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Right ventrivular ejection fraction obtained from TAPSE

Fracción de expulsión del ventrículo derecho obtenida a partir del TAPSE

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ABSTRACT

Introduction: American guidelines for echocardiographic evaluation from 2015 determine an abnormal TAPSE value below 17 mm; a right ventricle ejection fraction (RVEF) below 45% measured by a three-dimensional method (3D) is considered abnormal, it's widely validated by Magnetic Resonance Imaging (MRI). Kawel-Boehm et al, through MRI has established the reference parameters for adults and children. For men between 20-68 years the minimum normal RVEF value is 52% (52-72% range, 61% medium); in women from the same age range the minimum normal RVEF value is 51% (51-71% range, medium 61%). **Objective:** To make a comparison between the RVEF obtained by an echocardiographic method as the result of multiply the 2.9 constant * TAPSE against the MRI´s volumetrically measured RVEF. **Material and methods:** The TAPSE measuring was made in M mode; the MRI RVEF was determined by a standardized method in steady-state free precession cinematic sequences. **Results:** We analyzed 32 consecutives patients; 18 were men and 14 were women. The calculated TAPSE was 19.2 ± 4.8; the RVEF with the 2.9*TAPSE formula was 55.7 ± 13.8% and through MRI (p 0.67) 53.2 ± 14.8%. The RVEF measured by the testing method in comparison with the reference method does not show significant statistically difference; there is a good correlation with both methods through the Bland-Altman method. **Conclusions:** The RVEF can be echocardiographically measured by multiplying the TAPSE value with the 2.9 constant.

RESUMEN

Introducción: *Las Guías Americanas para la evaluación ecocardiográfica de 2015 determinan un valor TAPSE anormal inferior a 17 mm; una fracción de eyección del ventrículo derecho (FEVD) por debajo de 45% medido por un método en tres dimensiones (3D) se considera anormal, es ampliamente validado por imagen de resonancia magnética (RM). Kawel-Boehm et al, a través de la resonancia magnética ha establecido los parámetros de referencia para adultos y niños. Para los hombres entre 20-68 años, el valor normal mínimo de FEVD es 52% (rango 52-72%, 61% promedio); en mujeres de la misma franja etaria el valor normal mínimo de FEVD es 51% (rango 51-71%, promedio 61%).* ***Objetivo:*** *Hacer una comparación entre la FEVD obtenida por un método ecocardiográfico como el resultado de multiplicar la constante FEVD 2.9 * TAPSE, contra la medición volumétrica por RM.* ***Material y métodos:*** *La medición TAPSE se realizó en modo M; La FEVD por RM se determinó mediante un método estandarizado en secuencias cinemáticas de precesión libre en estado estacionario.* ***Resultados:*** *Se analizaron 32 pacientes consecutivos; 18 eran hombres y 14 eran mujeres. La TAPSE calculada fue de 19.2 ± 4.8; la FEVD con la fórmula 2.9 * TAPSE fue de 55.7 ± 13.8% y por medio de resonancia magnética (p 0.67) 53.2 ± 14.8%. La FEVD medida por el método de prueba en comparación con el método de referencia no muestra diferencia significativa estadísticamente; existe una buena correlación con ambos métodos a través del método de Bland-Altman.* ***Conclusiones:*** *La FEVD se puede medir ecocardiográficamente multiplicando el valor TAPSE por la constante 2.9.*

INTRODUCTION

The RV is a hollow cardiac chamber made up of thin walls, from 4 to 5 mm, with lower mass than the left ventricle (LV). In a cross-section of the heart the RV has a semilunar shape that embraces the almost circular LV; the interventricular septum seems to bulge to the RV chamber, however from a functionally point of view the interventricular septum is considered part of the LV *(Figure 1)*.[1]

The Transthoracic Echocardiography development (TTE) has made possible the real-time RV study; from an apical four chamber view; it seems like a triangular structure; it makes possible to see how the tricuspid valve inserts into the fibrous skeleton in a more apical point than the mitral valve.[2]

The American guidelines focused on the echocardiographic evaluation of the RV on adults from 2010 recognize several methods to determine the RV function.[3] The most used ones for their simplicity in the estimation of the RV function are the following:

- TAPSE: It is easy to obtain and it's a measurement of the RV longitudinal function, and it does not depend on the geometry of the RV; a TAPSE value < 16 mm indicates systolic dysfunction.[3]
- Fractional area change (in percentage); when the result is < 35% indicates systolic dysfunction.[3]

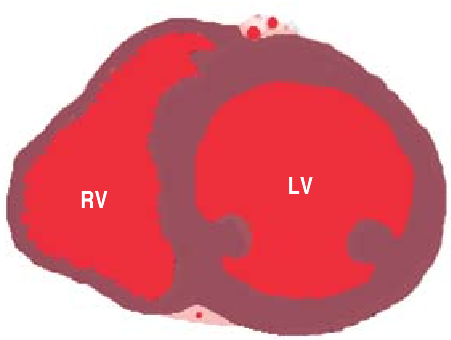

Figure 1. Cross section of the heart illustrating the semilunar shape of RV that embraces the LV with almost circular shape.

