

Diagnostic Accuracy of Emergency Ultrasonography Compression by Non-Radiologists or Cardiologists for Diagnosis of Deep Vein Thrombosis in Lower Extremity: An Evidence-Based Case Report

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ABSTRACT

Background: Deep vein thrombosis (DVT) is a medical condition with dangerous complications including lung thromboembolism which can cause death. However, the disease is often neglected, leading to delays in diagnosis and treatment. Patients with lower extremity DVT clinical signs and symptoms usually cause diagnostic dilemmas, specifically for general practitioners (GP). Various diagnostic strategies have been proposed to diagnose DVT although they still have several limitations. Therefore, emergency compression US by non-radiologists or cardiologists needs to be further considered as a fast and accurate alternative. This study is aimed to analyze the potency of emergency compression US by non-radiologists or cardiologists to diagnose DVT in the lower extremity. **Methods:** A comprehensive literature search was conducted through PubMed, Scopus, and Cochrane Library. The articles were screened based on predetermined inclusion and exclusion criteria with the keywords emergency, general practitioners, compression US, and DVT. Critical appraisal was performed using the Oxford CEEBM Critical Appraisal Tools for Diagnostic studies criteria. **Results:** This study analyzed a total of five cross-sectional studies and one prospective cohort. The emergency compression US performed by general practitioners and emergency physicians had a sensitivity of 86-93% and specificity of 90-97.1%. This analysis produced reliable results for diagnosing DVT in bedside settings compared to compression or doppler US performed by experts. **Conclusion:** Emergency compression US performed by general practitioners and emergency physicians had great potential to be a fast and accurate method for diagnosing and excluding DVT in lower extremities. However, standardized training is necessary to produce the highest diagnostic accuracy.

Keywords: Compression US, emergency physician, diagnosis, deep vein thrombosis, Lower extremity.

INTRODUCTION

Deep vein thrombosis (DVT) is a frequently neglected disease, with life-threatening effects such as lung embolization, which can cause death among patients. Cao et al¹ (2021) have revealed that among 25 hospitals, 10 out of

100 patients admitted to the hospital will have lower extremities DVT. Another study has also shown that DVT can cause death and disabilities among outpatients.² Currently, DVT affects one out of 1000 people worldwide,³ although there are no specific data in Indonesia. A study

conducted at Cipto Mangunkusumo General Hospital in 2008 has shown that DVT prevalence in Indonesia in post-gynecological surgery patients is 33.3%.⁴ Specifically, almost 200.000 outpatients are diagnosed with DVT each year, without including many potential outpatients who are undiagnosed.^{3,5} When left untreated, one out of three patients with DVT will progress into lung embolization significantly, which can cause death in more than 20% of these patients.^{3,6} Therefore, rapid and accurate diagnosis, as well as management of DVT, are urgently needed.

DVT symptoms are usually unspecified, which can make diagnosis difficult. Furthermore, patients with lower extremities DVT signs and symptoms commonly possess diagnostic dilemmas, specifically for general practitioners. Diagnosis based on only clinical findings can cause misdiagnosis, unnecessary exposure to anticoagulant therapies, and even more additional costs. Therefore, rapid, and accurate diagnosis of DVT is needed to start anticoagulant therapies administration and reduce the risk of lung embolization that possesses a fatal prognosis among patients.⁶⁻⁸

An optimal diagnostic strategy has been proposed for diagnosing DVT. This includes the Wells score, which is assessed as not adequately accurate to be used in primary care settings, while d-dimer tests are not always available.^{9,10} Studies have also shown that the d-dimer test only excludes DVT in less than half of patients with DVT suspicion, and cannot confirm the diagnosis. Venous ultrasonography (US) using doppler is still recommended as the main modality in evaluating DVT comprehensively. However, it consumes more time in transferring the patients to the radiology department and depends on the availability of experts in examining and interpreting this modality.¹¹

Prospective studies have shown the potency of compression US as an alternative method in confirming or excluding DVT diagnosis.¹² This technique has several benefits including universal availability among many settings, the ability to be performed by various operators, and using any kind of US machine, making it suitable in primary care settings. This method is usually performed by experts, radiologists,

and cardiologists. However, the availability of experts, radiologists, and cardiologists in primary care settings often possess problems in diagnosing DVT. Studies have shown that general practitioners in primary care settings also have the potential to diagnose DVT rapidly and accurately. This can increase DVT management and prevent inpatient evaluation, laboratory, or the use of any scoring in emergency settings.¹³ However, the diagnostic accuracy of the emergency compression US method performed by non-radiologists or cardiologists is still unclear. Thus, this is the first evidence-based case report that aims to analyze the diagnostic accuracy of the emergency compression US method done by non-radiologists or cardiologists in diagnosing lower extremities DVT.

