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**Original Research Article**

# Predictivity of right ventricular outflow tract velocity-time integral in detection of the size of secundum atrial septal defect in children

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## ABSTRACT

**Background:** Atrial septal defect (ASD) is a common congenital heart defect in children, with secundum ASD being the most frequent type. Unrepaired defects can cause right ventricular overload and pulmonary hypertension. While Qp:Qs ratio requires four parameters to detect shunts, the right ventricular outflow tract velocity-time integral (RVOT VTI) alone can indicate significant interatrial shunts and predict ASD size. This study aimed to evaluate RVOT VTI in predicting secundum ASD size in children.
**Methods:** This cross-sectional study was conducted in department of pediatric cardiology, Bangladesh Medical University, Dhaka, from July 2023 to June 2024. A total of 30 patients were selected as study subjects by a purposive sampling technique. The data were coded, entered, and analyzed using Statistical Package for the Social Sciences (SPSS) version 25.0.
**Results:** The results of this study indicate that the majority of children (60%) had an RVOT VTI >20 cm, and most secundum ASDs were moderate in size as measured by both TTE and TEE. A positive, though statistically non-significant, correlation was observed between RVOT VTI and ASD size measured by both TTE ($r=0.271$, $p<0.147$) and TEE ($r=0.303$, $p<0.104$). ROC analysis identified RVOT VTI cut-off values of 19 cm and 15 cm for differentiating large and moderate-to-large ASDs, with corresponding accuracies of 60% and 93.3%, respectively. The 15 cm cut-off demonstrated higher diagnostic performance, showing 96% sensitivity and 75% specificity.
**Conclusions:** This study highlighted the potential role of RVOT VTI as a useful, non-invasive parameter for estimating the size of secundum ASDs in pediatric patients. It demonstrated that RVOT VTI can help distinguish between small, moderate, and large defects. At a cut-off value of 19 cm, RVOT VTI showed an accuracy of 60% in differentiating large ASDs from small to moderate ones.

**Keywords:** Congenital heart disease, Right ventricular outflow tract, Secundum atrial septal defect

## INTRODUCTION

An atrial septal defect (ASD) occurs when there is a failure to close the communication between the right and left atria.[1] Congenital heart disease (CHD) ranks among the most commonly identified congenital conditions, affecting an estimated 0.8% to 1.2% of live births globally.[2,3] In children atrial septal defect is a common congenital heart disease, which occurs in 6-10% of all congenital heart diseases. For diagnosed ASDs, the overall prevalence has been estimated at 2 to 3.89 per 1000 children.[4] Based on location and embryology, ASD is classified as ostium primum type, ostium secundum type, sinus venosus type, and coronary sinus type.[5] Secundum ASDs are the most common (75% of cases), usually located at the level of the fossa ovalis.[6] Under normal physiologic conditions, the pressure in the left atrium is relatively higher than the right atrium; therefore, blood flows from the left atrium to the right atrium, causing a left-to-right shunt. The amount of left-to-right shunt is determined by the defect size and the compliance of the right and left ventricles.[7] Increased pulmonary blood flow from an unrepaired large lesion and a persistent left-to-right shunt leads to gradual vascular remodeling and pulmonary arterial hypertension.[8] To evaluate the size, shape, and location of an atrial communication-multiple views should be used, including the subxiphoid, apical, left parasternal, and high right parasternal.[9] The subxiphoid window typically allows the best visualization of the interatrial septum and other related structures in the pediatric population, whereas in adolescence and adulthood, the subxiphoid window is often inadequate because of the distance from the probe to the interatrial septum. In that case, the parasternal window should be used for the assessment of the interatrial septum. Sometimes, a full assessment of the interatrial septum might not be possible with TTE. Thus, a transesophageal echocardiogram (TEE) could be required.[4] Furthermore, the TEE can be used to assess the size of an ASD more precisely and guide procedural planning.[10] But TEE is not available everywhere. For small children, it is an invasive technique that necessitates sedation, and its expense restricts its utilization.[11] To evaluate a presumed shunt lesion in the TTE, the ratio of pulmonary shunt to systemic shunt volume (Qp:Qs) is an established method. Small differences between left and right ventricular stroke volumes can be detected by using this ratio. Left-to-right shunting causes increased blood flow through the pulmonary circulation in these patients.[12] If the ratio is greater than one, a left-to-right shunt should be considered.[13] Four parameters are needed to calculate Qp:Qs-LVOT (left ventricular outflow tract) diameter, RVOT (right ventricular outflow tract) diameter, and the VTI of both outflow tracts. In some patients, due to poor image quality, measurement of outflow tract diameters becomes difficult, and false measurement leads to a wrong assumption.[12] Right ventricular outflow tract (RVOT) flow velocity determination is an essential part of the investigation of pulmonary blood flow in adults.[14] It is a key anatomic and physiologic interface between the RV and pulmonary vasculature and can provide important information in patients with known or suspected increased pulmonary blood flow.[15] RVOT VTI represents the distance that a column of blood travels during one cardiac cycle across the right ventricular outflow.[9] By using a single parameter, RVOT VTI, an atrial shunt lesion can be detected. A low RVOT VTI can predict the absence, while a high RVOT VTI can predict the presence of significant shunt lesions where Qp:Qs calculation is not possible.[12] As it can detect the significant interatrial shunt, it can also predict the size of ASD. So, aim of this study was to assess RVOT VTI in detecting the size of secundum ASD in children.

