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Research Article

The value of echocardiography in predicting pulmonary thromboembolic disease

Vladimir M. Grigorov[1], Jan D. Esser[2], Mladen V. Grigorov[3], Valentina Y. Belcheva[4], Evgeni E. Grigorov[5], Maya P. Radeva-Ilieva[6]

1 *Faculty of Medicine, Medical University – Pleven, Pleven, Bulgaria*
2 *Arwyp Medical Centre, Kempton Park, South Africa*
3 *Sveti Georgi Multi-Profile Hospital for Active Treatment, Montana, Bulgaria*
4 *Trakia University – Medical College, Stara Zagora, Bulgaria*
5 *Faculty of Pharmacy, Medical University – Varna, Varna, Bulgaria*
6 *Department of Pharmacology, Toxicology and Pharmacotherapy, Faculty of Pharmacy, Medical University – Varna, Varna, Bulgaria*

Corresponding author: Evgeni E. Grigorov (evgeni.grigorov@mu-varna.bg)

Summary

This is a 200-patient retrospective single-centre study focused on evaluating the contribution of echocardiography (Echo) findings as an initial screening tool in selecting intensive care unit (ICU) patients with suspected pulmonary embolism (PE) for further diagnostic evaluation with ventilation/perfusion (V/Q) scintigraphy. These 200 patients with suspected PE were referred for a V/Q scan. Of them, 24 had Echo findings of a dilated right ventricle (RV), and 8 of the 24 (33%) had a positive V/Q scan for PE. Seven of those 8 patients (88%) had large pulmonary emboli. Of the remaining 176 patients (without dilated RV), the V/Q scan was positive for pulmonary emboli in 39 cases (22%). If evaluating only the patients positive for pulmonary emboli on V/Q scan (47 patients), 8 of them (17%) had a dilated RV, and 39 (83%) did not have a dilated RV. Thus, we found that Echo mainly contributed to identifying patients with life-threatening large pulmonary thrombo-embolic disease. In contrast to the above, echocardiography was non-contributory in the presence of small PE. This finding was in congruence with the existing literature.

Key words: Echocardiography, prediction, pulmonary thromboembolic disease, value

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Introduction

Venous thromboembolism (VTE) can clinically manifest as either deep venous thrombosis (DVT) or pulmonary embolism (PE). PE has various clinical presentations, including sudden unexplained dyspnea, tachypnoea, chest pain, cough, haemoptysis, syncope, palpitations, tachycardia, cyanosis, fever, hypotension, right heart failure, pulmonary hypertension, and leg swelling (Bajc et al. 2009a; Konstantinides et al. 2015; Raja et al. 2015). The condition can be challenging to diagnose clinically as, even in severe and life-threatening cases, the symptoms are not specific to just PE and also manifest in other pathological conditions (Grifoni et al. 2000). The case, expanding the tools to correctly and timely arrive at the diagnosis, is important for various reasons, as emphasised by the following data:

- VTE is currently the third most frequent acute cardiovascular complication after myocardial infarction and stroke (Raskob et al. 2014);
- a rising tendency in annual PE incidence rates has been registered according to longitudinal studies (de Miguel-Díez et al. 2014; Dentali et al. 2016; Lehnert et al. 2018; Keller et al. 2020);
- the actual incidence is likely even higher – for every nonfatal PE, there are 2.5 cases of fatal PE only diagnosed postmortem (Bikdeli et al. 2019);
- untreated PE has a high morbidity and a 30-day mortality rate estimated to be 30% (Flinterman et al. 2012);
- the heavy annual financial burden for VTE is estimated to total up to €8.5 billion in the European Union (Barco et al. 2016).

The current diagnostic workup process for PE begins with calculating a score using the Wells' Criteria, a widely validated pre-test probability instrument used to determine the likelihood of PE presence (Wells et al. 2001; Wolf et al. 2004). The model is made up of 7 criteria with points assigned to them as follows: clinical signs and symptoms suspected of DVT (3 points), PE as the number one diagnosis or equally likely (3 points), heart rate > 100 BPM (1.5 points), immobilisation at least three days or surgery in previous four weeks (1.5 points), prior objectively diagnosed VTE (1.5 points), hemoptysis (1 point), and active malignancy (1 point). The resulting score dictates the direction of further investigation. If a score of ≤4 points obtains a D-dimer, and if it is unremarkable, PE is eligible for exclusion. However, if the score proves remarkable, further investigation with a VQ scan or computed tomography pulmonary angiography (CTPA) has to be done. Instead, a score of ≥5 immediately promotes using VQ Scan or CTPA (Wells et al. 2001). Although the Wells criteria are a very useful tool, a D-dimer elevation does not always mean a PE is present. D-dimer is a fibrin degradation product released in circulation during fibrinolysis. It can be elevated in nonthrombotic conditions (e.g., acute kidney injury, cancer, heart failure, etc.) as well as in thrombotic conditions, yet it does not necessarily always imply PE (Chopra et al. 2012; Kline et al. 2012; Riley et al. 2016). In addition, a large number of false-positive results should also be taken into consideration.