Table I. Differences between 4 method used to estimate RV function published by the American Society of Echocardiography in 2010 and 2015.

Method	Normal value, guidelines 2010	Normal value, guidelines 2015
TAPSE	< 16 mm	< 17 mm
Pulsed tissue Doppler S wave	< 10 cm/s	< 9.5 cm/s
RV FAC	< 35%	< 35%
RV 3D EF	< 44%	< 45%

RV = Right Ventricle, TAPSE = Tricuspid annular plane systolic excursion, RV FAC = Right ventricular fractional area change, RV 3D EF = Right ventricular ejection fraction.

In the most recent actualization, published in 2015, where the recommendations for the left and right heart chambers measuring are issued; an abnormal TAPSE value is updated to < 17 mm as well as an abnormal fractional area change < 35%. The three-dimensional method (3D) with an abnormal RVEF < 45% is recommended for its systematic use in echocardiographic laboratories with experience and suitable 3D platforms; it has been widely validated with MRI that it is very useful in patient that had gone through cardiac surgery recently; however it has its flaws like intraventricular changes that affect septum's mobility, volume dependent, bad acoustic window, irregular heartbeat.[4]

According to recent recommendations the normal RV dimensions in adults from a apical four chamber view are the following: a base diameter 25-41 mm, 19-35mm in its medium diameter and in its longitudinal diameter 59-83 mm; it provides several other methods for systolic function estimation; the following values indicates abnormality: TAPSE < 17 mm, a Doppler tissue pulsed S wave < 9.5 cm/s; fractional area change < 35%, RV 3D EF < 45%. In contrast with the 2010's previous guideline in this actualization we found a TAPSE difference of 1mm, Doppler tissue pulsed S wave 0.5 cm/s and for the 3D method a difference of 1%; these features are shown in *table I*.

The undoubtedly complexity of the RV has motivated its study in many other ways far from the TTE, those includes radioisotopes use and the MRI; this last method is used as the reference method due to its high resolution.

Kaul S and cols in 1984 found a good correlation between the RV function and TAPSE (r = 0.92); comparing it with radioisotope angiography in 30 patients; they obtained a better correlation using the TAPSE than the fractional area change (r = 0.81).[5]

Movahed and Milne in 2008 published a study in 152 patients to correlate the RVEF with the left ventricle ejection fraction (LVEF) through a triggered radionuclides resting angiography; they found a strong correlation when they took in count a ejection fraction < 50% ($r = 0.41$, $p < 0.001$) in contrast with a lack of correlation when they analyzed it with an ejection fraction for both ventricles ≥ 50%. In patients with an ejection fraction < 30% the correlation was stronger between both ventricles ($r = 0.75$, $p = 0.03$).[6]

Kawl-Boehm et al, in 2015, published the MRI reference parameters for adults and children. For the RV they used data from the previous studies which included a total of 153 men and 135 women. For men between 20-68 years the RVEF minimum normal value is 52% (52-72% range, 62% medium); in women of the same age range the RVEF minimum normal value is 51% (51-71% range, 61% medium); through a sub analysis the RVEF lowest normal value for men < 60 years is 50% (50-78% range, 64% medium) and for men > 60 years is 55% (52-76%, 64% medium). The RVEF lowest normal value for women < 60 years is 52% (52-76% range, 64% medium) and for women > 60 years is 58% (58-82% range, 70% medium).[7]

Tao Yang et al, in 2013 published a study that included patients with the diagnosis of pulmonary arterial hypertension where they compared different echocardiographic methods such as TAPSE, S wave and fractional area change with the RVEF through MRI. They established a significant correlation ($r = 0.440$, $p = 0.015$ for TAPSE; $r = 0.444$, p 0.016 for S'; $r = 0.416$, $p = 0.022$ for the fractional area change).[8]