## METHODS

This cross-sectional study was conducted in department of pediatric cardiology, Bangladesh Medical University, Dhaka, from July 2023 to June 2024. All ASD patients between 5 to 18 years of age with poor echo window visiting at department of pediatric cardiology, Bangladesh Medical University, were considered as the study population. The study included all patients aged 5 to 18 years with secundum atrial septal defect (ASD) and poor echocardiographic window who attended the department of pediatric cardiology at Bangladesh Medical University. Patients were excluded if they had a clear echo window on transthoracic echocardiography (TTE), ASD associated with structural pulmonary stenosis, other types of ASD, ASD combined with other congenital heart diseases, or if their parents were unwilling to provide consent for participation. A total of 30 patients were selected as study subjects by a purposive sampling technique. All demographic, clinical, and echocardiographic data were prospectively recorded on a pre-designed data collection sheet. The data were coded, entered, and analyzed using Statistical Package for the Social Sciences (SPSS) version 25.0. Categorical data were expressed as frequencies and percentages. Numerical data were reported as mean±standard deviation (SD). Pearson’s correlation coefficient (r) was used to delineate the correlation between different parameters. To assess the accuracy of RVOT VTI for TTE and TEE to differentiate between large ASDs, an optimum cut-off value was determined via receiver operating characteristics (ROC) with area under the curve (AUC). Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated. For all analytic tests, the level of significance was set at 5% and a p value $<0.05$ was considered statistically significant. Approval from the institutional review board of Bangladesh Medical University, Dhaka, was obtained.

## RESULTS

The Table 1 shows the demographic characteristics of the studied subjects. The mean age of the studied children was 14.3±3.4 years. Mean weight and mean height were 41.5±11.5 and 148.3±12.3 cm, respectively. Mean body surface area (BSA) was 1.27±0.24 $m^2$.

**Table 1: Demographic characteristics of the study subjects (n=30).**

| Demographic variables | Mean±SD | Range |
|---|---|---|
| **Age (years)** | 14.3±3.4 | 5-18 |
| **Body weight (kg)** | 41.5±11.5 | 17-61 |
| **Height (cm)** | 148.3±12.3 | 110-167 |
| **BSA ($m^2$)** | 1.27±0.24 | 0.70-1.61 |

