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Original Contribution

Blood pressure for outcome prediction and risk stratification in acute pulmonary embolism☆,☆☆,★,★★

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ABSTRACT

Introduction: Risk stratification of patients with acute pulmonary embolism (PE) is crucial in deciding appropriate therapy management. Blood pressure (BP) is rapidly available and a reliable parameter. We aimed to investigate BP for short-term outcome in acute PE.

Materials and methods: Data of 182 patients with acute PE were analyzed retrospectively. Logistic regression models were calculated to investigate associations between BP and in-hospital-death as well as myocardial necrosis. Moreover, receiver operating characteristic (ROC) curves and cutoff values for systolic and diastolic BPs predicting in-hospital death and myocardial necrosis were computed.

Results: A total of 182 patients (61.5% female; mean age, 68.5 ± 15.3 years) with acute PE event were included in the study. Five patients (2.7%) died in the hospital.

Logistic regression models showed a significant association between in-hospital death and systolic BP ≤ 120 mm Hg (odds ratio [OR], 22.222; 95% confidence interval [CI], 2.370-200.00; $P = .00660$), systolic BP ≤ 110 mm Hg (OR, 22.727; 95% CI, 3.378-142.857; $P = .00130$), systolic BP ≤ 100 mm Hg (OR, 16.129; 95% CI, 2.304-111.111; $P = .00513$), systolic BP ≤ 90 mm Hg (OR, 22.727; 95% CI, 3.086-166.667'; $P = .00220$), and diastolic BP ≤65 mm Hg (OR, 14.706; 95% CI, 1.572-142.857; $P = .0184$), respectively. Association between myocardial necrosis and systolic BP0 >100 mm Hg (OR, 5.444; 95% CI, 1.052-28.173; $P = .0433$) was also significant.

Receiver operating characteristic analysis for systolic BP predicting in-hospital death revealed an area under the curve of 0.831 with a cutoff value of 119.5 mm Hg. Receiver operating characteristic analysis for diastolic BP predicting in-hospital death showed an area under the curve of 0.903 with a cutoff value of 66.5 mm Hg.

Conclusions: Systolic and diastolic BPs are excellent prognosis predictors of patients with acute PE. Systolic BP of 120 mm Hg or less and diastolic BP of 65 mm Hg or less at admission are connected with elevated risk of in-hospital death.

1. Introduction

Current guidelines emphasise the central role of early-risk stratification of patients with an acute pulmonary embolism (PE) [1–3]. Early-risk stratification in acute PE event is necessary to identify PE patients with higher risk of early death, who could benefit from more intensive surveillance and especially more aggressive therapy [1,4,5]. Early-risk stratification in acute PE is crucial in deciding appropriate therapy management.

Systolic and diastolic blood pressure (BP) values are rapidly available and reliable parameters. It is well known that PE patients with hypotension are at high risk for dying in short term [2,3,6] with a mortality rate greater than 15% [6,7]. However, both important clinical scores Geneva and pulmonary embolism severity index (PESI) identified hypotension with systolic BP <100 mm Hg as a significant predictor of adverse prognosis [3,8,9], whereas both the European Society of Cardiology guideline and the American Heart Association (AHA) statement recommend a systolic BP less than 90 mm Hg as a critical indicator of

Abbreviations: AHA, American Heart Association; AUC, area under the curve; BP, blood pressure; CT, computed tomography; ESC, European Society of Cardiology; ICOPER, International Cooperative Pulmonary Embolism Registry; PE, pulmonary embolism; PESI, pulmonary embolism severity index; ROC, receiver operating characteristic; RVD, right ventricular dysfunction; V/Q scan, ventilation-perfusion scan.

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★ All authors contributed toward the study conception, design, acquisition of data, analysis, and interpretation of data.

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early death in acute PE [2,3]. Although the mentioned systolic BP values to predict worse outcome are not far apart, there is no general-purposed consensus about the systolic and diastolic BP cutoff values for risk stratification and to predict worse outcome in acute PE. In the European Society of Cardiology guidelines and AHA statement, risk stratification process of acute PE through BP values focuses on systolic BP only [2,3]. We hypothesized that the diastolic BP is at least equally important for risk stratification of acute PE than systolic and should also included in risk stratification strategies.

The aim of our study was to investigate the systolic and diastolic BPs for risk stratification and to predict worse outcome in acute PE and especially to calculate cutoff values to predict in-hospital death and myocardial necrosis in acute PE.

2. Methods and patients

We performed a retrospective analysis of patients with a confirmed diagnosis of acute PE, who were treated in the internal medicine department between May 2006 and June 2011. Patients with PE were identified with a search in the hospital information system database for the diagnostic code of PE (*International Classification of Diseases* code: I26).

3. Enrolled subjects

Patients were eligible for this study

1. if the diagnosis of acute PE was confirmed by identified filling defect in the pulmonary artery system in computed tomography (CT) pulmonary angiogram of the chest or positive venous ultrasound/phlebography of an extremity consistent with deep vein thrombosis (DVT) in patients with typical symptoms of PE (chest pain or dyspnea) and a detected positive D-dimer or scintigraphic ventilation-perfusion scan read as high probability for PE;
2. if the PE patients were treated in the Internal Medicine department of the hospital; and
3. if the patients were at least 18 years old.

All CT and scintigraphic images were analyzed by experienced radiologists. If diagnosis of PE was not confirmed by the criteria above, the patients were not included in this study.

