BENHA MEDICAL JOURNAL bmj

Print ISSN 1110-208X.

Online ISSN 2357-0016

Diagnostic Accuracy of Different Echocardiographic Parameters in Pulmonary Embolism

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Received: 2 July 2024

Accepted:20 September 2024

Abstract:

Background: Pulmonary embolism is a potentially fatal medical condition. The objective of this study was to determine specificity and sensitivity of different echocardiographic parameters in PE and test the role of early systolic notch in predicting the side and localization of PE. **Aim:** This research investigated the diagnostic accuracy of different echocardiographic parameters and the role of early systolic notch in predicting side and localization of PE. **Subjects Methods:** This observational study was done in Benha University and Nasr City Hospitals, from August 2023 to March 2024. One-hundred and fifty patients were included to study the diagnostic accuracy of different echocardiographic parameters in PE. All subjects underwent history taking, clinical examination, Echocardiography and CTPA. **Results**: We included group (I) 67 patients with pulmonary emboli and group (II) 83 patients without pulmonary emboli in the study (mean age 65.54 ±11.14 years, 44.6% males). Patients of group I had significantly higher difference in D dimer, early systolic notch of pulsed wave across pulmonary valve, basal RV dimensions, Basal right ventricular/left ventricular ratio >1, Maconneell sign, 60/60 sign, Flattened inter ventricle septum, dilated IVC with collapsibility <50%, Pulmonary artery systolic pressure, TR Vmax (P values= less than.0001 each), patients of group II had higher TAPSE (Pvalue=0.001). Pulmonary emboli were significantly higher in main pulmonary artery and bilateral in group Ia (patients with PE and ESN) with (P values . 0.012, . 0.003) respectively. **Conclusions:** Echocardiography is priceless tool in PE diagnosis, echocardiographic parameters of PE have low sensitivity but high specificity, and additionally early systolic notch can help in predicting side and localization of pulmonary emboli.

Keywords: Diagnostic Accuracy, Echocardiograph, Pulmonary Embolism, Early systolic notch, CTPA

Introduction

Pulmonary embolism (PE) is a significant global health concern that can lead to serious illness and death. PE annual incidence rate is 1.15 per 1000 in the United States (US)[1,5]. Bedside echocardiography is an indispensable diagnostic tool in management of acute pulmonary embolism [6,10]. This work aimed to determine the value of demographic features, risk factors, clinical presentation, clinical labs and the diagnostic accuracy of different echocardiographic parameters in pulmonary embolism diagnosis, also the role of the early systolic notch in predicting the side and localization of pulmonary emboli.

Patients and methods

This observational cross section study included 165 patients aged 18 years and above, both genders, presented with suspected pulmonary embolisms at the Cardiology Department of Benha University Hospital and Nasr City Hospital for Insurance from August 2023 to March 2024. Five pregnant patients, 5 patients with more than mild chronic kidney disease (eGFR less than 60 ml/min) [3] , one patient refused to undergo CTPA, 2 patients with poor sonographic imaging and 2 patients with documented allergy to dye were excluded. The final studied group comprised of 150 patients.

We obtained written informed consent from all participants, and the study received approval from the Ethical Committee of Benha University Hospitals (MS30-6-2023).

Demographic data, cardiovascular risk factors, and duration of presentation were recorded. All patients underwent thorough clinical examination. Laboratory investigations were done for all patients including D dimer (Using the standard D-dimer cut off of 500 ng/mL or higher led to an increase in the number of patients flagged for the potential presence of PE) [18] and troponin (All studies utilized a cut off of 0.5 ng/mL (0.5 mcg/L) to detect elevated troponin levels) [19]. The simplified Wells` score was calculated for all participating patients and its value was more than 1 implying that pulmonary embolism was likely probable in all included patients. [4,14]

Echocardiography:

All patients underwent echocardiographic examination, before CTPA, Philips Epic 7C device was used in both institutes. Echocardiographic parameters were performed according to the latest guidelines [20].

The cut-off value of normal right ventricular basal, mid, and longitudinal diameter was no more than 41 mm, 35 mm, and 83 mm respectively [21], and the cut-off value of normal proximal and distal right ventricular outflow tract (RVOT) was no more than 30 mm and 27 mm respectively [21] .