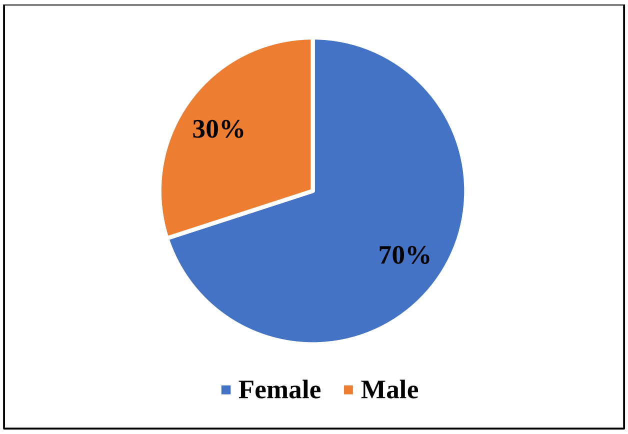


**Figure 1: Gender distribution of the study subjects under study (n=30).**

The Figure 1 shows that among the study subjects, 21 (70%) were female, while 9 (30%) were male.

In Table 2, the RVOT VTI values showed that the majority of children (60%) had readings greater than 20 cm, suggesting increased right ventricular outflow tract velocities, which could be associated with larger shunt volumes. Regarding secundum ASD size, as measured by TTE and TEE, both modalities identified half of the cases (50%) as moderate in size. However, TEE detected a higher number of small ASDs (13.3% versus 6.7%) and fewer large ASDs (36.7% versus 43.3%) compared to TTE. Overall, the findings indicate that most children presented with moderate to large ASDs and elevated RVOT VTI values (>20 cm), suggesting a relationship between ASD size and increased right heart flow dynamics.

**Table 2: Echocardiographic characteristics of study subjects (n=30).**

| Parameters | Category | Frequency (%) | Additional comparison (TEE versus TTE) |
|---|---|---|---|
| RVOT VTI (cm) | <15 | 04 (13.3) | - |
| | 15-20 | 08 (26.6) | - |
| | >20 | 18 (60.0) | - |
| ASD Size (mm) | <10 (small) | 02 (6.7) by TTE/04 (13.3) by TEE | TEE detected more small ASDs than TTE |
| | 10-20 (moderate) | 15 (50.0) by TTE/15 (50.0) by TEE | Both methods identified the same proportion of moderate ASDs |
| | >20 (large) | 13 (43.3) by TTE/11 (36.7) by TEE | TTE detected slightly more large ASDs than TEE |

**Table 3: Distribution of the study subjects by size of secundum ASD (n=30).**

| Size of ASD (mm) | Frequency by TTE (%) | Frequency by TEE (%) |
|---|---|---|
| **<10 (small)** | 02 (6.7) | 04 (13.3) |
| **10-20 (moderate)** | 15 (50.0) | 15 (50.0) |
| **>20 (large)** | 13 (43.3) | 11 (36.7) |

The Table 3 compares the size distribution of secundum ASDs as measured by TTE and TEE. According to TTE, 50% of the patients had moderate-sized ASDs, 43.3% had large ASDs, and only 6.7% had small ASDs. TEE, on the other hand, identified 50% of cases as moderate, but a slightly higher proportion (13.3%) as small and a lower proportion (36.7%) as large.

