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Comparison between multiplanar and rendering modes in the assessment of fetal atrioventricular valve areas by 3D/4D ultrasonography

Comparação entre os modos multiplanar e renderizado na avaliação da área das valvas atrioventriculares fetais por meio da ultrassonografia 3D/4D

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Abstract

Objective: To compare the agreement of multiplanar and rendering modes in the assessment fetal atrioventricular valves (mitral and tricuspid) areas by three-dimensional (3D) ultrasonography using the software spatio-temporal image correlation (STIC).

Methods: We conducted a prospective cross-sectional study with normal pregnant women, with single fetuses, between 18-33 weeks. To measure the areas, we used the plan of four-chamber view. In the case of multiplanar, the plane was rotated on the axis "Z" from the heart to position at 9h. For rendering, the green line (region of interest - ROI) was placed from the atria of the heart perpendicular to the crux. The agreement was assessed by a Bland-Altman (limits of agreement) using the relative difference between the measures: ((rendering mode) - (multiplanar mode)) / (average).

Results: 328 fetuses were evaluated. We have not identified the occurrence of systematic error between methods: the average relative difference was 1.62% (-2.07% to 5.32%, confidence interval 95%) in the mitral and 1.77% (-1.08% to 4.62%) in the tricuspid valve. The limits of agreement between methods were -65.26% to 68.51% for the mitral and -49.91% to 53.45% for the tricuspid.

Conclusions: There was no systematic error between modes and thus the observed values for the area of fetal atrioventricular valves can be used for comparisons needs to be corrected. However, relatively large variations may be observed when repeating the measurement area by different modes.

Keywords: Comparison; Fetus; Atrioventricular valves; Area; Three-dimensional ultrasonography.

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Abbreviations, acronyms & symbols	
2D	Two-dimensional
3D	Three-dimensional
4D	Four-dimensional
AFI	Amniotic fluid index
CAPES	Coordenação de Aperfeiçoamento de Pessoal de Nível Superior
LMP	Last menstrual period
ROI	Region of interest
SPSS	Statistical Package for the Social Sciences
STIC	Spatio-temporal image correlation
UNIFESP	Federal University of São Paulo

Resumo

Objetivo: Avaliar a concordância entre as medidas das áreas das valvas atrioventriculares (mitral e tricúspide) fetais realizadas por ultrassonografia tridimensional (3D) pelo software *spatio-temporal image correlation* (STIC) usando os modos multiplanar e renderizado.

Métodos: Estudo prospectivo de corte transversal avaliando fetos de gestações únicas, consideradas saudáveis, entre 18 a 33 semanas de idade gestacional. Para a medida das áreas, utilizou-se o plano de quatro câmaras cardíacas.

No caso do multiplanar, o plano foi rodado no eixo “z” de forma o coração se dispuser em 9h. Para o renderizado, a linha verde (região de interesse - ROI) foi posicionada a partir dos átrios, perpendicular à cruz do coração. A concordância foi avaliada pelo método de Bland-Altman (limites de concordância) utilizando a diferença relativa entre as medidas: ((modo renderizado) – (modo multiplanar)) / (média).

Resultados: 328 fetos foram avaliados. Não identificamos a ocorrência de erro sistematizado entre os métodos: a diferença relativa média foi de 1,62% (-2,07% a 5,32%, intervalo de confiança de 95%) na mitral e de 1,77% (-1,08% a 4,62%) na tricúspide. Os limites de concordância entre os métodos foram de -65,26% a 68,51% para a mitral e de -49,91% a 53,45% para a tricúspide.

Conclusões: Não foi observado erro sistematizado entre os modos e desta forma os valores observados para a área das valvas atrioventriculares fetais podem ser utilizados para comparações sem necessidades de correções. Entretanto, variações relativamente grandes podem ser observadas ao se repetir a medida da área pelos diferentes modos.

Descritores: Comparação. Feto. Valvas atrioventriculares. Área. Ultrassonografia tridimensional.

INTRODUCTION

Approximately 8% of birth defects are cardiac malformations and 50% of these are considered major factors that increase early and late mortality rates. Developmental disorders of the chordae and papillary muscles, such as thickening and partial or total agenesis of valvular tissue are primarily responsible for dysplasia, atresias, and mitral and tricuspid valve defects of varying degrees as well as other important disorders [1].

