

ABBREVIATED PAPER

The value of electrocardiography in predicting inpatient mortality in patients with acute pulmonary embolism: A cross sectional analysis

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ABSTRACT

Introduction: Pulmonary embolism (PE) is a significant global cause of mortality, ranking third after myocardial infarction and stroke. ECG findings may play a valuable role in the prognostication of patients with PE, with various ECG abnormalities proving to be reasonable predictors of haemodynamic decompensation, cardiogenic shock, and even mortality. This study aims to assess the value of electrocardiography in predicting inpatient mortality in patients with acute pulmonary embolism, as diagnosed with computed tomography pulmonary angiogram.

Method: This study was a cross sectional analysis based at Tygerberg Hospital, Cape Town, South Africa. Eligible patients were identified from all CT-PA performed between 1 January 2017 and 31 December 2019 (2 years). The ECGs were independently screened by two blinded emergency physicians for predetermined signs that are associated with right heart strain and higher pulmonary artery pressures, and these findings were analysed to in-hospital mortality.

Results: Of the included 81 patients, 61 (75 %) were female. Of the 41 (51 %) patients with submassive PE and 8 (10 %) with massive PE, 7 (17 %) and 3 (38 %) suffered inpatient mortality ($p = 0.023$) respectively. Univariate ECG analysis revealed that complete right bundle branch block (OR, 8.6; 95 % CI, 1.1 to 69.9; $p = 0.044$) and right axis deviation (OR, 5.6; 95 % CI, 1.4 to 22.4; $p = 0.015$) were significant predictors of inpatient mortality.

Conclusion: Early identification of patients with pulmonary embolism at higher risk of clinical deterioration and in-patient mortality remains a challenge. Even though no clinical finding or prediction tool in isolation can reliably predict outcomes in patients with pulmonary embolism, this study demonstrated two ECG findings at presentation that were associated with a higher likelihood of inpatient mortality. This single-centre observational study with a small sample precludes concrete conclusions and a large follow-up multi-centre study is advised.

African Relevance

- The burden of pulmonary embolism is increasing in low- and middle-income countries, likely because of the pro-thrombotic state of the prevalent HIV/TB co-infection.
- Prognosticating pulmonary embolism is complex, especially in those patients where lysis or surgery is not indicated initially.
- ECG is cheap, reasonably available, and easy to perform, and the findings in pulmonary embolism are dynamic and correlate with the degree of right heart strain.
- Clinical predictors of deterioration, especially in patients with a submassive PE, may indicate that the benefits of closer monitoring or even lysis/surgery outweigh the risk.

Introduction

Pulmonary embolism represents the third leading cause of mortality globally after myocardial infarction with an overall mortality of 30 % [1]. The burden of disability-adjusted life years from thromboembolism is significantly higher in low- and middle-income countries (LMICs) compared to high-income countries (HICs) [2]. The pro-thrombotic state associated with HIV and TB likely contributes to the higher incidence of PE in LMICs [3–5].

PE is classified into different categories based on the presence or absence of hypoperfusion/shock and right ventricular dysfunction (RVD), allowing for tailored medical and interventional therapies [6]. However, patients with submassive PE (haemodynamically stable but

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with RVD) are particularly at risk, as their condition can rapidly deteriorate, leading to overt right ventricular failure and death [7]. Clot burden on computed tomography (CT) scan poorly predicts adverse outcomes, but rather the physiological changes to the right ventricle as seen on CT scan or ultrasound [6].

Electrocardiographic (ECG) findings have shown potential in predicting the prognosis of patients with PE, including haemodynamic decompensation, cardiogenic shock, and mortality [8]. Certain ECG abnormalities such as precordial T-wave inversion (TWI) and the presence of a Qr pattern in V1, have been associated with poor outcomes and increased mortality rates [9].

