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Cardiac strain in right ventricular myocardial infarction and pulmonary embolism

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Aim. To study the prospects of using parameters of right ventricle (RV) longitudinal strain (LS) during systole for the differential diagnosis of RV myocardial infarction (RVMI) and pulmonary embolism (PE).

Material and methods. The study included 83 patients who were hospitalized with RVMI or PE in the period from December 2017 to May 2019. The study of RV LS using the two-dimensional speckle-tracking echocardiography was carried out in 30 patients with RVMI (group 1), 15 patients with high-risk PE (group 2), and 38 patients with intermediate-risk PE (group 3).

Results. The mean values of RV global LS in patients of groups 1 and 2 did not differ (12,8±2,69 and 12,0±2,56%, respectively) and were significantly lower than in patients of group 3 (15,9±3,03%). The ratio of the interventricular septum (IVS) LS to the RV free wall (FW) LS in the group 1 (1,04±0,43) was significantly lower than in the groups 2 (1,61±0,52) and 3 (1,29±0,38). The ratio of the LS of the RVFW basal segment to the apical segment in group 1 (0,60±0,37) was also significantly lower than in groups 2 (1,69±1,57) and 3 (1,67±1,33).

Conclusion. In patients with RVMI, there is a comparable decrease in the LS of the RVFW and IVS, and the LS of the basal segment decreases to a greater extent than the apical one. In patients with PE, the decrease in the LS of the RVFW is more pronounced than in IVS, and the LS of the apical segment decreases to a greater extent than the basal one. These differences can be used for the differential diagnosis of RVMI and PE.

Key words: right ventricular strain, right ventricular myocardial infarction, pulmonary embolism.

Relationships and Activities: not.

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According to the 2019 ESC guidelines [1], echocardiography is the method of choice in patients with suspected pulmonary embolism (PE)-related shock. If computed tomographic pulmonary angiography (CTPA) is not possible, identification of right ventricle (RV) overload is sufficient for diagnosis of PE. Nevertheless, the guidelines note that for the differential diagnosis of RV myocardial infarction (RVMI) and PE, additional echocardiographic criteria can be required.

The reason for this reservation was a study by Casazza F, et al. [2], which showed that the McConnell sign does not allow to differentiate RV dysfunction caused by pressure overload from dysfunction associated with reduced blood supply. The authors noted that differences in pulmonary arterial pressure also do not always allow differentiating RVMI and high-risk PE. This because in the first case left ventricular (LV) dysfunction can be accompanied by a noticeable increase in pulmonary blood pressure, and in the second, due to severe RV dysfunction, pulmonary arterial pressure may be relatively low. In addition, studying of critically ill patients showed that it is often not possible to obtain the visualization quality needed to accurately assess the tricuspid pressure gradient.

Taking all these points together, it seems relevant to study the possibilities of using speckle-tracking echocardiography for differential diagnostics of RVMI and PE.

The aim of the study was to compare the parameters of longitudinal systolic strain in patients with RVMI and PE.

Material and methods

The study included 83 patients who were hospitalized in the Tver Regional Clinical Hospital from December 2017 to May 2019. This study was performed in accordance with the Helsinki declaration and Good Clinical Practice standards. The medical ethics committee of Tver State Medical University approved this study. All patients signed informed consent.

Group 1 consisted of 30 patients with RVMI and related shock. There were following diagnostic criteria for RVMI: 1) right coronary artery (RCA) occlusion on coronary angiography, 2) RV dilatation on echocardiography performed at hospital admission (Philips CX50), 3) ST-segment elevation in leads V3R and V4R. All patients with RVMI underwent primary percutaneous coronary intervention with stent implantation in the RCA.

The diagnosis of PE was verified by CTPA. Group 2 consisted of 15 patients with PE and related shock (high-risk PE). Group 3 included 38 patients with signs of RV overload, but without severe systemic hemodynamic impairment (intermediate-risk PE, group 3).

Echocardiography (Vivid S70, GE) in patients of the 1st and 2nd groups was carried out on the first day after hemodynamic stabilization; in patients of group 3 — on one day with CTPA. RV diastolic dimension was measured in the longitudinal parasternal view, and tricuspid annular plane systolic excursion (TAPSE) in the four-chamber view. Pulmonary artery systolic pressure (PASP) was estimated by tricuspid regurgitation velocity. Visualization and estimation of ultrasound parameters were performed in accordance with ASE and EACVI guidelines [3].

To assess the RV longitudinal systolic strain by two-dimensional speckle-tracking echocardiography (2DSTE), in accordance with consensus document [4, 5], RV-focused four-chamber view was used with determination of basal, middle, and apical longitudinal strain of RV free wall (RVFW) and interventricular septum (IVS). According to EACVI/ASE guidelines [3, 6], absolute strain values were used. The global RV strain was calculated as the average strain for all six RV segments, the RVFW and IVS strain — as the average strain of the three related segments. The ratio of IVS and RVFW strain (IVS/RVFW), as well as basal and apical strain of the RVFW (B/A RVFW) and IVS (B/A IVS) were estimated.

