UDC: 616.127-005.8-036.8-073.432.19

The diagnostic value of three-dimensional echocardiography and speckle tracking echocardiography in patients after myocardial infarction with right ventricle involvement (clinical case)

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The inferior myocardial infarctions (MI) of left ventricle (LV) are often complicated with right ventricle (RV) involvement. The traditional echocardiographic parameters lack diagnostic accuracy in assessment of RV function. Speckle tracking echocardiography and three-dimensional echocardiography are promising diagnostic tools in quantification of RV.

The purpose of the study was to present the role of speckle tracking echocardiography and three-dimensional echocardiography in patients after inferior MI with RV involvement.

It was described a clinical case of a 67-year old male after recent inferior MI with RV involvement. The speckle tracking analysis and three-dimensional echocardiography was performed one and six months after coronary event. The initial study revealed decreased longitudinal strain of RV free wall segments, especially in the apical region. The RV global longitudinal strain was -8,8 % (normal range ≤ -20 %). The RV end-diastolic volume index was 100.9 ml/m^2 (normal range <87 ml/m^2) and RV end-systolic volume index was 69.8 ml/m^2 (normal range <44 ml/m^2), indicating its severe enlargement. The three-dimensional RV ejection fraction (EF) was 31 % (normal range >45 %).The analysis on the sixth month revealed improvement of RV contractility in all segments with global longitudinal strain of -14.2 %. The RV volumes decreased by 10 % and EF was raised from 31 to 33 %, reflecting positive cardiac remodeling during follow-up period.

Conclusions. Speckle tracking echocardiography and three-dimensional echocardiography provide additional diagnostic information in patients after MI with RV involvement and can be used for patients' follow-up.

Key words: three-dimensional echocardiography, speckle tracking echocardiography, infarction, right ventricle.

Zaporozhye medical journal 2018; 20 (6), 867–872

DOI: 10.14739/2310-1210.2018.6.146203

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Діагностична цінність тривимірної ехокардіографії та спекл-трекінг ехокардіографії в пацієнтів після інфаркту міокарда з залученням правого шлуночка (клінічний випадок)

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Інфаркти міокарда (ІМ) нижньої стінки лівого шлуночка (ЛШ) часто ускладнюються ураженням правого шлуночка (ПШ). Стандартним ехокардіографічним показникам бракує діагностичної точності в оцінюванні функції ПШ. Спекл-трекінг ехокардіографія та тривимірна ехокардіографія – перспективні діагностичні інструменти для кількісного оцінювання стану ПШ.

Мета роботи – представити роль спекл-трекінг ехокардіографії та тривимірної ехокардіографії у хворих після ІМ нижньої стінки з залученням ПШ.

Описали клінічне спостереження 67-річного чоловіка після недавнього ІМ нижньої локалізації з залученням ПШ. Спекл-трекінг аналіз і тривимірну ехокардіографію виконали через 1 і 6 місяців після коронарної події. Початкове дослідження визначило зниження поздовжнього стрейну вільної стінки ПШ, особливо в апікальній ділянці. Глобальний поздовжній стрейн ПШ становив -8,8 % (норма ≤ -20 %). Кінцево-діастолічний індекс ПШ становив 100,9 мл/м^2 (норма <87 мл/м^2), кінцево-систолічний індекс – 69,8 мл/м^2, що свідчило про його істотну дилатацію. Тривимірна фракція викиду (ФВ) ПШ дорівнювала 31 % (норма >45 %). Аналіз через 6 місяців визначив поліпшення скоротливості всіх сегментів ПШ зі значенням глобального поздовжнього стрейну -14,2 %. Об'єми ПШ зменшилися майже на 10 %, а ФВ збільшилася з 31 % до 33 %, показуючи позитивне ремоделювання серця за період спостереження.

Висновки. Спекл-трекінг ехокардіографія та тривимірна ехокардіографія мають додаткову діагностичну інформативність у пацієнтів після перенесеного ІМ із залученням ПШ і можуть бути використані для динамічного спостереження.

