ORIGINAL ARTICLE

UDC: 616.24-005.7-037
DOI: https://doi.org/10.2298/VSP240109023B

Sex differences in the prognostic value of computed tomography pulmonary angiography parameters for intrahospital acute pulmonary embolism-related death

Polno zavisne razlike u prognostičkom značaju parametara dobijenih kompjuterizovanom tomografskom angiografijom pluća za intrahospitalnu smrtnost kod akutne plućne embolije

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Abstract

Background/Aim. Multidetector computed tomography pulmonary angiography (MCTPA) has emerged as the most suitable method for diagnosing acute pulmonary embolism (APE) in hemodynamically stable patients. In addition to its diagnostic role, MCTPA facilitates the measurement and calculation of certain parameters that can be used as prognostic markers for outcomes in APE. Since the introduction of the method, there have been a lot of studies that pointed out there may be a significant difference in the prognostic value of MCTPA for APE concerning sex. **Methods.** The study population consisted of consecutive patients with a diagnosis of APE confirmed by MCTPA. Positive MCTPA findings and a diagnosis of APE were established if the patient had at least one segmental artery thrombus. APE severity was estimated using the simplified Pulmonary Embolism Severity Index (sPESI). All-cause and APE-related intrahospital deaths were the coprimary outcomes of this study. **Results.** In total, 1,612 patients were enrolled in the study (750 men and 862 women). Women with a centrally positioned pulmonary thrombus detected on MCTPA were more likely to die from PE-related death than those without one (10.4% vs. 4.2%, respectively; $p = 0.016$). Women with a right ventricle (RV) and left ventricle (LV) diameter ratio (RV/LV) > 1 died almost twice as often as those with a ratio ≤ 1 (15.5% vs. 8.6%, respectively; $p = 0.017$). Women with an RV/LV > 1 detected with MCTPA were significantly more likely to die from PE than those with a ratio ≤ 1 (11% vs. 5.2%, respectively; $p = 0.017$). Women who died from PE-related causes had a significantly higher value of the embolic burden score system (EBSS) than did the surviving women (18.00 vs. 11.00, respectively; $p = 0.025$). Independently of age, sPESI, and renal function, the presence of a central thrombus [odds ratio (OR) 2.278, 95% confidence interval (CI): 1.050–4.944, $p = 0.037$] and the RV/LV ratio > 1 (OR 2.015, 95% CI: 1.042–3.893, $p = 0.037$) were associated with intrahospital PE-related death in women. **Conclusion.** In women, MCTPA parameters, a centrally placed thrombus, the RV/LV ratio, and the EBSS had prognostic significance for PE-related mortality. The

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RV/LV ratio had prognostic significance for all-cause intrahospital mortality. In men, the MCTPA parameters had no prognostic significance for both overall and PE-related mortality.

Key words:
computed tomography angiography; mortality; multidetector computed tomography; pulmonary embolism; sex; treatment outcome.