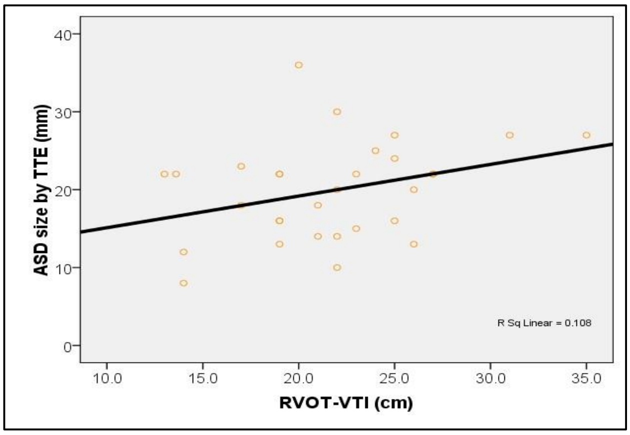


**Figure 2: Correlation between RVOT-VTI and secundum ASD size determined by TTE (n=30).**

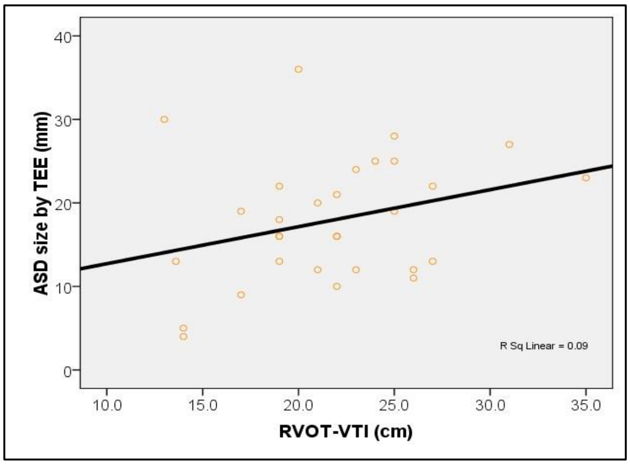


**Figure 3: Correlation between RVOT-VTI and secundum ASD size by TEE (n=30).**

The scatter diagram in Figure 2 shows a positive correlation between RVOT-VTI and ASD size measured by TTE (r=0.271, p<0.147).

This scatter diagram in Figure 3 shows a positive correlation between RVOT-VTI and secundum ASD size measured by TEE (r=0.303, p<0.271).

**Table 4: Correlation between RVOT-VTI and secundum ASD Size (n=30).**

| Independent variable (X) | Dependent variable (Y) | Correlation coefficient (r) | Significance (p value) |
|---|---|---|---|
| **RVOT-VTI in TTE** | ASD size by TTE | 0.271 | < 0.147 |
| **RVOT-VTI in TTE** | ASD size by TEE | 0.303 | < 0.104 |

The Table 4 shows the correlation between RVOT VTI (measured via TTE) and the size of secundum ASD as measured by both TTE and TEE. A positive correlation was observed in both cases- between RVOT VTI and ASD size measured by TTE (r=0.271, p<0.147), and between RVOT VTI and ASD size measured by TEE (r=0.303, p<0.104). Although these correlations suggest a trend toward increasing VTI with larger ASD size, they did not reach statistical significance.

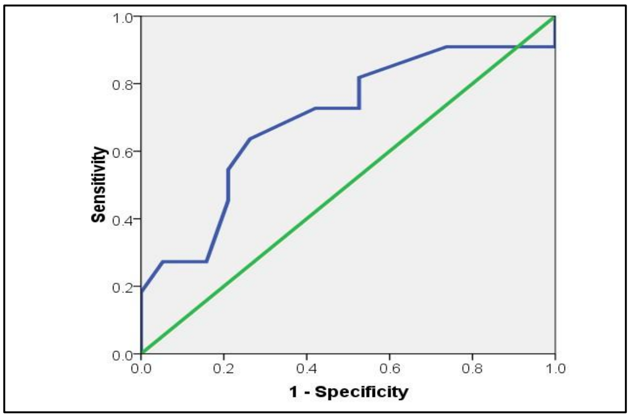


**Figure 4: The ROC curve analysis for differentiating large from small-medium sized secundum ASDs measured by TEE (n=30).**

The Figure 4 shows the accuracy of RVOT-VTI in differentiating large from small to moderate secundum ASDs; an optimum cut-off value was determined via ROC curve analysis. The best cut-off value for RVOT-VTI that maintained moderate sensitivity while preserving specificity was determined to be 19, with an area under the curve of 0.696 (95% CI=0.489-0.903, p=0.078).