Ключові слова: тривимірна ехокардіографія, спекл-трекінг ехокардіографія, інфаркт міокарда, правий шлуночок.

Запорізький медичний журнал. – 2018. – Т. 20, № 6(111). – С. 867–872

Диагностическая ценность трехмерной эхокардиографии и спекл-трекинг эхокардиографии у пациентов после инфаркта миокарда с вовлечением правого желудочка (клинический случай)

М. Ю. Колесник

Инфаркты миокарда (ИМ) нижней стенки левого желудочка (ЛЖ) часто осложняются поражением правого желудочка (ПЖ). Стандартным эхокардиографическим показателям не хватает диагностической точности в оценке функции ПЖ. Спекл-трекинг эхокардиография и трехмерная эхокардиография – перспективные диагностические инструменты количественной оценки состояния ПЖ.

Цель работы – представить роль спекл-трекинг эхокардиографии и трехмерной эхокардиографии у больных после ИМ нижней стенки с вовлечением ПЖ.

Ключевые слова: трехмерная эхокардиография, спекл-трекинг эхокардиография, инфаркт миокарда, правый желудочек.

Запорожский медицинский журнал. – 2018. – Т. 20, № 6(111). – С. 867–872

Описано клиническое наблюдение 67-летнего мужчины после недавнего ИМ нижней локализации с вовлечением ПЖ. Спекл-трекинг анализ и трехмерную эхокардиографию проводили через 1 и 6 месяцев после коронарного события. Начальное исследование определило снижение продольного стрейна свободной стенки ПЖ, особенно в апикальной зоне. Глобальный продольный стрейн ПЖ составил -8,8 % (норма ≤-20 %). Конечно-диастолический индекс ПЖ составил 100,9 мл/м^2 (норма <87 мл/м^2), конечно-систолический индекс – 69,8 мл/м^2, что свидетельствовало о его значительной дилатации. Трехмерная фракция выброса (ФВ) ПЖ составила 31 % (норма >45 %). Анализ через 6 месяцев определил улучшение сократимости всех сегментов ПЖ со значением глобального продольного стрейна -14,2 %. Объемы ПЖ уменьшились на 10 %, а ФВ увеличилась с 31 % до 33 %, отражая положительное ремоделирование сердца за период наблюдения.

Выводы. Спекл-трекинг эхокардиография и трехмерная эхокардиография имеют дополнительную диагностическую информативность у пациентов после перенесенного ИМ с вовлечением ПЖ и могут использоваться для динамического наблюдения.

The signs of right ventricle (RV) involvement are present in up to 40 % of patients with inferior myocardial infarction (MI) [1]. However, the diagnosis of right ventricle (RV) infarction is a challenging task. The use of additional right precordial leads (V_3R and V_4R) should be considered to identify concomitant RV infarction according to the 2017 European Society of Cardiology (ESC) guidelines on acute MI in patients presenting with ST-segment elevation [2]. Despite these recommendations, the RV acute ischemia often remains underdiagnosed in a real clinical practice.

Another important issue is the echocardiographic evaluation of RV systolic function. The 2015 guidelines for cardiac chamber quantification by echocardiography suggest using at least one or a combination of several parameters for RV function assessment (*Table 1*) [3].

Most of these parameters reflect only longitudinal contractility that can lead to inappropriate assessment of RV condition. Moreover, it is impossible to perform volumetric measurements and to calculate ejection fraction (EF) using two-dimensional echocardiography. The explanation is that no geometric assumption can be made for RV due to its complex structure.

Advanced ultrasound techniques might overcome these limitations. It is mentioned in the guidelines, that 3D-echocardiography-derived RV EF should be considered as a method of quantifying RV systolic function in laboratories with appropriate 3D platforms and experience [3]. Speckle tracking echocardiography might be another useful technique, which allows to quantify global and regional RV contractility.