The presence of RV/LV ratio of more than 1, D-shaped septum, dilated inferior vena cava with impaired collapsibility [2], TV max velocity of above than 2.8 m/s [7], and pulmonary artery systolic pressure (sPAP) were evaluated [8].

Tricuspid annular plane systolic excursion (TAPSE) was estimated with a normal cut-off value equal to 17 mm [2]. The presence of a 60/60 sign and early systolic notch of pulsed wave across pulmonary valve were recorded [9].

Computed tomography pulmonary angiography (CTPA):

All patients underwent CTPA, after echocardiographic examination, using Philips CT (computed tomography) scanner in both institutes, the type of used dye was iopromide. The Timing bolus technique was the technique used in both hospitals. In this technique, a small amount of contrast material (10 mL) is injected, followed by a dynamic scan with a region of interest (ROI) placed over the pulmonary artery. Usually, 60 to 150 mL of intravenous contrast is given at a rate of about 5 mL/s. The results are noted: acute pulmonary embolism on CT is identified

by a central filling defect within a vessel surrounded by contrast, which appears as a "polo mint" when viewed perpendicular to the vessel's long axis, or a "railway sign" when seen parallel to the vessel's long axis [1,13].

Patients were divided according to (CTPA) results into group I consisting of 67(44.6%) patients who have been definitively diagnosed with pulmonary embolism and group II consisting of 83(55.3%) patients without pulmonary embolism.

Statistical analysis:

The recorded data were analyzed using version 23.0 of the Statistical Package for the Social Sciences (SPSS Inc., Chicago, Illinois, USA).Evaluation of diagnostic performance was performed using diagnostic specificity, sensitivity, PPV, NPV, and accuracy. P-value <0.05 was considered significant.

Results:

There were no significant differences between the two groups in terms of age, gender, cardiovascular risk factors, presentation, modified Wells score, and troponin levels; however, the D-dimer level was significantly higher in group I with a p-value of 0.001. Table 1

Table 1: Comparison among groups as regard, demographic data, medical history & risk factors, presentation, clinical examination, duration of complaints by hour since admission to discharge, and laboratory investigations

Demographic data		**group I (n=67)**	**group II (n=83)**	**Test value**	**p-value**	**Sig.**
Age (years)		64.52±10.80	66.55±11.48	1.105	0.271	NS
Gender	**Male**	32 (47.8%)	35 (42.2%)	0.270	0.603	NS
	Female	35 (52.2%)	48 (57.8%)			
Medical History & Risk Factors	**DM**	7 (10.4%)	7 (8.4%)	0.175	0.676	NS
	HTN	9 (13.4%)	10 (12.0%)	0.065	0.798	NS
	Smoker	31 (46.3%)	35 (42.2%)	0.251	0.616	NS
	Dyslipidemia	13 (19.4%)	12 (14.5%)	0.636	0.425	NS
Presentation	**Dyspnea**	34 (50.7%)	38 (45.8%)	0.354	0.552	NS
	Chest and back pain	14 (20.9%)	23 (27.7%)	0.916	0.338	NS
	Syncope	3 (4.5%)	4 (4.8%)	0.007	0.931	NS
	Altered mental status	1 (1.5%)	7 (8.4%)	3.482	0.062	NS
	Hemoptysis	1 (1.5%)	2 (2.4%)	0.152	0.696	NS
	Weakness (upper limbs , lower limbs or generalized)	1 (1.5%)	2 (2.4%)	0.152	0.696	NS
	Swelling in the leg (edema , deep venous thrombosis or ischemia)	3 (4.5%)	0 (0.0%)	3.786	0.056	NS
Clinical Examination	**SBP (mmHg)**	118.49±27.14	121.81±22.11	0.826	0.410	NS
	DBP (mmHg)	88.44±12.06	85.43±10.05	-1.667	0.098	NS
	PP (mmHg)	45.69±10.56	48.03±15.06	1.076	0.284	NS
	HR (bpm)	116.58±13.07	114.17±12.26	-1.162	0.247	NS
	Saturation (SpO_2 %)	60 (89.6%)	79 (95.2%)	1.706	0.192	NS
Duration of complaints (hour)		47.55±13.68	47.09±14.58	1.058	0.386	NS
Labs	**D dimer (µg/mL)**	9.90±3.16	3.28±1.66	-16.483	Less than 0.001	HS
	Troponin (ng/ml)	45 (67.2%)	45 (54.2%)	2.593	0.107	NS