Apstrakt

Uvod/Cilj. Metoda multidetektorske kompjuterizovane tomografske angiografije pluća (MKTAP) se pokazala kao najpogodnija metoda za dijagnostikovanje akutne plućne embolije (APE) kod hemodinamski stabilnih bolesnika. Pored svoje dijagnostičke uloge, MKTAP olakšava merenje i izračunavanje određenih parametara koji se mogu koristiti kao prognostički markeri za ishode APE. Od uvođenja metode, urađen je veliki broj studija koje su ukazivale na to da može postojati značajna polno zavisna razlika u prognostičkoj vrednosti MKTAP u odnosu na ishod APE. **Metode.** Ispitivanu populaciju činili su konsekutivni bolesnici sa dijagnozom APE potvrđenom primenom MKTAP. Pozitivni MKTAP nalazi i dijagnoza APE postavljani su ako je bolesnik imao najmanje jedan tromb segmentne arterije. Težina APE procenjivana je korišćenjem indeksa *simplified Pulmonary Embolism Severity Index* (sPESI). Primarni ishodi ove studije bili su intrahospitalni smrtni ishodi nastali kao posledica APE i smrtni ishodi izazvani svim ostalim uzrocima. **Rezultati.** U studiju je ukupno bilo uključeno 1 612 bolesnika (750 muškaraca i 862 žene). Kod žena koje su imale centralno postavljeni tromb u plućima, otkriven putem MKTAP, zabeležena je veća učestalost intrahospitalnih smrtnih ishoda usled plućne embolije (PE), nego kod onih bez centralno postavljenog tromba (10,4% vs. 4,2%, redom; $p = 0,016$). Kod žena kod kojih je odnos između prečnika desne komore (DK) i leve komore (LK) (DK/LK) iznosio > 1, smrtnost je bila skoro dva puta češća od onih kod kojh je taj odnos bio ≤ 1 (15,5% vs. 8,6%, redom; $p = 0,017$). Kod žena kod kojih je odnos DK/LK, detektovan metodom MKTAP, iznosio > 1, verovatnoća smrtnog ishoda usled PE bila je značajno veća u poređenju sa ženama kod kojih je taj odnos bio ≤ 1 (11,0 % vs. 5,2%, redom; $p = 0,017$). Žene koje su umrle od posledica PE, imale su značajno višu vrednost skora embolijskog opterećenja (*embolic burden score system* - EBSS) nego žene koje su preživele (18,00 vs. 11,00, redom; $p = 0,025$). Nezavisno od starosti, sPESI i funkcije bubrega, prisustvo centralno postavljenog plućnog tromba [*odds ratio* – (OR) 2,278; 95% *confidence interval* – (CI): 1,050–4,944; $p = 0,037$] i odnos DK/LK > 1 (OR 2,015; 95% CI: 1,042–3,893, $p = 0,037$) bili su kod žena povezani sa intrahospitalnim smrtnim ishodom koji je nastao usled PE. **Zaključak.** Kod žena, parametri MKTAP, centralno postavljeni tromb, odnos DK/LK prečnika i EBSS imali su prognostički značaj za mortalitet zavisan od PE. Odnos prečnika DK i LK imao je prognostički značaj i za smrtnost izazavnu svim uzrocima, tokom hospitalizacije. Kod muškaraca, MKTAP parametri nisu imali prognostički značaj za ukupni mortalitet i smrtnost od PE.

Ključne reči:
angiografija, tomografska, kompjuterizovana; mortalitet; tomografija, kompjuterizovana, multidetektor; pluća, embolija; pol; lečenje, ishod.

Introduction

Multidetector computed tomography pulmonary angiography (MCTPA) was introduced in 1998 and was subsequently compared with conventional pulmonary angiography and spiral computed tomography in various studies. Consequently, it has emerged as the most suitable method for diagnosing acute pulmonary embolism (APE) in hemodynamically stable patients. Thereafter, MCTPA has become the method of choice for diagnosing pulmonary embolism (PE) in hemodynamically stable patients [1–4]. In patients with suspected PE, the percentage of positive findings is, on average, 8.3%, whereas according to the Prospective Investigation of Pulmonary Embolism Diagnosis II study, the sensitivity and specificity are 83% and 96%, respectively [5, 6]. Since 2008, multidetector MCTPA has been the cornerstone in diagnosing APE, following the recommendations of the European Society of Cardiology (ESC) on the APE guidelines. These guidelines advocate its use in patients with elevated D-dimer levels and a low or intermediate clinical pretest probability, as well as in those who have not undergone D-dimer testing but present with a high clinical pretest probability [7, 8]. In addition to its diagnostic role, MCTPA facilitates the measurement and calculation of certain parameters that can be used as prognostic markers for outcomes in APE. Appropriate qualification and quantification of MCTPA findings may contribute to the risk stratification of patients with APE. Arterial blood pressure at the time of admission serves as a fundamental parameter for risk stratification in APE, in conjunction with right ventricle (RV) dysfunction assessment through echocardiography or MCTPA and cardiac troponin blood level measurement. On this basis, the risk stratification comprises four risk strata according to the ESC mortality risk model [9–11]. The clinical presentation of APE and its comorbidities may differ between men and women [12–14]. The overall intrahospital (Ih) survival from APE is generally lower in women compared to men. However, after adjusting for age, it is observed that women tend to be older than men in most registries. Consequently, the prognosis between sexes may be more comparable than initially perceived [15]. Different sex-related features of RV function, as determined using magnetic resonance imaging or 3D echocardiography, may explain some clinical and outcome differences between sexes [16, 17]. In summary, healthy men exhibit a larger RV mass and volume, as well as a higher cerebrovascular accident volume, while women