Table 1. Parameters for the echocardiographic assessment of RV function

Parameter, unit	Calculation	Abnormality threshold
TAPSE, mm	Tricuspid annular longitudinal excursion by M-mode (mm), measured between end-diastole and peak systole	<17 mm
Pulsed tissue Doppler S wave, cm/sec	Peak systolic velocity of tricuspid annulus by pulsed-wave DTI (cm/sec), obtained from the apical approach	<9.5 cm/sec
Pulsed Doppler RIMP	RIMP (Tei index) by pulsed Doppler: RIMP = (TCO − ET)/ET	>0.43
FAC, %	RV FAC in RV-focused apical four-chamber view: RV FAC (%) = 100 ×(EDA − ESA)/EDA	<35 %

TAPSE: tricuspid annulus peak systolic excursion; **DTI**: Doppler tissue imaging; **RIMP**: right ventricle index of myocardial performance; **TCO**: tricuspid valve closure-to-opening time; **ET**: ejection time; **FAC**: fraction area change; **EDA**: end-diastolic area; **ESA**: end-systolic area.

Table 2. Segmental values of RV longitudinal strain

Visit	RV free wall			Interventricular septum		
	Basal segment	Medium segment	Apical segment	Basal segment	Medium segment	Apical segment
1 month	-14	-10	-5	3	-10	-11
6 month	-17	-17	-13	-13	-12	-13

The purpose

The purpose of the study was to present the role of speckle tracking echocardiography and three-dimensional echocardiography in patient with inferior MI and RV involvement.

Clinical case presentation

67-year old male was admitted to the catheterization laboratory of Zaporizhzhia Regional Center of Cardiovascular Diseases with severe chest pain, lasting for 6 hours. His ECG showed ST elevation in II, III, aVF leads up to 10 mm and V_3R – V_6R right precordial leads up to 4 mm. Urgent coronary angiography revealed proximal right coronary artery occlusion, which was successfully treated with bare metal stent. His past medical history was positive for arterial hypertension and gout for 15 years. The patient was treated with valsartan 160 mg, bisoprolol 5 mg and allopurinol 200 mg before admission.

The early rehabilitation period passed without significant complications. The patient was examined twice – on the first and the sixth month after coronary event in the University Clinic of Zaporizhzhia State Medical University. His clinical condition was stable. The patient didn't suffer from heart attacks. His ECG showed pathological Q-waves in II, III, aVF, V_4R, V_5R and V_6R (*Fig. 1*).

The conventional echocardiography was performed on Vivid E9 XD Clear (GE Vingmed Ultrasound, Horten, Norway) equipped with matrix phased array probe M5Sc. The main findings of the examination included increased left ventricle (LV) wall thickness and enlarged left atrium volume index. The LV EF was 52 % by Simpson method. The wall motion abnormalities consisted of basal septal, basal inferior and medium basal hypokinesia. The LV global longitudinal strain was -15.2 % (normal range ≤ -20 %). The basal RV diameter was 5.2 cm (normal range < 4.1 cm) and mid-cavity diameter was 4.9 cm (normal range > 3.5 cm) in RV-focused apical view (*Fig. 2*). The conventional parameters of RV systolic function revealed preserved tricuspid annulus peak systolic excursion (16 mm) and pulsed tissue Doppler S wave (9 cm/s), whereas fractional area change was decreased (28 %).

The speckle tracking analysis was performed off-line with 2D Strain software on Echopac 113 work station (Gen-

