Original Article

# Classifying the Size of an Atrial Septal Defect According to Echocardiographic Parameters and its Association with the Clinical Presentation in Pediatrics

*Lívia de Castro Ribeiro,[1] Rose Mary Ferreira Lisboa da Silva,[1] Henrique de Assis Fonseca Tonelli,[1] Adriana Furletti Machado Guimarães,[1] Fátima Derlene da Rocha Araújo,[1] Zilda Maria Alves Meira,[1] Sandra Regina Tolentino Castilho,[1] Alan Alvarez Conde,[1] Lícia Campos Valadares[1]*

*Universidade Federal de Minas Gerais,[1] Belo Horizonte, MG – Brazil*

## Abstract

**Background: Few studies are using linear echocardiographic measurements for classifying the size of Atrial Septal Defect (ASD).**

**Objectives: Investigate the relationship between ASD hemodynamic repercussions and ASD diameter to the mitral annulus diameter (MI/ASD) ratio and ASD diameter to the interatrial septum diameter (ASD/septum) ratio, and describe cutoff points to classify the size of the defect.**

**Methods: An observational, prospective, cross-sectional study, including subjects aged 1 month and 18 years diagnosed with isolated ASD. Hemodynamic repercussion was quantified by clinical evaluation, tricuspid annulus (TA) Z-score, subjective estimation of the enlargement of the right chambers, and the relationship between systemic and pulmonary flows (QP/QS) on echocardiography. Its association with ASD/septum and MI/ASD measurements was also studied. A value of $p < 0.05$ was considered statistically significant.**

**Results: Thirty-five subjects, mean age 6.3 years, 69% female, mean ASD 13.5 mm. There was a correlation between MI/ASD and the clinical classification of ASD (Pearson: -0.61; $p < 0.001$), ASD/septum (Pearson: -0.80; $p < 0.001$), and QP/QS (-0.76; $p < 0.001$). There was a correlation between ASD/septum and the clinical classification of ASD (Pearson: 0.56; $p < 0.001$), QP/QS (0.63; $p = 0.001$), subjective assessment of the right chambers (0.62; $p < 0.001$), and a weak correlation with the TA Z-score (0.35; $p = 0.04$). According to the operating characteristic curve for the stable variable classification of ASD according to the subjective right chamber's size, an area of 0.85 was obtained for ASD/septum ($p = 0.001$). The cutoff point of 0.27 for large ASD showed sensitivity of 85%, specificity of 86.7%, positive predictive value (PPV) of 86%, negative predictive value (NPV) of 85.2%, and positive likelihood ratio of 6.39.**

**Conclusions: ASD/septum was associated with the hemodynamic repercussion of ASD and was useful in detecting large ASD.**

**Keywords: Atrial Heart Septal Defects; Echocardiography; Tricuspid Valve; Atrial Septum.**

## Introduction

Atrial Septal Defect (ASD) is a congenital structural alteration of the heart in which blood is mixed between the atria through a defect in the Atrial Septum or adjacent structures. Isolated ASD is the third most common cardiac malformation, corresponding to approximately 15% of all congenital heart diseases.[1] The prevalence of ASD is twice as high among females compared to males.[2] Transthoracic echocardiographic examination is the most widely used method for diagnosing and evaluating ASD in the pediatric population and is sufficient for adequately defining the lesion and its hemodynamic repercussions in most cases. The linear measurement of the defect, the Atrial Septum Size defect ratio (ASD/septum), the repercussion in the right chambers (signs of volumetric overload), and the measurement of the pulmonary flow/systemic flow (QP/QS) ratio are commonly used to assess the defect size. The ASD/septum measurement has been used informally in clinical practice, with no systematization based on studies and without reliable cutoff points for size classification. The measurement of QP/QS during echocardiography has a major limitation, represented by low reproducibility[3] and difficulty performing.[4] The objectives of the study were to investigate, through clinical and echocardiographic assessments, the relationship between ASD hemodynamic repercussion and the measurements of the Mitral Annulus diameter to the ASD diameter (MI/ASD) ratio and the (ASD/septum) ratio, and describe the cutoff points of these

**Mailing Address: Livia de Castro Ribeiro •**
Hospital das Clínicas da Universidade Federal de Minas Gerais. Rua Alfredo Balena, 110. Postal code: 30130-100. Belo Horizonte, MG – Brazil
E-mail: liviadecastromed85@gmail.com
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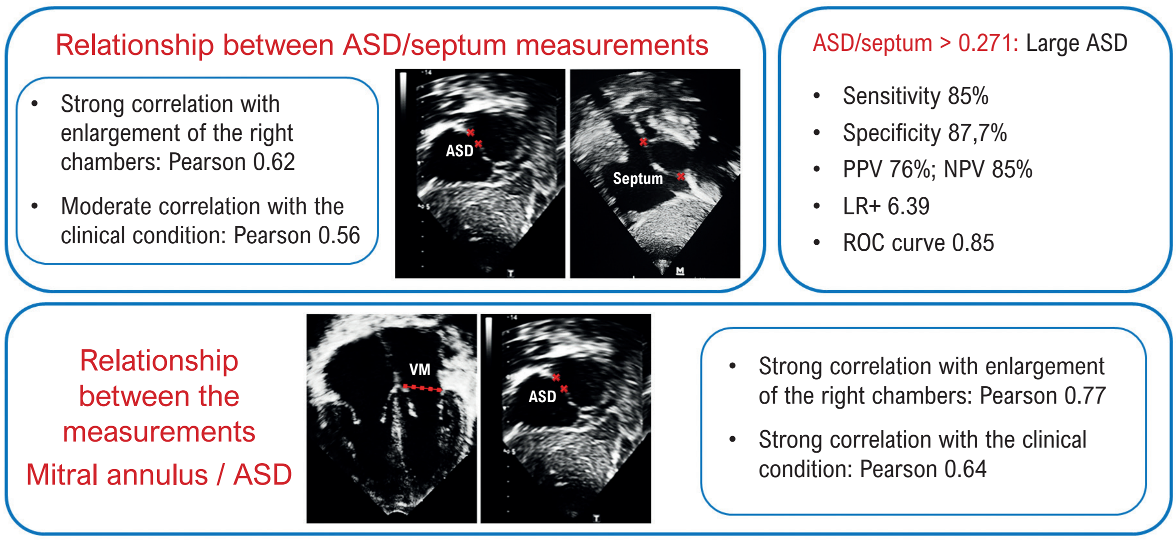
**Central Illustration:** **Classifying the Size of an Atrial Septal Defect According to Echocardiographic Parameters and tts Association with the Clinical Presentation in Pediatrics**