demonstrate a superior RV ejection fraction. These differences in RV function between sexes might be an important determinant of APE outcomes.

This study aimed to evaluate the association of several MCTPA parameters with Ih all-cause and PE-related mortality in patients with APE, focusing on sex differences.

Methods

This retrospective analysis was performed using data from the Regional Pulmonary Embolism Registry, which was founded in 2015 and was approved by the Ethics Committee of the Military Medical Academy, Belgrade, Serbia (No. 161/2019, from December 18, 2019). Male and female patients, aged > 18 years, with confirmed APE diagnosis after multidetector MCTPA investigation, were included. During the study period, spanning from January 2015 to May 2022, a total of 1,612 patients were enrolled. They were recruited from five university cardiology or pulmonology clinics: the Military Medical Academy in Belgrade, the Institute of Pulmonary Diseases of Vojvodina in Sremska Kamenica, Serbia, the University Clinical Center of Niš, Serbia, the University Clinical Hospital Center Zemun in Belgrade, and the University Clinical Center of Kragujevac, Serbia. Additionally, patients were enrolled from one general hospital in Pančevo, Serbia and three centers outside of Serbia, specifically the Clinic of Cardiology of the University Hospital Banja Luka in Bosnia and Herzegovina, the Clinic of Cardiology of the University Hospital Podgorica in Montenegro, and the Clinic of Cardiology of the University Hospital Skopje, North Macedonia.

MCTPA examination was performed at the time of admission of patients with suspected PE if their hemodynamic status permitted it; otherwise, it was performed as soon as the patient was hemodynamically stabilized. A positive MCTPA finding and diagnosis of APE were established if the patient had at least one segmental artery thrombus. MCTPA was conducted with a 35 cm field of view, 1 mm section thickness, 70 mL contrast material volume, and a 4 mL/s contrast material injection rate. The radiologist identified central thrombotic masses in the main, left and right pulmonary artery (PA), or lobar branches and peripheral thrombotic masses at the segmental or subsegmental PA level (Figure 1). Additionally, the right-to-left ventricle diameter ratio (RV/LV ratio) just below the tricuspid annulus was noted, along with the embolic burden score system (EBSS) [18]. The score, calculated based on the presence of clots in segmental or proximal branches, assigns a value to the proximal clot site equal to the number of segmental branches arising distally. A clot in a segmental artery receives a score of 1. Thus, the maximum scores are 3 for the right upper lobe arteries, 2 for the middle lobe, 5 for the right lower lobe arteries, 2 for the left upper lobe and lingual arteries, and 4 for the left lower lobe arteries, culminating in a maximum possible score of 18.

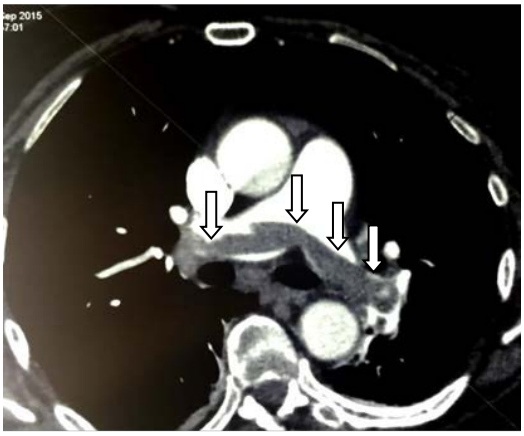

Fig. 1 – Computed tomography pulmonary angiography: massive pulmonary embolism with central thrombotic mass in the main, left, and right pulmonary artery (arrows).

