

# Echocardiography does not predict mortality in hemodynamically stable elderly patients with acute pulmonary embolism

## Authors:

Eveline Hofmann, MD\*; Andreas Limacher, PhD, MAS, MSc†; Marie Méan, MD\*,‡; Nils Kucher, MD§; Marc Righini, MD||; Beat Frauchiger, MD¶; Jürg-Hans Beer, MD#; Joseph Osterwalder, MD, MPH††; Markus Aschwanden, MD‡‡; Christian M. Matter, MD§§; Martin Banyai, MD||||; Michael Egloff, MD¶¶; Olivier Hugli, MD MPH†††; Daniel Staub, MD‡‡; Henri Bounameaux, MD||; Nicolas Rodondi, MD, MAS\*,‡‡‡; Drahomir Aujesky, MD, MSc\*

## Author Affiliations:

\*Department of General Internal Medicine, Bern University Hospital, Bern, Switzerland (Drs Hofmann, Méan, Rodondi, and Aujesky); †Clinical Trials Unit Bern, Department of Clinical Research, and Institute of Social and Preventive Medicine, University of Bern, Bern, Switzerland (Dr. Limacher); ‡Department of General Internal Medicine, Lausanne University Hospital, Lausanne, Switzerland (Dr. Méan); §Division of Angiology, Bern University Hospital, Bern, Switzerland (Dr. Kucher); ||Division of Angiology and Hemostasis, Geneva University Hospital, Geneva, Switzerland (Drs Righini and Bounameaux); ¶Department of Internal Medicine, Cantonal Hospital of Frauenfeld, Frauenfeld, Switzerland (Dr. Frauchiger); #Department of Internal Medicine, Cantonal Hospital of Baden, Baden, Switzerland (Dr. Beer); ††Emergency Department, Cantonal Hospital of St. Gallen, St. Gallen, Switzerland (Dr. Osterwalder); ‡‡Division of Angiology, Basel University Hospital, Basel, Switzerland (Drs Aschwanden and Staub); §§Cardiovascular Research, Institute of Physiology, Zurich Center for Integrative Human Physiology, University of Zurich, and Division of Cardiology, Zurich University Hospital, Zurich, Switzerland (Dr. Matter); ||||Division of Angiology, Cantonal Hospital of Lucerne, Lucerne, Switzerland (Dr. Banyai); ¶¶Department of Endocrinology, Diabetes, Hypertension and Nutrition, Geneva University Hospital, Geneva, Switzerland (Dr. Egloff); †††Emergency Department, Lausanne University Hospital, Lausanne, Switzerland (Dr. Hugli); ‡‡‡Institute of Primary Health Care, University of Bern, Bern, Switzerland (Dr. Rodondi)

**Running headline:** Echocardiography in pulmonary embolism

**Corresponding Author:**

Eveline Hofmann, MD  
Department of General Internal Medicine  
Bern University Hospital, Inselspital  
3010 Bern, Switzerland  
Email: [eveline.hofmann@insel.ch](mailto:eveline.hofmann@insel.ch)  
Phone: +41 (0) 31 632 21 11  
Fax: +41 (0) 31 632 88 85

## ABSTRACT

**Background:** The evidence on the prognostic value of transthoracic echocardiography (TTE) in elderly, hemodynamically stable patients with pulmonary embolism (PE) is limited.

**Objectives:** To evaluate the prevalence of common echocardiographic signs of right ventricular (RV) dysfunction and their prognostic impact in hemodynamically stable patients aged  $\geq 65$  years with acute PE in a prospective multicenter cohort.

**Methods:** TTE was performed by cardiologists. We defined RV dysfunction as a RV/left ventricular ratio  $>0.9$  or RV hypokinesis (primary definition) or the presence of  $\geq 1$  or  $\geq 2$  of 6 predefined echocardiographic signs (secondary definitions). Outcomes were overall mortality and mortality/non-fatal recurrent venous thromboembolism (VTE) at 30 days, adjusting for the Pulmonary Embolism Severity Index risk score and highly sensitive troponin T values.

**Results:** Of 400 patients, 36% had RV dysfunction based on our primary definition, and 81% ( $\geq 1$  sign) and 53% ( $\geq 2$  signs) based on our secondary definitions, respectively. Using our primary definition, there was no association between RV dysfunction and mortality (adjusted HR 0.90, 95% CI 0.31-2.58) and mortality/non-fatal VTE (adjusted HR 1.09, 95% CI 0.40-2.98). Similarly, there was no statistically significant association between the presence of  $\geq 1$  or  $\geq 2$  echocardiographic signs (secondary definitions) and clinical outcomes.

**Conclusion:** The prevalence of echocardiographic RV dysfunction varied widely depending upon the definition used. There was no association between RV dysfunction and clinical outcomes. Thus, TTE may not be suitable as a stand-alone risk assessment tool in elderly patients with acute PE.