Reliably predicting clinical deterioration or mortality in patients with acute PE would enable the identification of individuals who will require closer monitoring and may benefit from thrombolysis or thrombectomy procedures, specifically in the submassive category. This study aims to evaluate the value of electrocardiography in predicting inpatient mortality in patients with acute pulmonary embolism.

Methods

This study was a cross sectional analysis that received ethical approval from the University of Cape Town Human Research Ethics Committee (HREC Ref: 722/2020).

This study was conducted at Tygerberg Hospital, a tertiary level hospital in Cape Town, South Africa. Patients with suspected PE were risk stratified according to their pre-test probabilities [10].

All adult patients (≥12 years old) with a confirmed PE as diagnosed by a radiologist reported CT scan during the study period of 3 years (1st of January 2017–31st of December 2019) were eligible for inclusion. Patients with missing or incomplete data, septic emboli, and chronic PE, were excluded. Convenience sampling included only diagnosis via CT scans as the proportion of diagnosis via scintigraphy were negligible and would have complicated data collection.

Data were collected in three phases. First, eligible cases were collated from the Picture Archiving and Communication System (PACS) database by exporting all CT-PA studies performed and reported on by a radiologist during the study period. CT outcome was then dichotomised as either positive or negative for pulmonary embolism. Phase 2 entailed the extraction of all clinical information, including all ECGs done at the time of diagnosis, and the demographic details of all CT-PA positive patient from the Enterprise Content Manager (ECM) database. Two emergency physicians, blinded to the clinical history, PE classification, and patient outcomes, independently analysed all ECGs in phase 3. ECGs were assessed for the presence or absence of pre-determined characteristics [9,11]. The definitions and measurements of ECG characteristics were standardised by the researchers prior to the initiation of phase 3 to minimise information bias (supplementary table). The only disagreements were due to differences in measurements, and this was resolved by consultation and joint remeasurement.

Categorical data were presented as frequencies and proportions (%) and continuous variables as median and inter-quantile ranges.

Categorical data were assessed for non-random associations with the use of the Chi² test. Continuous variables were assessed for significant differences with the Mann-Whitney U test. The prognostic value of electrocardiography to predict inpatient mortality was assessed univariately by calculating diagnostic odds ratios and p-values. Data were analysed with the help of IBM SPSS Statistics version 27 and statistical significance was defined as *p* < 0.05.

Results

During the 36 month study period, 301 patients received a CT-PA for a suspected PE, of which 99 (33 %) were positive. Eighty-one (82 %) patients were included in the final sample (Fig. 1).

The median age of the sample was 43 years (Table 1), with a female preponderance (*n* = 61, 75 %). Ten (12 %) patients suffered inpatient mortality, of which nine (90 %) were females. The most prevalent comorbidities included hypertension (*n* = 33, 41 %), HIV/AIDS (*n* = 24, 30 %), and cardiac failure (*n* = 10, 12 %). Risk factors for the development of a PE were similarly distributed between the two groups. There were no significant differences between the vital signs on presentation between the two groups: median systolic BP 116 vs 120 mmHg, *p* = 0.636; median diastolic BP 72 vs. 77 mmHg, *p* = 0.351; median HR 108 vs 110 bpm, *p* = 0.874 and SpO₂ 94% vs 95 %, *p* = 0.203.

Of the 41 (51 %) patients with submassive PE and eight (10 %) with massive PE, seven (17 %) and three (38 %) suffered inpatient mortality (*p* = 0.023) respectively. Two out of the seven (9 %) patients who received thrombolysis died and of the three patients who had embolectomies, all survived to hospital discharge. The cause of death was attributed to the PE in all non-survivors and no complications of thrombolysis were described.