Furthermore, we assessed the severity of the disease and renal function upon admission to check for potential confounding factors linked to MCTPA parameters and mortality outcomes. For the estimation of PE severity, we used the simplified Pulmonary Embolism Severity Index (sPESI) [19] instead of the Europeans Society of Cardiology (ESC) stratification of PE severity mortality risk score (low, intermediate-low, intermediate-high, and high-risk PE), because sPESI does not include RV function as does the ESC score, and, in that way, we can estimate the predictive value of MCTPA parameters of RV dysfunction in addition to sPESI score. Today, the diagnosis of acute PE is established by MCTPA. This way, we can omit echocardiography assessment of RV except in high-risk PE patients who could not go immediately to MCTPA. sPESI encompasses critical clinical features of patients, some of which predominantly result from PE (systolic arterial pressure, heart rate, and arterial oxygen saturation), while others relate to patient-specific characteristics (age > 80 years, presence of malignant disease, and chronic heart or lung disease). Additionally, renal function is a significant independent predictor of mortality in patients with APE [20].

The co-primary outcomes of this study were all-cause and PE-related Ih deaths. PE-related death was delineated as the A2 subclass of death, adhering to the definition of PE-related death recommended by the Subcommittee on Predictive and Diagnostic Variables in Thrombotic Disease [21]. This entails death occurring with MCTPA-proven PE, provided there is no more plausible cause of death.

Statistical analyses

Data analyses were performed using SPSS version 26.0 (SPSS, Inc., Chicago, IL, USA). Results were expressed as mean ± standard deviation or median with interquartile range (25th–75th percentile) depending on data distribution. The Kolmogorov-Smirnov test was used to assess the normality of the data distribution. Categorical variables were presented as frequencies, and the differences between sexes were

analyzed using the Chi-square test. For parametric continuous variables, the mean values were compared using the independent samples Student's *t*-test. The Mann-Whitney *U* test was used for nonparametric continuous variables.

Univariate and multivariate binary regression models were used to determine the MCTPA parameter prediction values for all-cause and PE-related Ih deaths concerning sex. The sPESI, consisting of the aforementioned clinical parameters, was used as a binary variable (0 points and > 0 points) for adjusting the odds ratio (OR) for the MCTPA parameters. An adjustment was also performed for the presence of severe renal failure (creatinine clearance < 30 mL/min) as an important variable for predicting Ih death. Statistical significance was set at $p < 0.05$ for all comparisons.

Results

In total, 1,612 patients were enrolled in the study (750 men and 862 women), and the average age was 64 ± 16 years (Table 1). Female patients were significantly older than male patients (66.5 ± 15.1 vs. 60.4 ± 15.8 years, respectively) ($p < 0.001$). In addition, most patients aged > 75 years were women (31.9% vs. 17.7%). Various comorbidities presented differently in women and men. Women were more likely to have type 2 diabetes (22.0% vs. 17.6%), a glomerular filtration rate < 30 mL/min (11.0% vs. 5.8%), arterial hypertension (66.6% vs. 53.9%), and anemia (33.0 vs. 21.1%) compared to men. In contrast, men were more likely to smoke than women.

In males and females, the mortality rate did not significantly differ between patients with and without central thrombosis on MCTPA (Table 2). The total Ih mortality rate was 12.3% for centrally positioned thrombus vs. 9.9% for peripheral thromboembolism in women. In men, the rate was 9.4% for both central and peripheral thrombus positions. However, when considering only PE-related deaths, a significant difference was observed in women but not in men. Female patients who had central thrombosis on MCTPA were more likely to die from PE than those who did not have central thrombosis (10.4% vs. 4.2%).

