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The correlation of severity of pulmonary embolism in CT Angiography with electrocardiogram (ECG) findings in patients with acute pulmonary thromboembolism

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KEYWORDS

Pulmonary emboli; Electrocardiogram; CT angiography

A B S T R A C T

The most common diagnostic modality for pulmonary emboli is CT angiography (CTA). Because of the availability and inexpensive, taking an electrocardiogram (ECG) is the first step in the patients suspicious to pulmonary emboli. However, ECG does not provide any sensitive or specific manifestations for diagnosis of pulmonary emboli. We aim to evaluate the correlation between severity of pulmonary emboli in CTA and ECG changes. In this study, 102 patients whom were diagnosed with massive or submassive pulmonary emboli due to Qanadli index in CTA studies were evaluated. ECG was taking in all patients. There are 35 previously reported pathologic changes in ECG which were all evaluated in these patients. The correlation between ECG findings and pulmonary emboli severity in CTA was evaluated. Massive emboli were present in 56.9% and submassive emboli in 43.1% of cases. In 76.5% of cases, pathologic changes in ECG considering emboli were present. In cases with massive emboli compared to submassive emboli, ECG changes (86.2% vs. 63.6%) and mean pathologic findings in ECG (5.82±2.95 vs. 4.25±2.84) were significantly higher. Prevalence of $S_1O_3T_3$, S_1&S_aVL>1.5 mm, ST depression in V_1-V_3, ST elevation in V_1-V_3, Negative T wave in V_1-V_3, Right axis deviation, RVH criteria, P-pulmonale, QR pattern in V_1 were significantly higher in massive emboli group. ECG changes and number of pathologic findings were higher in massive emboli group. Most significant changes were Negative T and ST depression or elevation in V_1-V_3 and right heart involvement findings and could predict severity of pulmonary emboli.

Introduction

Pulmonary thromboembolism (PTE) is a common result of deep venous thrombosis (DVT) that affects the lower limbs (1). Untreated PTE has a high chance of recurrence and high mortality rate. This condition accounts for 10% of hospital deaths (2). Pulmonary embolism symptoms are general and are seen in other pulmonary, pleural, cardiac, and digestive diseases as well. As a result of associated complications of PTE, the clinical signs and symptoms of this condition may be masked and hard to diagnose (1). Pulmonary angiography is the standard means of diagnosis. However, the mortality and morbidity associated with this method are approximately 0.5% and 1%, respectively (3). The use of this method is also limited due to its aggressive and costly nature as well as its unavailability (4). With the invention of multi-slice CT scanners, a new era of CT angiography began. Aggressive diagnostic examinations have been replaced by non-aggressive CT angiography (CTA) methods. Currently, the common means of diagnosing PTE is CTA (5). Electrocardiogram (ECG) is also the first thing to do for patients suspected of pulmonary embolism (6). Considering the relationship between pulmonary artery pressure and ECG changes and the difference between the pulmonary artery pressure and Qanadli index o CTA it seems that ECG is useful for cases suspected of pulmonary embolism (7).

ECG may result in a wide range of PTE manifestations. The manifestations vary from normal rhythm to arrhythmia, heart blocks, changes in the electrical heart axis, changes in the depolarization cycle (changes in the T-wave depolarization, depression and increased ST segment), and elongation the QT segment (7-11). ECG does not provide any specific or sensitive measure or manifestation of PTE. In any event, a properly interpreted ECG of PTE can lead to precise diagnosis and thus can influence the prognosis and finally lead to a proper treatment. It is perhaps possible to use ECG as an inexpensive, non-aggressive and available means of examination to avoid unnecessary CTA, which is an aggressive and expensive method (9, 12).

Hence, following the literature review it was decided to compare ECG changes with severity of pulmonary embolism based on the Qanadli index in CTA so as to find a significant relationship between severity of pulmonary embolism and ECG changes. The result of this comparison can be used to begin treatment based on ECG results before CTA (when CTA is not available or when there are counter-indications) in the case of patients suspected of severe acute pulmonary embolism. The objective of this study was to determine the relationship between the severity of pulmonary embolism in CTA and ECG findings obtained from patients with acute pulmonary embolism.

Methods

A descriptive-analytical study was carried out in the radiology department of Tabriz University of Medical Sciences on patients suspected of embolism. This study was aimed to find the relationship between the severity of pulmonary embolism in CTA and ECG findings of patients with acute pulmonary embolism.