**Clinical Trial Registration:** <http://clinicaltrials.gov>. Identifier: NCT00973596.

**Keywords:** echocardiography, pulmonary embolism, mortality

## INTRODUCTION

Evidence suggests that echocardiographic signs of right ventricular (RV) dysfunction or pulmonary hypertension (hereafter called signs of RV dysfunction) are associated with a 2-fold increase in short-term overall mortality in hemodynamically stable patients with acute pulmonary embolism (PE) [1, 2]. Several professional societies have therefore incorporated transthoracic echocardiography (TTE), alone or in combination with cardiac biomarkers, into their risk assessment strategies for hemodynamically stable patients with acute PE [3, 4]. According to current recommendations, fibrinolysis may be considered in selected hemodynamically stable patients with RV dysfunction [3, 4]. TTE has been widely adopted into clinical practice and despite its costs and the need for a trained physician, currently more than a third of patients diagnosed with acute PE undergo TTE [5, 6].

Although elderly patients have more severe venous thromboembolism (VTE) and a higher short-term mortality rate than younger patients [7, 8], the prognostic performance of TTE to predict mortality has not been specifically examined in elderly patients with acute PE. The aim of this study was to prospectively evaluate the prevalence of common echocardiographic signs of RV dysfunction and their prognostic impact in elderly patients with acute PE.

## **METHODS**

### **Cohort sample**

This study was conducted between September 2009 and June 2012 as part of a prospective, multicenter cohort study to assess long-term medical outcomes and quality of life in patients aged  $\geq 65$  years with an acute VTE from all five Swiss university and four high-volume non-university hospitals [9]. Consecutive patients aged  $\geq 65$  years with an acute VTE were identified in the inpatient and outpatient services of all participating study sites. Exclusion criteria were catheter-related thrombosis, insufficient German or French-speaking ability, no follow-up possible (i.e., terminal illness), an inability to provide informed consent (i.e., severe dementia), or previous enrollment in the cohort. The study was approved by the Institutional Review Board at each participating center. The detailed study methods were previously published [9]. For the present study, we only considered hemodynamically stable patients with an acute symptomatic, objectively confirmed PE [9]. Hemodynamic stability was defined as a systolic blood pressure of  $\geq 90$  mm Hg at the time of PE diagnosis.

### **Baseline data collection**

Trained study nurses prospectively collected baseline demographic characteristics, comorbid conditions, type of PE (unprovoked vs. provoked), localization of PE, vital signs, routine laboratory findings (hemoglobin, serum creatinine), and anticoagulation-related treatments. In addition, we recorded whether the patient was admitted to the intensive care unit or received intravenous catecholamines, cardiopulmonary resuscitation, vena cava filter, fibrinolysis, or thromboembolectomy in the hospital.

We also collected venous blood samples at the time of PE diagnosis. Samples were immediately centrifuged, frozen, and stored at -80°C and sent for analyses to a core laboratory. Plasma concentrations of N-terminal pro-brain natriuretic peptide (NT-proBNP) and highly sensitive troponin T (hsTnT) were measured quantitatively using a Cobas e601 automated immunoanalyser (electrochemiluminescence methods, Hoffmann-La Roche, Rotkreuz, Switzerland).

### **Echocardiographic examination**

Patients underwent TTE at the time of study enrollment to assess RV function. All TTEs were performed by on-site cardiologists according to a standardized protocol. The cardiologists were blinded to patients' baseline characteristics and treatments. The following six signs of RV dysfunction/pulmonary hypertension were recorded: 1) RV/LV end-diastolic diameter ratio  $>0.9$  in the apical four chamber view, 2) RV hypokinesis (defined as a moderately or severely abnormal motion of RV free wall), 3) paradoxical septal motion, 4) decreased or absent inspiratory collapse of the inferior vena cava, 5) shortened pulmonary acceleration time in the parasternal short axis view ( $\leq 100$  ms), and 6) increase in RV/right atrial gradient in the apical four chamber or parasternal short axis view ( $\geq 30$  mm Hg) [10-14]. For the present analysis, we considered only patients who had TTE within three days of PE diagnosis [15].

We used the presence of a RV/LV ratio  $>0.9$  or RV hypokinesis as our primary definition of RV dysfunction, as suggested by the American Heart Association [3]. However, because the definition of RV dysfunction varies widely across studies, we also defined RV dysfunction as the presence of at least one and at least two of six echocardiographic signs described above, respectively (secondary definitions).

## **Study outcomes**

The primary outcome was overall mortality within 30 days of PE diagnosis. The secondary outcome was overall mortality/non-fatal recurrent VTE at 30 days. Recurrent VTE was defined as symptomatic, objectively confirmed recurrent PE or a new symptomatic deep vein thrombosis [9]. Follow-up included a face-to-face patient interview and hospital chart review at 90 days, complemented by proxy interviews and an interview of the patient's primary care physician. A committee of three blinded clinical experts adjudicated all outcomes and classified the cause of all deaths as definitely due to PE, possibly due to PE, or due to another cause [9]. Final classifications were made on the basis of the full consensus of this committee.

## **Statistical analysis**

We compared baseline characteristics and descriptive outcome data of patients with and without RV dysfunction using the Fisher's exact test for categorical data and the Wilcoxon rank-sum test for continuous variables as appropriate. In patients treated with vitamin K antagonists, we compared the percentage of time spent in the therapeutic INR range (2.0-3.0) using analysis of variance [16]. We used Kaplan-Meier curves and the log-rank test to compare the cumulative overall mortality and overall mortality/recurrence of non-fatal VTE within 30 days in patients with and without RV dysfunction.