A significant difference in all-cause mortality was found in female patients with RV/LV > 1 on MCTPA compared to those without it (Table 2). Women with an RV/LV > 1 died almost two-fold more than those with a ratio ≤ 1 (15.5% vs. 8.6%). The mortality rate for this parameter did not significantly differ in male patients. In contrast, when considering RV/LV > 1 only PE-related deaths, significant differences were observed in women. Women with RV/LV > 1 on MCTPA were more likely to die from PE than those with a ratio ≤ 1 (11.0% vs. 5.2%).

In both sexes, no significant differences were found in all-cause mortality in patients according to the EBSS based on MCTPA findings (Table 2). However, when focusing exclusively on PE-related deaths, notable differences emerged among female patients. Women who succumbed to PE-related deaths exhibited significantly higher EBSS values compared to those who survived (18.00 vs. 11.00). In contrast, no significant difference in EBSS values was found among male patients who died as a consequence of PE compared to the ones who survived.

The results of the univariate and multivariate binary regression analyses for the predictive value of MCTPA parameters for all-cause and PE-related Ih deaths concerning sex are presented in Table 3. An RV/LV ratio greater than 1

Table 1

Basic characteristics of patients

Characteristics	Male	Female	*p*-value	Missing data
Total number	750 (46.5)	862 (53.5)		
Age (years)	60.4 ± 15.8	66.5 ± 15.1	< 0.001†	0
Age > 75 years	133 (17.7)	275 (31.9)	< 0.001‡	0
Body mass index (kg/m^2)	27.3 ± 4.4	27.5 ± 5.1	< 0.001†	491 (30.5)
COPD	84 (11.2)	86 (10.0)	0.474‡	0
Malignancy	95 (12.7)	122 (14.2)	0.424‡	0
Deep vein thrombosis	85 (38.7)	307 (36.8)	0.455‡	41 (2.5)
Type 2 diabetes	132 (17.6)	190 (22.0)	< 0.05‡	1 (0.1)
Coronary disease	91 (12.2)	94 (11.0)	0.485‡	8 (0.5)
Stroke	50 (6.7)	65 (7.5)	0.570‡	2 (0.1)
Chronic heart failure	115 (15.3)	122 (14.2)	0.551‡	0
Creatinine clearance: < 60 mL/min	222 (29.8)	343 (40.1)	< 0.001‡	12 (0.7)
Creatinine clearance: < 30 mL/min	43 (5.8)	94 (11.0)	< 0.001‡	15 (0.9)
Arterial hypertension	402 (53.9)	572 (66.6)	< 0.001‡	7 (0.4)
Smoking	176 (25.3)	103 (12.8)	< 0.001‡	111 (6.9)
Anemia	157 (21.1)	281 (33.0)	< 0.001‡	
Systolic blood pressure (mmHg)	122.91 ± 24.37	122.71 ± 26.21	< 0.05†	1 (0.1)
Diastolic blood pressure (mmHg)	75.70 ± 14.86	74.08 ± 14.86	0.253†	17 (1.1)
Heart rate	98.9 ± 22.6	99.2 ± 23.0	0.482†	0
sPESI > 0 / 0	499 (66.6) / 250 (33.4)	610 (70.8) / 252 (29.2)	0.082	1 (0.1)
SpO_2 < 90% or PaO_2 < 55mmHg	189 (27.6)	211 (28.1)	0.879	178 (11)
RVSP	47.25 ± 18.21	48.17 ± 17.18	0.649†	207 (12.8)

COPD – chronic obstructive pulmonary disease; sPESI – simplified pulmonary embolism severity index; SpO_2 – oxygen saturation; PaO_2 – partial pressure of oxygen; RVSP – right ventricular systolic pressure.
Results are shown as numbers (percentages) or mean ± standard deviation.
†Independent samples test; ‡Chi-square test.