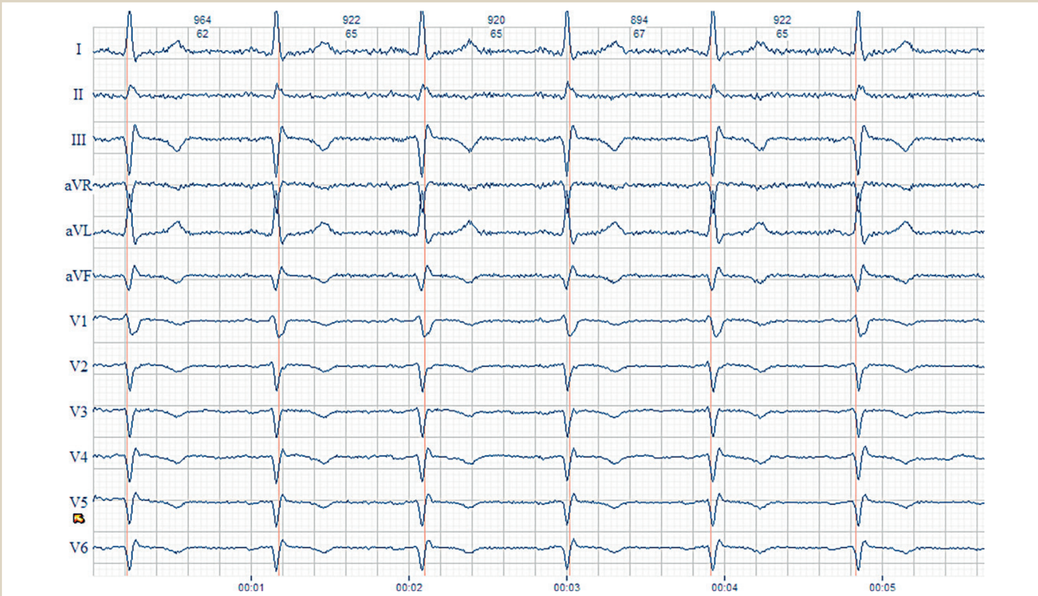

Fig. 1. Surface 12-lead ECG with right precordial leads (V1R-V6R). Description is in the text. Voltage – 10 mm/mV, speed – 50 mm/s.

eral Electric, USA). We used recently published consensus document on standardization of left atrial, right ventricular and right atrial deformation imaging using two-dimensional speckle tracking echocardiography [4]. This paper suggests using RV focused apical four-chamber view for image aquisition. Global RV longitudinal strain was reported as average of 6 segments of the RV free wall and the interventricular septum (*Fig. 3*).

The segmental values of RV free wall longitudinal strain were decreased, especially in the apical region (*Table 2*). The apical segment of the interventricular septum had positive strain, reflecting pathological systolic elongation due to tethering effect of the adjustment segments. The RV global longitudinal strain was – 8.8 % (normal range ≤ -20 %). The strain analysis on the sixth month revealed improvement in the RV contractility in all segments with calculated global

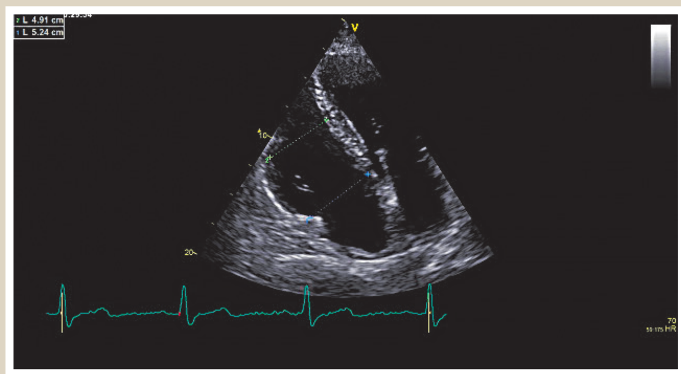

Fig. 2. The RV-focused apical view, end-diastolic frame. Two-dimensional standard echocardiography, gray scale mode.

