Cardiology in the Young

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Comparison of post-operative transesophageal and transthoracic echocardiogram findings following atrioventricular septal defect repair

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Brief Report

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Abstract

Success of atrioventricular septal defect repair is defined by post-operative atrioventricular valve function and presence of residual intracardiac shunting. We evaluated differences in interpretation of atrioventricular valve function and residual defects between transesophageal and transthoracic echocardiography in a contemporary cohort of infants undergoing atrioventricular septal defect repair. Among 106 patients, we identified an increase in left and right atrioventricular valve regurgitation, right atrioventricular valve inflow gradient, and increased detection rate of residual intracardiac shunting on transthoracic compared to transesophageal echocardiograms, although residual shunts identified only on transthoracic echocardiogram were not haemodynamically significant. Findings may help inform expectation of post-operative transthoracic echocardiogram findings based on intraoperative assessment.

Success after atrioventricular septal defect repair depends on the degree of stenosis or regurgitation of the atrioventricular valves and residual intracardiac shunting with function of the left atrioventricular valve being an independent risk factor for re-operation.[1–4] Intraoperative transesophageal echocardiography provides this information before the patient leaves the operating room. However, changes in haemodynamic states and technical factors may lead to differences in findings and interpretation of the intraoperative transesophageal echocardiogram and post-operative transthoracic echocardiogram. Understanding the expected changes in valve function is valuable to help inform decision to return to cardiopulmonary bypass to address residual lesions. Current literature addressing this question is conflicted; some studies have shown worsening of atrioventricular valve regurgitation on post-operative transthoracic echocardiogram[2] while others have not shown any predictive capacity of intraoperative transesophageal echocardiogram on post-operative transthoracic echocardiogram.[5–6] Additionally, expected change in inflow gradients of the atrioventricular valves has not been reported on. We sought to evaluate changes in interpretation of valve function and detection of residual lesions that occur between post-operative transesophageal and transthoracic echocardiograms among a contemporary cohort of children undergoing atrioventricular septal defect repair.

Methods

The Children's Healthcare of Atlanta IRB approved this retrospective study. We identified patients who underwent two-ventricle atrioventricular septal defect repair at 0-12 months old from 2018–2022. Complete, intermediate, and partial balanced atrioventricular septal defects were included. Patients with left-sided obstructive lesions, unbalanced or initial single ventricle palliations, and those with inadequate imaging were excluded. Echocardiograms were retrospectively reviewed for all patients and the study team measured atrioventricular valve mean inflow gradients from midesophageal and four-chamber views on transesophageal and transthoracic echocardiograms respectively. Angle correction for Doppler interrogation is not used routinely at our institution. Transesophageal imaging following the final cardiopulmonary bypass run was used if multiple runs were undertaken. Our centre routinely obtains a complete post-operative transthoracic echocardiogram within the week following the operation; this complete study was examined if multiple post-operative studies were obtained.

A single study team member blinded to both the clinical outcomes and grade of atrioventricular valve regurgitation on prior studies reviewed all studies to subjectively grade the degree of atrioventricular valve regurgitation. A secondary team member reviewed 50 total transthoracic and transesophageal studies for interrater reliability assessment. Additionally, to obtain a centre-wide experience, degree of atrioventricular valve regurgitation was obtained from the echocardiogram report. A regurgitation score was created by converting degree of

Table 1. Comparisons of post-operative transesophageal and transthoracic echocardiogram variables