Table 2

Treatment outcomes in relation to central thrombosis or RV/LV > 1 based on MCTPA findings and the EBSS score in male and female patients

Parameters	Male		Female		Missing data
	Intrahospital death	Alive	Intrahospital death	Alive	
Central thrombus					
no	30 (9.4)	288 (90.6)	38 (9.9)	345 (90.1)	635 (39.4)
yes	13 (9.4)	125 (90.6)	17 (12.3)	121 (87.7)	
p-value	1.000†		0.533†		
Central thrombus (PE)					
no	16 (5.3)	288 (94.7)	15 (4.2)	345 (95.8)	679 (42.1)
yes	9 (6.7)	125 (93.3)	14 (10.4)	121 (89.6)	
p-value	0.703†		< 0.05†		
RV/LV >1					
no	26 (7.4)	326 (92.6)	38 (8.6)	403 (91.4)	453 (28.1)
yes	21 (11.4)	164 (88.6)	28 (15.5)	153 (84.5)	
p-value	0.166†		< 0.05†		
RV/LV >1 (PE)					495 (30.7)
no	15 (4.4)	326 (95.6)	22 (5.2)	403 (94.8)	
yes	15 (8.4)	164 (91.6)	19 (11.0)	153 (89.0)	
p-value	0.099†		< 0.05†		
EBSS	11.00 (5.00–18.00)	12.00 (8.00–18.00)	11.50 (7.00–18.00)	11.00 (7.00–16.00)	682 (42.3)
p-value	0.424‡		0.361‡		
EBSS (PE)	13.50 (9.75–18.00)	12.00 (8.00–18.00)	18.00 (9.00–18.00)	11.00 (7.00–16.00)	726 (45)
p-value	0.236†		< 0.05‡		

MCTPA – multidetector computed tomography pulmonary angiography; EBSS – Embolic Burden Score System; PE – pulmonary embolism; RV/LV – the ratio between right ventricle and left ventricle diameter.
Results are shown as numbers (percentages) or median (25-75 percentile).
†Chi-square test; ‡Mann-Whitney *U* test.

Table 3

Univariate and multivariate binary regression analysis of MCTPA parameters as the predictors of all-cause and PE-related hospital death

Parameters	Univariate predictors OR (95% CI; *p*-value)	Multivariate predictors OR (95% CI; *p*-value)
All-cause death men		
age (OR *per* year)#	1.028 (1.011–1.046; < 0.001)	-
sPESI	8.129 (3.238–20.404; < 0.001)	6.569 (2.594–16.638; < 0.001)
severe renal failure*	8.147 (4.196–15.821; < 0.001)	5.899 (3.006–11.578; < 0.001)
central thrombus on MCTPA	-	
RV/LV ratio > 1.0	1.606 (0.877–2.940; 0.125)	-
All-cause death women		
age (OR *per* year)#	1.037 (1.019–1.055; < 0.001)	-
sPESI	4.134 (2.113–8.089; < 0.001)	4.150 (1.741–9.892; 0.001)
severe renal failure*	3.899 (2.343–6.488; < 0.001)	3.629 (1.941–6.788;< 0.001)
central thrombus on MCTPA	1.276 (0.694–2.343, 0.433)	-
RV/LV ratio > 1.0	1.941 (1.151–3.272; 0.013)	1.726 (1.004–2.967; 0.048)
PE-related death men		
age (OR *per* year)#	1.022 (1.001–1.043; 0.040)	-
sPESI	6.297 (2.236–17.735; < 0.001)	5.320 (1.871–15.129; < 0.001)
severe renal failure*	6.111 (2.677–14.002, < 0.001)	4.512 (1.948–10.449; < 0.001)
central thrombus on MCTPA	1.296 (0.588–3.012; 0.547)	-
RV/LV ratio > 1.0	1.988 (0.949–4.166; 0.069)	
PE-related death women		
age (OR *per* year)#	1.034 (1.012–1.058; 0.003)	-
sPESI	5.017 (1.982–12.699; < 0.001)	4.610 (1.064–19.967; 0.041)† 3.799 (1.310–10.905; 0.014)‡
severe renal failure*	4.502 (2.450–8.271; < 0.001)	3.271 (1.335–8.014; 0.010) † 3.705 (1.745–7.867; 0.001)‡
central thrombus on MCTPA	2.661 (1.248–5.674; 0.011)	2.278 (1.050–4.944; 0.037)
RV/LV ratio > 1.0	2.275 (1.198–4.320; 0.012)	2.015 (1.042–3.893; 0.037)