In 2012 Speiser et al, publish an interesting study with 76 patients in which they analyze the correlation between the MRI measured TAPSE and the MRI volumetric RVEF; they also measured the TAPSE through TTE the same day in all patient that went through MRI; with an abnormal cut point of < 20 mm. They found an appropriate correlation between the TTE TAPSE with the MRI measure ($r = 0.85$, $p = 0.001$), they also found and adequate correlation between the MRI TAPSE with a normal and a deteriorate RVEF ($r = 0.72$, $p = 0.001$). With the MRI TAPSE measurement they made a RVEF estimation when they multiplied such value * 2.5.[9]

The TAPSE has proven to be a useful and simple tool for distinguish between patients with a normal and abnormal right ventricle function; it is an easy obtained measurement by using the M-mode which is a widely available echocardiographic tool.

Objective

To show that the 2.9 constant multiplied by the TTE TAPSE value, in millimeters, makes possible the estimation of the right ventricle ejection fraction in percentage (RVEF % = 2.9*TAPSE)

MATERIAL AND METHODS

We designed a cross-section study to measure the right heart chambers diameters; the TAPSE and the pulmonary systolic pressure (PSP) through TTE; as well as the right heart cavities diameters and RVEF through MRI the same day in a consecutive 32 patients sample between January 2013 and December 2014 in the West National Medical Center «*Ignacio García Téllez*» from the Mexican Social Security Institute in *Guadalajara*, Mexico; all of them were above 18 years and were being studied for left ventricle disease.

The exclusion criteria were: heart surgery with right ventricle remodeling secondary a complex congenital defects, complex congenital cardiac malformations with right ventricle affection or the absence of the RV due to its own formation abnormalities; patients that are bearers of any endovascular device or prosthesis non compatibles with MRI studies; patients who went through MRI but not TTE on the same day.

Data collection through TTE

The echocardiographics measurements were made by an echocardiographer cardiologist certified by the Mexican Board of Echocardiography, using an Philips iE33 equipment; every patient were collocated in left lateral decubitus for the apical four chamber view and in supine decubitus for the subxiphoid axis with electrocardiography record. The RA diameter, the RV, the tricuspid annulus and the cava vein were measured in 2D mode; TAPSE value was measured in M-mode; the tricuspid valve maximum regurgitant gradient was obtained through continuous Doppler for the PSP estimation *(Figure 2)*.

MRI data collection

All patients were evaluated using the Siemens Magnetom Symphony Maestro Class 1.5T multichannel MRI model. We used body (integrated) and superficial (chest) radiofrequency antennas. All studies were performed using electrocardiographic synchronization. We used contrast-free steady-state free precession (SSFP) sequences in the four chambers and short axis (which includes the totality of both ventricles: cut thickness 8 mm; increment 10 mm). The four chamber axes were used to measure de RV and RA diameters. The telesystolic and teledyastolic volumes were measured using a workstation specialized in post-processing and analysis of biventricular cardiac function (Siemens Argus). The ventricular volumes measurements were made by tracing in short axes SSFP sequences of the RV endocardial contour; it was made covering the whole RV and excluding the cavity behind the tricuspid valve (because it is considered as a part of the RA) *(Figure 3)*. The ejection fraction and the beat-volume estimation are made in an automatic way by the system when it has both volumes (teledyastolic and telesystolic). The RV beat-volume was validated when it was compared with the LV beat-volume: in the absence of a shunt or valvular regurgitation it was considered as valid a RV beat-volume with the same or with a difference no higher than 10 mL in respect with the LV beat-volume.

FEVD% = 2.9*TAPSE equation

In order to obtain the 2.9 constant the minimum normal RVEF was analyzed by three different diagnostic methods: by TTE, equilibrium radioisotope and MRI which are describe in the following section.