We examined the association between RV dysfunction and clinical outcomes using a Cox-regression model. We adjusted all models for the Pulmonary Embolism Severity Index risk score and hsTnT. The Pulmonary Embolism Severity Index is a validated prognostic score and comprises 11 clinical variables, including demographics (age, gender), comorbid diseases (cancer, heart failure, and chronic lung disease), and vital signs (altered mental status, pulse, systolic blood pressure,



respiratory rate, arterial oxygen saturation, and temperature) [17]. Given that NT-proBNP is another marker for RV dysfunction, we did not adjust for this parameter [18]. Because RV dysfunction may be transitory, we also examined the association between RV dysfunction and clinical outcomes in the subgroup of patients who had TTE within one day of PE diagnosis [19]. Missing values in covariates used for adjustment were assumed as normal. We considered *P*-values <0.05 to be statistically significant. All analyses were performed using Stata 14.0.

## RESULTS

### Study sample

Overall, 685 hemodynamically stable patients with PE were initially enrolled in our study. After exclusion of 285 (42%) patients (277 had no TTE within three days and 8 withdrew consent early or did not allow use of their data), our final sample comprised 400 patients. Excluded patients were more likely to be women (53% vs. 44%,  $P=0.02$ ) and to have hospital-acquired PE (22% vs. 14%,  $P=0.007$ ) or anemia (43% vs. 35%,  $P=0.029$ ) than analyzed patients. The other baseline characteristics, including illness severity based on the Pulmonary Embolism Severity Index, were comparable. There were no differences in mortality, intensive care admission, catecholamine use, fibrinolysis, cardiopulmonary resuscitation, or thromboembolectomy (data not shown).

Patients with RV dysfunction based on our primary definition were older and were more likely to have a history of VTE, unprovoked, central, or lobar PE, a heart rate  $\geq 110$ /minute, a respiratory rate  $\geq 30$ /minute, and an arterial oxygen saturation  $< 90\%$  than patients without RV dysfunction (Table 1). Patients with RV dysfunction had also a higher proportion of NT-proBNP  $> 500$  pg/ml, and were more likely to be admitted to the intensive care unit, receive fibrinolysis, and have cardiopulmonary resuscitation than patients without RV dysfunction. In patients treated with vitamin K antagonists, the percentage of time in the therapeutic range did not vary between patients with and without RV dysfunction (61% vs. 63%,  $P=0.37$ ).

The prevalence of echocardiographic signs of RV dysfunction varied from 15% for RV hypokinesis to 54% for pulmonary acceleration time  $\leq 100$  ms (Table 2). Overall, 36% of patients had a RV/LV end-diastolic diameter ratio  $> 0.9$  or RV hypokinesis (primary definition), and 81% and 53% had  $\geq 1$  and  $\geq 2$  signs of RV dysfunction, respectively (secondary definitions).

## **Comparison of outcomes**

Fifteen patients (3.8%) died within 30 days of the index PE. Of these, 5 died from definite/possible PE, 3 from cancer, 1 from left ventricular heart failure, 1 from other pulmonary causes, 2 from bleeding, 2 from sepsis, and 1 from an unknown cause. One patient (0.3%) had recurrent non-fatal VTE. Only 3 patients (0.8%) died within 7 days, all from definite/possible PE. Patients with RV dysfunction based on our primary definition had the same cumulative incidence of overall mortality and mortality/recurrence of non-fatal VTE than patients without RV dysfunction (Figure 1, Panel A and B). Based on our primary definition, the 30-day overall mortality was 4.2% and 3.5% for patients with and without RV dysfunction, respectively ( $P=0.79$ ), with no difference in definite/possible fatal PEs (2.1% vs. 0.8%;  $P=0.35$ ). Using the presence of  $\geq 1$  and  $\geq 2$  echocardiographic signs to define RV dysfunction, the overall mortality was 4.3% vs. 1.3% ( $P=0.32$ ) and 4.7% vs. 2.7% ( $P=0.43$ ), respectively.

## **Association between RV dysfunction and clinical outcomes**

RV dysfunction based on our primary definition was not associated with overall mortality (adjusted hazard ratio [HR] 0.90, 95% confidence interval [CI] 0.31-2.58) and the combined outcome of overall mortality/recurrence of non-fatal VTE within 30 days (HR 1.09, 95% CI 0.40-2.98) (Table 3). Using secondary definitions of RV dysfunction, patients with RV dysfunction were somewhat more likely to experience death or death/non-fatal recurrence of VTE than patients without RV dysfunction but the association did not reach statistical significance (Table 3). When we restricted the analysis to the 189 patients (47%) who had TTE within one day of PE diagnosis, the results did not change markedly (results not shown).

