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Research Paper

Assessment of right ventricular function in healthy people using tissue Doppler imaging

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ABSTRACT

Introduction: A growing body of evidence is being gathered regarding the right ventricle's (RV) unique function, adaptation, and compensatory role. Echocardiography should probably enable prompt diagnosis and treatment assessment at the initial stage.

Aim: The study aimed to assess the structural and functional features of the RV in healthy individuals.

Material and methods: The study included 185 healthy adults aged 16 to 85 years. Everyone who participated in the study had an echocardiographic examination using a standard method and an RV tissue Doppler imaging (TDI) in pulsed mode from the base of the free wall. On the RV TDI, we measured the velocity of the *s*, *e*, and *a* wave, and the duration of isometric contraction times (ICT), ejection time (ET), and isometric relaxation time (IRT) in milliseconds.

Results and discussion: In 51% of participants, the ratio of early and late diastolic speeds (*e*/*a*) was less than 1. It was detected in 21% of people under 40 and 64% of cases in people over 40. RV exhibits distinct embryological origins and functional characteristics compared to LV. Its unique structural components and muscle fiber orientation contribute to its contractile function, with longitudinal fibers playing a predominant role in RV emptying. Echocardiography, particularly TDI, provides valuable insights into RV function and pathology. The study highlights the importance of age-related changes in RV diastolic function, emphasizing that early diastolic myocardial relaxation declines with age, necessitating increased atrial contraction.

Conclusions: The patient's age must be considered while analyzing the RV function's TDI in clinical practice.

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1. INTRODUCTION

A growing body of evidence is being gathered regarding the right ventricle (RV) unique function, adaptation, and compensatory role in healthy individuals and people with cardiovascular diseases. Studies of the RV and early assessment of data changes are becoming extremely prevalent.[1–3]

The RV is the connecting link of the cardiopulmonary system. Its function may change as a result of heart pathologies, as well as pulmonary diseases and other circulation disorders. Inadequate emphasis is frequently given to evaluating RV function in comparison to left ventricle (LV). However, in cases of severe, progressive RV dysfunction and pulmonary hypertension, the clinical outcome is usually poor.

The pressure-volume ratio is currently the most widely used method for assessing RV systolic and diastolic function. This involves an invasive intervention, which is associated with certain risks and requires special equipment and trained medical personnel. Tissue Doppler imaging (TDI) allows non-invasive assessment of RV function.[4] The popularity of the method is due to its simplicity, availability, and high sensitivity.[5]

TDI is widely used to study LV systolic and diastolic function.[6] As TDI values are less dependent on cardiac pre- and afterload, they reflect cardiac diastolic function more accurately than transmitral Doppler.[7] Its systolic wave allows the systolic function of the LV to be assessed via the semi-quantitative method.[8] In other words, analyzing the TDI curve can provide information on the systolic and diastolic function of the RV. It should be mentioned that there is still no final agreement on the normal parameters of the RV TDI, and the number of studies conducted in this direction is limited, which is the reason why this topic attracted our interest.

2. AIM

The study aimed to assess the structural, functional features, and qualitative characteristics of the RV in healthy individuals.

3. MATERIAL AND METHODS

The study included 185 healthy adults who did not have acute or chronic diseases of the cardiovascular or respiratory system, diabetes, etc. These individuals serve as a baseline for evaluating normal RV structure and function. The average age of them was 46.16 ± 12.06 years; 101 of them were female, 84 males.

Anthropological and some clinical indicators of the examined people are presented in Table 1.

Everyone who took part in the study had an echocardiographic and doppler echocardiographic examination using a standard method. Research was conducted with the VIVID-7 echocardiograph (GE Medical Systems, Chicago, IL, USA). Besides the standard indicators, we measured mitral (MAPS) and tricuspid annular plane systolic excursion (TAPS) in milimeters on echocardiogram recorded in M-mode on apical four-chamber view. In the parasternal short-axis section at the level of the aortic bulb, we measured the systolic and diastolic diameters of the right ventricular outflow tract (RVoutDdiast, RVoutDsyst) and the amplitude of the systolic movement of the RV wall in milimeters. The RV outflow tract fractional shortening in systole was determined by the formula:

Table 1. Anthropological and clinical indicators of the individuals examined.