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*PPV: positive predictive value; ASD: Atrial Septal Defect; NPV: negative predictive value; LR: likelihood ratio; ROC: receiver operating characteristic.*

ratios that would allow the defect to be classified based on its size.

## Methods

This was an observational, prospective, cross-sectional study. The population consisted of 35 subjects with isolated ASD with a single orifice on echocardiographic examination, of both genders, aged between 1 month and 18 years. The study, the Informed Consent Form (ICF), and the Understanding Form (UF) were approved by the Ethics and Research Committee of the university hospital where the research was carried out. The subjects signed the ICF or UF and then underwent echocardiographic examination and clinical evaluation. Those with significant congenital heart disease (excluding patent foramen ovale, mild mitral, tricuspid, and aortic regurgitation, and bicuspid aortic valve without stenosis), cardiomyopathy (primary or secondary), chronic anemia, and pulmonary hypertension not attributed to the presence of ASD were excluded. The convenience sampling method was used.

The echocardiographic examination was performed with a TOSHIBA device, model APLIO 400, with pediatric and adult transducers with frequencies of 2.5 MHz and 5.0 MHz, respectively, by a pediatric echocardiographer, and the clinical evaluation was performed by a pediatric cardiologist, both members of the team, and blinded to the clinical assessment and vice versa. The clinical assessment was performed on the same day as the echocardiographic evaluation, immediately after it. The degree of repercussion in the right chambers was assessed subjectively, comparing the areas of the Right Atrium (RA) to those of the Left Atrium (LA) and the areas of the Right Ventricle (RV) to those of the Left Ventricle (LV), in a two-dimensional mode, apical four-chamber view,[5] since linear and area measurements of the RA and RV have not been consistently standardized for the pediatric population.[6-8] Comparatively, if the right chambers had a smaller, equal, or larger area than the left chambers, the increase was considered absent or mild, moderate, or significant, respectively. Measurements of the interatrial septum and the ASD diameter were performed in two-dimensional mode, in the subcostal section of the Atrial Septum, with the aid of Color Doppler to identify the edges of the defect.[6] To measure the Atrial Septum, the vertical distance between the end of each vena cava was standardized. The ASD was measured in the region with the greatest distance between the edges throughout the cardiac cycle. The ASD/septum ratio was calculated, and this measurement was compared with the hemodynamic repercussion. The magnitude of the shunt through the ASD was estimated by calculating the systemic flow/pulmonary flow (QP/QS) ratio.[6] The diameters of the Mitral and Tricuspid Annuli were measured in two-dimensional mode, in protodiastole. The parasternal longitudinal long axis view of the LV and RV inflow tract were used to measure the anteroposterior diameters (mitral and tricuspid, respectively) and the apical four-chamber view to measure the laterolateral diameters[7] (Figure 1). The diameters were indexed in the form of a Z-score using the Boston reference.[9-11] The Tricuspid Annulus (TA) Z-score values were also used to classify the degree of ASD repercussion in the right chambers. The

