Journal of Experimental and Clinical Medicine
https://dergipark.org.tr/omujecm

Research Article

J Exp Clin Med
2024; 41(3): 496-499
doi: 10.52142/omujecm.41.3.8

Right ventricular function assessment in healthy people using tissue doppler imaging

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Received: 24.12.2023 • **Accepted/Published Online:** 02.04.2024 • **Final Version:** 30.09.2024

Abstract

A growing body of evidence is being gathered regarding the Right Ventricle's (RV) unique function, adaptation, and compensatory role. A widely accessible diagnostic technique, such as echocardiography, should probably enable prompt diagnosis and treatment assessment at the initial stage. The aim of the study was to assess the structural and functional features of the RV in healthy individuals. The study included 185 healthy adults whose ages varied from 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 waves, and the duration of Isometric Contraction Times (ICT), Ejection Time (ET), and Isometric Relaxation Time (IRT) in milliseconds. In 51% of participants, the e/a ratio was <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.

Keywords: cardiovascular diseases, right ventricle, tissue doppler imaging, echocardiography

1. Introduction

A growing body of evidence is being gathered regarding the RV's 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.

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 right ventricular function in comparison to Left Ventricle (LV). However, in cases of severe, progressive right ventricular dysfunction and pulmonary hypertension, the clinical outcome is usually poor.

The pressure-volume ratio is currently the most widely used method for assessing right ventricular 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 right ventricular function (1). The popularity of the method is due to its simplicity, availability, and high sensitivity (2).

TDI is widely used to study left ventricular systolic and diastolic function (3). As TDI values are less dependent on cardiac pre- and afterload, they reflect cardiac diastolic function more accurately than Transmitral Doppler (4). Its systolic wave allows the systolic function of the LV to be assessed via the semi-quantitative method (5). 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.

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

2. 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. The average age of them was 46,16 ±12.06 years. 101 of them were female, 84 males.

Table 1. Anthropological and clinical indicators of the individuals examined

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

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

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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. Besides the standard indicators, we measured mitral (MAPS) and tricuspid annular plane systolic excursion (TAPS) in millimeters 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 (RV out D diast, RV out D syst) and the amplitude of the systolic movement of the RV wall in millimeters. The RV outflow tract fractional shortening in systole was determined by the formula:

RVoutFS%=(RvoutDdiast- RVoutDsyst)/ RvoutDdiast%

Right ventricular 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 TDE, we also measured the duration of the phases of the heart cycle in milliseconds:

- Isometric contraction times (ICT) - from the end of the late diastolic peak to the beginning of the systolic peak

- Duration of isotonic contraction (ET) - From the beginning of the systolic peak to its end

- 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. Microsoft Excel 2016 was used.

3. Results

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

The table shows that the velocity of s1 in healthy subjects was 12.418±3.83 cm/s, s 13.39±2.51 cm/s, e- 13.17±3.38, a 13.86±4, 09. Indicators between women and men did not reliably differ from each other.

Table 2. Indicators of RV TDI in healthy individuals

Indicators	Maximum and minimum values	Standard deviation
s1 sm/sec	26 – 5	12.41±3.83
s sm/sec	24 - 8	13.39±2.51
e sm/sec	24 – 5	13.17±3.38
a sm/sec	29 – 6	13.81±4.09
e/a	2.43 – 0,38	1.02±0.38
Isom Cont (ICTRV)	128 - 33	38.22±16.83
Isom Rel (IRTRV)	70 - 1	11.79±12.99
RVET	381-219	291.44±29.14
AccTimeS1	76 - 15	39.84±9.41

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; Isom Cont (ICTRV) - right ventricular isometric contraction time; Isom Rel (IRTRV) – right ventricular relaxation time; RVET- right ventricular ejection time; AccTimeS1- acceleration time of isometric contraction of the RV