Indicator	
Quantity of patients, *n*	185
Male, *n*(%)	84(45.4)
Female, *n*(%)	101(54.6)
Age, years	46.2 ± 12.1
Heart rate, bpm	70.79 ± 8.54
Systolic blood pressure, mm Hg	122.7 ± 13.6
Diastolic blood pressure, mm Hg	75.8 ± 10.03

$$\text{RVoutFS\%} = \frac{\text{RVoutDdiast} - \text{RVoutDsyst}}{\text{RVoutDdiast\%}}$$

RV color (coll TDI) and pulsed-wave TDI were recorded with the patient in the left side-lying position, transmitting from the four-chamber apical position: the lateral wall of the LV, the interventricular septum (IVS), and the lateral wall of the RV, atrioventricular valve. A 6 mm control volume was embedded on the lateral wall of the RV near the tricuspid valve attachment point. There were 4 waves represented on the TDI:

1. Positive wave, early systolic movement velocity (in the isometric contraction phase) (s1).
2. Positive wave, the maximum speed of systolic movement in the ejection phase (s).
3. Negative wave, early diastolic velocity (e).
4. Negative wave, late diastolic (atrial systole) flow velocity (a).

We measured the maximum speed of all four named waves in cm/s on the recorded Doppler during the next three heart cycles, after which we calculated their average value.

On the TDI, we also measured the duration of the phases of the heart cycle in miliseconds:

1. Isometric contraction times (ICT) – from the end of the late diastolic peak to the beginning of the systolic peak.
2. Duration of isotonic contraction (ET) – from the beginning of the systolic peak to its end.
3. Isometric relaxation time (IRT) – from the end of systole to the beginning of the early diastolic peak.

The variational statistics method was used to process the material. We estimated the quantitative indicators' average and standard deviation (SD). Microsoft Excel 2016 was used.

4. RESULTS

The results of the conducted research are given in Table 2.

The table shows that the velocity of s1 in healthy sub-

Table 2. Indicators of RV TDI in healthy individuals.

Indicators	Maximum	Minimum	mean ± SD
s1, cm/s	26	5	12.41 ± 3.83
s, cm/s	24	8	13.39 ± 2.51
e, cm/s	24	5	13.17 ± 3.38
a, cm/s	29	6	13.81 ± 4.09
e/a	2.43	0.38	1.02 ± 0.38
ICTRV	128	33	38.22 ± 16.83
IRTRV	70	1	11.79 ± 12.99
RVET	381	219	291.44 ± 29.14
AccTimeS1	76	15	39.84 ± 9.41

Comments: s1 – the maximum velocity of the RV in the phase of isometric contraction; s – the maximum velocity of the RV in the ejection phase; e – the maximum velocity of the RV in the early diastole (fast filling) phase; a – the maximum velocity of the RV in the late diastole (right atrial systole); e/a – the ratio of early and late diastolic speeds; ICTRV – right ventricular isometric contraction time; IRTRV – right ventricular relaxation time; RVET- right ventricular ejection time; AccTimeS1 – acceleration time of isometric contraction of the RV.

jects was 12.418 ± 3.83 cm/s, s 13.39 ± 2.51 cm/s, e 13.17 ± 3.38, a 13.86 ± 4.09 cm/s. Indicators between women and men did not reliably differ from each other.

The analysis revealed the following regularities: the s1 wave velocity was weakly correlated with the subjects' age, the tricuspid flow's A wave velocity, the s and a waves of the LV TDI, and was negatively correlated with the tricuspid flow E/A and the LV TDI e/a ratio. The s-wave velocity was moderately correlated with the E- and A-wave velocities of the tricuspid flow and the s-wave velocity of the LV TDI. The e wave velocity was moderately directly correlated with the E and A wave velocities of the tricuspid flow, mitral flow E wave velocity, and LV TDI e wave velocity. It was weakly correlated with the LV TDI s wave and pulmonary artery systolic flow acceleration time. Its negative correlation to age was made clear. The velocity of the a wave was in direct correlation with age and the a wave of the LV TDI, in a moderate correlation with the s wave of the LV TDI, in a weak correlation with the velocity of the A wave of the tricuspid flow, and in a negative correlation with the E wave of the mitral flow and the e wave of the LV TDI, with e/a ratio of LV TDI and pulmonary artery systolic flow acceleration time and in marked negative correlation with age, LV TDI a wave. The s1 to s ratio has a pronounced direct correlation with the e-wave velocity of the LV TDI, a weak correlation with age and the a-wave of the LV TDI, and a negative correlation with the acceleration time of the pulmonary artery systolic flow acceleration time, the e-wave of the LV TDI, tricuspid and mitral flow E/A to the ratio.