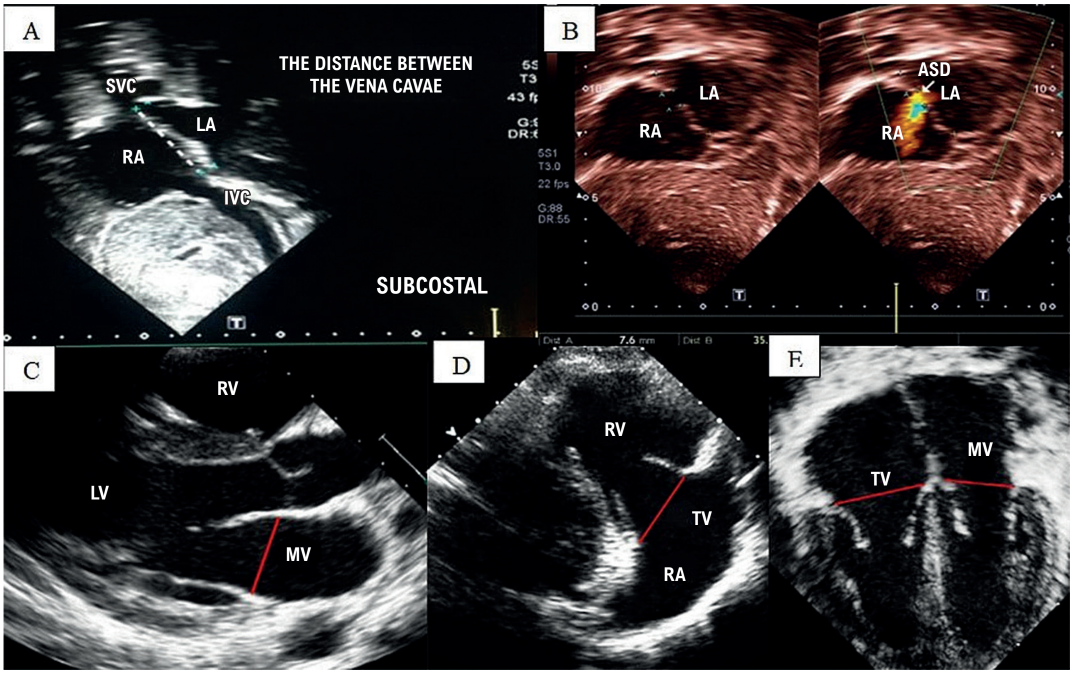


**Figure 1 –** *Measurement of the interatrial septum, ASD, and mitral and tricuspid annuli on echocardiographic examination. RA: right atrium; LA: left atrium; RV: right ventricle; LV: left ventricle; ASD: Atrial Septal Defect; IVN: inferior vena cava; SVC: superior vena cava; TV: tricuspid valve; MV: mitral valve.*

MI/ASD ratio was calculated, and this measurement was compared with the hemodynamic repercussion. ASD size classification by echocardiographic criteria was performed by subjective analysis and Z-score: Small ASD: the right chamber area is smaller than left chamber area and the TA Z-score ranges from +2 to +2.5; medium ASD: the right chamber area is equal to the left chamber area and the TA Z-score ranges from +2.5 to +3; large ASD: the right chamber area is larger than the left chamber area and the TA Z-score is > +3.

The clinical evaluation consisted of an examination of the cardiovascular system guided by criteria that allowed inferences to be made about the size of the ASD.[12] ASD size classification by clinical evaluation was performed according to Table 1, and the presence of at least three of the four findings for each column was considered.

Statistical analysis: Statistical analysis was performed using Statistical Package for Social Science (SPSS) software version 16.0. The results were expressed as numbers and proportions for categorical variables and as means ± standard deviation for continuous variables. The Shapiro-Wilk test was used to check the normal distribution of variables. Proportions were compared using the Chi-square test or Fisher's exact test when appropriate. For continuous data, the unpaired Student's T-test was used for two variables, or the One-Way ANOVA test was used to compare three or more variables. The Pearson coefficient was used to check the correlation between continuous. The correlation based on the coefficient (positive or inverse) was considered very weak (0.00–0.20), weak (0.21–0.40), moderate (0.41–0.60), strong (0.61–0.80), and very strong (0.81–1.00). The operating characteristic curve was applied to evaluate sensitivity, specificity, Positive Predictive Value (PPV), Negative Predictive Value (NPV), and the positive likelihood ratio of the ASD/septum ratio, considering the size of the septal defect. A P-value of $< 0.05$ was considered statistically significant.

## Results

Among the 35 subjects, 24 (69%) were female. The mean age was 6.3 ± 3.9 years, ranging from 0.4 to 17.2 years. The average weight, height, and body surface area were 21.2 kg, 112 cm, and 0.8 $m^2$, respectively. Comorbidities were present in 14% of the subjects (n = 5), including asthma (3), genetic syndrome under investigation (1), and neurological and psychomotor development delay in propaedeutics (1).

Regarding the findings on physical examination, 14 subjects (40%) had fixed splitting of the second heart sound, and 5 (14%) had a diastolic murmur in the tricuspid area. A systolic murmur in the pulmonary area was not detected in six subjects, was grade II in 16 subjects (46%), and grade III ≥ in 13 subjects (37%). RV impulse was not detected in 19 (54%) subjects.

On echocardiographic examination, all subjects had ostium secundum-type ASD. The data collected are summarized in Table 2.

**Table 1 – Classification of ASD size according to clinical criteria**

| Clinical Parameter | Size Classification | | |
|---|---|---|---|
| | Small | Medium | Large |
| Impulse in BEEI and subxiphoid region | Absent | Present | Present |
| Splitting of the second heart sound | Physiological | Fixed | Fixed |
| Ejection systolic murmur in the pulmonary area | Absent or grade I/VI | Grade II/VI | Grade > III/VI |
| Diastolic murmur in the tricuspid area | Absent | Absent | Present |

*BEEI: lower left sternal border.*

### Association and correlation between the variables

Table 3 shows the comparisons between clinical signs and echocardiographic measurements. There was no association between gender and any of the variables studied, whether in the clinical or echocardiographic context.

Twelve ASDs were clinically classified as small, 18 as medium, and 5 as large. The correlation between ASD size by clinical classification and echocardiographic findings is summarized in Table 4.

The MI/ASD diameter ratios showed a strong inverse correlation with the ASD/septum measurement. The Pearson coefficient with the anteroposterior and laterolateral measurements was -0.80 ($p < 0.001$). There was also a strong inverse correlation with the QP/QS measurement, with a Pearson coefficient of -0.71 ($p < 0.001$) for the anteroposterior measurement and -0.76 ($p < 0.001$) for the laterolateral measurement.

The ASD/septum diameter ratio showed a strong correlation with the QP/QS ratio with a Pearson coefficient of 0.63 ($p = 0.001$).

Regarding the size of the RV in the subjective assessment, the RV was larger than the LV in 17 subjects, was smaller in 10 subjects, and eight subjects had chambers of equivalent sizes. When assessing the RA, it was larger than the LA in 20 subjects, smaller in eight subjects, and seven subjects had chambers of equivalent sizes. The comparison and correlation between the degree of enlargement of the right chambers and the echocardiographic variables are shown in Tables 5 and 6.