CASE ILLUSTRATION

A 45-year-old female was admitted to the emergency department with unexplained persistent dyspnea three days before presentation and was not affected by activities or rest. The patient complained about pain in the lower extremities of both legs, with a pain visual analog scale of 7, which was partially relieved by paracetamol. There was also swelling of both legs in the past year before the presentation. The physical examination showed bilateral pitting edema positive and prolonged PT/APTT. However, initial assessment through anamnesis, physical examination, as well as laboratory and radiologic workup did not reveal any diagnosis related to the unexplained dyspnea. Echocardiography was also performed before exploring cardiovascular abnormalities, which may relate to the complaints, but no valve or functional abnormalities were found. Since the patient had swollen leg following the immobilization history, a doppler ultrasound compression emergency examination was carried out in both legs. The results showed many thrombi in both legs, which accumulated more in the left femoral artery and vein. Therefore, the patient was worked up using CT Scan to detect the lung embolization process that can cause dyspnea. The patient was diagnosed with DVT and lung emboli, which were treated with heparin and warfarin.

CLINICAL QUESTION

Is the emergency compression US performed by non-radiologists or cardiologists (general practitioners and emergency physicians) comparable to compression or doppler US performed by experts?

METHODS

A comprehensive literature search was carried out based on Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) using the predetermined PICO criteria in **Table 1** through PubMed, Cochrane, and Scopus databases. This was performed to identify studies about the potency of compression US conducted by general practitioners for diagnosing lower extremities DVT in emergency settings, until 11 February 2023 using the keywords listed in **Table 2**. A manual search was also conducted through systematic reviews

or cross-referencing to include more relevant studies. However, only studies in English and Bahasa Indonesia language were also included.

The studies were screened using predetermined eligibility criteria. These included observational studies, randomized controlled trials (RCT), systematic reviews, and meta-analyses, with outpatients suspected of DVT as the population. The intervention used was emergency compression US performed by non-experts, which were defined as general practitioners or emergency physicians using limited compression US (LCUS) or point-of-care ultrasonography-based compression US. The control was compression US or doppler US performed by radiologists or non-radiologist clinical experts. The outcomes measured were sensitivity, specificity, positive predictive value, negative predictive value, and diagnostic accuracy. Studies using the non-US method as control or based on expertise results without

Table 1. PICO Criteria.

PICO	Descriptions
Population	Patient with suspected DVT
Intervention	Emergency compression US performed by non-expert practitioners (general practitioners or emergency physicians)
Comparison	Compression US or Doppler US performed by experts (radiologists or non-radiologist clinical experts)
Outcome	Sensitivity, Specificity, and Diagnostic Accuracy

Table 2. Literature Searching Strategy.

Database	Searching Strategy (Keyword)	Hits	Articles passed inclusion criteria	Articles selected
PubMed (11 February 2023)	(Emergency OR GP OR "General Practitioner") AND ("Point-of-Care-Ultrasound" OR POCUS OR "Compression Ultrasonography" OR Ultrasonography) AND ("Deep Vein Thrombosis" OR DVT)	578	18	4
Cochrane (11 February 2023)	((("emergency"):ti,ab,kw OR (GP):ti,ab,kw OR ("general practitioner"):ti,ab,kw) AND ((("point-of-care-ultrasound"):ti,ab,kw OR (POCUS):ti,ab,kw OR ("compression ultrasonography"):ti,ab,kw OR ("ultrasonography"):ti,ab,kw) AND ((("deep vein thrombosis"):ti,ab,kw OR ("deep vein thromboses"):ti,ab,kw OR ("deep-vein thrombosis"):ti,ab,kw OR (DVT):ti,ab,kw))	22	3	0
Scopus (11 February 2023)	TITLE-ABS-KEY ("emergency") OR TITLE-ABS-KEY (gp) OR TITLE-ABS-KEY ("General Practitioner") AND TITLE-ABS-KEY ("Point-of-Care-Ultrasound") OR TITLE-ABS-KEY (pocus) OR TITLE-ABS-KEY ("Compression Ultrasonography") OR TITLE-ABS-KEY (ultrasonography) AND TITLE-ABS-KEY ("Deep Vein Thrombosis") OR TITLE-ABS-KEY (dvt)	479	21	2
Total		1079	42	6

experts performing the compression or doppler US, pediatric patients, and those without full-text availability were excluded. Subsequently, the included studies were appraised independently by two authors (AGIK and AP) according to the Oxford model of evidence-based medicine using the Validity-Importance-Applicability checklist for diagnostic studies, which was consulted to the third author (MSA) until consensus was reached.