In statistical processing, the mean and standard deviation were calculated. The significance of intergroup differences was determined using univariate analysis of variance and evaluated using the Newman-Keuls test. Frequency analysis was performed with chi-squared test and Bonferroni correction for multiple intergroup comparisons. Intergroup differences were considered significant with a probability of α error <5%. To determine the cut-off points of patients with RVMI and PE, we used a receiver operating characteristic (ROC) analysis.

Results

Table 1 shows that patients with RVMI (group 1) and pulmonary embolism (groups 2 and 3) were comparable in age, but the male proportion among RVMI patients was higher than among PE patients. The incidence of hypertension and diabetes was the same in all groups. Risk factors for pulmonary embolism, such as a history of venous thromboembolism, recent surgery or trauma, chronic lung diseases, and cancer, were rare in patients with RVMI and, in most cases, have occurred in patients with PE.

At the time of the examination, the levels of systolic blood pressure in patients of the 1st and 2nd groups did not differ and was significantly lower than in the 3rd group. Tachycardia and reduced oxygen

Table 1

Clinical characteristics of patients

Parameter	Group 1 (n=30)	Group 2 (n=15)	Group 3 (n=38)
Age, years	61,8±10,9	57,2±16,0	59,7±14,9
Men, n (%)	27 (90,0)	8 (53,3)[1]	22 (57,9)[1]
Hypertension, n (%)	19 (63,3)	8 (53,3)	19 (50,0)
Diabetes, n (%)	5 (16,7)	3 (20,0)	5 (13,2)
Risk factors for PE, n (%)	4 (13,3)	10 (66,7)[1]	24 (63,2)[1]
SBP, mm Hg	105,8±16,4	99,5±25,9	128,7±18,8[1,2]
HR >100 bpm, n (%)	5 (16,7)	10 (66,7)[1]	9 (24,3)[2]
SpO_2 <90%, n (%)	2 (6,7)	11 (73,3)[1]	8 (21,6)[2]
PASP, mm Hg	32,6±5,5	64,3±12,8[1]	59,6±19,0[1]
RV dimension, cm	3,70±0,39	3,71±0,54	3,55±0,49
TAPSE, cm	1,18±0,22	1,28±0,33	1,64±0,39[1,2]

Notes: data are presented as the mean and standard deviation or as absolute and relative values. [1,2] — significant differences with the 1st and 2nd group.

Abbreviations: PE — pulmonary embolism, SBP — systolic blood pressure, HR — heart rate, SpO_2 — blood oxygen saturation, PASP — pulmonary artery systolic pressure, RV — right ventricle, TAPSE — tricuspid annular plane systolic excursion.

Table 2

Data on myocardial strain

Parameter	Group 1 (n=30)	Group 2 (n=15)	Group 3 (n=38)
RV global strain, %	12,8±2,69	12,0±2,56	15,9±3,03[1,2]
Total RVFW strain, %	12,7±3,44	9,64±2,76[1]	14,6±4,48[2]
• basal, %	9,53±4,56	10,8±4,83	17,2±5,51[1,2]
• middle, %	12,2±4,67	9,60±3,09	15,1±5,14[1,2]
• apical, %	16,8±4,09	8,93±4,45[1]	12,5±4,72[1,2]
Total IVS strain, %	12,2±2,83	14,7±3,22[1]	17,3±2,69[1,2]
• basal, %	9,47±3,08	13,9±4,42[1]	17,9±3,54[1,2]
• middle, %	11,2±3,13	15,5±3,91[1]	18,7±3,57[1,2]
• apical, %	17,0±5,57	14,1±5,32	15,2±3,68
IVS/RVFW	1,04±0,43	1,61±0,52[1]	1,29±0,38[1,2]
B/A RVFW	0,60±0,37	1,69±1,57[1]	1,67±1,33[1]
B/A IVS	0,64±0,382	1,20±0,73[1]	1,27±0,45[1]

Notes: data are presented as the mean and standard deviation or as absolute and relative values. [1,2] — significant differences with the 1st and 2nd group.

