

Impact of Cardiovascular Events on In-Hospital Mortality in Pulmonary Embolism: An Explainable Machine Learning Analysis

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Background: Pulmonary embolism (PE) is a major cause of cardiovascular morbidity and in-hospital mortality. Concurrent cardiovascular events, myocardial infarction (MI), heart failure (HF), hypertension (HT), and stroke, are common in PE patients, yet their independent prognostic weight remains poorly quantified. Standard risk scores such as the Charlson Comorbidity Index conflate these individual events into a single composite, potentially masking their distinct contributions.

Aims: To quantify the independent prognostic contribution of individual cardiovascular events to in-hospital mortality in patients with acute pulmonary embolism using explainable machine learning.

Methods: We applied explainable machine learning to 129,328 acute PE admissions from the Spanish Minimum Basic Data Set (2016–2024), using LighGBM ensemble tree models and Shapley Values.

Results: LightGBM classifier achieved an AUROC of 0.769 and an Average Precision of 0.358. SHAP analysis identified age, malignancy, and ICU admission as dominant predictors; among cardiovascular events, heart failure ranked 4th (mean |SHAP|=0.166) and hypertension 6th (0.112). In-hospital mortality increased monotonically with cumulative cardiovascular burden: 12.5\%(0 events), 14.4\%(1), 17.8\%(2), and 20.9\%(≥3). Heart failure showed age-amplified SHAP contributions in patients aged ≥75 years.

Conclusions: Individual cardiovascular events have distinct and additive effects on in-hospital mortality in acute PE, with heart failure as a key age-dependent driver. Composite indices may mask these differences. Explainable machine learning supports more precise, individualized risk stratification.