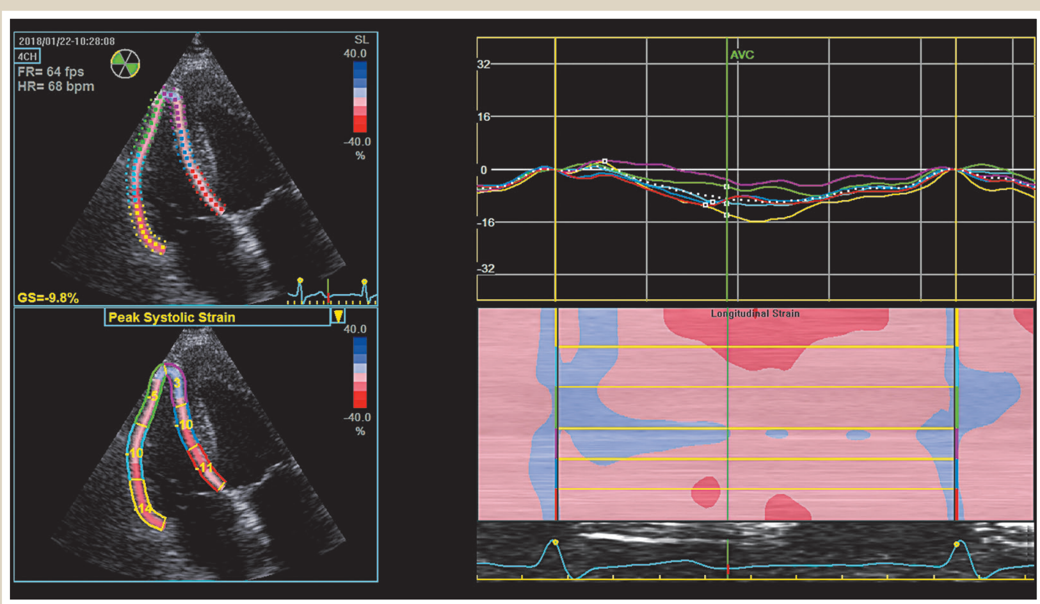

Fig. 3. The RV longitudinal strain analysis (the first month after MI).

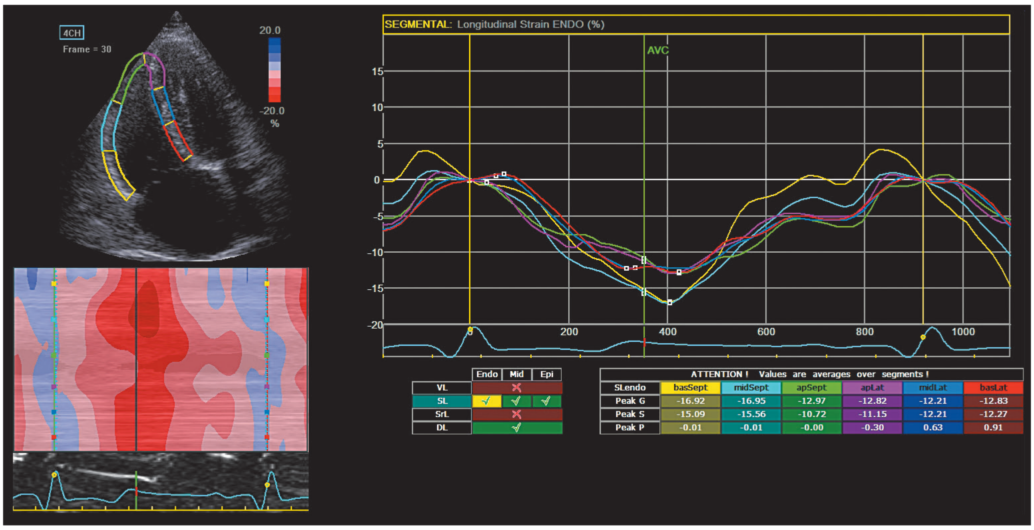

Fig. 4.
The RV longitudinal strain analysis (the sixth month after MI).