## DISCUSSION

In our prospective cohort study, we found no significant association between echocardiographic signs of RV dysfunction and clinical outcomes in hemodynamically stable elderly patients with acute PE, irrespective of the definition used. Depending on the definition of RV dysfunction, the prevalence of RV dysfunction varied widely and ranged from 36% using a restrictive (RV/LV end-diastolic diameter ratio  $>0.9$  or RV hypokinesis) to 81% using a broader definition (presence of  $\geq 1$  echocardiographic sign). Our findings are consistent with results from prior studies in which the prevalence of echocardiographic RV dysfunction varied greatly from 20% to 68% in hemodynamically stable patients with PE [20, 21]. This substantial heterogeneity in the prevalence has been attributed to the lack of standardization of criteria used to define RV dysfunction and differences in patient characteristics [22]. Moreover, inter-observer reliability of echocardiographic signs of RV dysfunction in hemodynamically stable patients with PE appears to be heterogeneous, the agreement between cardiologists varying from fair ( $\kappa=0.45$ ) for RV end-diastolic diameter measurement to good for RV hypokinesis ( $\kappa=0.70$ ) [23]. A future effort to establish more standardized, reliable criteria of RV function is needed.

In contrast to the majority of studies enrolling younger hemodynamically stable patients with PE [13, 15, 20, 21, 24-30], we did not find a relationship between echocardiographic RV dysfunction and short-term clinical outcomes in our sample of elderly patients. In particular, the specific set of echocardiographic criteria recommended by the American Heart Association (presence of RV/LV end-diastolic diameter ratio  $>0.9$  or RV hypokinesis) was not associated with adverse clinical events. There are several potential explanations for our results. First, only 33% of patients who died during follow-up died from definite/possible PE, indicating that short-term prognosis of elderly patients with acute PE may be more often driven by

comorbidities than by PE-related RV dysfunction. RV dysfunction may also reflect cardiac and pulmonary diseases rather than severity of PE in the elderly [31, 32]. Mortality from definite/possible PE did not differ by RV function in our study.

Second, patients with RV dysfunction were more likely to be admitted to the intensive care unit and to receive fibrinolysis than patients without RV dysfunction, which may have improved an otherwise poor prognosis. However, this scenario seems unlikely in light of the results of the PEITHO trial [33]. While fibrinolysis reduced the risk of decompensation in hemodynamically stable patients with PE who had RV dysfunction and elevated troponin in this trial, overall mortality did not differ, and the risk-benefit ratio of fibrinolysis was worse in patients aged >75 years [34]. Finally, although TTEs were performed according to a standardized protocol, readings were not centrally adjudicated and we have no information about reliability and technical quality of the exams. Although this may be a limitation, the quality of our TTEs is likely to be representative of the real world situation in many hospitals.

In a scientific statement, the American Heart Association recommends fibrinolysis as a treatment option for hemodynamically stable patients with PE who have evidence of moderate to severe RV strain [3]. According to the European Society of Cardiology, patients with stable PE who have both signs of RV dysfunction on TTE and elevated troponin should be closely monitored for clinical deterioration [4]. Our findings do not support the use of TTE in the risk stratification of elderly patients with PE, at least not as a stand-alone risk assessment tool. In a prior study, the use of TTE to risk-stratify patients with PE resulted in higher care levels and more advanced treatments but did not improve outcomes [6].

Our study has several potential limitations. First, we excluded 42% of patients, mostly, because TTE was not available within three days of PE diagnosis. However, excluded patients did not appear to be more severely ill or to have more adverse

outcomes than analyzed patients, making a selection bias unlikely. Second, because PE-related RV dysfunction may be transient and only about half of patients had TTE within one day of PE diagnosis, we may have not captured all patients with initial RV dysfunction. However, when restricting our analysis to patients who had TTE within one day of PE diagnosis, the results did not change. Third, we did not evaluate hemodynamic (PE-related) decompensation, we only collected information regarding PE-related processes of care (e.g., fibrinolysis, intensive care unit admission, administration of catecholamines, and cardiopulmonary resuscitation). However, managing physicians were not blinded to RV function and the utilization of these treatments may have been partially influenced by managing physicians' knowledge of patients' RV function. Thus, the use of these treatments may at least partially reflect guideline or expert recommendations and not the occurrence of hemodynamic decompensation. Fourth, as a predefined ancillary study within the SWITCO65+ prospective cohort, our study was not powered to detect mortality differences between patients with and without RV dysfunction. Specifically, there were not enough PE-related deaths to examine the association between RV dysfunction and PE-related mortality. Finally, our results may not be generalizable to more novel echocardiographic signs that were not examined in our study (e.g., tricuspid annular plane systolic excursion [TAPSE]) [35].

In conclusion, the prevalence of echocardiographic RV dysfunction varies widely based on the criteria used to define RV dysfunction in elderly, hemodynamically stable patients with acute PE. We did not find an association between RV dysfunction and short-term clinical outcomes. Our results do not support TTE as a stand-alone risk stratification tool in the elderly with acute PE.

**Conflict of interest statement**

The authors have no conflict of interest.

**Acknowledgments**

This work was supported by a grant of the Swiss National Science Foundation (no. 33CSCO-122659/139 470). We thank all collaborators of the SWITCO65+ study.