OR – odds ratio; CI – confidence interval; For other abbreviations, see Tables 1 and 2.
 # – sPESI = 0 compared to sPESI > 0; *creatinine clearance < 30 mL/min; †Model with central thrombus on MCTPA; ‡Model with RV/LV ratio > 1.0.

on MCTPA was independently associated with sPESI in women. Additionally, severe renal failure was linked to an increased risk of all-cause Ih death [OR 1.726, 95% confidence interval (CI): 1.004–2.967, $p = 0.048$]. Specifically, the presence of a central thrombus (OR 2.278, 95% CI: 1.050–4.944, $p = 0.037$) and an RV/LV ratio > 1 (OR 2.015, 95% CI: 1.042–3.893, $p = 0.037$) were associated independently with PE-related death, but only in women.

Discussion

The study results demonstrated that MCTPA parameters at the time of admission in patients with APE had different prognostic values in men and women. A central thrombus, an RV/LV ratio > 1, and the EBSS index were associated with PE-related Ih death in women but not in men. Additionally, an RV/LV ratio > 1 was associated with all-cause Ih death only in women. The association of the presence of a central thrombus and an RV/LV ratio > 1 with Ih PE-related death in women was significant even after adjusting for age, sPESI, and renal function estimated at admission to the hospital. To our knowledge, this study is the first to suggest early prognostic values for APE using admission MCTPA parameters concerning sex.

MCTPA is instrumental in identifying the precise location of thrombus masses. PE is categorized into central PE, where thrombus masses reside in the main pulmonary artery tree, left and right pulmonary artery, or lobar branches, and peripheral PE, with thrombi located in the segmental and subsegmental branches. Central PE is associated with higher overall mortality rates compared to peripheral PE and more frequently necessitates reperfusion therapy. Consequently, Alonso Martinez et al. [22] investigated patient survival in relation to thrombus location. In their study of 530 patients, central PE was identified in 255 (48.5%) patients, while segmental or subsegmental peripheral thromboembolism was diagnosed in 275 (51.5%) patients. Survival curve analysis revealed superior survival outcomes in patients with segmental and subsegmental pulmonary thrombi than those with central pulmonary thrombi. However, no sex differences were studied. In our study, the total Ih mortality rate was 12.3% for central PE vs. 9.9% for peripheral PE in women. In men, the rate was 9.4% for both central and peripheral thromboembolism. When considering PE-related Ih mortality in women, the ratio was 10.4% for central PE and 4.2% for peripheral PE. Therefore, whether or not a central thrombus was determined on MCTPA when total mortality was observed, we did not find statistically significant differences between the sexes. However, when considering PE-related mortality alone, we found a statistically significant difference in women. Women in whom a central thrombus was detected on MCTPA were more likely to die than women in whom no central thrombosis was detected. However, a significant difference was not observed in men. Therefore, our study showed that a central thrombus on MCTPA can be a prognostic parameter for PE-related mortality in women.

Because the degree of obstruction of the pulmonary arterial network by thrombus masses in APE correlates with an increase in RV afterload, an important MCTPA parameter is the RV diameter, i.e., the RV/LV ratio. The ratio has a sensitivity of 92%, specificity of 100%, and prognostic factor of 100% [23–25]. According to the ESC, an RV/LV > 1 is a major prognostic factor for RV dysfunction [26–28]. An RV/LV ratio > 1.5 has a negative prognostic significance [29]. Meinel et al. [30] wrote an extensive meta-analysis in 2015, which included 49 studies with 13,162 patients with APE, showed that the RV/LV ratio on transverse computed tomography sections had the strongest predictive value among all the MCTPA parameters and had robust evidence for the prediction of adverse clinical outcomes in patients with APE. An abnormally increased RV/LV ratio (defined as > 1 in most studies) was associated with an approximately 2.5-fold greater risk of both all-cause mortality (OR 2.5, 95% CI: 1.8–3.5) and adverse outcomes (OR 2.3, 95% CI: 1.6–3.4), as well as a 5-fold risk for PE-related mortality (OR 5.0, 95% CI: 2.7–9.2).