RESULTS

The comprehensive literature search yielded a total of 1079 articles. The studies were screened for duplication, resulting in 870 articles being assessed further in this study. Subsequently, titles and abstracts were screened, and 42 studies that met the predetermined eligibility criteria

were included. Among these 42 studies, 3 were narrative literature reviews, 7 compared methods instead of the compression US performers, 17 were non-emergency compression US studies, 6 only assessed the agreement between compression US performers, and 3 mixed the outcome of experts and non-experts, therefore, they were further excluded from this study. Finally, one prospective cohort study and 5 cross-sectional studies were included in the critical appraisal and assessed qualitatively. The detailed planned procedure of the literature searching process was illustrated in **Figure 1**.

A total of 2058 patients was involved and the included studies varied across several regions including Asia, America, and Europe. All included studies used compression US performed

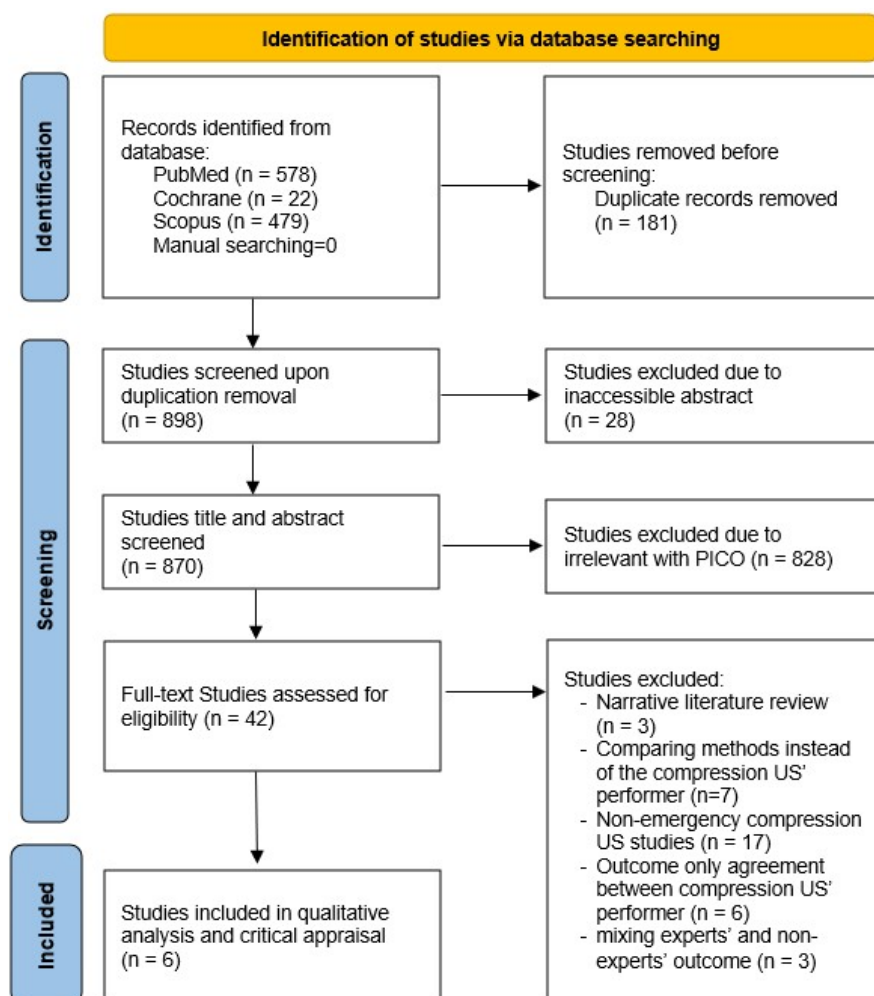


Figure 1. Detailed PRISMA flowchart of the literature search process.

by general practitioners or emergency physicians as their intervention and US by the experts, either duplex or compression in emergency settings. The detailed characteristics of the included studies and their outcomes were summarized in **Tables 3** and **4**, respectively.