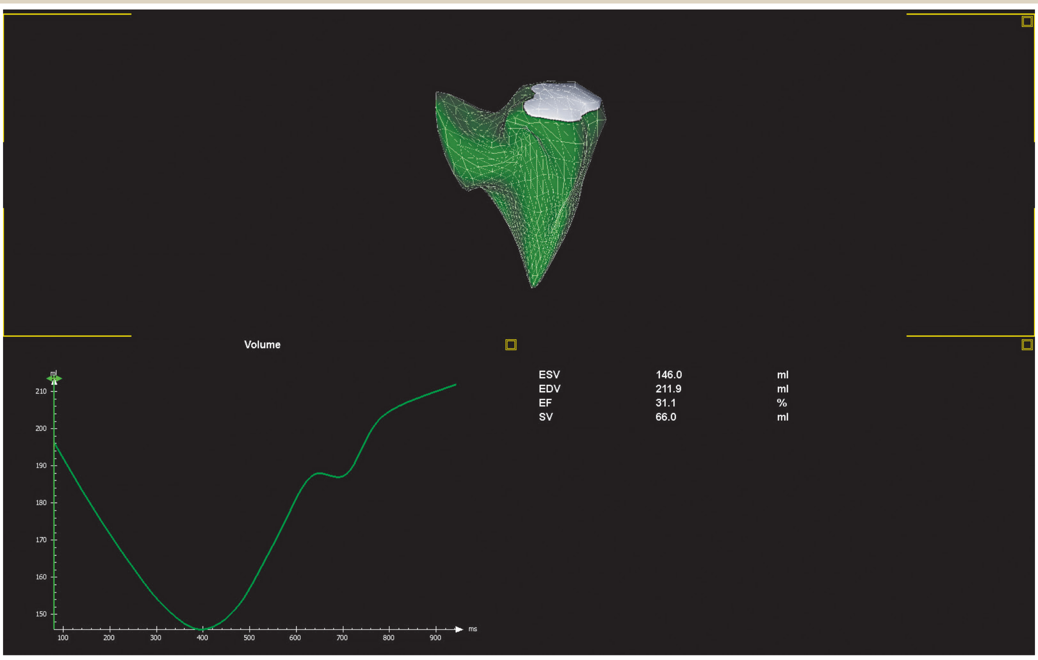

Fig. 5.
The generated 3D surface model of the RV, end-diastolic frame (upper panel). The volume loop during the whole cardiac cycle (lower left panel). The calculated RV volumes, SV and EF.

ESV: end-systolic volume; **EDV**: end-diastolic volume; **EF**: ejection fraction, **SV**: stroke volume.

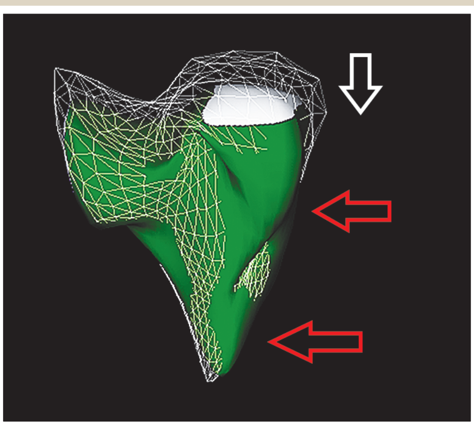

Fig. 6.
The generated 3D surface model of the RV, end-systolic frame. The fish-net white contour indicates end-diastolic frame. The longitudinal contractility remains preserved (white arrow), whereas radial contraction of RV free wall is severely decreased (red arrows).

longitudinal strain of – 14.2 % (normal range ≤ -20 %) (*Fig. 4*).

Six-beat full-volume 3D data set was obtained during breathhold using Vivid E9 (GE Vingmed Ultrasound, Horten, Norway) equipped with 4V probe. The calculation of RV volumes and EF was performed off-line using 4D RV-Function 1.2 software package (TomTec Imaging Systems GmbH, Germany). The RV endocardium was manually traced in four-chamber, sagittal (short-axis), and coronal planes, at end-diastole and end-systole. The alignment of the three planes required manipulation by slicing, rotating, and angulating in any of these three displayed orthogonal planes using a combination of software controls. Manual corrections of the RV contours were performed. The trabecular layer of the RV wall, papillary muscles, and moderator band were included in the RV cavity [5].

The RV end-diastolic and end-systolic volumes were 211.9 and 146 ml, respectively (*Fig. 5*). It is recommended to use parameters, indexed to body surface area (BSA) [3]. The RV end-diastolic volume index was 100.9 ml/m^2 (normal range <87 ml/m^2) and RV end-systolic volume index was 69.8 ml/m^2 (normal range <44 ml/m^2), indicating its enlargement. The RV EF was 31 %. Roughly, an RV EF of <45 % usually reflects abnormal RV systolic function, though some laboratories use age- and gender-specific values.