Considering the TA Z-score to classify the size of the ASDs, 25 were small, 5 were medium, and 5 were large. This classification was not associated with the clinical classification of ASD nor with the echocardiographic classification made according to the subjective assessment of the right chambers.

### Operating characteristic curve

Applying the operating characteristic curve, considering as the stable variable the classification of the ASD based on the subjective size of the right chambers, an area under the curve of 0.85 was obtained for the ASD/septum ratio. The curve and data with p-value and 95% confidence intervals are shown in Figure 2. The best cutoff point was 0.27, with a sensitivity of 85% and specificity of 86.7% for diagnosing large ASD. The PPV was 76%, and the NPV was 85.2%. The positive likelihood ratio was 6.39.

Regarding the variable classification of ASD according to the subjective size of the right chambers, an area under the curve of 0.14 was obtained for the MI/ASD ratio.

## Discussion

The main findings of this study were the strong inverse correlation between the MI/ASD ratio and the clinical classification of the ASD, and the 6.39 probability of diagnosing a large ASD based on an ASD/septum ratio greater than 0.27, according to the subjective size of the right chambers as summarized in the Central Illustration.

The universal form used by cardiologists to classify ASD size is based on several subjective factors in a clinical and echocardiographic context. The presence of symptoms, changes found during the physical examination, and echocardiographic findings are evaluated. Considering there is great variability in body surface area values in the pediatric population, the ASD diameter alone is not an adequate parameter to quantify the size of the lesion. Other parameters are taken into consideration to assess the size of the lesion, such as the QP/QS ratio,[6] the ASD/interatrial septum diameter ratio, and assessment of the degree of enlargement of the right chambers.[4,5]

At the time of the study, there was only one study[13] presenting normal values for linear and area measurements of the RA and RV, as indicated by the echocardiogram measurement guideline[7] for the pediatric population. This study had the limitations of being a single-center study carried out only with a Caucasian population aged 0 to 3 years. Therefore, the study could not be incorporated into clinical practice as it did not cover all pediatric age groups. Since then, two new publications[14,15] of reference values in pediatrics have emerged. Rajagopal *et al.,* described measurements of the area of the RA, but this was a single-center and retrospective study, the results of which have not yet been incorporated into clinical practice.[14] Gokhroo *et al.,* mentioned reference values for measurements, as recommended by the guideline, but the study was limited to the age group of 5 to 15 years.[15] Therefore, the enlargement of the right chambers is estimated subjectively, visually

**Table 2 – Measurements and ratio calculation of echocardiographic measurements**

| Variables | Medium | Minimum | Maximum | Standard deviation |
|---|---|---|---|---|
| ASD diameter (mm) | 13.46 | 2.70 | 37.70 | 8.33 |
| MI/ASD - LL | 2.04 | 0.62 | 6.30 | 1.49 |
| MI/ASD - AP | 2.00 | 0.52 | 6.80 | 1.48 |
| ASD/septum | 0.30 | 0.06 | 0.65 | 0.15 |
| QP/QS | 2.56 | 1.10 | 4.48 | 0.99 |
| TA diameter - LL (mm) | 23.38 | 14.40 | 38.60 | 5.14 |
| TA Z-score - LL | +1.40 | -1.63 | +5.28 | 1.74 |
| TA diameter - AP (mm) | 22.48 | 10.90 | 37.40 | 5.77 |
| TA Z-score - AP | +1.11 | -2.34 | +3.76 | 1.28 |
| MA diameter - LL (mm) | 18.18 | 11.40 | 25.80 | 3.41 |
| MA Z-score - LL | -0.39 | -2.34 | +2.09 | 1.15 |
| MA diameter - AP (mm) | 17.87 | 9.80 | 25.40 | 3.25 |
| MA Z-score - AP | -0.07 | -1.89 | +1.93 | 0.91 |

*ASD: atrial septal defect; mm: millimeters; MI/ASD: mitral annulus diameter/atrial septal defect diameter; LL: laterolateral; AP: anteroposterior; ASD/septum: atrial septal defect diameter/atrial septum diameter; QP/QS: pulmonary flow/systemic flow; TA: tricuspid annulus; AM: mitral annulus.*

**Table 3 – Comparison between clinical and echocardiographic parameters**

| Clinical Parameter | P-Value | | | | | |
|---|---|---|---|---|---|---|
| | MI/ASD – AP | MI/ASD – LL | ASD/septum | QP/QS | ASD SIZE according to ASCD* | TA Z-score |
| RV impulses | 0.028 | 0.018 | 0.15 | 0.35 | 0.025 | 0.56 |
| Splitting of the S2 | < 0.001 | < 0.001 | < 0.001 | 0.006 | < 0.001 | 0.12 |
| Pulmonary systolic murmur | 0.015 | 0.006 | 0.022 | 0.037 | 0.002 | 0.41 |
| Tricuspid diastolic murmur | 0.055 | 0.045 | 0.015 | 0.016 | 0.29 | 0.019 |

** Fisher's test. Other variables were analyzed using the unpaired Student's t-test. MI/ASD: mitral annulus diameter/atrial septal defect diameter; AP: anteroposterior; LL: laterolateral; ASD/septum: atrial septal defect diameter/atrial septal diameter; QP/QS: pulmonary flow/systemic flow; ASCD: subjective assessment of the right chambers; TA: tricuspid annulus; RV: right ventricle; S2: second heart sound.*

comparing the area of the right chambers with that of the left chambers in the apical four-chamber view in two-dimensional mode. The QP/QS ratio, despite being an objective measure, is very prone to errors and difficult to measure.[16]