After completing the eligibility screening, the included studies were appraised for their validity, importance, and applicability using the University of Oxford Center for Evidence-Based Medicine Diagnostic Critical Appraisal Tools.¹⁹

Table 3. Study Characteristics.

Author (Publication Year)	Study Design	Study Location	Sample Size	Median/ Range/ Mean Age	Intervention	Control
Abbasi et al (2012) ¹⁴	Cross-sectional	Iran	81 outpatients submitted to the ED	47.2 ± 18.6 years old	Emergency Compression US by EP	Duplex US by second-year radiology residents
Canakci et al (2020) ¹⁵	Cross-sectional	Turkey	266 outpatients submitted to the ED	63 years (IQR: 48-74)	Emergency POCUS by EP	Doppler US or Compression US by radiologists
Crisp et al (2010) ¹⁶	Cross-sectional	America	199 outpatients submitted to the ED	18 years and above	Emergency Compression US by EP	Duplex US by radiologists
Garcia et al (2018)	Cross-sectional	Spain	109 outpatients submitted to the ED	68 ± 16 years old	Bedside Emergency POCUS by EP	Duplex US by radiologists
Kim et al (2015) ¹⁷	Cross-sectional	Canada	296 outpatients submitted to the ED	50 years old (IQR: 37-60)	Emergency LCUS by EP	Duplex US by radiologists
Mumoli et al (2017) ¹³	Prospective Cohort	Italy	1107 outpatients submitted to the ED	63.6 ± 15.2 years old (DVT); 63.8 ± 14.9 years old (without DVT)	Bilateral Proximal Compression US in lower extremities by general practitioners	Compression US by vascular US experts (Vascular Surgeons)

Abbreviations: ED: Emergency Department; EP: Emergency Physician; POCUS: point-of-care ultrasonography; USG: Ultrasonography; LCUS: Limited compression ultrasonography

Table 4. Study Outcomes.

Author (Publication Year)	Sensitivity (95% CI)	Specificity	PPV	NPV	Summary of Study Outcomes
Abbasi et al (2012) ¹⁴	85.9% (74.5-93)	41.2% (19.4-66.5)	84.6 % (73.1-92)	43.8 % (20.8-69.4)	<ul style="list-style-type: none"> - Lower extremities DVT diagnostic accuracy using emergency compression US by emergency physicians is 84.6% - Emergency Compression US by emergency physicians has acceptable sensitivity and accuracy, although has low specificity in diagnosing DVT. - Emergency Compression US sensitivity is higher in men compared to women
Canakci et al (2020) ¹⁵	93% (84-98)	93% (89-96)	83% (74-89)	97% (94-99)	<ul style="list-style-type: none"> - Positive likelihood ratio 14 (8-24) - Negative likelihood ratio 0.08 (0.03-0.19) - POCUS has high sensitivity and specificity in examining popliteal and femoral veins performed by emergency physicians in diagnosing DVT in suspected patients

Crisp et al (2010) ¹⁶	100% (92-100)	99% (96-100)	97.83% (88.47-99.94%)	100% (97.62-100%)	<ul style="list-style-type: none"> - Lower extremity emergency compression US by general practitioners and emergency physicians using portable US machines can accurately identify and exclude proximal lower extremity DVT - Emergency compression US results have been found to be equivalent directly compared to duplex US done by radiologists (Cohen Kappa 0.99 (95% CI: 0.958-1))
Garcia et al (2018) ¹⁸	93.2% (83.8-97.3)	90% (78.6-97.3)	91.7% (81.9-96.4%)	91..8% (80.8-96.8%)	<ul style="list-style-type: none"> - Lower extremity DVT compression US performed by emergency physicians using emergency physician diagnostic accuracy: 91.7% (85-95.6) - Emergency physicians have an equivalent competency level compared to radiologists in diagnosing DVT with emergency compression US, although substantial training is needed to achieve and maintain their performance.
Kim et al (2015) ¹⁷	86% (73-94)	93% (89-96)	73.44% (60.91-83.70)	96.55% (93.32-98.5)	<ul style="list-style-type: none"> - Positive likelihood ratio 12.11 (95% CI: 7.56-19.40) - Negative likelihood ratio 0.16 (95%CI: 0.08-0.30) - Emergency physicians who have performed LCUS training could diagnose DVT with the average accuracy - LCUS by emergency physicians has good diagnostic accuracy, although not adequately sensitive to exclude DVT as a stand-alone test.
Mumoli et al (2017) ¹³	90% (88.2-91.8)	97.1% (96.2-98.1)	87.4% (85.4-89.3)	97.8% (96.9-98.6)	<ul style="list-style-type: none"> - DVT diagnostic accuracy using emergency compression US by general practitioners: 95.8% (94.7-97) - Agreement between general practitioners and experts were equivalent (Cohen Kappa 0.86) - Compression US could be a reliable tool to diagnose DVT in emergency patients - Although emergency compression US by general practitioners resulted in suboptimal sensitivity. However, this method could be an alternative accurate method to diagnose DVT. - Emergency compression US by general practitioners could reduce time-to-diagnosis and maximize optimal management.