## References

- 1 Sanchez O, Trinquart L, Colombet I, Durieux P, Huisman MV, Chatellier G, Meyer G. Prognostic value of right ventricular dysfunction in patients with haemodynamically stable pulmonary embolism: a systematic review. *Eur Heart J* 2008; **29**: 1569-77.
- 2 Coutance G, Cauderlier E, Ehtisham J, Hamon M. The prognostic value of markers of right ventricular dysfunction in pulmonary embolism: a meta-analysis. *Crit Care* 2011; **15**: R103.
- 3 Jaff MR, McMurry MS, Archer SL, *et al.* Management of massive and submassive pulmonary embolism, iliofemoral deep vein thrombosis, and chronic thromboembolic pulmonary hypertension: a scientific statement from the American Heart Association. *Circulation* 2011; **123**: 1788-830.
- 4 Konstantinides S, Torbicki A, Agnelli G, *et al.* 2014 ESC Guidelines on the diagnosis and management of acute pulmonary embolism: The Task Force for the Diagnosis and Management of Acute Pulmonary Embolism of the European Society of Cardiology (ESC) Endorsed by the European Respiratory Society (ERS). *Eur Heart J* 2014.
- 5 Spirk D, Willenberg T, Aujesky D, *et al.* Use of biomarkers or echocardiography in pulmonary embolism: the Swiss Venous Thromboembolism Registry. *QJM* 2012; **105**: 1163-9.
- 6 Stamm JA, Long JL, Kirchner HL, Keshava K, Wood KE. Risk stratification in acute pulmonary embolism: frequency and impact on treatment decisions and outcomes. *South Med J* 2014; **107**: 72-8.
- 7 López-Jiménez L, Montero M, González-Fajardo JA, *et al.* Venous thromboembolism in very elderly patients: findings from a prospective registry (RIETE). *Haematologica* 2006; **91**: 1046-51.
- 8 Spirk D, Husmann M, Hayoz D, *et al.* Predictors of in-hospital mortality in elderly patients with acute venous thrombo-embolism: the SWISS Venous ThromboEmbolic Registry (SWIVTER). *Eur Heart J* 2012; **33**: 921-6.



- 9 Mean M, Righini M, Jaeger K, *et al.* The Swiss cohort of elderly patients with venous thromboembolism (SWITCO65+): rationale and methodology. *J Thromb Thrombolysis* 2013; **36**: 475-83.
- 10 Ribeiro A, Lindmarker P, Juhlin-Dannfelt A, Johnsson H, Jorfeldt L. Echocardiography Doppler in pulmonary embolism: right ventricular dysfunction as a predictor of mortality rate. *Am Heart J* 1997; **134**: 479-87.
- 11 Kasper W, Konstantinides S, Geibel A, Tiede N, Krause T, Just H. Prognostic significance of right ventricular afterload stress detected by echocardiography in patients with clinically suspected pulmonary embolism. *Heart* 1997; **77**: 346-9.
- 12 Palmieri V, Gallotta G, Rendina D, *et al.* Troponin I and right ventricular dysfunction for risk assessment in patients with nonmassive pulmonary embolism in the Emergency Department in combination with clinically based risk score. *Intern Emerg Med* 2008; **3**: 131-8.
- 13 Grifoni S, Olivetto I, Cecchini P, *et al.* Short-term clinical outcome of patients with acute pulmonary embolism, normal blood pressure, and echocardiographic right ventricular dysfunction. *Circulation* 2000; **101**: 2817-22.
- 14 Fremont B, Pacouret G, Jacobi D, Puglisi R, Charbonnier B, de Labriolle A. Prognostic value of echocardiographic right/left ventricular end-diastolic diameter ratio in patients with acute pulmonary embolism: results from a monocenter registry of 1,416 patients. *Chest* 2008; **133**: 358-62.
- 15 Pruszczyk P, Goliszek S, Lichodziejewska B, *et al.* Prognostic Value of Echocardiography in Normotensive Patients With Acute Pulmonary Embolism. *JACC Cardiovasc Imaging* 2014.
- 16 Rosendaal FR, Cannegieter SC, van der Meer FJ, Briet E. A method to determine the optimal intensity of oral anticoagulant therapy. *Thromb Haemost* 1993; **69**: 236-9.
- 17 Aujesky D, Obrosky DS, Stone RA, *et al.* Derivation and validation of a prognostic model for pulmonary embolism. *Am J Respir Crit Care Med* 2005; **172**: 1041-6.

- 18 Klok FA, Mos IC, Huisman MV. Brain-type natriuretic peptide levels in the prediction of adverse outcome in patients with pulmonary embolism: a systematic review and meta-analysis. *Am J Respir Crit Care Med* 2008; **178**: 425-30.
- 19 Chung T, Emmett L, Mansberg R, Peters M, Kritharides L. Natural history of right ventricular dysfunction after acute pulmonary embolism. *J Am Soc Echocardiogr* 2007; **20**: 885-94.
- 20 Jimenez D, Aujesky D, Moores L, *et al.* Combinations of prognostic tools for identification of high-risk normotensive patients with acute symptomatic pulmonary embolism. *Thorax* 2011; **66**: 75-81.
- 21 Becattini C, Casazza F, Forgione C, *et al.* Acute pulmonary embolism: external validation of an integrated risk stratification model. *Chest* 2013; **144**: 1539-45.
- 22 ten Wolde M, Sohne M, Quak E, Mac Gillavry MR, Buller HR. Prognostic value of echocardiographically assessed right ventricular dysfunction in patients with pulmonary embolism. *Arch Intern Med* 2004; **164**: 1685-9.
- 23 Kopecka D, Briongos S, Castillo H, *et al.* Interobserver reliability of echocardiography for prognostication of normotensive patients with pulmonary embolism. *Cardiovasc ultrasound* 2014; **12**: 29.
- 24 Sanchez O, Trinquart L, Planquette B, *et al.* Echocardiography and pulmonary embolism severity index have independent prognostic roles in pulmonary embolism. *Eur Respir J* 2013; **42**: 681-8.
- 25 Stein PD, Matta F, Janjua M, Yaekoub AY, Jaweesh F, Alrifai A. Outcome in stable patients with acute pulmonary embolism who had right ventricular enlargement and/or elevated levels of troponin I. *Am J Cardiol* 2010; **106**: 558-63.
- 26 Kucher N, Rossi E, De Rosa M, Goldhaber SZ. Prognostic role of echocardiography among patients with acute pulmonary embolism and a systolic arterial pressure of 90 mm Hg or higher. *Arch Intern Med* 2005; **165**: 1777-81.
- 27 Zhu L, Yang Y, Wu Y, Zhai Z, Wang C. Value of right ventricular dysfunction for prognosis in pulmonary embolism. *Int J Cardiol* 2008; **127**: 40-5.