Despite these points, more recent investigations have proved that if used correctly, a clinical strategy combining pre-test probability estimation and D-dimer measurement, if unremarkable, can allow the safe discharge of PE-suspected patients without superfluous investigation or unnecessary interim treatment (Sendama and Musgrave 2018). However, if the estimated D-dimer is elevated, or if the Wells score suggests high pre-test probability, then CTPA or a V/Q scan as the endpoint diagnostic tests can confirm or rule out PE presence (Coche et al. 2003; Anderson et al. 2007; Bajc et al. 2009b). The decision on which one to choose can be based on facility resources, or if both are available, then CTPA tends to be the gold standard (Konstantinides et al. 2014; Raja et al. 2015). This is because PE can be entirely ruled out only in cases with high pre-test PE probability with a normal V/Q scan. In any lower probability pre-test, a normal V/Q scan is non-diagnostic. If suspicion remains high, a CTPA is needed to rule out a PE. There are scenarios where a CTPA is impossible to perform (e.g., acute renal failure, pregnancy, contrast allergy), and a V/Q scan is thus chosen. Yet, in the absence of additional obstacles, a CTPA is recommended. CTPA also presents with some risks. Although allergic reactions to intravenous contrast

and contrast-induced nephropathy should be considered, radiation exposure remains the most relevant risk. The amount of ionising radiation sometimes approaches 20 millisieverts (mSv), with values >10 mSv being associated with increased carcinogenic risk (for leukaemia, thyroid cancer, and breast cancer) (Huppmann et al. 2010; Lapner and Kearon 2013). This risk becomes even more relevant in critically ill patients as they have an even greater risk of exposure due to often undergoing repeated computed tomography scans (Prentice and Wipke-Tevis 2019). In this regard, the COVID-19 pandemic presented an unprecedented challenge to the healthcare system since COVID-19-infected patients are prone to thrombosis and PE, and the symptoms of COVID-19 may mimic or overlap with those of PE, thus making causality identification more difficult and repeated exposure to imaging more prevalent (Klok et al. 2020). At the same time, standard diagnostic tests, including CTPA, may not be easily obtained due to concerns about staff exposure. Thus, alternatively, Echo can be an essential adjunct in establishing the potential presence of PE (Rosovsky et al. 2020).

Echo changes are generally seen with significant RV overload. The diagnosis of mild PE is more complex because it does not usually affect the size of the RV (Goldhaber 2002; Torbicki et al. 2008). Furthermore, the RV sometimes accommodates and minimally enlarges even in severe PE. Despite its lower PE sensitivity, Echo screening can contribute to selecting patients for V/Q scan based on RV dilation presence. It can serve as a useful screening tool, especially when combined with others like specific ECG changes (S1, Q3, T3, right bundle branch block, right axis deviation, and in longstanding cases, P pulmonale, that may support the presence of RV overload as well and potential PE presence (Bajc et al. 2009b). Thus, this study is a retrospective analysis of data aiming to evaluate the contribution of Echo in selecting ICU patients with suspected PE for V/Q scintigraphy. Elevated pulmonary artery pressure is a particularly revealing sign in younger patients and patients who do not have pulmonary disease (ECHOpedia 2013).

Material and methods

After the initial clinical assessment, each patient received a chest X-ray, ECG, D-dimer, and echo evaluation. The Echo evaluation focused on recording the middle segment of the RV – specifically the mid-right ventricle diameter (mid-RVD), as criteria for RV dilation were based on mid-RVD and not the length of the RV. In addition, pulmonary arterial pressure was also recorded. The practical method of acquiring our data consisted of placing the transducer for RV assessment apically, as low as possible, since a higher position tends to overestimate the RV size. The upper limit was accepted as 33 mm for the proximal aspect. It is generally accepted that the LV is 2/3, and the RV is 1/3 of the size of the heart. A mid-RV diameter (RVD) of 27–33 mm was defined as NORMAL; 34–37 mm – MILDLY DILATED; 38–41 mm – MODERATELY DILATED; >42 mm – SEVERELY DILATED (ECHOpedia 2013). A measurement of the RV at the mid-ventricle level above 35 mm was defined as right ventricular dilatation (ECHOpedia 2013).