Abbreviations: US= Ultrasonography; DVT = Deep Vein Thrombosis; POCUS = *Point-of-care* Ultrasonography; LCUS = Limited Compression Ultrasonography

All studies were found to have good validity and applicability. Since the included studies were not systematic reviews and meta-analyses, they were judged as level II in terms of evidence level. Although they were observational studies with good validity, importance, and applicability. A detailed summary of the critical appraisal was illustrated in **Table 5**, while a detailed critical appraisal per study was provided in the supplementary material.

DISCUSSION

DVT was found to be an emergency case that required rapid and accurate methods to diagnose. However, challenges regarding ideal radiography modality limitations can lead to late management initiation. This study highlighted that compression US in emergency settings performed by general practitioners or emergency physicians can present accurate and reliable results in detecting DVT diagnosis

Table 5. Critical Appraisal Summary of Included Studies.

Author (Publication Year)	Study Design	Validity			Importance				Applicability	LOE
		R	RS	B	Sens	Spec	PPV	NPV		
Abbasi dkk ¹⁴ (2012)	Cross-sectional	✓	✓	✓	85.9% (74.5-93)	41.2% (19.4-66.5)	77.6% (64.4-87.1)	39.1% (20.5-61.2)	✓	II
Canacki dkk ¹⁵ (2020)	Cross-sectional	✓	✓	?	93% (84-98)	93% (89-96)	83% (74-89)	97% (94-99)	✓	II
Crisp dkk ¹⁶ (2010)	Cross-sectional	✓	✓	✓	100% (92-100)	99% (96-100)	45/46 = 97,83%	153/153= 100%	✓	II
Garcia dkk ¹⁸ (2018)	Cross-sectional	✓	✓	✓	93.2 (83.8-97.3)	90.0 (78.6-97.3)	91.7% (81.9-96.4)	91.8% (80.8-96.8)	✓	II
Kim dkk ¹⁷ (2015)	Cross-sectional	✓	✓	✓	86% (73-94)	93% (89-96)	47/64 = 73.44%	224/232= 96.55%	✓	II
Mumoli dkk ¹³ (2017)	Prospective Cohort	✓	✓	✓	90% (88.2-91.8)	97.1% (96.2-98.1)	87.4% (85.4-89.3)	97.8% (96.9-98.6)	✓	II

Abbreviations: R = Representative, RS = Reference Standard; B = Blinding and Gold standard; Sens = sensitivity; Spec = specificity; PPV = *positive predictive value*; NPV = *negative predictive value*; App = Applicability; LOE = Level of Evidence; ✓ = Yes; ? = unclear

at the bedside settings, compared to experts-performed compression or duplex US. This was demonstrated by all included studies showing high sensitivity, specificity, and diagnostic accuracy in diagnosing lower extremities.

Crisp et al¹⁶ (2010) revealed that lower extremity compression US performed by general practitioners and emergency physicians using portable US machines can accurately identify and exclude proximal lower extremity DVT. This was demonstrated through the high sensitivity and specificity of emergency compression US, accompanied by equivalent results compared to the radiology department-performed duplex US with the Cohen Kappa of 0.99 (95% CI: 0.958-1). The result highlighted that emergency compression US by emergency physicians was equivalent compared to the duplex US by radiologists, which needed more time. A similar previous meta-analysis in 2013¹² showed that emergency compression US performed by emergency physicians had pooled sensitivity of 96.1% (95%CI: 90.6-98.5) and pooled specificity of 96.8% (95%CI: 94.6-98.1) based on bivariate analysis. Although the meta-analysis included many types of US which were not considered in this study. The results showed the high potential of emergency compression US method used by non-experts doctors to produce accurate results when applied in clinical settings, requiring rapid diagnosis.