Abbreviations: RV — right ventricle, RVFW — right ventricle free wall, IVS — interventricular septum, IVS/RVFW — the ratio of the IVS strain to the RVFW strain, B/A — the ratio of the basal strain to the apical.

saturation were observed in most patients of the 2nd group, in a quarter of group 3 patients, and in some cases in the 1st group. PASP >30 mm Hg were in 15 (50,0%) patients with RVMI and in all patients with PE. Moreover, PASP in patients with PE was on average 2 times higher than in patients with RVMI. RV dilatation was observed in all patients, a TAPSE decrease ⩾1,7 cm — in all patients of the 1st and 2nd group and 25 (65,8%) patients of the 3rd group. The average values of RV dimension and TAPSE in the 1st and 2nd groups were almost the same; in the 3rd group, RV dimension was slightly lower (p>0,05), and the TAPSE was significantly higher than in groups 1 and 2.

The average values of RV global strain in 1st and 2nd groups were lower than in 3rd group and did not differ from each other (Table 2). However, in the 1st group, the average values of IVS and RVFW strains were almost equal to each other, and their ratio was close to 1. In the 2nd group, the IVS/RVFW ratio was

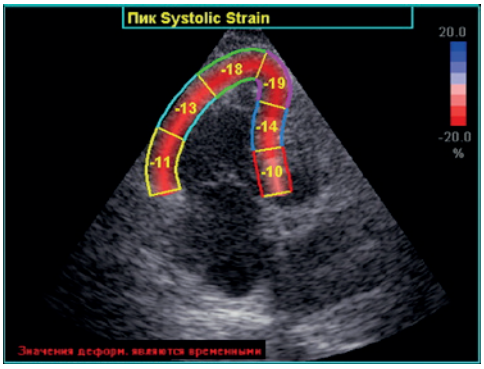

Figure 1. RV myocardial strain in a patient with RVMI.
Note: the global strain is 14,2%; the RVFW strain (14,0%) is comparable with the IVS strain (14,3%); the RVFW strain is reduced from the apical segments to the basal; the ratio of the basal strain to the apical is 0,61.

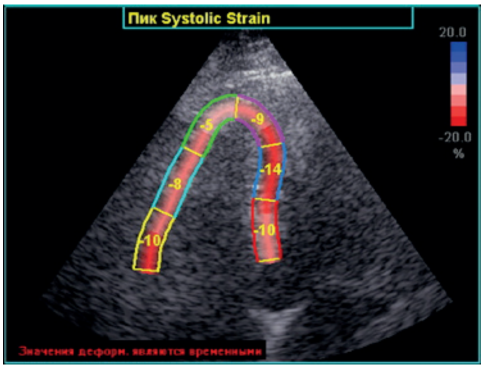

Figure 2. RV myocardial strain in a patient with PE.
Note: the global strain is 9,3%, the RVFW strain (7,4%) is 1,5 times less than the IVS strain (11,0%); the RVFW strain decreases from the basal segments to the apical; the ratio of the basal strain to the apical is 2,0.

1,61, and in the 3^{rd} group — 1,29. Thus, a decrease of RV global strain in patients with PE is associated, first of all, with a decrease in RVFW strain, while in patients with RVMI — equally with IVS and RVFW decrease.

According to ROC analysis, the cut-off point for patients with RVMI and PE is IVS/RVFW value of 1,18 (area under the curve — 76,5%). The sensitivity of the criterion is 70%, the specificity — 80%.

In patients with RVMI, RVFW strain decrease from apical segments to basal (p<0,001), and in patients with PE — from basal to apical segments (p<0,001). As a result, the B/A RVFW ratio in patients with RVMI was on average 0,60, and in patients with PE — 1,68. The cut-off point of patients with RVMI and PE is the B/A RVFW ratio of 0,94 (area under the curve — 90,2%). The sensitivity of this criterion is 89%, the specificity — 87%.

In patients with RVMI, both IVS and RVFW strains decrease from apical to basal segments (p<0,001), as a result of which the B/A IVS ratio was 0,64. In patients with PE, the average values of the IVS basal and middle strains do not differ and exceed the apical strain (p<0,01), as a result of which the B/A IVS ratio was 1,25. The cut-off point of patients with RVMI and PE is the B/A IVS of 0,85 (area under the curve — 88,6%). The sensitivity of the criterion is 79%, the specificity — 87%.

It should be noted that the B B/A IVS correlates both with the B/A RVFW (r=0635, p<06001) and the IVS/RVFW (r=0662, p<0,001). However, there is no correlation between the B/A RVFW and the IVS/RVFW (r=0,18, p>0,05), which allows them to be used as part of the combined criterion for the PE diagnosis. At least one of the considered signs (IVS/RVFW ⩾1,18 or B/A RVFW ⩾0,94) was observed in 52 (98,1%) patients with PE and only 13 (33,3%) patients with RVMI. The sensitivity of this criterion for PE diagnosis approaches 100%, which allows to rule out this pathology if the patient does not have any of the listed signs. Both of these signs were detected in 32 (60,4%) patients with PE and none of the patients with RVMI, which indicates 100% specificity of this combination for RV pressure overload and allows diagnosing PE.