Spatio-temporal image correlation (STIC) facilitates cardiac volume acquisition and stores the data for later analysis and reconstruction of the anatomy by presenting an image in the multiplanar and rendering mode showing the positioning of vessels; it also enables real-time assessment of movement throughout a cardiac cycle by using the cine loop technique [2]. The multiplanar mode displays the image in three orthogonal planes (axial, sagittal, and coronal), which can be manipulated in all three axes (x, y, z). The order rendered by the determination of virtual planes allows for better morphological assessment of cardiac structures such as the septum and the atrioventricular valves [3]. A few studies in the literature have evaluated the area of the atrioventricular valves using

STIC, but no studies have compared the use of multiplanar and rendered imaging [4].

The objective of this study was to compare multiplanar and rendering three-dimensional (3D) ultrasonography using STIC for the evaluation of fetal atrioventricular valves in normal pregnant women.

METHODS

We conducted a prospective cross-sectional study evaluating the healthy fetuses of singleton pregnancies between 18 and 33 weeks of gestational age. The Ethics Committee of the Federal University of São Paulo (UNIFESP) approved the study (n° 0135/10), and all patients who agreed to participate voluntarily signed a consent form. Inclusion criteria were singleton pregnancies with a live fetus and gestational age determined by last menstrual period (LMP) and confirmed by ultrasound in the first trimester. Exclusion criteria were as follows: oligohydramnios (amniotic fluid index [AFI] below the 5th percentile for gestational age according to the table proposed by Moore and Cayle) [5]; a fetus with a dorsal anterior presentation (between 11 o'clock and 1 o'clock); fetuses with an estimated weight 2

standard deviations above or below the mean according to the table proposed by Hadlock et al. [6]; pregnant women with chronic diseases that could affect fetal growth and development; strong attenuation of the sound beam due to maternal obesity and abdominal scarring; fetal malformation diagnosed by ultrasonography; and women who were smokers and/or users of illicit drugs.

The examinations were performed by a single examiner (LCR), and all pregnant women were evaluated only once; no postnatal results were obtained. All examinations were performed using a Voluson 730 Expert (General Electric Medical Systems, Healthcare, Zipf, Austria) device equipped with a convex volumetric transducer (Rab4-8L). Analyses were performed offline by the same examiner using 4D View software (version 9.0, GE Medical Systems, GmbH & Co OHG).

Cardiac volumes were acquired by segmenting the four cardiac chambers (reference plane); most of the time the fetus was lying with the spine at the 6 o'clock position. An acquisition angle of 20–40° and an acquisition time of 10–15s were standard. To measure the area of the atrioventricular valves by the rendering method, the heart was rotated along the “z” axis such that the cardiac apex was at the 6 o'clock position. We used the green line (region of interest [ROI]) positioned from the atrium bordering the cross of the heart. The area measurements were performed manually during early ventricular systole, at which time, both valves were fully opened (Figure 1A). For the multiplanar method, the heart was rotated along the “z” axis so that the heart apex was at the 9 o'clock position and the atrioventricular valves were visualized automatically in the sagittal plane (Figure 1B). The measurements were performed in the same way as for the rendering method.