A statistically significant difference of high magnitude was observed between the groups,as regard, the presence of an early systolic notch (ESN) in 23 patients (34.3%) in group I versus 3 (3.6%)in group II (p-value 0.001).RV diameter at base and mid-cavity level was significantly higher in group I (p-value 0.001). Twenty-seven patients (40.3%) in group I had basal right ventricular/left ventricular ratio >1 versus 9 patients (10.8%) in group II, representing a high substantial difference statistically with p-value (p<0.001).TAPSE, sPASP, and TR Vmax showed a high substantial difference statistically between groups, patients in group I had worse TAPSE, higher sPASP & TR Vmax (p-value 0.001) for all three parameters. Table 2

Table 2: Comparison among both groups as regard echocardiographic parameters.

Echo parameters	group I (n=67)	group II (n=83)	Test value	p-value	Sig.
Early systolic notch(ESN)	23 (34.3%)	3 (3.6%)	24.245	Less than 0.001	HS
Right ventricular diameter at the base level (mm)	37.67±7.16	33.69±6.40	-3.59	Less than 0.001	HS
Right ventricular diameter at mid-cavitary level (mm)	31.23±5.93	27.98±5.32	-4.621	Less than 0.001	HS
Right ventricular longitudinal diameter (mm)	76.80±12.59	72.34±11.74	-2.422	0.026	S
Proximal RVOT diameter (mm)	32.82±6.24	30.65±5.82	-2.198	0.030	S
Distal RVOT diameter (mm)	26.16±4.97	24.11±4.58	-2.623	0.010	S
Basal right ventricular/left ventricular ratio >1	27 (40.3%)	9 (10.8%)	17.582	Less than 0.001	HS
Maconneell sign (Positive)	15 (22.4%)	2 (2.4%)	14.659	Less than 0.001	HS
60/60 sign (Positive)	27 (40.3%)	4 (4.8%)	16.854	Less than 0.001	HS
Flattened inter ventricle septum (Positive)	38 (56.7%)	22 (26.5%)	13.996	Less than 0.001	HS
IVC (mm)	19.78±4.12	14.42±4.17	-7.868	Less than 0.001	HS
IVC collapsibility <50%	22 (32.8%)	6 (7.2%)	15.918	Less than 0.001	HS
TAPSE (mm)	14.70±4.73	22.05±5.07	9.094	Less than 0.001	HS
Pulmonary artery systolic pressure (mmHg)	38.03±19	22.90±6	-5.682	Less than 0.001	HS
TR Vmax, (m/s)	2.39±0.46	1.68±0.32	-11.121	Less than 0.001	HS

When comparing different echo parameters as regard, their diagnostic accuracy for pulmonary embolism, the presence of ESN is considered the best single echocardiographic parameter in diagnosing pulmonary embolism with 34.3% sensitivity, 96.4% specificity, negative predictive value (NPV) 64.5%,positive predictive value (PPV)88.5% and accuracy 68.7%, followed by basal right ventricular/left ventricular ratio >1 with 40.3% sensitivity, 89.2% specificity, PPV 75%, NPV64.9% and accuracy was 67.3%. When testing the combination of different echo parameters accuracy for detecting pulmonary embolism combining all 7 parameters (ESN, dilated right ventricle dimensions, basal right ventricular/left ventricular ratio >1, Maconneell sign,60/60 sign, Flattened inter ventricle septum and IVC collapsibility <50%) we got 100%

specificity and 100% PPV and 73.9% accuracy in diagnosing pulmonary embolism Table 3.