The Figure 5 shows the accuracy of RVOT-VTI in differentiating between moderate to large secundum ASDs from small; an optimum cut-off value was determined via ROC curve analysis. The best cut-off value for RVOT-VTI that maintained high sensitivity while preserving optimal specificity was determined to be 15, with an area under the curve of 0.920 (95% CI=0.819-1.000, p=0.019).

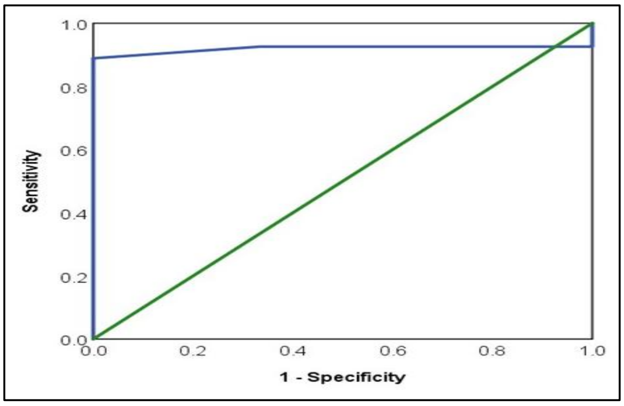


**Figure 5: The ROC curve analysis for differentiating large and moderate from small-sized secundum ASDs measured by TEE (n=30).**

This table shows the diagnostic performance of RVOT VTI (measured by TTE) for differentiating ASDs according to size (measured by TEE). The sensitivity of RVOT VTI at a cut-off value of 19 cm was 81.8%; however, its specificity was 47.2%, with a positive predictive value (PPV) of 47%, negative predictive value (NPV) of 81% and accuracy of 60%. The sensitivity of RVOT VTI at a cut-off value of 15 cm is 96%, specificity of 75%, with a positive predictive value (PPV) of 96%, negative predictive value (NPV) of 75% and accuracy of 93.3%.

**Table 5: Accuracy of RVOT-VTI in differentiating secundum ASDs according to size (n=30).**

| RVOT VTI (cm) | ASD group compared | ASD cases | SEN (%) | SPE (%) | PPV (%) | NPV (%) | Accuracy (%) |
|---|---|---|---|---|---|---|---|
| **>19** | Large (n=11) versus small-moderate (n=19) | 9 / 11 | 81.8 | 47.4 | 47 | 81 | 60.0 |
| **≤19** | | 2 / 11 | – | – | – | – | – |
| **>15** | Moderate-large (n=26) versus small (n=4) | 25 / 26 | 96.0 | 75.0 | 96 | 75 | 93.3 |
| **≤15** | | 1 / 26 | – | – | – | – | – |