In 51% of people studied, the RV TDI e/a ratio was less than 1. It is noteworthy that this tendency appeared in people over 20. It was detected in 21% of people under 40 years of age and 64% of cases in people over 40.

The LV TDI data, in particular, the indicators of its diastolic function (e, a waves and e/a ratio) depend to some extent on the age of the subject, which is expressed in a decrease in the speed of the e wave and an increase in the speed of the A wave. The e/a ratio decreases and becomes less than 1. This dependence appears in healthy people after the age of 60 and is due to the diastolic dysfunction developed against the background of age-related fibrosis of the LV. A similar trend is observed in relation to the RV, but it manifests itself much earlier.

Echocardiographic indicators of the studied patients are presented in Table 3.

The velocity indicator of the tissue doppler curve taken in the color tissue mode exactly replicated the dynamics of the impulse tissue doppler data, despite having a lower numerical value due to the physical properties of these modes being different. Due to data averaging, the speed of tissue doppler curves taken in color mode is approximately 20% slower than the speed of tissue doppler curves taken in impulse mode (Table 4).

4. DISCUSSION

The RV originates from a different embryological source than the LV and possesses transcriptional and translational differences in pressure-overload hypertrophy; this refers to divergent gene and protein expression levels in energy me-

Table 3. Structural echocardiographic parameters of LV and RV and atria.

Indicator	Minimum	Maximum	SD
LVDd, mm	36	60	48.06 ± 4.35
LVDs, mm	23	40	30.67 ± 3.21
LVPWd, mm	6	12	8.77 ± 1.22
IVSd, mm	6	11	8.77 ± 1.22
LVVol d, mL	42	144	84.24 ± 21.21
LVVol s, mL	15	67	31.23 ± 10.21
LAD, mm	25	41	32.11 ± 4.06
RVWd subc, mm	2	5	3.46 ± 0.7
RVDd subc, mm	18	39	27.87 ± 4.38
RVDdmax, mm	21	41	29.55 ± 4.38
RVDdmid, mm	12	40	20.43 ± 4.71
RVout d, mm	20	47	30.6 ± 4.86
RVout s, mm	6	24	13.04 ± 2.86
RAD, mm	20	41	30.6 ± 4.88

Comments: LVDd – the diameter of the LV cavity in diastole (at the end of diastole); LVDs – the diameter of the LV cavity in systole (at the end of systole); LVPWd – the thickness of the back wall of the LV in diastole; IVSd – the thickness of the interventricular septum in diastole; LVVol d – the volume of the LV in diastole; LVVol s – LV volume in systole; LAD – the maximum diameter of the left atrium in systole; RVWd subc – right ventricular wall thickness in diastole from the subcostal position; RVDd subc – the maximum diameter of the RV cavity in diastole with a subcostal approach; RVDd max – the maximum diameter of the RV cavity at the level of the atrio-ventricular ring in diastole in the 4-chamber apical position; RVDd mid – the maximum diameter of the RV cavity in the middle section of the ventricle, in diastole in the 4-chamber apical position; RVout d – diastolic diameter of the RV outflow tract in the parasternal position; RVout s – systolic diameter of the RV outflow tract in the parasternal position; RAD – right atrial diameter in systole.

Table 4. Functional echocardiographic parameters of the LV and RV and atria.

Indicator	Minimum	Maximum	SD
LVD fr Short%	25.6	71.8	36.35 ± 4.6
LV EF%	50	75.8	63.21 ± 5.78
LVET, s	224	425	295.84 ± 30.31
MAPS, mm	10	20	15.68 ± 1.87
TAPS, mm	13	31	23.44 ± 3.15
PulmAT, s	100	166	131.79 ± 14.07
RVET, s	222	403	306.52 ± 32.83
RVoutFS%	42.86	76.6	57.47 ± 5.89
Transmitral flow			
e, sm/s	42	119	69.91 ± 14.84
a, sm/s	33	93	58.81 ± 12.69
e/a	0.59	2.85	1.24 ± 0.37
DT, s	145	322	198.25 ± 36.48
Tricuspid flow			
e tr, sm/s	28	84	50.05 ± 9.91
a tr, sm/s	24	68	37.34 ± 7.69
e/a tr	0.71	2.21	1.37 ± 0.29
DT tr, ms	152	480	277.62 ± 60.32

