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Estimation of prognostic value of computed tomography (CT) procedure in pulmonary embolism

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Abstract: Due to the fact that the signs and symptoms of pulmonary embolism (PE) are nonspecific, its diagnosis continues to pose a challenge for both clinicians and radiologists. Helical computed tomography (CT) of the pulmonary arteries is deemed accurate test for the detection of PE and is gaining increasing acceptance in daily clinical practice as a first-line test for diagnosing acute PE.
The purpose of this work is to estimate the prognostic value of CT procedure in patients with diagnosed pulmonary embolism. Retrospective estimation of the embolic pulmonary index (PE index - Quanadli), diameter of pulmonary trunk (dAP), diameter of the aorta (dA), ratio dAP/dA, dimension of the right heart ventricle (dRV), left heart ventricle (dLV), and the ratio dRV/dLV were performed using sequential angio-CT procedures in patients with diagnosed pulmonary embolism. The research embraced a group of 43 patients with CT diagnosed pulmonary embolism (24 women, 19 men), aged from 26 - 91 years (mean age 66.9: women 72.2, men 60.1). In the tested material, the value of the Quanadli index ranged from 15 - 77, the diameter of the arteria pulmonalis trunk from 1.8 - 4 cm, the diameter of the aorta from 2.38 - 4.99 cm, the ratio of the pulmonary trunk diameter and the diameter of the aorta from 0.54 - 1.11, the dimension of the right heart ventricle from 2.24 - 5.93 cm, the dimension of the left heart ventricle from 2.04 - 5.58 cm and the ratio of both heart ventricles measurements ranged between 0.6 - 2.55. Three persons from the analyzed group of patients died during the hospitalization period (1 woman and 2 men aged 47, 64 and 61). The Quanadli index for these persons amounted to: 57.5, 42.5 and 50, accordingly. In conclusion, the Quanadli index is an objective and repeatable indicator which is easy to utilize in a standard way when dealing with patients suffering from pulmonary embolism diagnosed using CT examination. High values of the Quanadli index – above 40% – should be a signal to consider fibrynolytic treatment. The Quanadli index is not useful in assessing the risk of death of patients suffering from pulmonary embolism.

Key words: pulmonary embolism, computed tomography, embolic pulmonary index, PE index, Quanadli index

INTRODUCTION

Pulmonary embolism is the third most common acute cardiovascular disease after myocardial infarction and stroke; it results in thousands of deaths each year because of the fact that it often remains undetected; its nature is protean, and therefore it is frequently overlooked and misdiagnosed, even by experienced clinicians [1-4].

Pulmonary embolism is predominantly an older age disease and the age-related increase in venous thromboembolic events is greater among men than women. In patients younger than 55, the incidence of PE is higher in females. The overall age- and sex-adjusted annual incidence of venous thromboembolism is reported to be 117 per 100,000 and 48 per 100,000 (deep venous thrombosis (DVT) 48 per 100,000, PE 69 per 100,000) [5].

If untreated, pulmonary embolism is fatal in up to 30% of cases, but the death rate can be reduced to 2-10% if PE is appropriately diagnosed and treated promptly [6-8].

The diagnosis of pulmonary embolism continues to pose a challenge to both clinicians and radiologists because its signs and symptoms are nonspecific. Common symptoms of PE are dyspnea with or without associated anxiety, pleuritic chest pain; hemoptysis may also develop with several other conditions including pneumonia, COPD exacerbation, congestive heart failure or lung cancer. Lightheadness and syncope may be caused by PE, but may also result from several other causes of hypoxemia or hypotension [9, 10].

Objective and fast diagnosis of pulmonary embolism is mandatory because it is a potentially lethal disease [11]. Risk stratification is important because optimal management, monitoring and therapeutic strategies depend on the prognosis [12]. Only 20-30% of patients presenting the signs and symptoms suggestive of PE have the disease as confirmed by objective diagnostic tests [11].

Helical computed tomography (CT) of the pulmonary arteries is an accurate test for the detection of PE and is gaining increased acceptance in daily clinical practice as a first-line study for diagnosing acute PE [13]. Helical CT is a relatively noninvasive, widely available, safe, cost–effective method of quick and comprehensive diagnosis of acute PE by directly imaging the intravascular clot [14].

Recent advances in single detector row helical CT include improvements in x-ray tube technology and faster gantry rotation, which allow for increased body coverage by using narrower collimation [13]. These advances have been associated with improved sensitivity and specificity of the technique

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(sensitivities range from 64% - 100% and specificities range from 89 - 100%) [15].