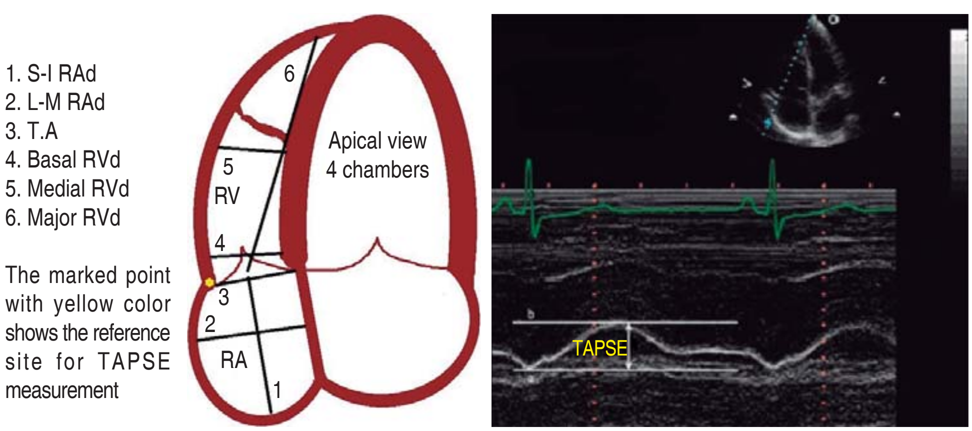

Figure 2.

Scheme that illustrates the right cardiac chambers measurements and the TAPSE in M mode.

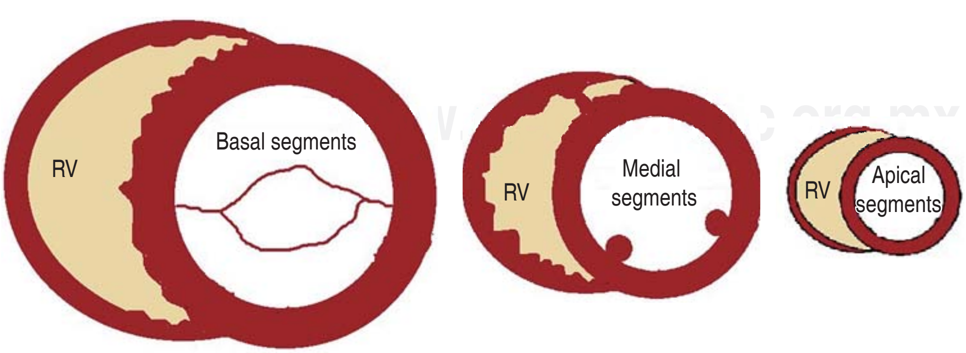

Figure 3.

Scheme that illustrates the RV volumetric measurement to determine the RVEF.

Table II. Lower normal LVEF determined by 3D TTE, average in mens 51.4%, average in women 53%.

	Aune et al (2010)	Fukuda et al (2012)	Chahal et al (2012)	Muraru et al (2013)
Mens	49%	53%	White 49%, Indian 52%	54%
Women	49%	55%	White 52%, Indian 52%	57%

LVEF = Left ventricular ejection fraction, 3D TTE = Three-dimensional transthoracic echocardiogram.

Table III. Clinical characteristics.

Mens	Women	< 60 year old	> 60 year old	Patients with PHT	Low RVEF
18	14	22	10	8	13

PHT = Pulmonary hypertension.

Through TTE an abnormal TAPSE value is considered < 17 mm; we part from this value because it's derived from a 4,803 patient study.[4] In the same study the RVEF determined by 3D echocardiography is considered normal if it is above 45%.[4] The relation between both is 2.65 (45/17 = 2.65).

On the other hand, the relation that exist between the blood volume that flows through the RV is the same as the one that flows through the LV (output relation 1:1, in the absence of shunts) maintaining the circulatory homeostasis. The LVEF value is normal if it is higher than 52% in men on a 2D mode and above 51.4% if it is obtained by a 3D method; in women the normal value was 54 and 53% for 2D and 3D modes respectively; those values were calculated by taking in consideration the minimal normal values from the studied series and measuring an average value for the 3D results in all the populations included *(Table II)*.[4] All of them are minimum values above 50%. Given the fact that the correlation between RVEF and LVEF using radioisotopes were good when it was considered a value less than 50% and it was not when were higher than 50%,[6] the ratio that holds a TAPSE minimum normal value of 17 with respect to a RVEF/LVEF < 50% will be 2.88 (49/17 = 2.88).

The minimum normal MRI RVEF value for men below 60 years was 50% and for men above 60 years was 55%; when we speak about women whom are below 60 years the minimum normal value was 52% and above 60 years it was 58%.[7] The average value was 53.8%.

There is good correlation between an echocardiographic TAPSE with a normal MRI RVEF.[9] Under this consideration a minimum normal TAPSE value of 17 mm should be able to detect patients with a minimum normal RVEF. The good relation between a normal MRI RVEF and TAPSE make possible to calculate a 3.16 value (53.8/17 = 3.16).