Rao *et al.,* presented the method of classifying the size of the residual shunt after ASD percutaneous closure considering the parameters of flow diameter greater than 2 mm and RV measurements with a percentile > 95% but did not propose a classification of the magnitude of the lesion itself.[17]

There are no studies in the literature that evaluate the ASD/septum ratio to classify ASD size. Lin *et al*., used measurements of the Interatrial Septum and ASD in two-dimensional and color mode with the use of artificial intelligence in a population with an average age of 3 years and demonstrated good accuracy in detecting defects and cases that could be subjected to percutaneous closure of the lesion by measuring the free edges of the septum. However, this study did not evaluate the degree of hemodynamic repercussion, the classification of the lesion size, or the need for treatment.[18] The measurements chosen in this study were the MI/ASD and ASD/septum ratios, as a way of indexing ASD measurement to a cardiac structure, and should be easy to measure. The ASD was measured using the largest linear diameter.

**Table 4 – Correlation between ASD size by clinical classification and echocardiographic variables**

| Echocardiographic variables | Pearson coefficient | P-Value |
|---|---|---|
| ASD size: subjective assessment of the right chambers | 0.52 | 0.001 |
| ASD size: TA Z-score assessment | 0.26 | 0.13 |
| TA Z-score - Anteroposterior | 0.34 | 0.045 |
| TA Z-score - Laterolateral | 0.34 | 0.048 |
| ASD/septum | 0.56 | <0.001 |
| QP/QS | 0.62 | 0.002 |
| MI/ASD - Anteroposterior | -0.58 | <0.001 |
| MI/ASD - Laterolateral | -0.61 | <0.001 |

*ASD: atrial septal defect; TA: tricuspid annulus; ASD/septum: atrial septal defect diameter/atrial septal diameter; QP/QS: pulmonary flow/systemic flow; MI/ASD: mitral annulus diameter/atrial septal defect diameter.*

Considering that lesions may be asymmetrical, the diameter measurements taken may not necessarily reflect the largest diameter of the lesion. The most reliable measurement would be calculating the ASD area, which is done through 3D echocardiography and magnetic resonance imaging, but these exams are not as widely available in clinical practice.[19,20] Thus, to avoid greater bias, diameter measurements were performed with images of good technical quality and using the same subcostal view in all subjects. The subcostal view is very similar to the mid-esophageal bicaval view of the transesophageal echocardiographic examination, which is used to guide percutaneous closure of the ASD with a prosthesis.[6] Boon *et al.*, demonstrated that 2D echocardiographic examination is a reliable method for measuring the diameter of the ASD, especially in cases where the septum is firm, corresponding to 85% of the cases of ostium secundum ASD.[21]

The MI/ASD measurement showed a strong inverse correlation with the clinical classification of ASD and with the classification by subjective assessment of the right chambers. Despite this, it was not possible to define cut-off points for this variable to classify the size of the defect. Although it is intuitive to imagine that the smaller the ratio, the greater the deficit in LV filling and mitral annulus development, it can be speculated that such a relationship is not so linear with the size of the ASD to the point of enabling assertive size calculation.

The ASD/septum measurement showed a moderate correlation with the clinical classification of ASD and a strong correlation with the classification by subjective assessment of the right chambers. It was not possible to define cutoff points for classifying the magnitude of ASD considering its clinical classification. This finding may be explained by the small number of large ASDs classified by the clinical method. A cutoff point of 0.27 was found for the ASD/septum ratio to identify large ASDs compared with the subjective assessment of the size of the right chambers. The same was not possible for medium-sized ASDs, perhaps also due to the small number of subjects with medium ASD according to the classification by subjective assessment of the right chambers.

The QP/QS ratio is one of the parameters found in the guidelines for indicating ASD closure in the adult population.[22] It showed a strong correlation with the MI/ASD and ASD/septum measurements and with the clinical and echocardiographic classification of ASD by a subjective assessment of the right chambers. It may have great

**Table 5 – Comparison between the degree of enlargement of the right chambers according to subjective assessment and echocardiographic variables**

| Variables | Degree of enlargement of the right chambers | | | | | | p-value (ANOVA) |
|---|---|---|---|---|---|---|---|
| | Mild | Standard deviation | Moderate | Standard deviation | Major | Standard deviation | |
| ASD diameter (mm) | 5.15 | 2.27 | 11.8 | 6.12 | 17.37 | 8.01 | 0.001 |
| MI/ASD -AP | 4.07 | 1.69 | 1.78 | 0.84 | 1.24 | 0.48 | < 0.001 |
| MI/ASD -LL | 4.15 | 1.58 | 1.86 | 0.85 | 1.25 | 0.52 | < 0.001 |
| ASD/septum | 0.13 | 0.06 | 0.29 | 0.14 | 0.36 | 0.13 | < 0.001 |
| QP/QS | 1.19 | 0.10 | 2.45 | 0.93 | 3.05 | 0.84 | 0.007 |
| TA Z-score -AP | -0.17 | 0.00 | +1.00 | 1.28 | +1.66 | 1.04 | 0.001 |
| TA Z-score - LL | -0.04 | 1.30 | +1.17 | 0.75 | +2.06 | 1.81 | 0.01 |

*ASD: atrial septal defect; mm: millimeters; RA: right atrium; RV: right ventricle; MI/ASD: mitral annulus diameter/atrial septal defect diameter; AP: anteroposterior; LL: laterolateral; ASD/septum: atrial septal defect diameter/atrium septal diameter; QP/QS: pulmonary flow/systemic flow; TA: tricuspid annulus.*