Since no similar study had been previously carried out, the sample size was determined based on the results of the pilot study with a power of 80%, Type I error of 0.05, and acceptable dissimilarities. In this study, a total of 10 samples were selected as the samples for the pilot study. Based on the examination results a total of 62 patients were selected for studies. To this end, all patients with pulmonary CTA results confirming pulmonary embolism were included in the study.

The exclusion criteria for the study included a history of cardiopulmonary diseases, history of anti-arrhythmic drug use, history of electronic disorders or metabolic acidosis. All of the patients were subjected to ECG. Afterwards, based on the Qanadli index the severity of pulmonary artery occlusion was expressed in quantitative terms. To this end, pulmonary artery branches were divided into 10 segments including 3 segments in the upper lobe, 2 segments in the middle lobe and 5 segments in the lower lobe.

Next, the severity of occlusion was ranked using the following options: zero occlusion (0); partial occlusion (1); and full occlusion (2). In this process, the number of involved veins was multiplied by the degree of occlusion in each vein and the sum of the results was used as the final score. Therefore, the score of full occlusion of one lung arteries was 20 and that of two lungs was 40. If occlusion occurred in proximal arteries it was considered to be equal to the occlusion of segmental arteries originating from it. However, if the occlusion occurred in sub-segmental arteries, the occlusion was considered to be equal to the partial occlusion of the same segment. Next, the table was used by a radiologist to analyze and record the severity of involvement of pulmonary arteries based on the Qanadli index. The ECG changes of patients were also analyzed and recorded by a cardiac electro-physiologist.

Moral Considerations

All of the actions were taken to achieve the treatment goals set for the patients. The formal consent of all patients was obtained for including them in the study after explaining the whole process. This study was also approved by the ethics committee of the university. In addition, the patients were assured that their participation in this study was voluntary and they could leave the study whenever they were willing to. They were also assured that their names would remain secret. No additional expense was also imposed on the patients.

Statistical Analysis

All of the research data was analyzed using SPSS 16. Descriptive statistical methods (frequency and percentage) were also used for statistical examinations. The statistical results obtained for the two groups were tested using the independent T-test method while qualitative findings were examined using the Chi-square test method. The exact fisher test was also used when needed. In addition, the sensitivity, specificity, and positive and negative predictive values for the potential of ECG changes and a combination of changes influencing the diagnosis of massive or submassive embolism were also calculated. A p-value lower than 0.05 was considered to be significant in this study.

Result and Discussion

In the present study, 110 patients suspected of PTE were selected based on the inclusion and exclusion criteria as well as their willingness to participate in the study. A total of 8 patients were also excluded from the study.

The mean age of patients was 55.75 ± 18.31 years and their ages fell in the 19-84 years interval. Of the 102 patients, 47 patients (46.1%) were male and 55 patients (53.98%) were female.

The cause of embolism was unknown in 41 patients (40.2%). Moreover, the cause of embolism in 21, 7, 8, 10, 7, 4, and 3 patients was surgery or trauma (20.6%), immobility (bed-ridden embolism; 6.9%), pregnancy and childbirth (7.8%), cancer or DVT caused by cancer or its chemotherapy side effects (9.7%), history of embolism or DVT (6.9%), CVA (3.9%), and intravenous drug abuse (2.9%), respectively. In one patient the cause of embolism was psychological disorders (1%). 61 patients (59.8%) had a history of diseases. That is to say, 30, 7, 4, 5, 6, 4, and 2 patients had histories of HTN, cancer/chemotherapy, lymphoma, DVT, diabetes, HLP, and vertebral fractures, respectively. One patient also had a history of vasculitis, spinal tuberculosis, and psychological conditions. Doppler ultrasonography was carried out for 22 patients (21.6%). Of the 22 patients, 8 were DVT positive and 14 were DVT negative. In other cases, CTA was directly requested based on clinical suspicion and examination results.

According to the CTA findings, 58 patients (56.9%) suffered from massive embolism and 44 patients (43.1%) suffered from sub-massive embolism.

ECG was performed on all patients. Based on the positive ECG results, 78 patients (76.5%) were diagnosed with embolism. Figure (1) shows the ECG results based on CTA findings. Patients with massive embolism showed ECG pathologic changes that were significantly higher than those demonstrated by patients with sub-massive embolism (P=0.008).The mean number of pathologic findings for patients with massive embolism was 5.82 ± 2.95 while that of patients with submassive embolism was 4.25 ± 2.84. Therefore, the number of findings for the massive embolism group was significantly higher (P=0.04).