Both mediastinal and parenchymal structures are evaluated with spiral CT, thrombus is visualized directly via the use of this technique [4, 18]. Pulmonary emboli are visible as mural or eccentric filling defects which can be located centrally and may totally or partially occlude the pulmonary artery [17]. In acute pulmonary embolism which manifests as complete arterial occlusion, the affected artery may be enlarged. Partial filling defects due to acute pulmonary embolism are often centrally located, but when eccentrically located they form acute angles with the vessel wall [16]. Many patients with an initial suspicion of PE receive other diagnoses, sometimes for such potentially life-threatening diseases as aortic dissection, pneumonia, lung cancer and pneumothorax. Due to the spiral CT method, not only intravascular thromboembolic filling defects, but also other manifestations of precedent pulmonary thromboembolic, including parenchymal infarction, pleural effusion, vascular remodeling (dilation, pouches, thrombotic wall thickening) and oligemia can be readily visualized [4].

PURPOSE

The purpose of this work is to estimate the prognostic value of CT procedure in patients with diagnosed pulmonary embolism.

MATERIALS AND METHODS

While carrying out this project, retrospective estimations of the embolic pulmonary index (PE index), the diameter of pulmonary trunk (dAP), diameter of the aorta (dA), and ratio dAP/dA, and dimensions of the right heart ventricle (dRV) and the left heart ventricle dLV, as well as the ratio dRV/dLV, were carried out in sequential angio-CT procedures of patients with diagnosed pulmonary embolism.

The CT procedures were performed with the help of a one-detector row spiral scanner Emotion from Siemens, in layers of 3mm thickness, with pitch of 1.5. The CT scans were performed after intravenous application of nonionic contrast in the quantity 1 ml/kg of patient's body weight at the speed of 3.5 ml/sec.

For the purpose of obtaining the optimal opacity of pulmonary arteries, the option of Bolus Tracking was used, with region of interest (ROI) marked on the trunk of the arteria pulmonalis. The scanning started at the value of strengthening set to 100 Hounsfield units (HU).

Forty-three patients with CT diagnosed pulmonary embolism (24 women, 19 men), aged from 26 - 91 years (mean age 66.9: women 72.2, men 60.1) took part in the research.

The evaluations of the diameter of the pulmonary trunk and diameter of the aorta were carried out based on CT scans (Fig. 1); these evaluations were followed by measurement of the left and right heart ventricles (Fig. 2).

Following these measurements, the range of measurements of the pulmonary trunk, the aorta and right and left heart ventricle was calculated.

The Quanadli index was estimated for every patient. The index is defined as the product of the values N x D, where N is the value of the proximal clot site and D is the degree of obstruction, defined as 1 for partial obstruction and 2 for total obstruction. For this purpose, the partition of arterial tree was used, including 10 segmental branches for each lung (3 to the upper lobes, 2 to the middle lobe, and 5 to each lower lobe).

Mutual correlations of evaluated parameters were qualified by means of the Person's linear correlation coefficient. The value of the statistically essential probability is $P<0.05$.

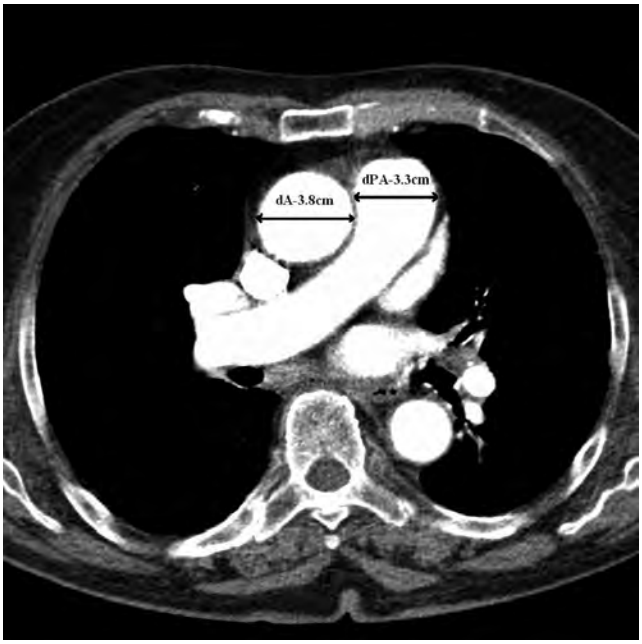

Figure 1 Measurement of diameter of the aorta and pulmonary trunk (axial section).