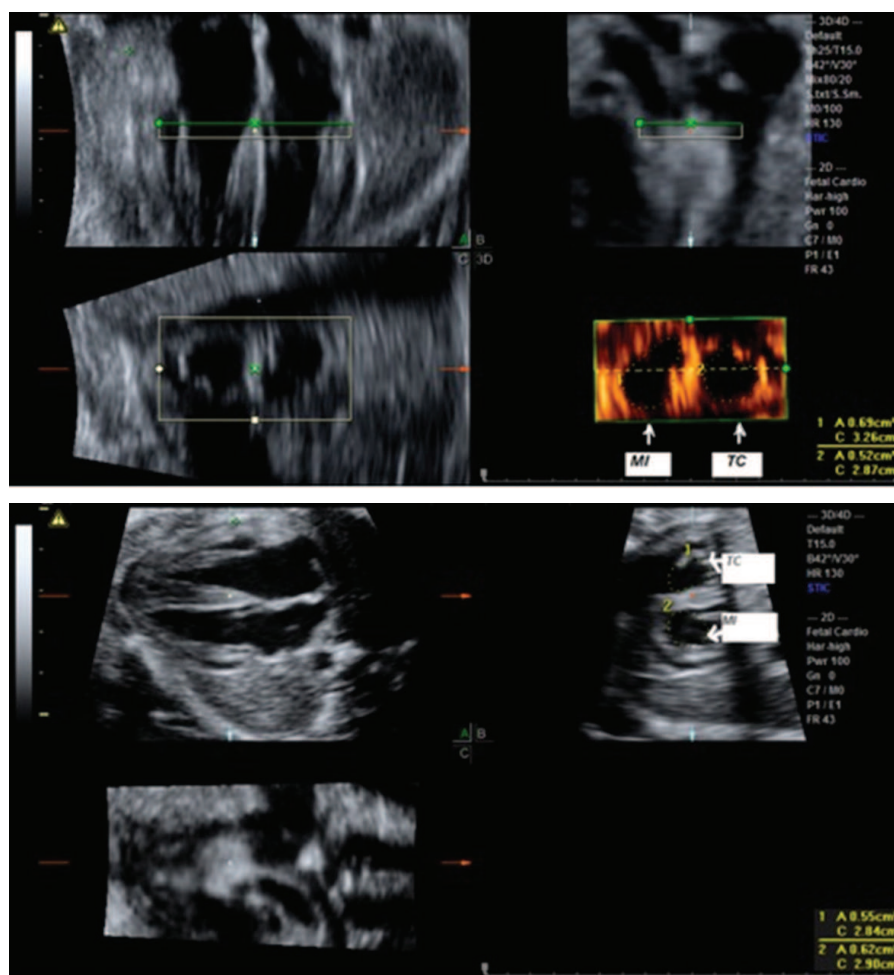


Fig. 1 - (A) Rendering image of atrioventricular valve at the initial moment of ventricular systole, with the extent of their respective areas performed manually. (B) Image by multiplanar method of atrioventricular valves in the sagittal plane at the time of initial ventricular diastole and the extent of their respective areas (MI: mitral, TC: tricuspid)

Data were stored in Excel 2007 (Microsoft Corp., Redmond, WA, USA) and analyzed using Statistical Package for the Social Sciences (SPSS) version 18.0 for Windows (SPSS Inc., Chicago, IL, USA) and GraphPad Prism version 5.0 for Windows (GraphPad Software, San Diego, CA, USA). Agreement was assessed using the Bland-Altman method [7]. Evaluation of the correlation between absolute measures ([mode rendering] - [multiplanar mode]) revealed that this was highly dependent on the average measure (which in turn was dependent on gestational age). In this case, the estimated limits of agreement would not be valid for the entire gestational period evaluated (they would be overestimated for the start of pregnancy and underestimated for the final stages). However, the relative difference ([rendering mode] - [multiplanar mode]/[average]) between the methods was relatively constant during the pregnancy assessments; therefore we have presented only those results.

RESULTS

The initial sample comprised 340 women, but 12 patients were excluded from the study because of artifacts that occurred during cardiac volume acquisition ($n = 10$) or because the fetal weight was predicted to be above the 90th percentile ($n = 2$). Thus, 328 fetuses were evaluated in total. We did not detect any systematic error between methods: the average relative difference was 1.62% (95% confidence interval -2.07 to 5.32%) for the mitral valve and 1.77% (-1.08 to 4.62%) for the tricuspid valve. The limits of agreement between methods were -65.26 to 68.51% for the mitral valve and -49.91 to 53.45% for the tricuspid valve (Table 1, Figure 2).

DISCUSSION

In this study, we compared multiplanar and rendering imaging for evaluating fetal atrioventricular valve area by 3D ultrasonography using STIC software. The advantages