Two emergency physicians assessed all ECGs individually (*n* = 81). Tachycardia (HR ≥100/minute) was the most common ECG feature (*n* = 59, 73 %) and the most sensitive (90 %) predictor of in-hospital death. Complete right bundle branch block (RBBB) and incomplete RBBB were the most specific predictors of in-hospital death, with a specificity of 97 % and 92 % respectively. TWI in leads V1-V4 (82 %), TWI in II (86 %), Q-wave in AvF (89 %) were reasonably specific changes that predicted in-hospital mortality. Unadjusted diagnostic odds ratios (OR) of ECG characteristics to predict in-hospital mortality (Table 2) found a complete RBBB (OR, 8.6; 95 % CI, 1.1 to 69.9; *p* = 0.044) and right axis deviation (RAD) (OR, 5.6; 95 % CI, 1.4 to 22.4; *p* = 0.015) to be significant predictors of in-hospital mortality.

Discussion

Despite the high mortality and prevalence of PE in LMICs, predicting rapid clinical deterioration and death remains challenging. Limited availability of resources to diagnose and monitor RVD, as well as the lack of validated clinical decision and prediction rules in high HIV/TB settings, contribute to this difficulty. Nevertheless, this study, despite its

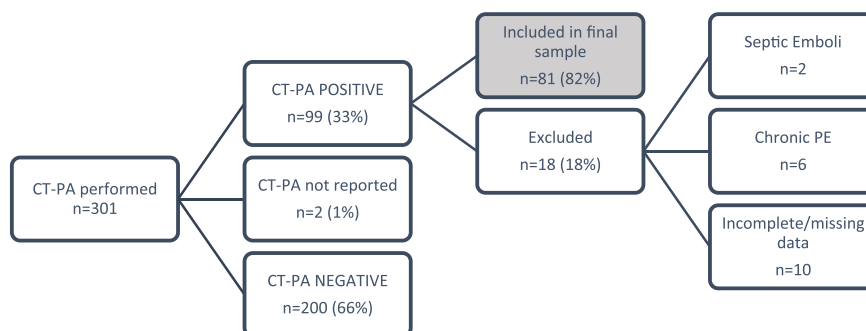


Fig. 1. Flow of participants.

Table 1
Patient demographics and clinical characteristics for each patient outcome (n = 81).