Finally, with the aim of include all the patients with an minimum normal RVEF of 45% by 3D ETT, 50% by radioisotopes equilibrium and 53.8% by MRI, with a TAPSE minimum normal value of 17 mm, the multiplication factor will be between 2.65 (2.65*17 = 45), 2.88 (2.88*17 = 49) and 3.16 (3.16*17 = 53.8): the average value was 2.896; by simplification 2.9.

Statistical analysis

We used SPSS v. 24. The differences between right cardiac chambers by both diagnostic tests were analyzed using the t-student statistic formula; with a confidence interval of 95% (95% CI) with + two standard deviation (SD): latero-medial right atrium diameter (RA-LMd); supero-inferior right atrium diameter (S-I RAd), tricuspid valve annulus diameter (T.A.), RV basal diameter (BASAL RVd), RV medial diameter (MEDIAL RVd); RV longitudinal diameter (MAJOR RVd). Any p-value < 0.05 was considered as significant.

For every referred parameter in the previous paragraph we calculated the Pearson correlation coefficient.

Table IV. Averages obtained by TTE and MRI.

	S-I RAd (mm)	L-M RAd (mm)	T.A (mm)	BASAL RVd (mm)	MEDIAL RVd (mm)	MAJOR RVd (mm)	SPP (mmHg)	TAPSE (mm)	RVEF (%)
TTE	46 ± 14.3	40 ± 11.1	27 ± 5.1	33 ± 6.8	28 ± 6.2	69 ± 9.8	30 ± 13.1	19 ± 4.8	55 ± 13.8
MRI	47 ± 17.6	39 ± 8.8	29 ± 5.1	37 ± 7.9	32 ± 7.8	68 ± 12.5			53 ± 14.8

TTE = Transthoracic echocardiogram, MRI = Magnetic resonance imaging, S-I RAd = Supero-inferior right atrium diameter, L-M RAd = Latero-medial right atrium diameter, T.A = Tricuspid annulus, BASAL RVd = Basal right ventricular diameter, MEDIAL RVd = Medial right ventricular diameter, MAJOR RVd = MAJOR right ventricular diameter, SPP = Pulmonary systolic pressure, RVEF = Right ventricular ejection fraction, mmHg = Millimeters of mercury.

Table V. P Pearson for the dimensions obtained by TTE and MRI.

	S-I RAd (mm)	L-M RAd (mm)	T.A (mm)	BASAL RVd (mm)	MEDIAL RVd (mm)	MAJOR RVd (mm)
P Pearson	0.85	0.67	0.47	0.44	0.57	0.48

TTE = Transthoracic echocardiogram, MRI = Magnetic resonance imaging, S-I RAd = Supero-inferior right atrium diameter, L-M RAd = Latero-medial right atrium diameter, T.A = Tricuspid annulus, BASAL RVd = Basal right ventricular diameter, MEDIAL RVd = Medial right ventricular diameter, MAJOR RVd = Major right ventricular diameter.

Table VI. t Student test derived analysis for a sample.

Parameters	Difference from the average	SD	95% CI	Value of p
S-I RAd	-1.4	9.4	-4.798 to 1.986	0.038
L-M RAd	0.62	8.3	-2.387 to 3.625	0.099
TA	-2.2	5.24	-4.071 to -0.2791	0.956
BASAL RVd	-4.14	7.8	-6.961 to -1.326	0.339
MEDIAL RVd	-3.2	6.7	-5.609 to -0.7847	0.138
MAJOR RVd	0.6	12.5	-3.931 to 5.138	0.147

SD = Standard deviation, CI = Confidence interval, S-I RAd = Supero-inferior right atrium diameter, L-M RAd = Latero-medial right atrium diameter, T.A = Tricuspid annulus, BASAL RVd = Basal right ventricular diameter, MEDIAL RVd = Medial right ventricular diameter, MAJOR RVd = MAJOR right ventricular diameter, statistically significant $p < 0.05$.

The 2.9*TAPSE RVEF value and the one obtained by MRI were compared with a lineal regression model and with the t student test for a sample with a 95% CI ± two SD; we considered as statically significant any p value < 0.05. The TTE and MRI correlation was analyzed by the Bland-Altman method.

RESULTS

We included 32 patients from January 2013 to December 2014. Our sample was conformed with 18 men and 14 women. The average 2.9*TAPSE RVEF value was 55.7 ± 13.8% and for the MRI one 53.2 ± 14.8%. All the demographic data is shown in *table III* and the average values in *table IV*.