So far, 35 pathologic findings associated with embolism have been identified. All of these findings were considered in this study and were taken into account in examining patients with massive and submassive embolism. Of the pathologic findings, PR-displacement, presence of indeterminate-axis (180 to -90), low complex voltage, and QRS lower than 5 mm in precordial leads were not seen in any of the participants.

Tables (1) and (2) present the ECG pathologic findings for the massive and submassive embolism groups. As seen in these tables, except for QRS complex<5mm in the limb leads, ST elevation in AVR, ST elevation in V_1, New c right bundle branch block (RBBB) which is higher in the submassive embolism group, the frequency of findings for the massive embolism group is higher. However, the only significant difference between the groups was in the frequency of $S_1O_3T_3$ pattern, S_1&S_aVL>1.5 mm, ST depression in V_1-V_3, ST elevation in V_1-V_3, Negative T wave in V_1-V_3, Right axis deviation, RVH criteria, P pulmonale and QR pattern in V_1 which was significantly higher in the massive embolism group.

Table (3) shows the results of assessing the sensitivity and specificity of the combination of the above significant parameters. By combining the significant differences between the two groups, some combinations were obtained with high sensitivity and specificity in the diagnosis of massive embolism. ST elevation, St depression and T negative in V_1-V_3 findings had the highest frequency. By assessing these combinations along with other parameters sensitivity declined and specificity increased. However, in the assessment of the above parameters with or without other parameters sensitivity increased and specificity decreases. The highest specificity and positive predictive value for ST elevation or depression and/or T negative in V_1-V_3, RVH criteria, ST elevation or depression and/or T negative in V_1-V_3 and QR pattern in V_1 were 100% while ST elevation or depression and/or T negative in V_1-V_3, $S_1O_3T_3$, S_1 and SaVL>1.5mm and right axis deviation showed the highest sensitivity and negative predictive value.

Table.1 ECG finding in patients with massive and submassive PTE

ECG finding	PTE		P
	Massive	Submassive	
HR>95	23(39.7%)	14(31.8%)	0.41
$S_1O_3T_3$ pattern	18(31%)	6(13.8%)	0.04*
S_1&S_aVL>1.5 mm	21(36.2%)	7(15.9%)	0.02*
Q in III & aVF, but not II	5(8.6%)	3(6.8%)	0.73
$S_1S_2S_3$ pattern	7(12.1%)	3(6.8%)	0.37
ST depression in V_1-V_3	15(25.9%)	4(9.1%)	0.03*
Negative T wave in V_1-V_3	17(29.3)	5(11.4%)	0.02*
ST elevation in V_1-V_3	11(19%)	2(4.5%)	0.03*
ST depression in the inferior leads	13(22.4%)	5(11.4%)	0.14
Negative T waves in the inferior leads	7(12.1%)	3(6.8%)	0.5
ST elevation in aVR with concomitant ST depression in I, V_4-V_6	7(12.1%)	2(4.5%)	0.18
ST depression in V_4-V_6	10(17.2%)	5(11.4%)	0.4
ST elevation in AVR	3(5.2%)		0.46
ST elevation in V_{3R}-V_{5R}	3(5.2%)	2(4.5%)	0.88
ST elevation in III	10(17.2%)	6(13.8%)	0.62
ST elevation in V_1	5(8.6%)	7(15.9%)	0.25

*_Significant

Table.2 ECG finding in patients with massive and submassive PTE

ECG finding	PTE		P
	Massive	Submassive	
New i-RBBB	9(15.5%)	5(11.4%)	0.54
New c-RBBB	2(3.4%)	2(4.5%)	0.77
Right axis deviation	13(22.4%)	3(6.8%)	0.03*
Precordial TZ≥V5	26(44.8%)	14(31.8%)	0.18
RVH criteria	8(13.8%)	1(2.3%)	0.04*
P-pulmonale	10(17.2%)	2(4.5%)	0.04*
New AF/atrial flutter	4(6.9%)	1(2.3%)	0.38
QR pattern in V_1	8(13.8%)	1(2.3%)	0.04*
QR pattern in aVR	8(13.8%)	4(9.1%)	0.46
Late R in aVR	4(6.9%)	0	0.5
Pseudo-infarction pattern	13(22.4%)	3(6.8%)	0.06*
Electrical alternans	2(3.4%)	0	0.5
QRS complex<5 mm in the limb leads	2(3.4%)	2(4.5%)	0.77
ST depression in aVR	1(1.7%)	0	0.9
ST depression in V_1	3(5.2%)	0	0.25
ST elevation in V_1 & ST depression in V_2	3(5.2%)	0	0.25