## DISCUSSION

The mean age of the study population was 14.3±3.4 years, with a range from 5 to 18 years. The mean body weight of the studied children was 41.5±11.5 kg, range 17.0-61.0 kg; mean height was 148.3±12.3 cm, range 110-167 cm; and mean body surface area (BSA) was 1.27±0.24 $m^2$, range 0.70-1.61 $m^2$. Female preponderance is seen in the study, which includes females 21 (70%) and males 9 (30%) with a female: male ratio of 2.3:1. This is probably due to the overall known female: male ratio for secundum ASD is 2:1.[16] Symptomatology of the study cohort includes palpitation (60%), followed by chest pain (36.7%) as the predominant symptom. Recurrent RTI was present in 26.7% children. In this study, breathing difficulty was present in 23.3% and poor feeding was present in 20% patients. Only 3.3% patients had feeding difficulty, which was evident by suck pause suck cycle. Palpitation and chest pain were found in the older age group, most probably due to dilatation of the right-sided chamber. A retrospective study was conducted in 74 ASD patients, in which the most prominent presenting features were shortness of breath (70.3%), chest pain (43.2%), and palpitations (33.8%).[17] Most of the patients, 18(60%), had RVOT VTI of >20 cm, followed by between 15-20 cm in 08 (26.6%) and <15 cm in 04 (13.3%) patients. This finding correlates with the size of the secundum ASD. ASD was classified as small <10 mm, moderate (10-20 mm), and large (>20 mm). Similarly classified by another author.[18] In this study, TTE classified 50% of the children with moderate ASDs, while 43.3% were classified with large ASDs, and only 6.7% with small ASDs. In contrast, TEE identified 36.7% as having large ASDs, 50% as moderate, and 13.3% as small ASDs. If the ASD was >10 mm by TTE, a positive correlation was likely found between the RVOT-VTI (measured by TTE) and the ASD size measured by TTE (r=0.271, p<0.147) and TEE (r=0.303, p<0.104). An optimum cut-off value was determined via the Receiver operating characteristic (ROC) curve analysis. The best cut-off value for RVOT-VTI that maintained moderate sensitivity while preserving specificity in differentiating large from small to moderate was determined to be 19, with an area under the curve of 0.696 (95% CI=0.489-0.903, p=0.078). This indicates that almost 70% of large ASDs could be accurately diagnosed with RVOT-VTI values greater than 19 cm in children diagnosed with ASDs by TEE, with an accuracy of 60%. The accuracy of RVOT-VTI in distinguishing moderate to large from small ASDs measured by TEE was also assessed. The sensitivity of RVOT-VTI at a cut-off value of 15 for differentiating moderate-to-large ASDs from smaller sizes was calculated to be 92.6%, yielding a specificity of 66.7%. The positive predictive value was 96%, while the negative predictive value stood at 75%. The overall diagnostic accuracy was calculated to be 93.3%. A similar study by Denenberg et al showed that RVOT VTI at 21 cm is the cut-off value with the best sensitivity (72.6%) and specificity (76.8%) for the diagnosis of a significant shunt lesion.[12] The AUC was 0.819 (95% CI 0.776-0.862). Finally, at a cut-off value of 19, RVOT-VTI demonstrated a sensitivity of 81.8% in differentiating large ASDs from small to medium sizes in TEE while exhibiting a specificity of 47.4% for excluding individuals without large ASDs. The positive predictive value (PPV) was calculated to be 47.4%, indicating that identified cases indeed had large ASDs, whereas the negative predictive value (NPV) was 81%, reflecting the probability that those identified as not having large ASDs were accurately identified. The accuracy of RVOT-VTI in distinguishing moderate to large from small ASDs measured by TEE was assessed. The sensitivity of RVOT-VTI at a cut-off value of 15 based on the ROC curve for differentiating moderate-to-large ASDs from smaller sizes was calculated to be 92.6%, yielding a specificity of 66.7%. The positive predictive value was 96%, while the negative predictive value stood at 75% reflecting the probability that those identified as not having moderate to large ASDs were accurately classified. The accuracy of RVOT-VTI in distinguishing moderate-large from small secundum ASDs measured by TEE was calculated to be 93.3% and distinguishing large from small to moderate was 60%.

The study was conducted in a single hospital with a small sample size. So, the results may not represent the whole community.

## CONCLUSION

This study emphasizes the utility of RVOT VTI as a potentially valuable non-invasive tool for predicting the size of secundum ASDs in children. It can predict the size of the secundum ASD, whether it is small or moderate, or large. At the cut-off value of 19 cm, RVOT VTI can differentiate large secundum ASDs from small to moderate with an accuracy of 60%. At the cutoff value of 15 cm, it can differentiate moderate to large from small-sized ASDs with an accuracy of 93.3%.

### *Recommendations*

Based on the findings of this study, it is recommended that RVOT VTI measurement by transthoracic echocardiography be considered as a supportive, non-invasive screening tool in the preliminary evaluation of children with suspected secundum ASDs. Given its higher accuracy (93.3%) at the 15 cm cut-off for identifying moderate-to-large defects, clinicians may utilize this parameter to prioritize further assessment with TEE or plan for timely intervention. However, due to its lower specificity at the 19 cm cut-off, RVOT VTI should be used in conjunction with other echocardiographic parameters rather than as a standalone diagnostic tool.

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