Subgroup analysis of group I according to the presence of ESN revealed that ESN presence is significantly higher in patients with bilateral more than isolated right or left pulmonary emboli (p-value 0.012) and also ESN presence was founded more when the main pulmonary artery was involved more than lobar or segmental involvement (p-value 0.003).Table 4; Figure 1,2

Table 3: Diagnostic accuracy for echocardiographic parameters in prediction of occurrence of pulmonary embolism

Echo parameters	Sens.%	Spec.%	PPV%	NPV%	Accuracy%
1- Early systolic notch (ESN)	34.3%	96.4%	88.5%	64.5%	68.7%
2- Dilated right ventricle dimensions.	31.3%	92.8%	77.8%	62.6%	65.3%
3- Basal right ventricular/left ventricular ratio >1	40.3%	89.2%	75.0%	64.9%	67.3%
4- Maconneell sign	22.4%	97.6%	88.8%	65%	64%
5- 60/60 sign	40.3%	95.1%	87%	66.3%	70%
6- Flattened inter ventricle septum	56.7%	73.5%	63.3%	67.8%	66.0%
7- IVC collapsibility <50%	32.8%	92.8%	78.6%	63.1%	66.0%

Table 4: Comparison among PE with and without ESN according to localization and side of PE [Total 67 in PE]

	(group I a) PE with ESN (n=23)	(group I b) PE without ESN (n=44)	Test value	Sig.
	The side PE at any level			
Bilateral	20 (87.0%)	22 (50%)	7.310	0.007 (S)
Unilateral	3 (13%)	22 (50%)		
	The localization of PE			
Main pulmonary	15 (65.22%)A	13 (29.55%)B	11.374	0.003 (S)
Lobar	6 (26.09%)A	10 (22.73%)A		
Segmental	2 (8.70%)B	21 (47.73%)A		

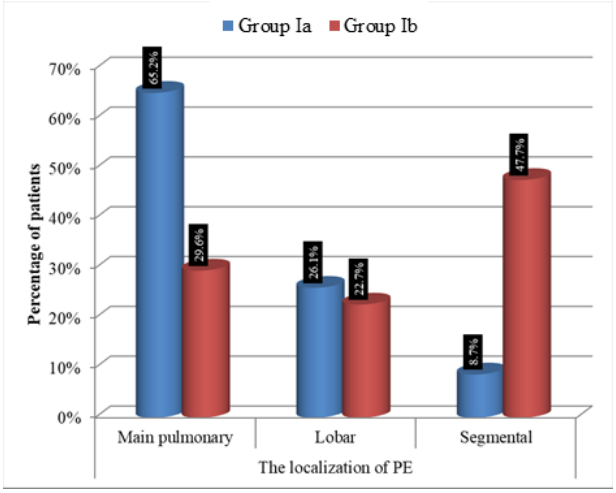

Figure 1: ESN and Localization of PE

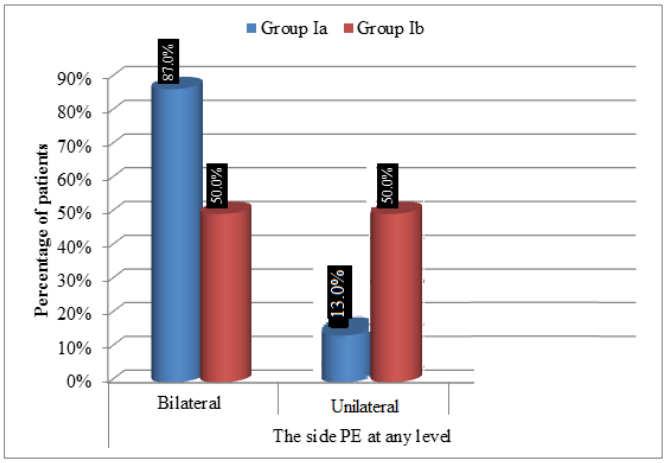

Figure 2: ESN and side of PE.

Discussion

Pulmonary embolism is a major factor in illness and death, yet it is frequently unrecognized and not diagnosed adequately [10, 11].