	Total	In-hospital death 10 (12%)	Survived to hospital discharge 71 (88%)	P
Gender (n, column%)				
Male	20 (25%)	1 (10%)	19 (27%)	.250
Female	61 (75%)	9 (90%)	52 (73%)	
Age categories (n, column%)				
12-17	2 (2%)	1 (10%)	1 (1%)	.252
18-25	7 (9%)	0 (0%)	7 (10%)	
26-35	17 (21%)	1 (10%)	16 (23%)	
36-45	20 (25%)	1 (10%)	19 (27%)	
46-55	18 (22%)	3 (30%)	15 (21%)	
56-65	7 (9%)	2 (20%)	5 (7%)	
>65	10 (12%)	2 (20%)	8 (11%)	
Referral from (n, column%)				
Community health centre	14 (17%)	0 (0%)	14 (20%)	.052
District hospital	42 (52%)	6 (60%)	36 (51%)	
*GP	4 (5%)	2 (20%)	2 (3%)	
Home	16 (20%)	1 (10%)	15 (21%)	
Inter-department	2 (2%)	1 (10%)	1 (1%)	
*WCRC	3 (4%)	0 (0%)	3 (4%)	
Co-morbidities (n, proportion)				
HIV/AIDS	24 (30%)	2 (20%)	22 (31%)	.476
TB	8 (10%)	0 (0%)	8 (11%)	.264
Hypertension	33 (41%)	1 (10%)	32 (45%)	.035
Cardiac Failure	10 (12%)	3 (30%)	7 (10%)	.070
Stroke	7 (9%)	1 (10%)	6 (9%)	.870
COPD	4 (5%)	0 (0%)	4 (6%)	.441
Risk Factors (n, proportion)				
Recent immobilisation	12 (15%)	0 (0%)	12 (17%)	.159
Recent long haul travel	7 (9%)	1 (10%)	6 (9%)	.870
Recent surgery	8 (10%)	0 (0%)	8 (11%)	.264
Recent trauma	7 (9%)	0 (0%)	7 (10%)	.299
Malignancy	2 (3%)	0 (0%)	2 (3%)	.591
*DVT	10 (12%)	1 (10%)	9 (13%)	.810
Other	24 (30%)	2 (20%)	22 (31%)	.476
Tobacco use	25 (31%)	4 (40%)	21 (31%)	.564
Obesity	23 (28%)	2 (20%)	21 (31%)	.594
Prior PE	2 (3%)	0 (0%)	2 (3%)	.583
Prior DVT	5 (6%)	2 (20%)	3 (4%)	.060
Prior TB	10 (12%)	3 (30%)	7 (10%)	.082
Hormonal/contraceptive Rx	4 (5%)	0 (0%)	4 (6%)	.435
Presenting Symptoms (n, proportion)				
Chest pain	55 (68%)	5 (50%)	50 (70%)	.195
Dyspnoea	74 (91%)	10 (100%)	60 (90%)	.299
Cough	53 (65%)	7 (70%)	46 (65%)	.746
Haemoptysis	9 (11%)	1 (10%)	8 (11%)	.905
Syncope	6 (7%)	1 (10%)	5 (7%)	.738
Clinical Signs (n, proportion)				
Tachypnoea	57 (70%)	8 (80%)	49 (70%)	.427
Tachycardia	61 (75%)	8 (80%)	53 (75%)	.713
Cyanosis	0	0	0	
Pyrexia	0	0	0	
Lower limb swelling/pain	27 (33%)	4 (40%)	23 (32%)	.633
Special Investigations (n, proportion)				
Raised Troponin T (n=37)	12 (32%)	1 (10%)	11 (33%)	.737
Raised D-dimer (n=38)	36 (95%)	4 (40%)	32 (94%)	.618
Right ventricular strain on *POCUS (n=31)	21 (68%)	2 (20%)	19 (68%)	.967
Classification of PE (n, column%)				
Massive	8 (10%)	3 (30%)	5 (7%)	.023
Submassive	41 (51%)	7 (70%)	34 (48%)	.190
Low-Risk	32 (39%)	0	32 (45%)	.006
Treatment Received (n, proportion)				
Mechanical ventilation	6 (7%)	3 (30%)	3 (4%)	.004
Thrombolysis	7 (9%)	2 (20%)	5 (7%)	.172
Embolectomy	3 (4%)	0	3 (4%)	.508

* GP, general practitioner; WCRC, Western Cape Rehabilitation Centre; COPD, DVT, deep vein thrombosis; POCUS, point-of-care ultrasonography. Statistically significant different variables are highlighted; Gender were self-reported; Percentages may not add to 100 % because of rounding.

Table 2
Univariate analysis of ECG characteristics to predict in-hospital mortality.

	Total N=81	In-hospital death N=10	OR (95% CI)	P	Sensitivity	Specificity
Tachycardia ≥100 *bpm	59 (73%)	9 (90%)	1.358 (0.264- 6.997)	.714	90%	30%
Atrial fibrillation	1 (1%)	0				
TWI in leads V1-V2	24 (30%)	3 (30%)	1.020 (0.240- 4.330)	.978	30%	70%
TWI in leads V1-V3	20 (25%)	3 (30%)	1.361 (0.317- 5.851)	.678	30%	76%
TWI in leads V1-V4	14 (17%)	1 (10%)	0.496 (0.058- 4.263)	.523	10%	82%
S wave in lead I	35 (43%)	6 (60%)	2.171 (0.563- 8.386)	.260	60%	59%
TWI in lead AvF	25 (31%)	2 (20%)	0.522 (0.103- 2.656)	.433	20%	68%
TWI in lead II	12 (15%)	2 (20%)	1.525 (0.282- 8.245)	.624	20%	86%
TWI in lead III	38 (47%)	3 (30%)	0.441 (0.105- 1.843)	.262	30%	51%
S _I Q _{III} T _{III} pattern	16 (20%)	0				
Incomplete RBBB	7 (9%)	1 (10%)	1.204 (0.130- 11.181)	.870	10%	92%
Complete RBBB	4 (5%)	2 (20%)	8.625 (1.064- 69.886)	.044	20%	97%
Q wave in lead III	25 (31%)	1 (10%)	0.218 (0.026- 1.820)	.159	10%	66%
Q wave in lead AvF	9 (11%)	1 (10%)	0.875 (0.098- 7.842)	.905	10%	89%
Right axis deviation	21 (26%)	6 (60%)	5.600 (1.398- 22.428)	.015	60%	79%
Left axis deviation	3 (4%)	0				
Low voltage	3 (4%)	0				
Qr in V1	11 (14%)	2 (20%)	1.722 (0.315- 9.427)	.531	20%	87%