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 left ventricular TDI, and was negatively correlated with the tricuspid flow E/A and the left ventricular 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 left ventricular 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, left ventricular TDI e wave velocity, weakly correlated with the left ventricular 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 left ventricular TDI, in a moderate correlation with the s wave of the left ventricular 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 left ventricular TDI, with e/a ratio of left ventricular TDI and pulmonary artery systolic flow acceleration time and in marked negative correlation with age, left ventricular TDI a wave. The s1/s ratio has a pronounced direct correlation with the e-wave velocity of the left ventricular TDI, a weak correlation with age and the a-wave of the left ventricular TDI, and a negative correlation with the acceleration time of the pulmonary artery systolic flow acceleration time, the e-wave of the left ventricular TDI, tricuspid and mitral flow E /A to the ratio.

In 51% of people studied, the RV TDI e/a ratio was less than one. 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 left ventricular 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. 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 the table (Table 3, Table 4, Table 5).

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

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

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

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

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

LVD fr Short% - fractional shortening of the left ventricular cavity diameter; LV EF% - left ventricular ejection fraction; LVET sec - left ventricular ejection time; MAPS mm - mitral annulus systolic movement amplitude; TAPS mm - the amplitude of the systolic movement of the tricuspid ring; PulmAT sec - systolic flow acceleration time in the pulmonary artery; RVET sec - right ventricular ejection time; RVoutFS% - fractional shortening of the diameter of the right ventricular outflow tract in systole; e sm/sec – early diastolic filling speed of the LV with transmitral flow; a sm/sec - 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 sec - LV early filling flow deceleration time; e tr sm/sec - early diastolic filling speed of the RV with three-door flow; a tr sm/sec - - 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 msec - flow deceleration time of early right ventricular filling with tricuspid flow

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

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

TDI LVlat - tissue dopplerography of the lateral wall of the LV; s sm/sec - maximum systolic speed of the lateral wall of the LV; e sm/sec - speed of early diastolic movement of the lateral wall of the LV; a sm/sec - speed of late diastolic movement of the lateral wall of the LV; ICT msec - isometric contraction time of the LV; IRT msec - left ventricular isometric relaxation time; LVET msec - left ventricular ejection time; TDI IVS - tissue dopplerogram of interventricular septum; s sm/sec - maximum systolic speed of interventricular septum; e sm/sec - speed of early diastolic movement of interventricular septum; a sm/sec - speed of late diastolic movement of interventricular septum; ICT sec - time of isometric contraction of interventricular systole; IRT sec - isometric relaxation time of the ventricular septum; LVET sec - ventricular septal ejection time

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.

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 metabolism, contractile elements, remodeling of the extracellular matrix, calcium handling, and cardiac muscle tissue development (6). The RV can be divided into components the sinus (the pumping chamber) and the infundibulum (7). 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 (EchoCG) 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 (8,9,10) 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 <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 (11). This suggests an age-related limitation in early diastolic myocardial relaxation that requires an increase in atrial contraction force to maintain appropriate ventricular filling.

The indicators we obtained can be used in clinical practice to analyze RV TDI. The age of the patients must be taken into account while analyzing the TDI of the RV.

Conflict of interest

The authors declared no conflict of interest.

Funding

No funding was used for the study.

Acknowledgments

None to declare.

Authors' contributions

Concept: S.U., M.T, Design: T.V., Data Collection or Processing: S.U., M.T., T.V., Analysis or Interpretation: S.U., M.T, T.V., Literature Search: S.U., T.V., Writing: S.U., M.T, T.V.

Ethical Statement

This study meets the requirements set by the Helsinki Declaration and the National Health Council according to resolution 196/96, in which the patient's anonymity and the information obtained in the present study are guaranteed.

Before starting the study, we received approval from the Research and Ethics Committee of Caucasus University (CU 37-21.01.23.). Therefore, data were analyzed only after approval of the study in order to ensure that all requirements for human research have been met accordingly.

Before participating in the study, selected individuals were given informed consent forms. Their participation was completely voluntary, and they could refuse to participate in the research at any time. The respondents were aware that the study would be confidential.

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