*_Significant

Table.3 Sensitivity, Specificity, PPV and NPV of ECG finding in diagnosis of PTE

	Sensitivity	Specificity	PPV	NPV
ST elevation or depression and/or T negative in V_1-V_3	51.72%	75%	73.17 %	54.1 %
ST elevation or depression and/or T negative in V_1-V_3 and S_1&S_aVL>1.5mm	24.14%	93.18%	82.35 %	48.24 %
ST elevation or depression and/or T negative in V_1-V_3 and right axis deviation	8.62%	97.73%	83.33 %	44.79 %
ST elevation or depression and/or T negative in V_1-V_3 and RVH criteria	10.34%	100%	100%	45.83 %
ST elevation or depression and/or T negative in V_1-V_3 and p-pulmonale	12%	95.45%	77.78 %	45.16 %
ST elevation or depression and/or T negative in V_1-V_3 and QR pattern in V_1	8.62%	100%	100%	45.36 %
ST elevation or depression and/or T negative in V_1-V_3 and/or S_1 & SaVL>1.5mm	63.79%	63.64%	69.81 %	57.14 %
ST elevation or depression and/or T negative in V_1-V_3 and/or right axis deviation	65.52%	70.45%	74.51 %	60.58 %
ST elevation or depression and/or T negative in V_1-V_3 and/or RVH criteria	55.17%	72.73%	72.73 %	55.17 %
ST elevation or depression and/or T negative in V_1-V_3 and/or p-pulmonale	56.9%	75%	75%	56.9 %
ST elevation or depression and/or T negative in V_1-V_3 and/or QR pattern in V_1	56.9%	72.73%	73.33 %	56.14 %
ST elevation or depression and/or T negative in V_1-V_3 and $S_1O_3T_3$	22.41%	97.73%	92.86 %	48.86 %
ST elevation or depression and/or T negative in V_1-V_3 and/or $S_1O_3T_3$	60.34%	63.64%	68.63 %	54.90 %
ST elevation or depression and/or T negative in V_1-V_3 and/or $S_1O_3T_3$ and/or S_1 and SaVL>1.5mm	63.79%	56.82%	66.07 %	54.35 %
ST elevation or depression and/or T negative in V_1-V_3 and/or $S_1O_3T_3$ and/or S_1 and SaVL>1.5mm and/or right axis deviation	75.86%	52.27%	67.69 %	62.16 %

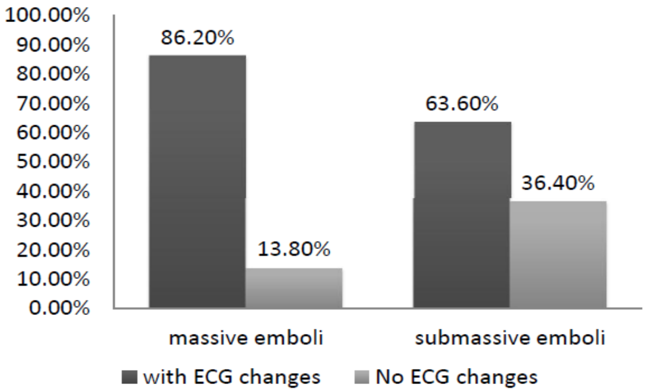

Figure.1 ECG finding based on CTA finding

PTE is usually in the form of deep venous thrombosis involving the abdomen and lower limbs. CTA is the golden standard for the diagnosis of PTE due to its availability and frequency (13). In the comparative studies carried out using lung scintigraphy CTA demonstrated a higher sensitivity (14). In addition, CTA has the advantage of revealing the pathologies of other structures in thorax (3, 4).

Qandali et al. carried out a prospective study on 158 patients using lung angiography as their reference method. They reported a sensitivity of 90% and specificity of 94% for CTA (15).