* bpm, beats per minute.
Statistically significant values highlighted.

small sample size, identified two ECG characteristics associated with a higher likelihood of inpatient mortality.

This study identified two ECG characteristics that were associated with an increased inpatient mortality: RAD and a complete RBBB with a 5.6- and 1.2-times higher odds respectively, in patients who did not survive to hospital discharge. However, the small sample size and low number of non-survivors resulted in wide confidence intervals. Sinus tachycardia was the most common and sensitive, while complete and incomplete RBBB were the most specific predictors of fatality. Although not statistically significant, TWI in V1-V4, TWI in lead II, and Q-wave in AvF were reasonably specific in predicting in-hospital death. A systemic review and meta-analysis conducted by Qaddoura et al. [12] found several ECG features predictive of in-hospital death, including S₁Q₃T₃, complete RBBB, TWI, ST-depression in V4-V6, ST-elevation in V1 and lead III, Qr in V1, RAD, AF, and RV transmural ischaemic pattern. These ECG changes reflect RVD in patients with large clot load and have been shown to predict a poorer outcome when present [13]. Therefore, patients presenting with a suspected PE with any of these signs, may require more intensive monitoring and management. Clinical decision rules to predict outcomes often incorporate CT scan findings or point of care ultrasound findings, lowering their utility in LMICs where access to these modalities is limited [14].

The limited sample size reduced the likelihood of identifying significant findings and prevented robust multivariate regression analysis. The sampling strategy excluded younger patients and those who received lung scintigraphy, potentially introducing selection bias. All-cause mortality as the outcome measure requires a thorough analysis

of confounders, yet confounders during hospital admission were not assessed (including the effect of conditions that contribute to chronic right heart strain). Future research should collect prospective data from multiple facilities and explore clinical outcomes in cases where clinical deterioration or death can be reliably predicted.

Conclusion

Identifying high-risk patients with pulmonary embolism and predicting their clinical deterioration and in-patient mortality is challenging. Although the sample size was small, this study suggests that complete RBBB and RAD may serve as predictors of mortality in pulmonary embolism patients. While no single finding or prediction tool can reliably determine outcomes, ECG findings hold promise. Due to the limitations of this single-centre observational study and small sample, further large-scale multi-centre research is recommended for conclusive results.

Dissemination of results

The findings of this study were presented at the Division of Emergency Medicine Cape Town, and at various forums to local emergency medicine clinicians.

Author contributions

Authors contributed as follows to the conception or design of the

work; the acquisition, analysis, or interpretation of data for the work; and drafting the work or revising it critically for important intellectual content: NR 50 %, CH 35 %, SL 15 %. All authors approved the version to be published and agreed to be accountable for all aspects of work.

Declaration of competing interest

The authors declared no conflicts of interest.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at [doi:10.1016/j.afjem.2024.01.004](https://doi.org/10.1016/j.afjem.2024.01.004).

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