- 28 Stein PD, Janjua M, Matta F, Pathak PK, Jaweesh F, Alrifai A, Chughtai HL. Prognosis based on creatine kinase isoenzyme MB, cardiac troponin I, and right ventricular size in stable patients with acute pulmonary embolism. *Am J Cardiol* 2011; **107**: 774-7.
- 29 Logeart D, Lecuyer L, Thabut G, *et al.* Biomarker-based strategy for screening right ventricular dysfunction in patients with non-massive pulmonary embolism. *Intensive Care Med* 2007; **33**: 286-92.
- 30 Vanni S, Nazerian P, Pepe G, *et al.* Comparison of two prognostic models for acute pulmonary embolism: clinical vs. right ventricular dysfunction-guided approach. *J Thromb Haemost* 2011; **9**: 1916-23.
- 31 Wilson SR, Ghio S, Scelsi L, Horn EM. Pulmonary hypertension and right ventricular dysfunction in left heart disease (group 2 pulmonary hypertension). *Prog Cardiovasc Dis* 2012; **55**: 104-18.
- 32 Freixa X, Portillo K, Paré C, *et al.* Echocardiographic abnormalities in patients with COPD at their first hospital admission. *Euro Resp J* 2013; **41**: 784-91.
- 33 Meyer G, Vicaut E, Danays T, *et al.* Fibrinolysis for patients with intermediate-risk pulmonary embolism. *N Engl J Med* 2014; **370**: 1402-11.
- 34 Cohen AT, Agnelli G, Anderson FA, *et al.* Venous thromboembolism (VTE) in Europe. The number of VTE events and associated morbidity and mortality. *Thromb Haemost* 2007; **98**: 756-64.
- 35 Lobo JL, Holley A, Tapson V, *et al.* Prognostic significance of tricuspid annular displacement in normotensive patients with acute symptomatic pulmonary embolism. *J Thromb Haemost* 2014; **12**: 1020-7.

## FIGURE LEGENDS

### Figure 1

#### **Panel A. Kaplan-Meier estimates of overall mortality by RV function\***

The cumulative incidence of overall mortality at 30 days was 4.2% for patients with RV dysfunction vs. 3.5% for patients without RV dysfunction ( $P=0.728$ ) by the log-rank test).

#### **Panel B. Kaplan-Meier estimates of overall mortality or recurrence of non-fatal venous thromboembolism by RV function\***

The cumulative incidence of the combined outcome of overall mortality and recurrence of non-fatal venous thromboembolism at 30 days was 4.9% for patients with RV dysfunction vs. 3.5% for patients without RV dysfunction ( $P=0.501$ ) by the log-rank test).

Abbreviations: RV= right ventricular.

\*RV dysfunction was defined as the presence of a RV/left ventricular end-diastolic diameter ratio  $>0.9$  or a right ventricular hypokinesis on transthoracic echocardiography.