In this study, our aim was to investigate the diagnostic accuracy of demographic data, risk factors, clinical presentation, clinical labs and echocardiographic parameters in PE diagnosis. Also, we searched the diagnostic value of early systolic notch in predicting side and localization of pulmonary emboli.

In the present study, there was an insignificant difference among the studied groups as regard, the demographic data including age and gender, medical history, risk factors for patients (DM, HTN, smokers or dyslipidaemia), presentation, duration of presentation and troponin level. This was in agreement with Aslaner et al. ,who discussed the demographic features , risk factors, laboratory investigations and presentation in patients who attended to emergency room by suspected pulmonary emboli , reported that there was an insignificant difference as regard, demographic data , medical history , risk factors , presentation , duration of presentation in patients or troponin level between pulmonary emboli or without pulmonary emboli, who presented by suspension of pulmonary emboli [12] .

D-dimer is a by-product of the blood clotting and breakdown process, released as a clot starts to dissolve [23]. In the current study the mean value of D-dimer in group I was 9.90±3.16 (ng/mL) versus in group II was 3.28±1.66 (ng/mL), with p-value ($p<0.001$). This was in agreement with Sikora-Skrabaka et al , who discussed the D-dimer value in diagnosing pulmonary embolism found that the mean plasma D-dimer level was significantly higher in the group with confirmed PE (5,056 ng/mL) compared to the group without PE diagnosis (2,920ng/mL); $P<0.05$ [17] .

In the acute rise in PA pressures, the RV does not have the chance to generate pressures more than 60 mm Hg so the acceleration time across RVOT is shortened giving the shape of early systolic notch [24]. In this study early systolic notch was found in group I in 23 (34.3%) patients compared to group II was in 3 (3.6%) patients, with p-value (0.001).This was in agreement with Aslaner et al., who also discussed the ESN diagnostic accuracy and its value in prediction the side and localization of pulmonary emboli, reported that a substantial difference in early systolic notch among patients with or without pulmonary emboli [12].

The abrupt rise in PA pressure that occurs in PE causes RV enlargement [25]. In this

study, there was a substantial difference among group I and group II as regard RV dimensions. They were higher in patients with pulmonary emboli. This was in agreement with Carlo Bova et al, who discussed the specificity and sensitivity of right ventricular dilatation in diagnosis of PE. They reported that right ventricular dilation has high specificity of 94% and poor sensitivity of only 31% in diagnosing PE [(16).]

Due to the abrupt rise in PA pressure that occurs in PE RV/LV ratio can be more than 1 [(25)]. In this study, there was a significant difference of basal right ventricular/left ventricular ratio >1 in both groups, with p-value (p<0.001), this sign had a sensitivity of 40.3% , a specificity of 89.2%. This was in agreement with Dresden et al., who discussed the specificity and sensitivity of basal right ventricular/left ventricular ratio >1, reported That right ventricular dilation observed through echocardiography had a sensitivity of 50% (with a 95% confidence interval of 32% to 68%) and a specificity of 98%[(15)] .

One of the signs that are specific to acute PE is McConnell sign because in chronic PE there is global RV hypokinesia to all RV [(26)] .In this study, there was a significant difference of McConnell sign among group I and group II, with p-value (0.001). , With a specificity of 97.6%, this sign had a sensitivity of 22.4%. .This was in agreement with Dresden et al. Who reported that the McConnell sign could diagnose acute pulmonary embolism with a specificity of 100% and a sensitivity of 20%[(15)] , but recent studies as Rafie et al., who explored new insights into the pathophysiology of McConnell's sign reported that McConnell's sign is not exclusively indicative of pulmonary embolism [(21)]

Acute PE can cause pressure overload and elevated diastolic pressures causing D shaped septum [(27)]. In this present study, a significant difference was observed in the prevalence of a flattened interventricular septum: 38 cases (56.7%) were found in group I, compared to 22 cases (26.5%) in group II, with a p-value of 0.001. This sign had a sensitivity of 56.7% and a specificity of 73.5%.This was consistent with the results of Bigdelu et al. , Who reported that the prevalence of D-shaped ventricles was significantly higher in patients with pulmonary embolism compared to the control group (p < 0.001 for all cases) [(16)..] 60/60 sign is an evidence of acute RV strain in acute PE[(28)] ,in the current study, There was a significant difference between the two groups regarding the 60/60 sign: it was present in 27 patients (40.3%) in group I, compared to just 4 patients (4.8%) in group II, with a p-value of 0.833. This sign showed a sensitivity of 40.3% and a specificity of 95.1%. These findings are consistent with those of Oh et al., who reported that the 60/60 sign is among the most specific indicators of pulmonary embolism. They found that the presence of this sign had sensitivity of 41% and a specificity of 91% in detecting acute PE in 358 patients[(2)].