**Table 6 – Correlation between the degree of enlargement of the right chambers according to subjective assessment and echocardiographic variables**

| Variables | Pearson coefficient | P-Value |
|---|---|---|
| ASD diameter (mm) | 0.61/0.66 RA/RV | < 0.001 RA/RV |
| MI/ASD -AP | -0.75 | <0.001 |
| MI/ASD -LL | -0.77 | <0.001 |
| ASD/septum | 0.62 | <0.001 |
| QP/QS | 0.61 | 0.002 |
| TA Z-score -AP | 0.58 | <0.001 |
| TA Z-score - LL | 0.50 | 0.002 |

*ASD: atrial septal defect; mm: millimeters; RA: right atrium; RV: right ventricle; MI/ASD: mitral annulus diameter/atrial septal defect diameter; AP: anteroposterior; LL: laterolateral; ASD/septum: atrial septal defect diameter/atrium septal diameter; QP/QS: pulmonary flow/systemic flow; TA: tricuspid annulus.*

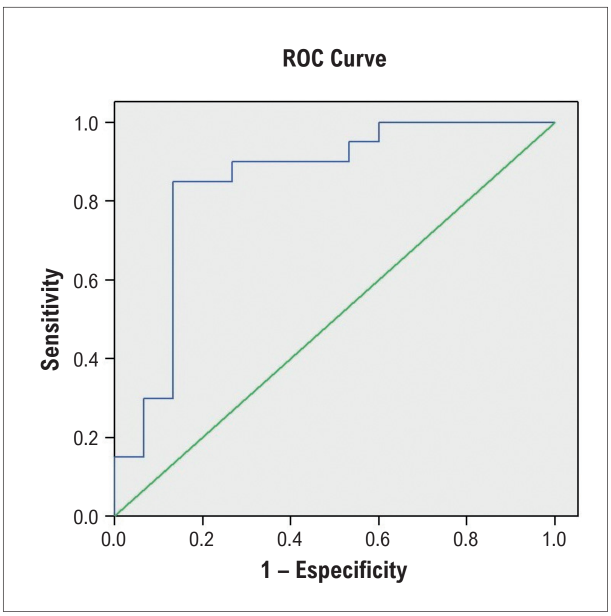


**Figure 2 –** *Operating characteristic curve for the ASD/septum ratio, considering as the stable variable the classification of the ASD based on the subjective size of the right chambers. ROC: receiver operating characteristic.*

variability[3,4] because of how the relationship is calculated, with four measurements being required: the radius and the velocity-time integral of the RV and LV outflow tract. An error in any of the four measurements can alter the final value of the relationship. Furthermore, the radius measurement is squared, which causes a radius measurement error to also be squared in the calculation.[16] Faherty *et al.,* correlated the QP/QS calculation values on echocardiography with those obtained by oximetry on catheterization in patients with hemodynamically significant ostium secundum ASD and found a weak correlation between the methods, with the echocardiographic method tending to overestimate the values obtained by oximetry.[23]

In clinical practice, it is common to repeat the measurement when the echocardiographer finds a value considered to be incompatible with the other findings. Therefore, the measurement is influenced by a subjective bias. In the study data collection protocol, the number of measurement repetitions for calculating the QP/QS ratio was not limited. Consequently, echocardiographers were free to choose the calculation value they considered to be the most reliable. This subjectivity bias may have contributed to the finding of a strong correlation between this measurement and the other variables studied.

The TA Z-score measurement showed a weak correlation with the clinical classification of ASD and a moderate correlation with the classification based on a subjective assessment of the right chambers. One explanation for such findings may be the lack of normalization of Z-score reference values for TA measurements in the literature. Despite the standardization of the measurement method of the most recent studies and their larger sample size compared to older studies,[24-26] there are still differences between the nomograms, which result in Z-scores that are very discordant with each other. The studies show differences between them, such as the body surface formula used, gender differentiation or lack of it, age range used, and intra-observer and interobserver variability.[27] Snyder *et al.,* demonstrated that there was no strong linear relationship between RV volume on cardiac magnetic resonance imaging and tricuspid valve Z-score on echocardiography in patients in the late postoperative period of Tetralogy of Fallot. Among patients with RV enlargement on MRI, the TA Z-score measurement on echocardiography showed a sensitivity of 45% to identify enlargement, with a Z-score > +2.[28] In the present study, the tricuspid valve diameter Z-score was observed within the normal range despite enlarged RV on a two-dimensional assessment compared to the LV in some subjects.

The classification of the magnitude of ASD by the TA Z-score value as described in the methodology was not associated with any of the parameters investigated in the physical examination and, consequently, with the clinical classification of ASD, nor it was associated with the classification of ASD according to a subjective assessment of the right chambers. In addition to the already-mentioned variability of Z-score normality values in the pediatric population, the choice of the Z-score range used for classification must be considered. In the study, different Z-score ranges were not compared, and the association of each of them with other methods of classifying ASD size was not evaluated.

Many of the results found in the study are in agreement with the literature data. Among them, the frequency of findings on physical examination and the proportion between genders.

The frequency was higher in females, in a proportion of 2.2:1, very close to that described in the literature of 2:1.[2] The percentages found of wide and fixed splitting of the second heart sound (S2), systolic murmur in the pulmonary area, and diastolic murmur in the tricuspid area were 66%, 83%, and 15%, respectively, similar to the values of 66%, 90%, and 12% described in the literature, respectively.[29] Regarding RV impulses, the presence and intensity of such a finding depend greatly on the patient's biotype.