**Table 1. Patient baseline characteristics by echocardiographic RV function**

|  | RV dysfunction*<br>(N=143) | No RV dysfunction<br>(N=257) | P-value |
|--|----------------------------|------------------------------|---------|
|  | n (%) or median (IQR)†     |                              |         |
| Age, years                             | 75.0 (70.0-84.0)           | 74.0 (69.0-80.0)             | 0.041   |
| Male gender                            | 78 (55)                    | 147 (57)                     | 0.674   |
| Active cancer‡                         | 17 (12)                    | 49 (19)                      | 0.069   |
| Heart failure§                         | 21 (15)                    | 25 (10)                      | 0.144   |
| Chronic lung disease                   | 19 (13)                    | 38 (15)                      | 0.766   |
| Prior history of VTE                   | 49 (34)                    | 62 (24)                      | 0.036   |
| Unprovoked index PE¶                   | 114 (80)                   | 177 (69)                     | 0.020   |
| Localization of PE#                    |                            |                              |         |
| Central                                | 62 (43)                    | 73 (28)                      | 0.003   |
| Lobar                                  | 73 (51)                    | 98 (38)                      | 0.015   |
| Segmental                              | 93 (65)                    | 179 (70)                     | 0.372   |
| Subsegmental                           | 41 (29)                    | 107 (42)                     | 0.013   |
| Isolated subsegmental                  | 5 (3)                      | 28 (11)                      | 0.013   |
| Unknown localization                   | 9 (6)                      | 9 (4)                        | 0.214   |
| Altered mental status                  | 6 (4)                      | 11 (4)                       | 1.000   |
| Heart rate ≥110 beats/minute           | 27 (19)                    | 23 (9)                       | 0.007   |
| Systolic blood pressure <100 mm Hg     | 4 (3)                      | 4 (2)                        | 0.464   |
| Temperature <36 C°                     | 11 (8)                     | 26 (10)                      | 0.588   |
| Respiratory rate ≥30 breaths/minute    | 11 (8)                     | 5 (2)                        | 0.017   |
| Arterial oxygen saturation <90%        | 31 (22)                    | 28 (11)                      | 0.005   |
| PESI risk class                        |                            |                              | 0.414   |
| I                                      | 1 (1)                      | 4 (2)                        |         |
| II                                     | 37 (26)                    | 85 (33)                      |         |
| III                                    | 48 (34)                    | 81 (31)                      |         |
| IV                                     | 35 (24)                    | 60 (23)                      |         |
| V                                      | 22 (15)                    | 27 (11)                      |         |
| Anemia††                               | 41 (29)                    | 98 (38)                      | 0.062   |
| Serum creatinine >1.5 mg/dl            | 11 (8)                     | 29 (11)                      | 0.299   |
| Highly sensitive troponin T >0.1 ng/ml | 13 (9)                     | 11 (4)                       | 0.082   |
| NT-proBNP >500 pg/ml                   | 91 (64)                    | 93 (36)                      | <0.001  |
| VKA therapy prior to PE diagnosis      | 8 (6)                      | 7 (3)                        | 0.173   |
| Initial parenteral anticoagulation     |                            |                              | 0.048   |
| Low molecular weight heparin           | 55 (39)                    | 132 (51)                     |         |
| Unfractionated Heparin                 | 65 (46)                    | 84 (33)                      |         |
| Fondaparinux                           | 21 (15)                    | 35 (14)                      |         |
| No parenteral anticoagulation          | 2 (1)                      | 6 (2)                        |         |
| Subsequent VKA therapy                 | 133 (93)                   | 231 (90)                     | 0.363   |

Continued

Continued

|                                     | <b>RV dysfunction*</b><br><b>(N=143)</b> | <b>No RV dysfunction</b><br><b>(N=257)</b> | <b>P-</b><br><b>value</b> |
|-------------------------------------|--|--|---------------------------|
|                                     | <b>n (%) or median (IQR)†</b>            |  |                           |
| Use of inferior vena cava filter    | 2 (1)                                    | 1 (1)                                      | 0.292                     |
| Admission to intensive care unit    | 25 (18)                                  | 22 (9)                                     | 0.010                     |
| Use of intravenous catecholamines‡‡ | 3 (2)                                    | 4 (2)                                      | 0.704                     |
| Cardiopulmonary resuscitation       | 3 (2)                                    | 0 (0)                                      | 0.045                     |
| Fibrinolysis§§                      | 11 (8)                                   | 4 (2)                                      | 0.004                     |
| Thromboembolectomy  l               | 0 (0)                                    | 1 (1)                                      | 1.000                     |

Abbreviations: RV= right ventricular; IQR= interquartile range; VTE= venous thromboembolism. PESI= Pulmonary Embolism Severity Index; PE= pulmonary embolism; VKA= vitamin K antagonist.

\*RV/left ventricular end-diastolic diameter ratio >0.9 or RV hypokinesis.

†Data were missing for heart rate (1%), systolic blood pressure (1%), temperature (3%), respiratory rate (21%), arterial oxygen saturation (5%), anemia (1%), creatinine (2%), hsTNT (11%), and NT-proBNP (11%).

‡Cancer requiring surgery, chemotherapy, radiotherapy, or palliative care during the last 3 months.

§Acute heart failure NYHA class II-IV during the last 3 months, history of systolic/diastolic heart failure, left/right heart failure, forward/backward heart failure, or left ventricular ejection fraction of <40%.

||Chronic obstructive pulmonary disease, active asthma, lung fibrosis, cystic fibrosis, or bronchiectasies.

#Absence of major surgery, estrogen therapy, or immobilization (fracture or cast of the lower extremity, bed rest >72 hours, or voyage in sitting position for >6 hours) during the last 3 months.

#Multiple localizations per patient were possible.

††Hemoglobin <130 g/l for men and <120 g/l for women.

‡‡Dopamin, dobutamin, adrenalin, noradrenalin, or vasopressin.

§§Systemic or catheter-based fibrinolysis.

||lCatheter-based or surgical thromboembolectomy.

**Table 2. Prevalence of echocardiographic signs of RV dysfunction (N=400)**

| <b>Echocardiographic sign</b>   | <b>n (%)<sup>*</sup></b> |
|---|--------------------------|
| RV/LV end-diastolic diameter ratio >0.9                               | 124 (31)                 |
| RV hypokinesis  | 58 (15)                  |
| Paradoxical septal motion   | 82 (21)                  |
| Reduced inspiratory collapse of the inferior vena cava                | 109 (27)                 |
| Pulmonary acceleration time ≤100 ms                                   | 216 (54)                 |
| RV/right atrial gradient ≥30 mm Hg                                    | 193 (48)                 |
| Presence of RV/LV end-diastolic diameter ratio >0.9 or RV hypokinesis | 143 (36)                 |
| Presence of ≥1 sign of RV dysfunction                                 | 324 (81)                 |
| Presence of ≥2 signs of RV dysfunction                                | 213 (53)                 |

Abbreviations: RV= right ventricular; LV= left ventricular.