Dilated IVC with loss of inspiratory collapse correlates with patients with PE [(29)]. In this study, a significant difference was observed in IVC collapsibility <50%, with 22 patients (32.8%) in group I showing this measure compared to 6 patients (7.2%) in group II with p-value (0.001).This was consistent with the results of Kurnicka et al. , who discussed the significant relation between dilated IVC and pulmonary emboli cases , IVC was 14mm(5–30mm) in 14 patients of 139 patients with suspected pulmonary emboli, and was 19.2 ± 4.0 mm in 7 patients with confirmed pulmonary emboli, while IVC was 14mm (5–30) mm in 132 patients without pulmonary emboli , p value 0.005 [(22)] .

In this study, a significant difference was found in TR Vmax and pulmonary artery systolic pressure between the two groups, with a p-value of less than 0.001. These results are consistent with those reported by Grifoni S et al., who noted a significant

difference in TR Vmax and pulmonary artery systolic pressure between patients with and without pulmonary embolism presenting to the emergency room with suspected pulmonary emboli. [27]
Obstruction of the pulmonary arterial bed can lead to RV dysfunction that is potentially reversible. [30] . In the present study, TAPSE was significantly different between group I and group II, being higher in patients who did not have PE, with p-value (p<0.001). This was consistent with the results of oh et al. 2023 who reported that TAPSE [mm], was higher in control patients versus patients with PE. [2]
In the current study, ESN can predict the side of pulmonary emboli ,In PE with ESN(Early systolic notch) patients (n =23) , pulmonary emboli were, bilateral in 20 (87.0%) patients and unilateral in 3 (13%) patients compared to PE without ESN patients , pulmonary emboli were , bilateral in 22 (50%) patients and unilateral in 22 (50%) patients , P value 0.007 .This is consistent with the results of Aslaner et al. who reported that, pulmonary emboli were, bilateral in (84.8%) patients and unilateral in (15.2%) patients compared to PE without ESN patients, pulmonary emboli were bilateral in (49.2%) patients and unilateral in (50.8%) patients, P value 0.002 . [12]
In the current study, ESN can predict the localization of pulmonary emboli ,In PE with ESN patients (n =23), pulmonary emboli were, in main pulmonary artery in 15 (65.22%) patients, in Lobar artery in 6 (26.09%) patients and in segmental artery in 2 (8.70%), compared to PE without ESN patients , pulmonary emboli were, in main artery in 13 (29.55%) , in Lobar artery in 10 (22.73%) and in Segmental artery in 21 (47.73%) patients , P value 0.003 .
This was consistent with the results of Aslaner et al. who reported that pulmonary emboli were, in main pulmonary artery in (63.6%) patients, lobar (27.3%) patients and segmental in (9.1%) patient compared to PE without ESN patients, pulmonary emboli were , in main pulmonary artery in (28.6%) patients, lobar in (22.2%) patients, segmental in (49.2%) patients, P value <.001.[12]

Conclusions:

Echocardiographic parameters of PE have low sensitivity but high specificity in diagnosis, additionally early systolic notch in an echocardiographic parameter that had the highest specificity of all echocardiographic parameters and can help cardiologists to predict side and localization of pulmonary emboli.
Limitations: small sample size, double not multi-center study and lack of follow up.

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To cite this article: Basant Zahid, Ali I. Attia, Ahmed A. Ahmed, Kamal R. Ghareeb. Diagnostic Accuracy of Different Echocardiographic Parameters in Pulmonary Embolism. BMFJ 2025;42(2):193-202.