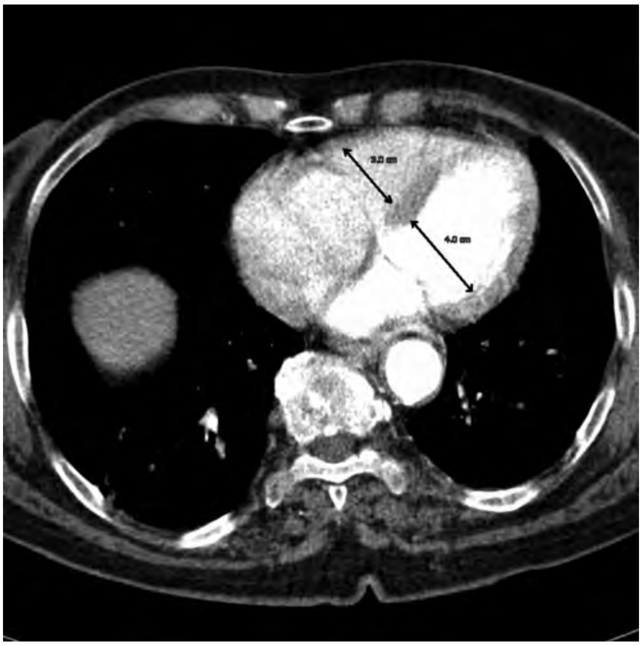

Figure 2 Measurement of the right ventricle width dRV and the left ventricle width dLV (axial section).

RESULTS

Minimum, maximum and average values of evaluated parameters in the group of 43 patients with pulmonary embolism are presented in Table 1.

Table 1 Minimum, maximum and average values of the evaluated parameters in patients with pulmonary embolism.

	Quanadli Index	dPA	dA	dPA/dA	dRV	dLV	dRV/dLV
Min	15	1.8	2.38	0.54	2.24	2.04	0.6
Max	77	4.0	4.99	1.11	5.93	5.58	2.55
Average	38.94	2.8	3.44	0.81	3.84	3.55	1.13
Standard deviation	±16.34	±0.49	±0.47	±0.14	±0.75	±0.78	±0.35

dPA – diameter of arteria pulmonalis trunk
dA – diameter of aorta
dPA/dA – ratio of pulmonary trunk diameter and diameter of the aorta
dRV – dimension of right heart ventricle
dLV – dimension of left heart ventricle
dRV/dLV – ratio of right and left heart ventricles

The Quanadli index smaller than or equal to 20% was discovered in 5 patients, was within the range of 21 - 30 in 12 patients, contained within the range of 31 - 40 in 6 patients, and in the 12 remaining patients was placed within the range of 41 - 50. The PE index greater than 50 and smaller than 60 was discovered in 2 patients. The PE index greater than 60 and smaller than 70 was discovered in 6 patients. The ratio of both heart ventricles measurements smaller than 1 was discovered in 13 patients, the index equal or greater than 1 was observed in 30 patients, with 5 within that number measuring above 1.5.

The values of evaluated parameters of three patients with pulmonary embolism who had died before the tests were concluded are presented in Table 2.

Table 2 Evaluated parameters of patients who died due to pulmonary embolism.

Sex	Age	Quanadli Index	dPA	dA	dPA/dA	dRV	dLV	dRV/dLV
F	47	57.5	2.80	3.00	0.93	3.23	4.73	0.68
M	64	42.5	3.05	3.93	0.77	3.71	3.51	1.05
M	61	50.0	2.24	3.53	0.63	3.07	3.92	0.78
Average value	57.3	50.0	2.70	3.49	0.78	3.34	4.05	0.84

The "rider" type of embolism (Fig. 3) was discovered in 8 patients, where the value of the Quanadli index fluctuated between 50 - 77 (average value of the index set at 59.63 with standard deviation of 10.86).

Minimum, maximum and average values of evaluated parameters in the group of 8 patients with the "rider" type of pulmonary embolism are presented in Table 3.

Table 3 Minimum, maximum and average values of evaluated parameters in patients with the "the rider" type of pulmonary embolism.

	Quanadli Index	dPA	dA	dPA/dA	dRV	dLV	dRV/dLV
Min	50.0	2.07	3.33	0.54	3.16	2.09	1.00
Max	77.0	3.28	4.99	0.98	5.40	4.19	2.55
Average	59.6	2.75	3.75	0.74	4.36	3.00	1.53
Standard Deviation	±10.9	±0.41	±0.53	±0.14	±0.77	±0.64	±0.53

Figure 3 Within the area of pulmonary trunk fork (forking to the right and left of the arteria pulmonalis) an oblong area of tissue density causing loss of contrast is visible which is symptomatic of large thrombus – the "rider" type embolus.

