound teaching in its medical education curriculum. Students from the fourth to the eighth year of Medicine were assessed. One ultrasound topic was covered in each term. In the fourth term the students learnt about the basic principles of ultrasound, cardiac and pulmonary windows, in the fifth term Doppler and vascular ultrasound, the sixth term included lessons on ultrasound of the liver, pancreas, bile ducts, spleen and FAST, and the seventh term approached ultrasound of the thyroid, urinary tract, muscles and soft tissues. And finally, in the eighth term ocular, nerve, obstetric and appendix ultrasound was taught. The assessment method consisted of a multiple-choice theory test and a cognitive assessment test. Based on the majority of students' opinions, it was concluded that ultrasound has improved medical education, the quality of the physical examination and care, and that the teaching of the various ultrasound modalities should be included in the medical curriculum[12].

A narrative review containing studies on the use of Point of Care Ultrasound (POCUS) in the context of deep vein thrombosis concluded that ultrasound is a tool with good accuracy in diagnosing deep vein thrombosis (DVT). The study compared the effectiveness of two-point (femoral vein and popliteal vein) and three-point (common femoral vein, femoral vein and popliteal vein) compression techniques. The false negative rate was similar between the two protocols – around 4%. As the three-point compression technique does not significantly increase the examination time and evaluates the common femoral vein, the study suggests that the three-point technique is preferable. The study limitations include the need to standardise compression techniques and training time, since a lack of training reduces the sensitivity and specificity of the test, which can lead to a higher rate of diagnostic errors[8]these were also limitations of our study.

A systematic review on the use of ultrasound to diagnose deep vein thrombosis (DVT) in the emergency setting also favoured the use of the three-point compression technique[13]as in our study. When comparing compression with the two-point and three-point technique, it was analysed that the sensitivity of the diagnosis of deep vein thrombosis (DVT) increases by 5% when the third compression point is included,

which is why we used the 3-point technique in our study. Furthermore, compressing more sites helps to reduce the false negative rate of the test, since the non-compressibility of a single point is already a diagnostic criterion for deep vein thrombosis (DVT). This study also demonstrated the need for adequate training to diagnose deep vein thrombosis (DVT). Performance varied according to the operator's level of speciality, with specialist doctors achieving 93% sensitivity compared to 77% for resident doctors[10].

Vascular compression ultrasound is the most accurate non-invasive method for diagnosing deep vein thrombosis (DVT)[6]. When Point of Care Ultrasound (POCUS) is not available or the professional is not trained to use it, patients often have to be hospitalised and undergo empirical anticoagulation until deep vein thrombosis (DVT) can be diagnosed or ruled out. This process not only entails unnecessary costs for the health system, but can also be very wearisome for the patient, who could be quickly diagnosed and treated if the examination were performed at the bedside. The agility provided by Point of Care Ultrasound (POCUS) is fundamental, considering that deep vein thrombosis (DVT) is a serious condition with a risk of complications such as pulmonary embolism, which has mortality rates of up to 30% when not treated properly. The early diagnosis of deep vein thrombosis (DVT) and the subsequent prevention of pulmonary embolism are particularly relevant in risk groups such as pregnant women, patients with kidney failure or those with contrast media allergy, who cannot undergo CT angiography due to their health conditions[8].

Another important benefit of Point of Care Ultrasound (POCUS) training is that students become more competent and confident doctors, able to provide more accurate diagnoses, which increases the quality of patient care. Moreover, the ability to conduct ultrasound examinations increases the capacity of future doctors to make more effective clinical decisions. This is due to the fact that accuracy in diagnosing deep vein thrombosis (DVT) using Point of Care ultrasound (POCUS) increases with the number of hours spent training with the equipment[8].

Incorporating Point of Care Ultrasound (POCUS) training into the medical curriculum also promotes the integration of advanced technologies into teaching, preparing students for a healthcare setting that is increasingly dependent on technological innovations. The ability to handle ultrasound equipment, interpret images and apply the knowledge acquired is an important differentiator for medical students, who must be able to combine theoretical knowledge with practical skills. Additionally, Point of Care Ultrasound (POCUS) training helps to locate and understand the relationships between anatomical structures, strengthening anatomical concepts. The use of ultrasonography facilitates a three-dimensional understanding and correlation between anatomical structures. Accordingly, knowledge of anatomy is also consolidated in a more tangible manner for a clinical context[7].

The standardisation of assessment methods for Point of Care Ultrasound (POCUS) competency is an area that still requires improvement. Some institutions have introduced ultrasound assessment in structured clinical examinations and advanced training programmes, while others use self-assessment or performance in practical simulations as an assessment method. However, one of the biggest challenges to implementing Point of Care Ultrasound (POCUS) is the limited availability of qualified instructors for hands-on training, which requires dividing classes into smaller groups, increasing the need for additional hours to cater for all students[9]a difficulty also faced in our study.

Finally, Point of Care Ultrasound (POCUS) training also serves as a stimulus for continuing medical education. As students become more familiar with ultrasound technology, they are encouraged to continue learning and keep up to date with new discoveries and advances in the field, which contributes to their training as more complete and capable professionals.

6. STUDY LIMITATIONS

This study has some limitations that should be taken into account when interpreting the results. The use of non-internationally validated tests devised by researchers, even if supported by existing literature, can have an impact on the reliability of knowledge measurements. Furthermore, the fact that the study was conducted in a single centre may also restrict the applicability of the results to other institutions or contexts.

Another important point is that the research took place in a controlled environment, using a model patient who did not have real venous thrombosis. This differs from real emergency situations, where the dynamics and conditions can be significantly different. The simulation may not accurately reflect the challenges faced by doctors in a real clinical scenario, but it should be emphasised that the skills acquired in performing a normal examination can be of great help to future doctors in situations where the patient actually presents deep vein thrombosis (DVT).

Finally, knowledge was assessed in a single lesson, which limits the students' depth of learning and information retention. The study depended on all the participants completing questionnaires before and after the class, but there was no longitudinal monitoring of learning in the medium and long term. It is therefore not possible to determine precisely to what extent the knowledge acquired has been sustained or consolidated over time.

7. CONCLUSION

Based on the results obtained in this study, the comparative analysis of knowledge before and after the class revealed a positive impact on the participants' theoretical learning about POCUS ultrasonography applied to suspected DVT. The intervention was effective in broadening the students' understanding of clinical signs, ultrasound signs and relevant anatomy, suggesting that similar training, inserted in real-life scenarios, can contribute to training students in clinical practice. However, it should be noted that the study did not assess practical skills or the impact on patients with DVT.

The knowledge acquired about DVT using POCUS can serve as a basis for future training in other medical areas. The results of this study support the importance of integrating Point of Care Ultrasound (POCUS) training into the undergraduate medical curriculum, promoting more comprehensive training in line with the needs of contemporary clinical practice.

In short, practical training in ultrasound not only enriches students' learning, but also raises the quality of patient care, contributing to the efficiency of the health system as a whole.

CONTRIBUTION OF THE AUTHORS

Graciliano José França contributed to the proofreading and editing. Amanda Terres Fausto, Giulia Ferreira Tonon, Julia Agibert Rohnelt, Kaori Tavares Kihana, Maria Luisa Gobbi Longhi, Sabrina Barancelli Pereira contributed to the composition of the paper.

CONFLICT OF INTEREST

We declare no conflict of interest.

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DECLARATION OF DATA AVAILABILITY

Research data is available in the body of the document

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