The Pearson correlation coefficient was appropriated for every RV morphologic measurement without significant statistical difference; only one p value < 0.05 was obtained and it was the S-I RVd; nevertheless the confidence interval include the unity. The Pearson correlation coefficient is exposed in *table V*. The medium difference, the SD value, the 95% confidence interval and p value are described in *table VI*.

The t Student test and the lineal regression model shows no significant statistical difference when they were applied to analyze the difference between the RVEF calculated by this study equation and the one measured by the reference method (reference t 0.721, calculated t 0.476, medium difference 2.5375, SD 19.9, 95% IC -4.64 to 9.71, p = 0.67).

Figure 4 was derived from the Bland-Altman model with a medium value of 2.53.

DISCUSSION

The improvement of today's techniques and the advent of new technologies applied on the anatomical and functional study of the

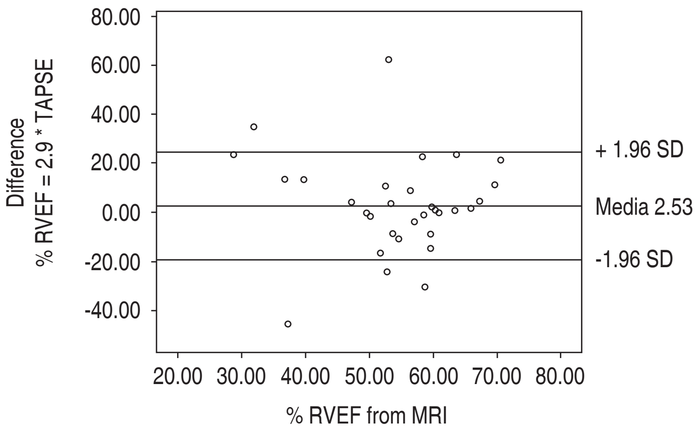

Figure 4. Analysis by the Bland-Altman method that compares the correlation between the RVEF by TTE and the RVEF through MRI. It shows a low average deviation value of 2.5%.

heart had made possible the extensive and intensive use of complex and expensive imaging techniques such as the cardiac MRI; which has been positioned as the reference standard for RVEF estimation.

The MRI nature as well as its special requirements for data processing does not allow all patients to be selected by this diagnostic method, in contrast, the echocardiogram is widely available even with high tech portable equipment which allows cardiac imaging study realization at the patient headboard.

The TAPSE as an a measurement of the RV longitudinal shortening was initially studied and validated by echocardiography; in recent times is has been adopted as well by the MRI; and like Speise and his team demonstrated: it correlates with the volumetric method RVEF value.

In our 32 patients studied with TTE the results maintains an appropriate relation with the MRI; the 2.9 constant was not randomly selected; fact that showed a good performance to express in percentage the RVEF when it was multiplied by the TAPSE value.

Given its simplicity, the TAPSE has shown to be the first approach by TTE for the RV systolic function estimation, especially if its value is below 17 mm. As shown by the results of our study the 2.9 constant will provide an easy and quick RVEF percentage estimation, for example: a patient with 16 mm TAPSE value has 46.6% RVEF, that barely surpass the normal value for 3D TTE and that is below the normal percentage in both adult men and women in reference to the MRI.

Limitations

Childrens, patients with a complex congenital structural cardiopathy, cardiac valve prothesis, peacemakers or other endoprothesis bearers weren't included in our analysis therefore it should not be applied to such populations. We recognize the relevance of an inter-observer variability analysis in a study like this one but we couldn't applied it because in the patient recruitment time our medical center only counted with one cardiac MRI radiology expert, we also couldn't make a healthy-patient group due to a MRI resource limitation.

We considerate that is necessary a validation study performed in the Mexican population; with a larger patient number with diverse cardiac diseases and with a healthy patient control group; it should be a multi-centric study; with a 3D and MRI RVEF measurement, performed at least with two cardiac MRI radiology experts and with a larger group of cardiologist with variable experience in echocardiography.

CONCLUSSIONS

The RVEF can be echocardiographically obtained by multiplying the TAPSE value by the 2.9 constant.

The comparison between the RVEF measured by the test method and the reference method shows no significant statistical difference (p 0.67). The data obtained by the Bland-Altman method shows good correlation between both methods with a 2.5% medium value deviation which is low.

The RA, RV and T.A diameters does not show significant statistical difference; their measurement through TTE maintains an appropriate correlation with the reference method (p Pearson 0.85 SI RAd, 0.67 L-M RAd, 0.57 T.A, 0.44 BASAL RVd, 0.57 MEDIAL RVd, 0.48 MAJOR RVd).

Acknowledgment

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