Thus, in patients with RVMI, a decrease in RV global strain is equally associated with a decrease in RVFW and IVS strains. Moreover, RV basal strain decreases to a greater extent than the apical (Figure 1). In patients with PE, a decrease in RV global strain is associated mainly with RVFW strain decrease and, to a much lesser extent, with IVS strain decrease. In PE, RV apical strain decreases to a greater extent than the basal (Figure 2). The revealed differences in RV strain can be used for the differential diagnosis of RVMI and PE.

Discussion

According to the literature data, the average RV global strain in healthy individuals is 24,3% [5], in patients with RVMI — 13,7% [7], and with PE — 13,1-17,2% [8-10]. In this study, close data were obtained both in patients with RVMI (12,8%) and PE (12,0-15,9%). However, the literature data on strain of various parts of the RV are not fully consistent with the results of this study. According to study by Platz E, et al. [11], IVS strain in healthy people is on average less than the RVFW strain (18,5 vs 24,9%). Study by Park SJ, et al. [7] showed the same ratio in patients with RVMI (13,5 vs 15,1%). However, according to the present study, the average values of the IVS and RVFW strains in patients with RVMI did not differ (12,2 and 12,7%).

In RVMI, the IVS/RVFW ratio reflects the severity of damage due to RCA occlusion. In the acute period, this ratio depends on the ischemic areas of IVS and RVFW, later on necrotic area. RVFW myocardium receives blood not only through the coronary arteries, but also through the thebesian arteries, as a result of which the reduced blood supply through RCA leads not so much to the myocytes' death as to their hibernation [12, 13]. Improving blood supply leads to the restoration of myocardial contractility and an increase in the RVFW strain, as a result of which the IVS/RVFW ratio decreases.

In this study, the assessment of myocardial strain in patients with RVMI was carried out on the first day after revascularization, and in the study by Park SJ, et al. [7] — in the first three days. This can explain the lower values of the RVFW strain (12,7 vs 15,7%) and the higher IVS/RVFW ratio (1,04 vs 0,89) in the current paper. It can be assumed that in the early stages, patients with extensive RV lesion have IVS/RVFW ratio significantly higher than 1, which is typical for PE. This is probably the reason for the low specificity (80%) of IVS/RVFW ratio as a criterion for PE diagnosis.

The second feature of myocardial strain in patients with RVMI is the predominance of the RVFW apical strain over the basal, while in healthy individuals, the RVFW strain decreases from basal segments to apical: 26,5, 25,7, and 21,5% [7]. The decrease of the basal and middle strain in RVMI is due to RCA supplies blood only to the basal and middle segments of RVFW and IVS, while apical segments receive blood from the left anterior descending artery. Obviously, the earlier the examination is carried out, the more the RVFW strain decreases and, as a result, the lower the ratio of the basal and apical strains. As the contractility of the basal segments of the RVFW is restored, this ratio increases, but, as a rule, does not reach the values observed in PE. This explains the rather high specificity (87%) of the second criteria for PE diagnosis that we proposed (B/A RVFW $\geqslant$0,94).

The decrease in RV strain in PE patients is associated not with ischemic lesion, as in RVMI, but with RV pressure overload and related dilatation. Dilation is accompanied by diastolic hyperextension of the myocardium, which reduces the longitudinal systolic strain, necessary for ejection of stroke volume. At the global level, this is manifested by a TAPSE decrease, at the myocardial level — by a strain decrease [14, 15].

It can be assumed that thin RVFW stretches more easily than IVS, and as a result of RV dilatation, the RVFW strain decreases to a greater extent than the IVS strain. Indeed, according to Descotes-Genon V, et al. [9], in PE patients without RV overload, the IVS strain, as normal, is less than the RVFW strain (17,2 vs 20,2%), and when the RV is overloaded, the IVS/RVFW ratio changes to the opposite: 13,5 vs 12,7%. The same IVS/RVFW ratio in patients with RV overload was revealed in study by Platz E, et al. [11] (15,0 vs 14,2%) and in the present study.

The ratio of RVFW basal and apical strains remains the same as in healthy people. According to study by Vitarelli A, et al. [8], the RVFW apical strain in healthy individuals is 1,23 times less than the basal (26,5 vs 21,5%), and in patients with PE — 1,22 times (19,1 and 15,6%). Similar ratio was found in the studied patients with PE.

Conclusion

The RV global strain is reduced both in patients with RVMI and PE. However, with RVMI, there is a comparable decrease of longitudinal strain in RVFW and IVS, while with PE, the decrease in RVFW strain is much more pronounced than in IVS strain. In addition, patients with RVMI have a decrease in RV strain from the apical segments to the basal, and in patients with PE, from the basal to the apical. The revealed differences can be used for the differential diagnosis of RVMI and PE.

Relationships and Activities: not.

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