Comments: LVD fr Short% – fractional shortening of the LV cavity diameter; LV EF% – LV ejection fraction; LVET – LV ejection time; MAPS – mitral annular plane systolic excursion in milimeters; TAPS – tricuspid annular plane systolic excursion in milimeters; PulmAT – systolic flow acceleration time in the pulmonary artery; RVET – RV ejection time; RVoutFS% – fractional shortening of the diameter of the RV outflow tract in systole; e – early diastolic filling speed of the LV with transmitral flow; a – late diastolic (atrial systole) filling speed of the LV with transmitral flow; e/a – ratio of early and late diastolic velocities with transmitral flow; DT – LV early filling flow deceleration time; e tr – early diastolic filling speed of the RV with three-door flow; a tr – the late diastolic filling speed of the RV with tricuspid flow; e/a tr – the ratio of the early and late diastolic filling rates of the RV with three-door flow; DT tr – flow deceleration time of early RV filling with tricuspid flow.

tabolism, contractile elements, remodeling of the extracellular matrix, calcium handling, and cardiac muscle tissue development.[9] The RV can be divided into components the sinus (the pumping chamber) and the infundibulum).[10] The RV wall is there the LV wall inner suffice is trabeculated. The muscle fibers of the RV have a longitudinal orientation from the valve annulus to the apex, and in this way obtain longitudinal contraction.

The RV has two-layer muscle fibers: superficial circumferential muscle fibers responsible for its inward movement and inner longitudinal fibers that result in longitudinal contraction. The longitudinally oriented fibers play a greater role in RV emptying compared with the LV. On the other hand, LV has a great influence on the contractile function of RV.

Echocardiography plays an important role in the evaluation of RV function and pathology. TDI of RV is a useful technique that is both robust and reproducible. The information about RV wall systolic and diastolic velocities and the intervals can be measured from one heart cycle which increases the reproducibility of the method.

Despite the detailed data about normal reference values of the systolic (s) wave on RV TDI in the literature,[11–13] there is little information about diastolic velocities and systolic time intervals. This study evaluated the reference values of PWD TDI for both RV in normal adult population in both genders.

According to research, in 51% of participants, the ratio of early and late diastolic speeds (e/a) was less than 1. It was detected in 21% of people under 40 years of age and 64% of cases in people over 40. The age of the patients must be taken into account while analyzing the TDI of the RV. Some other studies also show that RV e/a decreases with age.[14] This suggests an age-related limitation in early diastolic myocardial relaxation that requires an increase in atrial contraction force to maintain appropriate ventricular filling (Table 5).

5. CONCLUSIONS

1. RV has distinct embryological origins and functional characteristics compared to the LV.
2. Gene and protein expression in the RV differ significantly under pressure-overload conditions.
3. The RV's unique structural components and longitudinal muscle fibers play a key role in its contractile function.
4. Echocardiography, especially TDI, is essential for assessing RV function and pathology.

Table 5. Indicators of pulsed wave and two-dimensional color mode tissue Doppler.

Indicator	Minimum	Maximum	SD
TDI LVlat			
s, sm/s	5	16	10.25 ± 2.12
e, sm/s	4	26	12.86 ± 3.26
a, sm/s	5	18	9.82 ± 2.67
ICT, ms	35	148	73.17 ± 19.51
IRT, ms	20	124	61.36 ± 19.62
LVET, ms	209	386	292.9 ± 26.17
TDI IVS			
s, sm/s	6	13	8.68 ± 1.36
e, sm/s	4	17	10.18 ± 2.64
a, sm/s	5	14	9.54 ± 1.83
ICT, s	33	150	72.11 ± 17.47
IRT, s	30	124	72.17 ± 18.34
LVET, s	220	351	284.49 ± 28.84

Comments: TDI LVlat – tissue dopplerography of the lateral wall of the LV; s, sm/s – maximum systolic speed of the lateral wall of the LV; e, sm/s – speed of early diastolic movement of the lateral wall of the LV; a, sm/s – speed of late diastolic movement of the lateral wall of the LV; ICT, ms – isometric contraction time of the LV; IRT, ms – LV isometric relaxation time; LVET, ms – LV ejection time; TDI IVS – tissue dopplerogram of interventricular septum; s, sm/s – maximum systolic speed of interventricular septum; e, sm/s – speed of early diastolic movement of interventricular septum; a, sm/s – speed of late diastolic movement of interventricular septum; ICT, s – time of isometric contraction of interventricular systole; IRT, s – isometric relaxation time of the ventricular septum; LVET, s – ventricular septal ejection time.