The ASD type most frequently found is ostium secundum, responsible for approximately 85% of the cases.[30] In the study, it was the only type found, a finding that can be explained by the small sample size.

Among the parameters investigated by physical examination, all were associated with the subjective classification of the right chambers, except for the diastolic murmur in the tricuspid area. This fact can be explained by the low sensitivity of this parameter for the diagnosis of ASD.[29]

### Limitations

This study has some limitations because it is a single-center, cross-sectional study with a small sample size and a large age standard deviation. Furthermore, it was not possible to assess the intra-observer and interobserver variability regarding the clinical method and the echocardiographic examination, but the team was previously trained on the measurement protocol. No post hoc test was used to verify significant differences between the echocardiographic parameter measurements and the subjective assessment of the enlargement of the right chambers.

## Conclusions

The MI/ASD and ASD/septum measurements were associated with ASD size classification concerning the clinical parameters and subjective assessment of the size of the right chambers during an echocardiogram. The measurement of the ASD/septum ratio above 0.27 proved to be useful in identifying large ASDs based on the subjective enlargement of the right chambers, which was not found in small and medium-sized ASDs. It was not possible to define cut-off points for the MI/ASD measurement to classify ASD size. The TA Z-score measurement was not a good parameter for classifying ASD size.

## Author Contributions

Conception and design of the research: Tonelli HAF; acquisition of data: Ribeiro LC, Tonelli HAF, Araújo FDR, Furletti A, Meira ZMA, Castilho SRT, Valadares LC, Conde AA; analysis and interpretation of the data and writing of the manuscript: Ribeiro LC; statistical analysis: Silva RMFL; critical revision of the manuscript for intellectual content: Silva RMFL, Tonelli HAF.

**Potential Conflict of Interest**

No potential conflict of interest relevant to this article was reported.

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**Study Association**

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**Ethics Approval and Consent to Participate**

This study was approved by the Ethics Committee of the UFMG under the protocol number 53353116.3.0000.5149. All the procedures in this study were in accordance with the 1975 Helsinki Declaration, updated in 2013. Informed consent was obtained from all participants included in the study.

## References

1. Liu Y, Chen S, Zühlke L, Black GC, Choy MK, Li N, et al. Global Birth Prevalence of Congenital Heart Defects 1970-2017: Updated Systematic Review and Meta-Analysis of 260 Studies. Int J Epidemiol. 2019;48(2):455-63. doi: 10.1093/ije/dyz009.
2. Engelfriet P, Mulder BJ. Gender Differences in Adult Congenital Heart Disease. Neth Heart J. 2009;17(11):414-7. doi: 10.1007/BF03086294.
3. Quiñones MA, Otto CM, Stoddard M, Waggoner A, Zoghbi WA; Doppler Quantification Task Force of the Nomenclature and Standards Committee of the American Society of Echocardiography. Recommendations for Quantification of Doppler Echocardiography: A Report from the Doppler Quantification Task Force of the Nomenclature and Standards Committee of the American Society of Echocardiography. J Am Soc Echocardiogr. 2002;15(2):167-84. doi: 10.1067/mje.2002.120202.
4. Lai WW, Mertens LL, Cohen MS, Geva T, editors. Anomalies of the Atrium Septum. Echocardiography In Pediatric And Congenital Heart Disease: From Fetus to Adults. Hoboken: Wiley-Blackwell; 2009.
5. Anderson RH, Baker EI, Penny D, Redington AN, Rigby ML, Wernovsky G. Interatrial Communications. Paediatric Cardiology. Philadelphia: Churchill Livingstone; 2010. p. 523-46.
6. Silvestry FE, Cohen MS, Armsby LB, Burkule NJ, Fleishman CE, Hijazi ZM, et al. Guidelines for the Echocardiographic Assessment of Atrial Septal Defect and Patent Foramen Ovale: From the American Society of Echocardiography and Society for Cardiac Angiography and Interventions. J Am Soc Echocardiogr. 2015;28(8):910-58. doi: 10.1016/j.echo.2015.05.015.
7. Lopez L, Colan SD, Frommelt PC, Ensing GJ, Kendall K, Younoszai AK, et al. Recommendations for Quantification Methods During the Performance of a Pediatric Echocardiogram: A Report from the Pediatric Measurements Writing Group of the American Society of Echocardiography Pediatric and Congenital Heart Disease Council. J Am Soc Echocardiogr. 2010;23(5):465-95. doi: 10.1016/j.echo.2010.03.019.
8. Lang RM, Badano LP, Mor-Avi V, Afilalo J, Armstrong A, Ernande L, et al. 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. 2015;28(1):1-39.e14. doi: 10.1016/j.echo.2014.10.003.
9. zscore.chboston.org [Internet]. Boston: Boston Children's Hospital; 2023 [cited 2025 Mar 7]. Available from:: hhttps://zscore.chboston.org/.

10. Sluysmans T, Colan SD. Structural Measurements and Adjustments for Growth. In: Lai WW, Mertens LL, Cohen MS, Geva T, editors. Anomalies of the Atrium Septum. Echocardiography In Pediatric And Congenital Heart Disease: From Fetus to Adults. Hoboken: Wiley-Blackwell; 2009. p.158-74.

11. Colan SD. Normal Echocardiographic Values for Cardiovascular Structures. In: Lai WW, Mertens LL, Cohen MS, Geva T, editors. Anomalies of the Atrium Septum. Echocardiography In Pediatric And Congenital Heart Disease: From Fetus to Adults. Hoboken: Wiley-Blackwell; 2009. p. 765-85.