The analysis of generated 3D surface model revealed that longitudinal contractility was preserved, so the reduction in RV EF was mainly influenced by radial component of contractility (*Fig. 6*). The RV end-diastolic volume index decreased to 91.3 ml/m^2 and RV end-systolic volume index to 61.1 ml/m^2 with calculated EF about 33 % during the follow-up period. It indicates some degree of RV recovery after myocardial infarction. It's worth mentioning, that both speckle tracking and three-dimensional echocardiography demonstrated these positive trends of RV remodeling.

Discussion

The RV infarction is often underdiagnosed despite its frequent association with inferior-wall MI [6]. The presence of RV involvement leads to unfavorable prognosis. Recent meta-analysis compared the in-hospital mortality in patients with RV involvement in fibrinolytic and mechanical reperfusion era [7]. It was shown that the presence of the RV infarction leads to 3-fold higher risk of mortality despite new reperfusion technologies.

The two-dimensional echocardiography has some important limitations in the assessment of RV [8]. This cardiac chamber has a unique crescent shape and no geometrical assumption can be made. Therefore, it is impossible to calculate RV volumes using Simpson method. RV consists of three parts (inflow tract, apex and outflow tract), which can never be visualized in the same acoustic plane. There are several parameters for RV systolic function evaluation and there is no agreement, which of them is preferable.

Obviously, echocardiography should not delay the invasive treatment in patients with acute coronary syndrome with ST segment elevation. However, echocardiographic evaluation should be done in early perspective after primary percutaneous intervention. Speckle tracking echocardiography is a new promising technique, which might improve quantification of RV. Some studies confirmed the prognostic importance of this technology in patient with RV infarction. Particularly, Park S. J. et al. (2015) showed that RV global longitudinal strain had better sensitivity and specificity in prediction of major adverse cardiac events, than TAPSE and FAC [9]. Patients with strain value ≥ -15,5 % showed significantly lower 5-year survival rate. In the recent study RV free wall longitudinal strain ≥ -22 % was an important predictor of malignant arrhythmias independent of LV function in patients after acute MI [10].

Three-dimensional echocardiography could be another important diagnostic tool for RV assessment. It is the only technique, besides magnetic resonance imaging, which allows to calculate RV volumes and EF. There is a lack of prospective data confirming the prognostic role of this diagnostic modality. However, the previous studies with cardiac magnetic resonance estimated that RVEF <40 % was strongly associated with mortality [11, 12]. Considering good agreement between two methods, 3D echocardiography may potentially become the first-choice diagnostic tool for assessment of RV volumes and EF [5].

To sum up, the main finding of presented clinical case is significant RV injury in patient with inferior MI, despite preserved LV EF, which was diagnosed by new ultrasound imaging modalities. Speckle tracking echocardiography and three-dimensional echocardiography improve diagnostic accuracy in field of quantitative assessment of the RV ischemic damage.

Conclusions

The standard echocardiographic parameters of the RV quantification lack diagnostic accuracy in patients after MI with the RV involvement. Speckle tracking echocardiography and three-dimensional echocardiography provide additional diagnostic and prognostic information in patients after acute myocardial ischemia with the RV involvement. These diagnostic modalities can be used for patients' follow-up to assess cardiac remodeling process.

Prospects for further research. It is planned to work out the criteria of positive and negative remodeling of the RV after MI using speckle tracking echocardiography and three-dimensional echocardiography.

Conflicts of interest: author has no conflict of interest to declare.
Конфлікт інтересів: відсутній.

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Надійшла до редакції / Received: 16.08.2018
Після доопрацювання / Revised: 27.08.2018
Прийнято до друку / Accepted: 05.09.2018

References

[1] Namana, V., Gupta, S. S., Abbasi, A. A., Raheja, H., Shani, J., & Hollander, G. (2018). Right ventricular infarction. *Cardiovasc Revasc Med*, 19(1), 43–50. doi: 10.1016/j.carrev.2017.07.009.