4. Definitions

4.1. Definition of cardiac injury

Myocardial necrosis was defined as cardiac troponin I (cTnI) elevation greater than 0.4 ng/mL, according to the AHA scientific statement from 2011 [3].

5. Study parameters

The retrospectively analysis of the PE patients focused on BP, cardiac biomarkers, and in-hospital death.

6. Statistics

Patients with PE and with systolic BP less than 120 mm Hg were compared with PE patients with systolic BP of 120 mm Hg or greater with the help of Wilcoxon-Mann-Whitney *U* test as well as PE patients with systolic BP greater than 65 mm Hg compared with PE patients with systolic BP 65 mm Hg or less.

We performed logistic regression models to investigate the association between systolic as well as diastolic BP values and respectively in-hospital death and myocardial necrosis.

Receiver operating characteristic (ROC) analysis with area under the curve (AUC) for systolic and diastolic BPs predicting in-hospital death and myocardial necrosis, respectively, was computed for all PE patients of this study, for the high-risk patients with initial systolic BP less than 90 mm Hg and for the normotensive PE patients, respectively.

Commercially available software BIAS (version 10.04) (Epsilon Publishing House, University of Frankfurt, Germany) was used for the computerized analysis. *P* values less than .05 were considered statistically significant.

7. Results

Between May 2006 and June 2011, 182 patients with acute and confirmed PE event met the inclusion criteria and were included in the study. Pulmonary embolism patients' mean age was 68.5 ± 15.3 years (female: 70.8 ± 15.1 years; male: 64.9 ± 15.0 years). Most patients were of female sex (61.5% female, 38.5% male). Diagnosis of PE was made in 85.7% using CT, in 10.4% using ventilation-perfusion scan, and in 3.9% diagnosis made by positive venous ultrasound/phlebography of an extremity, which was consistent with DVT in patients with typical symptoms of PE (chest pain or dyspnea) and positive D-dimer level.

Of the total of 182 PE patients, 5 (2.7%) died in the hospital after the PE event.

The logistic regression models showed a significant association between in-hospital death and systolic BP ≤ 120 mm Hg (odds ratio [OR] , 22.222; 95% confidence interval [CI], 2.370-200.00; $P = .00660$), systolic BP ≤ 110 mm Hg (OR, 22.727; 95% CI, 3.378-142.857; $P = .00130$), systolic BP ≤ 100 mm Hg (OR, 16.129; 95% CI, 2.304-111.111,; $P = .00513$), systolic BP ≤ 90 mm Hg (OR, 22.727; 95% CI, 3.086-166.667; $P = .00220$), and diastolic BP ≤ 65 mm Hg (OR, 14.706; 95% CI, 1.572-142.857; $P = .0184$), respectively (Table 1).

Myocardial necrosis and systolic BP greater than 100 mm Hg (OR, 5.444; 95% CI, 1.052-28.173; $P = .0433$) were also significantly associated (Table 2).

The calculated ROC analysis for systolic BP predicting in-hospital death revealed an AUC of 0.831 with systolic BP cutoff value of 119.5 mm Hg for all PE patients. The percentage of misclassification, sensitivity, specificity, and positive and negative predictive values were calculated as 17.3%, 81.0%, 84.5%, 85.3%, and 80.0%, respectively (Fig. 1).

Computed ROC analysis for systolic BP for prediction of in-hospital death in high-risk PE patients with initial systolic BP of <90 mm Hg showed an AUC of 1.0 with systolic BP cutoff-value of 50.0 mm Hg. Percentage of misclassification, sensitivity, specificity, and positive and negative predictive values were calculated as 0.0%, 100.0%, 100.0%, 100.0%, and 100.0%, respectively.

In normotensive PE patients, calculated ROC analysis for systolic BP predicating in-hospital death revealed an AUC of 0.739 with systolic BP cutoff-value of 119.5 mm Hg. Percentage of misclassification, sensitivity, specificity, and positive and negative predictive values were calculated as 22.8%, 72.5%, 84.5%, 87.8%, and 66.7%, respectively.

Receiver operating characteristic analysis for diastolic BP predicting in-hospital death showed an AUC of 0.903 with diastolic BP cutoff value of 66.5 mm Hg for all PE patients. The percentage of misclassification,

Table 1
Univariate logistic regression to detect the coherence of in-hospital death and systolic BP values, diastolic BP values, sex, and age

	OR (95% CI)	*P*
Sex	0.391 (0.043-3.590)	.407
Age	1.001 (0.944-1.062)	.967
Systolic BP ≤120 mm Hg	22.222 (2.370-200.00)	.00660
Systolic BP ≤110 mm Hg	22.727 (3.378-142.857)	.00130
Systolic BP ≤100 mm Hg	16.129 (2.304-111.111)	.00513
Systolic BP ≤90 mm Hg	22.727 (3.086-166.667)	.00220
Diastolic BP ≤65 mm Hg	14.706 (1.572-142.857)	.0184
Diastolic BP ≤75 mm Hg	2.5027E + 05 (0.000-1.982E + 110)	.920
Diastolic BP ≤85 mm Hg	1.7562E + 05 (0.000-2.547E + 135)	.937
Systolic BP ≤120 mm Hg and diastolic BP ≤65 mm Hg	20.625 (3.106-136.941)	.00173