\*6% of patients had missing values for RV/LV ratio, 2% for RV hypokinesis, 3% for paradoxical septal motion, 11% for inspiratory collapse of the inferior vena cava, 22% for pulmonary acceleration time, and 23% for RV/right atrial gradient.

**Table 3. Association between echocardiographic RV dysfunction and clinical outcomes within 30 days**

|   | <b>Adjusted hazard ratio*<br/>(95% confidence interval)</b> |
|---|---|
| <b>RV/LV ratio &gt;0.9 or RV hypokinesis</b>                    |   |
| Overall mortality   | 0.90 (0.31-2.58)  |
| Overall mortality or recurrence of non-fatal VTE                | 1.09 (0.40-2.98)  |
| <b>Presence of <math>\geq 1</math> sign of RV dysfunction†</b>  |   |
| Overall mortality   | 2.22 (0.28-17.42)   |
| Overall mortality or recurrence of non-fatal VTE                | 2.52 (0.32-19.57)   |
| <b>Presence of <math>\geq 2</math> signs of RV dysfunction†</b> |   |
| Overall mortality   | 1.43 (0.48-4.20)  |
| Overall mortality or recurrence of non-fatal VTE                | 1.60 (0.55-4.64)  |

Abbreviations: RV= right ventricular, LV= left ventricular, VTE= venous thromboembolism.

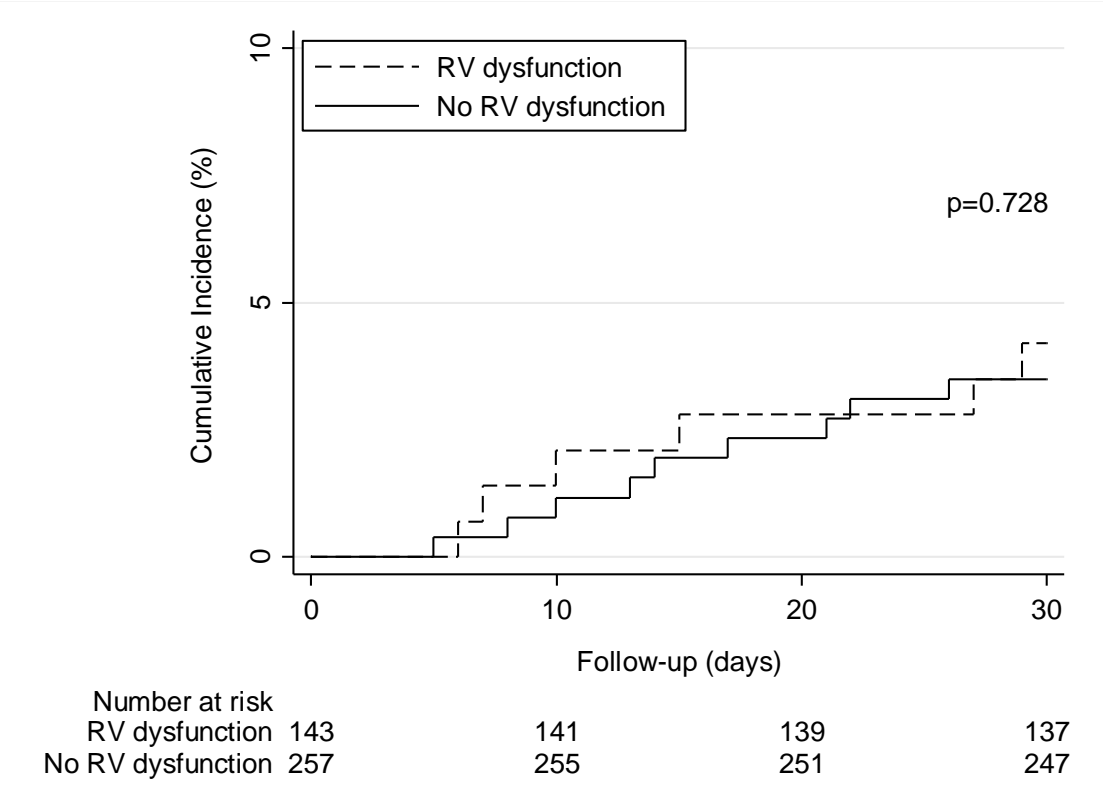
\*Adjusted for Pulmonary Embolism (PE) Severity Index risk score and hsTnT >0.1 ng/ml.

†RV/LV end-diastolic diameter ratio >0.9 in the apical four chamber view, RV hypokinesis, paradoxical septal motion, decreased or absent inspiratory collapse of the inferior vena cava, decrease in pulmonary acceleration time in the parasternal short axis view ( $\leq 100$  ms), or increase in RV/right atrial gradient in the apical four chamber or parasternal short axis view ( $\geq 30$  mm Hg).



**Figure.**

**A.**



**B.**