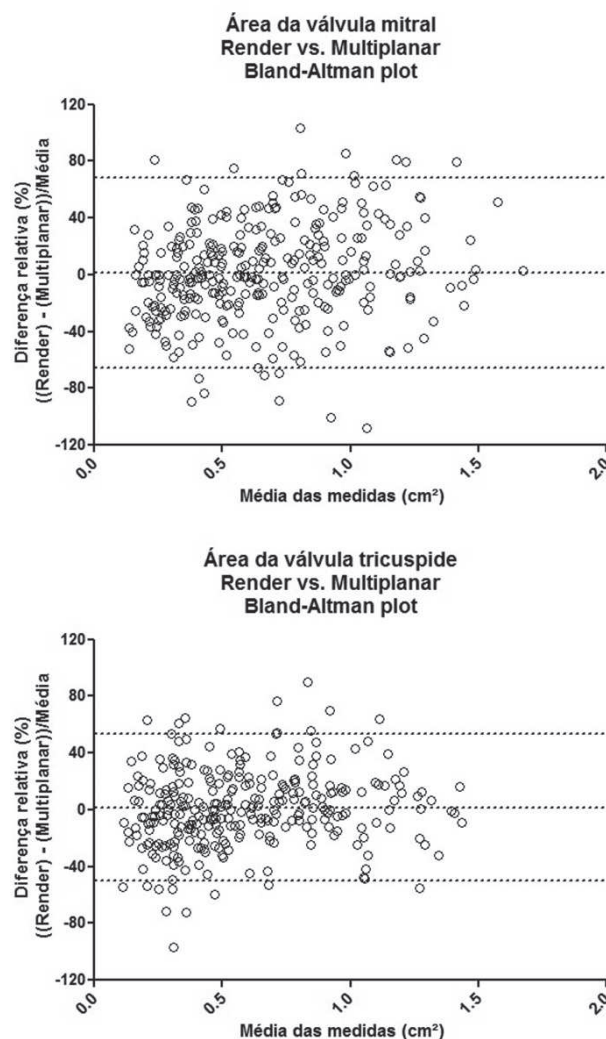


Fig. 2 - (A) Average relative difference between multiplanar and rendering modes plotted against the difference of means for measuring the area of the mitral valve. (B) Average relative difference between multiplanar and rendering modes plotted against the difference of means for measuring the area of the tricuspid valve

Table 1. Evaluation of the relative agreement between methods for estimating the area of fetal atrioventricular valves by three-dimensional ultrasonography.

	Average difference	Lower limit for concordance	Upper limit for concordance
Mitral valve % (95% CI)	1.62 (-2.07 to 5.32)	-65.26 (-86.83 to -43.69)	68.51 (46.93 to 90.08)
Tricuspid valve % (95% CI)	1.77 (-1.08 to 4.62)	-49.91 (-64.57 to -35.26)	53.45 (38.80 to 68.11)

CI = confidence interval, relative difference = [(rendering mode) - (multiplanar mode)]/(average)

of STIC for fetal cardiac evaluation are a reduced dependence on operator experience for obtaining diagnoses, and a shorter examination time for the acquisition of volumes and possibility to send data on patient volumes for analysis at centers of excellence in fetal cardiology [8]. Measuring the area of the atrioventricular valves is important for identifying early abnormal values and stenosis or weaknesses that could lead to severe hemodynamic disorders at birth. Such fetuses could be referred to intrauterine referral centers, decreasing the rates of perinatal morbidity and mortality.

The multiplanar method involves the evaluation of 3D orthogonal planes that are perpendicular to each other. The advantage of this method of ultrasonography relative to traditional two-dimensional (2D) ultrasonography resides precisely in the possibility of assessing the same structure in all three planes, making it easier to visualize and measure the structure. Particularly, in case of single 3D scanning of heart valves, it is possible to measure the areas of these structures through a number of rapid adjustments. The rendering method allows detailed visualization of a structure by adjusting variables such as the gamma-chroma curve. These settings produce an image with sharper an edge, which is, theoretically, a more reliable measure [4,9].

In this study, we did not observe any systematic errors between methods, and therefore, we determined that the observed areas of the fetal atrioventricular valves could be used for comparison without correction requirements. However, it should be noted that large variations were observed when the data were analyzed using the Bland-Altman method [7]. We believe that these variations were not because of sample size as an average of 20 patients were evaluated per gestational age, which is the number recommended by Royston for determining range values for parameters of fetal growth [10]. In addition, possible examiner bias was not a problem because all measurements were performed by a single examiner. This allows us to conclude that it is possible that the rendering method provided more reliable measurements of the area of the atrioventricular valves because they are small and irregular structures. However, only *in vivo* studies can confirm this assumption; however, such a study is not possible in our country because our laws do not permit the termination of pregnancy.

In summary, measurements of the area of fetal atrioventricular valves using both the multiplanar and rendering 3D ultrasound (STIC) methods were valid, but there were large variations between the techniques.

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