The dosage of radiation received during the scans is a major problem especially for patients with non-lethal embolism, people with low clinical risks of PTE, and female patients (16). Hence, it is possible to avoid unnecessary CTA by identifying other non-aggressive methods for assessing PTE and its severity.

The mortality caused by untreated pulmonary embolism is reported to be app. 30%. Hence, is it highly important to confirm diagnoses using a non-aggressive highly sensitive imaging method (17-19).

Clinical symptoms and laboratory findings about pulmonary embolism are general and cannot be used to diagnose PTE or determine the severity of embolism (17-19).
It is said that perhaps ECG findings can predict pulmonary thromboembolism and its clinical consequences. However, ECG of a patient with PTE may result in a wide range of manifestations (7-11). Therefore, ECG does not introduce a measure or sensitive/specific manifestation of PTE.

In previous studies, some of the common ECG findings (such as narrow T-wave, S1Q3T3, sinus-tachycardia, and RBBB) were used as predictors of PTE as well as the severity and prognosis of treatment (20).
Kukla et al. stated that ECG parameters are useful for the prediction of myocardial injury and assessment of prognosis for patients with acute pulmonary embolism (8). It is also reported that ECG changes depend on PTE size and perhaps this parameter can be used to diagnose sever embolism (21). In sum, 35 different findings about PTE patients have been reported. In this study, ECG changes including all of the 35 findings about massive and sub-massive embolism were studied. In 76.5% of pathological changes of ECG were in favor of embolism. Moreover, 86.2% of massive embolism patients showed ECG changes while 63.6% of submassive embolism patients showed such changes. Therefore, a significant statistical difference was seen in the results of the two groups. The number of pathological changes of ECG was higher in massive embolism. Among ECG findings, the frequency of S1Q3T3 pattern, S_1&S_aVL>1.5 mm, ST depression in V_1-V_3, ST elevation in V_1-V_3, Negative T wave in V_1-V_3, Right axis deviation, RVH criteria, P pulmonale and QR pattern in V_1 was considerably higher in the massive embolism group.

Similarly, Kanbay et al. also carried out a study and reported that ECG is valuable for revealing the severity of PTE based on anatomy (10). Golpe et al. also found out that ECG is related to the severity of PTE (11). In addition, Ferrari et al. showed that the T-invert is the most common abnormality of precordial lead that is associated with severity of PTE. That is to say, reoccurrence of T-invert was accompanied by PTE changes (7).

Geibel et al. stated that the presence of at least one of the reported ECG changes is an independent predictor of clinical consequences of the disease (22). However, in the present study no significant different was observed in the number of ECG changes and severity of embolism. Moreover, none of the findings could be used as a predictor for severe embolism.

The physiological basis of the ECG findings about PTE is not known yet, although it was suggested that ECG may reflect right ventricle distension (23). This relationship seems to be more complex today especially that no reliable relationship has been found between the manifestation and pattern of ECG changes and those of pulmonary hypertension or right ventricle hypotension diagnosed by echocardiography (7, 12, 22). In addition, although it seems more reasonable to assume that ECG findings about PTE are the result of myocardial ischemia or right ventricle wall stress, no study has managed to provide evidence of ischemia using enzymatic (creatine kinase) and scintigraphic examinations of patients demonstrating T-wave variations in their frontal precordial leads (24).

In spite of the aforementioned findings and the results of the present study, which reflect the role of some ECG changes in the severity of embolism, it is not possible to decisively determine the valuable changes. Moreover, no proper ranking or classification system is available for this purpose. However, the present study indicated that the simultaneous presence of several variables (4 to 5 ECG findings) can lead to a specificity and positive predictive value of 95-100% for different findings. In addition, assessment of the presence of one or several ECG findings led to a higher sensitivity and lower specificity.

Therefore, it shall be mentioned that CT scan is the primary means of assessing severity of PTE. However, when CT scan is not available and it is not possible to quickly transfer the patient to more advanced centers, these ECG changes can perhaps be used to diagnose patients in need of quicker and more optimal treatments. In any event, confirmation of this finding calls for more studies.

Conclusion

The level of ECG changes and the number of pathologic changes were higher in the massive embolism group. The majority of significant changes in ST-depression and negative-T were observed in different leads, which can be used as predictors of severity of PTE.

Suggestions

Based on the findings of the present study it can be said that ECG changes can be used in the diagnosis and determining the severity of PTE. However, it is necessary to carry out more studies with larger samples to obtain better and more accurate findings.

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