Pulmonary pressure was measured at the tricuspid valve, and values >36 mmHg (altitude 1600 m; barometric pressure 1028 HPA) were considered abnormal (ECHOpedia 2013). The RV outlet pressure value was occasionally measured on a parasternal short-axis view at the base. Enlargement of the RV and increased pulmonary arterial pressure were regarded as including criteria,

and suspicious PE patients were referred for a V/Q scan (ECHOpedia 2013). The study was conducted over 27 months when 200 patients underwent a V/Q scan. Demographic data are presented in Table 1.

Table 1. Demographic data of patients included in the study.

Age	
Maximum	94
Average	55
Median	54
Minimum	18
Gender	
Male	66
Female	134

Most of our patients had significant co-morbidities, including renal dysfunction, which, notably, represents a contraindication for CTPA. Even though different physicians may have treated the patients, the cardiac assessments were made by the same cardiologist. The latter was blinded as to the results of the D-dimer levels. Echo data regarding the left side of the heart were also collected (Table 2).

Table 2. Echocardiographic data regarding the left side of the heart.

Ejection Fraction	
Maximum	80%
Average	65%
Median	70%
Minimum	20%
Normal	187
Not Normal	13

Results

Echo of the 200 patients that matched the inclusion criteria showed that:

- 176 patients had a normal size RV;
- 24 patients had dilated RV (Table 3).

V/Q scans of the 200 patients that matched the including criteria showed that:

Table 3. Echocardiographic data regarding the right ventricle.

Echocardiographic data	
Normal RV	176
Dilated RV	24

- Of the 176 patients with normal RV, 39 (22%) had positive V/Q scans for pulmonary emboli.

- Of the 24 patients with RV dilatation, 8 (33%) had positive V/Q scans for pulmonary emboli, with 7 of them presenting with large emboli and 1 – with microemboli.

In total, 47 patients resulted with a V/Q positive for PE, with 8 of them (17%) previously registered with RV dilatation, while the remaining 39 (83%) did not show RV dilation on Echo examination (Table 4).

Table 4. The ventilation/perfusion scan results.

Pulmonary Embolism (PE)	
Positive	47
Negative	153
PE positive	
Normal RV	39
Dilated RV	8

Discussion

PE is often a "silent" killer, missed or not suspected in many cases. In recent years, the development of screening techniques, D-Dimers, and ventilation/perfusion scanning has made the use of CTPA more selective. However, it remains the gold standard for diagnosis. It appears from our analysis that Echo has managed to identify most of the patients with potentially life-threatening PE early. These findings have also been confirmed in other studies (Prosperi-Porta et al. 2022; Oh and Park 2023). Patients with clinically irrelevant PE were generally not identified because of the lack of hemodynamic changes and, subsequently, RV dilatation. We have to admit that the "negative" Echo on admission by itself does not preclude the subsequent development of PE (either clinically relevant or not), and the diagnosis of PE is not determined by Echo. The mean age of patients assessed in this study was 54; many had relevant co-morbidity. These factors already increase the risk for PE, complicating the diagnosis. Considering the limited time frames in ICU, PE management must be adapted to specific high-risk scenarios. Thus, echocardiographic screening would contribute to rapid decision-making by non-invasive and easily accessible methods.

Conclusion

As a screening technique, Echo is useful in ICU patients, particularly those with extensive co-morbidity. Echo findings mainly contribute to identifying patients with life-threatening PE risk, but they are non-contributory in the presence of clinically irrelevant PE.

Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statements

The authors declared that no clinical trials were used in the present study.

The authors declared that no experiments on humans or human tissues were performed for the present study.

The authors declared that no informed consent was obtained from the humans, donors or donors' representatives participating in the study.

The authors declared that no experiments on animals were performed for the present study.

The authors declared that no commercially available immortalised human and animal cell lines were used in the present study.

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Author contributions

Conceptualisation: VG, JDE, MG, MRI; writing—original draft: VG, JDE, EG; writing—review and editing: MG, VB; visualisation: MRI, VB; supervision: VG, EG. All authors have read and agreed to the final version of the manuscript.

Author ORCIDs

Maya P. Radeva-Ilieva https://orcid.org/0000-0001-5778-4043
Evgeni E. Grigorov https://orcid.org/0000-0002-8290-5182
Vladimir M. Grigorov https://orcid.org/0000-0002-1856-6569
Jan D. Esser https://orcid.org/0000-0001-5354-4958
Valentina Y. Belcheva https://orcid.org/0000-0002-3641-4745

Data availability

All of the data that support the findings of this study are available in the main text.

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