A study by Abbasi et al¹⁴ (2012) showed

that the overall diagnostic accuracy of the emergency compression US method in lower extremities DVT was 84.6%. This indicated that although emergency compression US had acceptable sensitivity and accuracy, low specificity was found in this method when used by emergency physicians in diagnosing DVT. This can be due to portable machine use, as well as the low experience and knowledge of the physician performing the compression US. However, Canacki et al¹⁵, Garcia et al¹⁸, Kim et al¹⁷, and Mumoli et al¹³ revealed that emergency compression US by general practitioners and emergency physicians had high sensitivity and specificity with the range of 86-93% and 90-97.1%, respectively. Some of these studies highlighted that the result was still suboptimal, thereby requiring substantial training.

Venography with contrasts had been the standard diagnostic criteria for patients with suspected lower extremities DVT. However, duplex US had become the first line in clinical settings and as a reference standard in clinical trials. The duplex US was commonly not available in 24-hours care settings due to the need for experts availability to interpret rapidly.^{20,21} As an alternative, emergency compression US can be practically used in emergency clinical settings that required rapid and accurate diagnosis. This was related to several examinations and methods to reduce mean time to diagnosis below 15 minutes for healthcare centers where

radiologists were not available 24 hours a day. The early anticoagulation therapy initiation can also optimize rapid and accurate management, preventing mortality and long inpatient stay in the emergency department, reducing costs and other unnecessary examinations, and be beneficial for emergency patients with unstable hemodynamics who cannot be transferred to the radiology department.^{11,20,21}

Emergency compression US can be used effectively and practically in emergency settings to diagnose DVT rapidly and accurately. However, the method also had several disadvantages, including operator dependent. Zitek et al²² (2016) found that non-expert doctors who were given short training had compression US sensitivity of only 57.1% compared to those performed by radiologists. Video analysis in this study also revealed several mistakes, including suboptimal visualization of the popliteal vein and the position of the thrombus, located above the superior femoral vein that can not be visualized by two-point compression US. Therefore, standardized, and measured training was still needed to produce the best diagnostic accuracy with this rapid and accurate method. Previous studies highlighted that this method was easy to learn and perform because it only required about two hours of supervision and hands-on experience for general practitioners or emergency physicians to achieve the skills needed to produce an adequate quality radiology image.^{16,23}

This study suggested that standardized training was still needed to achieve the highest sensitivity, specificity, and diagnostic accuracy. However, the emergency compression US method performed by general practitioners or emergency physicians can be the accurate and rapid method in diagnosing and excluding lower extremities DVT in emergency settings.

This study was the first evidence-based case report that analyzed the diagnostic accuracy of emergency compression US in diagnosing lower extremities DVT. The included studies had good validity and applicability, accurate sensitivity, and specificity, as well as positive and predictive values of the compression US method to be

implemented in clinical settings. However, the included studies were obtained from regions with a large number of samples, excluding Southeast Asia, specifically Indonesia, and no systematic reviews or meta-analyses were involved. This indicated that the results cannot be generalized because the method used was location-specific. Therefore, further considerations were required to implement this method in Indonesia and other countries with different demographics.

CONCLUSION

Emergency compression US performed by general practitioners or emergency physicians had high diagnostic accuracy. This indicated that the method can be used for diagnosing and excluding lower extremities DVT although standardized training was still needed to produce high sensitivity, specificity, and diagnostic accuracy. Based on the results, the sensitivity and specificity ranged from 86-93% and 90-97.1%, respectively. The emergency compression US performed by general practitioners and emergency physicians reduced time-to-diagnosis, optimized management, and enhanced 24-hour healthcare settings, thereby reducing costs. This method can also be used in unstable hemodynamic patients that were not transferred. Therefore, implementing the emergency compression US method by general practitioners and emergency physicians in clinical emergency settings after routine training and expert supervision was recommended to maximize the implementation of this method. Further studies in other regions such as Southeast Asia specifically in Indonesia were still needed to analyze the potency of this method in different sociodemographic conditions.

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The authors have nothing to declare.

COMPETING INTEREST

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