The Pearson linear correlation coefficients of Quanadli index and the other evaluated parameters in patients are presented in Table 4.

Table 4 Pearson linear correlation coefficients of Quanadli index and the other evaluated parameters in the study.

	dPA	dA	dPA/dA	dRV	dLV	dRV/dLV
Quanadli Index	0.294	0.346*	0.083	0.213	-0.080	0.240

* P<0.05

The Quanadli index was significantly positively correlated with the dimension of the aorta.

DISCUSSION

Helical CT has recently been introduced as a diagnostic strategy of pulmonary embolism and is deemed as a highly accuracy noninvasive test [19].

In the present study, we expand the concept of detection of pulmonary embolism to include evaluation of the degree of vascular obstruction. The specific index (CT obstruction index) proposed here to quantify vascular obstruction in helical CT, appears to be simple, repeatable, and highly correlated to an index described previously linked with selective pulmonary angiography.

The CT obstruction index could be used to grade the severity of pulmonary embolism and to monitor patients requiring objective repetitive evaluation. Further evaluations are needed to investigate the usefulness of CT obstruction index for determining stratification of patient risk and influencing therapeutic decisions [19].

In published works, it has been proved that the PE index is a significant indicator of death risk [20, 22].

The embolic pulmonary index above 60% is considered to be an especially high risk [20].

We consider that patients with massive pulmonary embolism and high PE index should be intensively treated with the use of fibrynolysis, but our data also suggests that fibrynolysis should also be taken into account as possible treatment in the group of patients scoring below 60% and at least 40%.

In our materials, the mean value of the PE index measured 38.94%, which was higher than the one described by Wu et al (22%) and Quanadli (29%) [19, 20].

We consider the symptoms of pulmonary embolism in CT proposed by Wittram as essential because they make possible the precise settlement of the diagnosis by using uniform criteria [16].

Ghanima at al. proposed a new classification to quantify the grade of severity of pulmonary embolism in which the most proximal level of PE is associated with the severity of PE. The score is constructed by assigning a number to each of the four main vessels: 1 for sub-segmental, 2 for segmental, 3 for lobar, and 4 for main pulmonary arteria (MPA). The mean score of the largest affected vessel in each lung, ranging from 1 - 4, was calculated and rounded off to the higher whole number. Ghanima does not assess total and partial obstruction of the vessels [21].

In our material, 8 patients had "rider" type embolism, but none of these patients died; we therefore consider this classification not to be especially useful in the risk assessment of the death of patients with pulmonary embolism.

Wu et al. proves that a high Quanadli index is a significant prediction of patient death; but in our materials 8 patients with "rider" type embolism received values of the PE index 50 and above, and all of them survived.

The CT obstruction index is not a reliable prognostic factor for in-hospital mortality after acute pulmonary embolism, especially when compared with CT indicators of RV dysfunction. In particular, an RV/LV ratio from axial views above a threshold value of 1.5, together with dilated systemic proximal veins and reflux of contrast material into the inferior vena cava, may be useful for recognising patients with a high risk of mortality [23].

In another study, the researchers suggest that there is no significant relationship between the diameters of the pulmonary artery and the ascending aorta and PE-related mortality, or between this ratio and the RV/LV ratio [22]. Our observations confirm this thesis.

The RV/LV ratio might be used to recognise the high risk patients who should receive the most aggressive form of fibrynolytic treatment [23].

The pulmonary embolic index possesses a significant correlation with the clinical appearance of PE, but it is not a significant predictor in the risk assessment of patients mortality [23].

The positive correlation of the Quanadli index with the dimension of the aorta showed by our work indicates that with patients suffering from massive pulmonary embolism, its size may lead to dysfunctions of peripheral circulation.

The connection between the ratio of the diameter of the pulmonary trunk and the aorta and PE does not have an essential prognostic significance [22].

CONCLUSIONS

The Quanadli index is an objective and repeatable indicator, easy to utilize in the standard way with patients suffering from pulmonary embolism diagnosed under CT examination. High values of the Quanadli index – above 40% – should be a signal to consider fibrynolytic treatment. The Quanadli index is not useful in the risk assessment of the death of patients with pulmonary embolism.

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