Jimenez et al. [31] studied 30-day all-cause mortality in 848 patients. Overall, 25 deaths (4.7%) (95% CI: 2.9%–6.5%) occurred in the group of 533 patients who entered the study with RV dysfunction on MCTPA, whereas 13 deaths (4.3%) occurred in the group of 302 patients who did not have RV dysfunction on MCTPA ($p = 0.932$). PE-related mortality within 30 days of PE diagnosis occurred more frequently in patients with RV dysfunction on MCTPA (1.9% vs. 0.3%, respectively, $p = 0.053$). In our study, the total Ih mortality for women was 15.5% when RV/LV > 1 and 8.6% when RV/LV ≤ 1. Conversely, in men, these percentages were 11.4% and 7.4%, respectively. Specifically, the rates of PE-related Ih mortality in women were 11.0% for RV/LV > 1 and 5.2% for RV/LV ≤ 1. In men, the PE-related Ih mortality rates were 8.4% and 4.4%, respectively. Therefore, our findings indicate that the RV/LV ratio serves as a prognostic indicator in women but not in men.

Quantifications of positive MCTPA findings using the Pulmonary Artery Obstruction Index (PAOI), EBSS, Qanadli score (the most commonly used), or modified Miller score were suitable for determining PE severity, risk stratification, and predicting long-term outcomes. However, some studies have correlated PAOI with RV dysfunction but not with long-term outcomes [32–36].

In a meta-analysis of PAOI by Vedovati et al. [33], 16 studies with 3,884 patients were included, and higher PAOI values were associated with an increased risk of 30-day mortality. Akhoundi et al. [37] showed a strong positive correlation between PAOI and the RV/LV ratio but found that PAOI could not be used to predict mortality or adverse outcomes. In our study, we did not find that EBSS could be used as a prognostic factor for overall patient mortality in PE. However, in women, EBSS was a useful prognostic sign for PE-related death, with a statistically significant difference. The average EBSS value was 18 in women who had died and 11 in women without fatal outcomes.

Therefore, our study showed that the EBSS could be a predictive parameter for PE-related mortality only in women.

Why do some MCTPA parameters have prognostic significance only in women? This may be explained by the difference in the structure of the RV. Ventetuolo et al. [38] demonstrated that sex hormones are associated with RV structure and function – notably, higher levels of androgens are linked to increased RV mass and volume. In a study of 517 consecutive patients with ST-elevation myocardial infarction (STEMI – a heart attack with a completely blocked coronary artery), Obradovic et al. [39] found that women were diagnosed with RV infarction significantly more often than men. However, the prognostic value of certain MCTPA parameters for PE-related mortality in women, and not in men, suggests a greater vulnerability of the RV in women, underscoring an area that warrants further investigation.

Conclusion

Our study has shown that computer tomography pulmonary angiography parameters, such as a centrally placed thrombus, the ratio between the right ventricle and left ventricle, and the scoring system, have prognostic significance for pulmonary embolism-related mortality in women. The ratio between right ventricle and left ventricle diameter has prognostic significance for all-cause intrahospital mortality in women. In men, the computer tomography pulmonary angiography parameters have no prognostic significance for both overall and pulmonary embolism-related mortality.

Acknowledgement

We would like to thank Editage (www.editage.com) for the English language editing.

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Received on January 9, 2024
Revised on February 11, 2024
Revised on February 25, 2024
Accepted on March 5, 2024
Online First April 2024