12. Sachdeva, R. Atrial septal defect. In: Allen HD, Driscoll DJ, Shaddy RE, Feltes TF, editors. Moss and Adams' Heart Disease in Infants, Children, and Adolescents: Including the Fetus and Young Adult. Philadelphia: Lippincott Williams & Wilkins; 2016. p. 739-56.

13. Cantinotti M, Scalese M, Murzi B, Assanta N, Spadoni I, De Lucia V, et al. Echocardiographic Nomograms for Chamber Diameters and Areas in Caucasian Children. J Am Soc Echocardiogr. 2014;27(12):1279-92.e2. doi: 10.1016/j.echo.2014.08.005.

14. Rajagopal H, Uppu SC, Weigand J, Lee S, Karnik R, Ko H, et al. Validation of Right Atrial Area as a Measure of Right Atrial Size and Normal Values of in Healthy Pediatric Population by Two-Dimensional Echocardiography. Pediatr Cardiol. 2018;39(5):892-901. doi: 10.1007/s00246-018-1838-3.

15. Gokhroo RK, Anantharaj A, Bisht D, Kishor K, Plakkal N, Aghoram R, et al. A Pediatric Echocardiographic Z-Score Nomogram for a Developing Country: Indian Pediatric Echocardiography Study - The Z-score. Ann Pediatr Cardiol. 2017;10(1):31-8. doi: 10.4103/0974-2069.197053.

16. Otto CM. Cardiopatias Congênitas em Adultos: Fundamentos de Ecocardiografia Clínica. Rio de Janeiro: Elsevier; 2010.

17. Rao PS. Role of Echocardiography in the Diagnosis and Interventional Management of Atrial Septal Defects. Diagnostics. 2022;12(6):1494. doi: 10.3390/diagnostics12061494.

18. Lin X, Yang F, Chen Y, Chen X, Wang W, Li W, et al. Echocardiography-Based AI for Detection and Quantification of Atrial Septal Defect. Front Cardiovasc Med. 2023;10:985657. doi: 10.3389/fcvm.2023.985657.

19. Mweri ST, Deng Y, Cheng P, Lin H, Wang H, Mkangara OB, et al. Evaluation of Atrial Septal Defect Using Real-Time Three-Dimensional Echocardiography: Comparison with Surgical Findings. J Huazhong Univ Sci Technolog Med Sci. 2009;29(2):257-9. doi: 10.1007/s11596-009-0225-y.

20. Beerbaum P, Körperich H, Esdorn H, Blanz U, Barth P, Hartmann J, et al. Atrial Septal Defects in Pediatric Patients: Noninvasive Sizing with Cardiovascular MR Imaging. Radiology. 2003;228(2):361-9. doi: 10.1148/radiol.2282020798.

21. Boon I, Vertongen K, Paelinck BP, Demulier L, van Berendoncks A, Maeyer C, et al. How to Size ASDs for Percutaneous Closure. Pediatr Cardiol. 2018;39(1):168-75. doi: 10.1007/s00246-017-1743-1.

22. Stout KK, Daniels CJ, Aboulhosn JA, Bozkurt B, Broberg CS, Colman JM, et al. 2018 AHA/ACC Guideline for the Management of Adults with Congenital Heart Disease: A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. Circulation. 2019;139(14):e698-e800. doi: 10.1161/CIR.0000000000000603.

23. Faherty E, Rajagopal H, Lee S, Love B, Srivastava S, Parness IA, et al. Correlation of Transthoracic Echocardiography-Derived Pulmonary to Systemic Flow Ratio with Hemodynamically Estimated Left to Right Shunt in Atrial Septal Defects. Ann Pediatr Cardiol. 2022;15(1):20-6. doi: 10.4103/apc.apc_139_21.

24. Sluysmans T, Colan SD. Theoretical and Empirical Derivation of Cardiovascular Allometric Relationships in Children. J Appl Physiol. 2005;99(2):445-57. doi: 10.1152/japplphysiol.01144.2004.

25. Zilberman MV, Khoury PR, Kimball RT. Two-Dimensional Echocardiographic Valve Measurements in Healthy Children: Gender-Specific Differences. Pediatr Cardiol. 2005;26(4):356-60. doi: 10.1007/s00246-004-0736-z.

26. Pettersen MD, Du W, Skeens ME, Humes RA. Regression Equations for Calculation of z Scores of Cardiac Structures in a Large Cohort of Healthy Infants, Children, and Adolescents: An Echocardiographic Study. J Am Soc Echocardiogr. 2008;21(8):922-34. doi: 10.1016/j.echo.2008.02.006.

27. Cantinotti M, Scalese M, Molinaro S, Murzi B, Passino C. Limitations of Current Echocardiographic Nomograms for Left Ventricular, Valvular, and Arterial Dimensions in Children: A Critical Review. J Am Soc Echocardiogr. 2012;25(2):142-52. doi: 10.1016/j.echo.2011.10.016.

28. Snyder K, Drant S, Carris E, Christopher A, Allada V. Tricuspid Valve Size Relationship to Right Ventricular Volume in Post-Operative Tetralogy of Fallot Patients. Pediatr Cardiol. 2022;43(4):887-93. doi: 10.1007/s00246-021-02800-0.

29. Geggel RL. Clinical Detection of Hemodynamically Significant Isolated Secundum Atrial Septal Defect. J Pediatr. 2017;190:261-4.e1. doi: 10.1016/j.jpeds.2017.07.037.

30. Naqvi N, McCarthy KP, Ho SY. Anatomy of the Atrial Septum and Interatrial Communications. J Thorac Dis. 2018;10(Suppl 24):2837-47. doi: 10.21037/jtd.2018.02.18.