5. Age-related changes affect RV diastolic function, with early diastolic myocardial relaxation declining and requiring increased atrial contraction.
6. Understanding these physiological variations is crucial for accurate clinical assessment of RV function.

Conflict of interest
None declared.

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None declared.

Ethics
Before starting the study, we received approval from the Research and Ethics Committee of Caucasus University (CU 37-21.01.24.).

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References
1 Oguanobi NI, Ejim EC, Anisiuba BC, Onwubere BJ, Ike SO, Ibegbulam OG. Echocardiographic findings in adult Nigerian sickle cell patients with cardiovascular autonomic dysfunction. *Pol Ann Med*. 2015;1;22(2):86–91. https://doi.org/10.1016/j.poamed.2015.04.009.

2 Mahjoob MP, Piranfar MA, Maghami E, Mazarei A, Khaheshi I, Naderian M. Diagnostic value of speckle tracking echocardiography (STE) in the determination of myocardial ischemia: a pilot study. *Pol Ann Med*. 2019;26(2):126–129. https://doi.org/10.29089/2019.19.00083.

3 Gromadziński L, Januszko-Giergielewicz B, Lipińska A, Pruszczyk P. Effect of type 2 diabetes on the left ventricular diastolic dysfunction in patients with chronic kidney disease, 3 and 4 stages. *Pol Ann Med*. 2014;21(1):8–13. https://doi.org/10.1016/j.poamed.2014.04.002.

4 Alam M, Wardell J, Andersson E, Samad BA, Nordlander R. Characteristics of mitral and tricuspid annular velocities determined by pulsed wave Doppler tissue imaging in healthy subjects. *J Am Soc Echocardiogr*. 1999;12(8):618–628. https://doi.org/10.1053/je.1999.v12.a99246.

5 Meluzín J, Špinarová L, Bakala J, et al. Pulsed Doppler tissue imaging of the velocity of tricuspid annular systolic motion. A new, rapid, and non-invasive method of evaluating right ventricular systolic function. *Eur Heart J*. 2001;22(4):340–348. https://doi.org/10.1053/euhj.2000.2296.

6 Appleton CP, Firstenberg MS, Garcia MJ, Thomas JD. The echo-doppler evaluation of left ventricular diastolic function: A current perspective. *Cardiol Clin*. 2000;18(3):513–546.

7 Gulati VK, Katz WE, Follansbee WP, Gorcsan J. Mitral annular descent velocity by tissue Doppler echocardiography as an index of global left ventricular function. *Am J Cardiol*. 1996;77(11):979–984. https://doi.org/10.1016/s0002-9149(96)00033-1.

8 Waggoner AD, Bierig SM. Tissue Doppler imaging: A useful echocardiographic method for the cardiac sonographer to assess systolic and diastolic ventricular function. *J Am Soc Echocardiogr*. 2001;14(12):1143–1152. https://doi.org/10.1067/mje.2001.115391.

9 Dell'Italia LJ. The right ventricle: anatomy, physiology, and clinical importance. *Curr Probl Cardiol*. 1991; 16:653–720. https://doi.org/10.1016/0146-2806(91)90009-y.

10 Muresian H. The clinical anatomy of the right ventricle. *Clin Anat*. 2016;29(3):380–398. https://doi.org/10.1002/ca.22484.

11 Zaidi A, Knight DS, Augustine DX. et al. Echocardiographic assessment of the right heart in adults: a practical guideline from the British Society of Echocardiography. *Echo Res Pract*. 2020;7(1):G19–G41. https://doi.org/10.1530/ERP-19-0051.

12 Tsipis A, Petropoulou E. Echocardiography in the Evaluation of the Right Heart. *US Cardiol Rev*. 2022;16:e08. https://doi.org/10.15420/usc.2021.03.

13 Lang Roberto M, Badano L, Mor-Avi V, Jonathan A, Anderson A, Laura E, Flachskampf Frank A, Elyse F, Goldstein Steven A, Tatiana K, Patrizio L. Recommendations for Cardiac Chamber Quantification by Echocardiography in Adults: An Update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. *Eur Heart J Cardiovasc Imaging*. 2015;16:233–271. https://doi.org/10.1093/ehjci/jev014.

14 D'Andrea A, Vriz O, Carbone A, Ferrara F, Di Maio M, Cocchia R, Tagliamonte G, Acri E, Driussi C, Pezzullo E, Citro R. The impact of age and gender on right ventricular diastolic function among healthy adults. *J Cardiol*. 2017;70(4):387–395. https://doi.org/10.1016/j.jjcc.2016.12.005.