[2] Ibanez, B., James, S., Agewall, S., Antunes, M. J., Bucciarelli-Ducci, C., Bueno, H., et al. (2018). 2017 ESC Guidelines for the management of acute myocardial infarction in patients presenting with ST-segment elevation: The Task Force for the management of acute myocardial infarction in patients presenting with ST-segment elevation of the European Society of Cardiology. *Eur Heart J*, 39(2), 119–177. doi: 10.1093/eurheartj/ehx393.

[3] Lang, R. M., Badano, L. P., Mor-Avi, V., Afilalo, J., Armstrong, A., Ernande, L., et al. (2015). Recommendations for cardiac chamber quantification by echocardiography in adults: an update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. *J Am Soc Echocardiogr*, 28(1), 1–39. doi: 10.1016/j.echo.2014.10.003.

[4] Badano, L. P., Kolias, T. J., Muraru, D., Abraham, T. P., Aurigemma, G., Edvardsen, T., et al. (2018). Standardization of left atrial, right ventricular, and right atrial deformation imaging using two-dimensional speckle tracking echocardiography: a consensus document of the EACVI/ASE/Industry Task Force to standardize deformation imaging. *Eur Heart J Cardiovasc Imaging,* 19(6), 591–600. doi: 10.1093/ehjci/jey042.
[5] Muraru, D., Spadotto, V., Cecchetto, A., Romeo, G., Aruta, P., Ermacora, D., et al. (2016). New speckle-tracking algorithm for right ventricular volume analysis from three-dimensional echocardiographic data sets: validation with cardiac magnetic resonance and comparison with the previous analysis tool. *Eur Heart J Cardiovasc Imaging,* 17(11), 1279–1289. doi.org/10.1093/ehjci/jev309.
[6] Ondrus, T., Kanovsky, J., Novotny, T., Andrsova, I., Spinar, J., & Kala, P. (2013). Right ventricular myocardial infarction: From pathophysiology to prognosis. *Exp Clin Cardiol*, 18(1), 27–30.
[7] Inohara, T., Kohsaka, S., Fukuda, K., & Menon, V. (2013). The challenges in the management of right ventricular infarction. *Eur Heart J Acute Cardiovasc Care,* 2(3), 226–234. doi: 10.1177/2048872613490122.
[8] Smolarek, D., Gruchała, M., & Sobiczewski, W. (2017). Echocardiographic evaluation of right ventricular systolic function: The traditional and innovative approach. *Cardiol J*, 24(5), 563–572. doi: 10.5603/CJ.a2017.0051.
[9] Park, S. J., Park, J. H., Lee, H. S., Kim, M. S., Park, Y. K., Park, Y., et al. (2015). Impaired RV global longitudinal strain is associated with poor long-term clinical outcomes in patients with acute inferior STEMI. *JACC Cardiovasc Imaging,* 8(2), 161–169. doi: 10.1016/j.jcmg.2014.10.011.
[10] Risum, N., Valeur, N., Søgaard, P., Hassager, C., Køber, L., & Ersbøll, M. (2018). Right ventricular function assessed by 2D strain analysis predicts ventricular arrhythmias and sudden cardiac death in patients after acute myocardial infarction. *Eur Heart J Cardiovasc Imaging,* 19(7), 800–807. doi: 10.1093/ehjci/jex184.
[11] Larose, E., Ganz, P., Reynolds, H. G., Dorbala, S., Di Carli, M. F., Brown, K. A., et al. (2007). Right ventricular dysfunction assessed by cardiovascular magnetic resonance imaging predicts poor prognosis late after myocardial infarction. *J Am Coll Cardiol,* 49(8), 855–862. doi: 10.1016/j.jacc.2006.10.056.
[12] Miszalski-Jamka, T., Klimeczek, P., Tomala, M., Krupiński, M., Zawadowski, G., & Noelting, J. (2010). Extent of RV dysfunction and myocardial infarction assessed by CMR are independent outcome predictors early after STEMI treated with primary angioplasty. *JACC Cardiovasc Imaging,* 3(12), 1237–1246. doi: 10.1016/j.jcmg.2010.09.018.