	TEE	TTE	*p*
Physiologic data			
Heart rate (beats per minute)	136 ± 15	135 ± 20	0.44
Systolic blood pressure (mmHg) ($N = 104$)	75 ± 12	87 ± 13	<0.001
Diastolic blood pressure (mmHg) ($N = 104$)	42 ± 7	53 ± 11	<0.001
Haematocrit (%)	37.4 ± 3.5	41.2 ± 5.4	<0.001
Systolic function			
Left ventricular systolic function normal	87/106 (82.1%)	94/106 (88.7%)	0.19
Right ventricular systolic function normal	94/106 (88.7%)	83/106 (78.3%)	0.08
Left AVV function			
Inflow gradient (mmHg) ($N = 105$)	3.1 ± 2.1	3.4 ± 1.9	0.25
Blinded regurgitation score[a,b]	1.7 ± 0.8	2.1 ± 1.2	<0.001
Centre-wide regurgitation score[c]	1.8 ± 0.9	2.0 ± 1.1	0.05
Blinded ≥ moderate regurgitation	3/106 (2.8%)	15/106 (14.2%)	<0.001
Centre-wide ≥ moderate regurgitation	3/106 (5.7%)	12/106 (11.3%)	0.21
Right AVV function			
Inflow gradient (mmHg) ($N = 68$)	1.8 ± 1.0	2.3 ± 1.5	0.01
Blinded regurgitation score[a,b]	1.5 ± 0.7	2.0 ± 1.0	<0.001
Centre-wide regurgitation score[c]	1.7 ± 0.8	2.0 ± 1.0	0.004
Blinded ≥ moderate regurgitation	2/106 (1.9%)	10/106 (9.4%)	0.02
Centre-wide ≥ moderate regurgitation	3/106 (2.8%)	12/106 (11.3%)	0.02

Data are reported as mean ± standard deviation for continuous variables unless otherwise noted and *N* (%) for categorical variables. $N = 106$ for each group unless otherwise noted.
TEE = transesophageal echocardiogram; TTE = transthoracic echocardiogram; AVV = atrioventricular valve.
[a]AVV regurgitation was scored using a scale of 1-6 where 1 = none, 2 = mild, 3 = mild to moderate, 4 = moderate, 5 = moderate to severe, 6 = severe AVV regurgitation. AVV regurgitation scores are presented as mean ± standard deviation.
[b]Blinded regurgitation score is derived from blinded, retrospective analysis of images.
[c]Centre-wide regurgitation score is derived using the determinations of degrees of AVV regurgitation tabulated from clinical reports.

regurgitation to a numeric scale of 1-6 with 1 being no regurgitation and 6 being severe. Identification rate and size of residual shunting lesions were compared between modalities. Continuous data were compared using a paired *t*-test or the Wilcoxon rank-sum test. Categorical data were compared using McNemar rank-sum test. Interrater variability between assessment of moderate or greater atrioventricular valve regurgitation was assessed using Cohen's kappa. A *p*-value <0.05 was considered significant. Statistical analysis was completed using IBM SPSS Statistics version 28.0.0.0.

Results

106 patients were included; 43 (40.6%) of whom were male. Ninety-two (86.8%) patients had trisomy 21. Ninety-three (88%) had complete atrioventricular septal defect, while 11 (10%) had partial and 2 (2%) had transitional defects. The mean age at the time of surgery was 160 ± 45 days with a mean weight of 5.34 ± 1.01 kg. Transthoracic echocardiogram was completed at median of 3 days after surgery.

Qualitative assessments of left and right atrioventricular valve regurgitation were present in all reports. Heart rates were not significantly different between transesophageal and transthoracic echocardiograms, but blood pressure and haematocrit were higher at the time of transthoracic echocardiogram (Table 1). Mean left atrioventricular valve inflow gradient did not change significantly while there was an increase in the right atrioventricular valve inflow mean gradient from transesophageal to transthoracic echocardiogram. On both reviews of blinded atrioventricular valve scoring and centre-wide experience, the left and right atrioventricular valve regurgitation increased from transesophageal to transthoracic imaging with a higher proportion of patients with moderate or greater left and right atrioventricular valve regurgitation on transthoracic compared to transesophageal imaging on blinded analysis (Table 1, Figure 1A, 1C). Blinded analysis is demonstrated in Figure 1. When individual patients were analysed, most atrioventricular valve regurgitation scores were the same, or increased or decreased by one category from transesophageal to transthoracic imaging (Figure 1B, 1D). A small portion of patients had a change by two or more categories, predominantly attributable to increased regurgitation. There were 12 (11%) and 1 (1%) patients with left (Figure 1B) and 10 (9%) and 1 (1%) patients with right atrioventricular valve regurgitation (Figure 1D) that increased or decreased by two or more categories, respectively.

There was moderate to substantial agreement for regurgitation assessment both between the blinded reader and the centre-wide experience ($k = 0.6$ and 0.7 for right atrioventricular valve transesophageal and transthoracic studies respectively and 0.7 and 0.7 for left atrioventricular valve transesophageal and transthoracic studies respectively). Between the two blinded readers, there was moderate agreement for left atrioventricular

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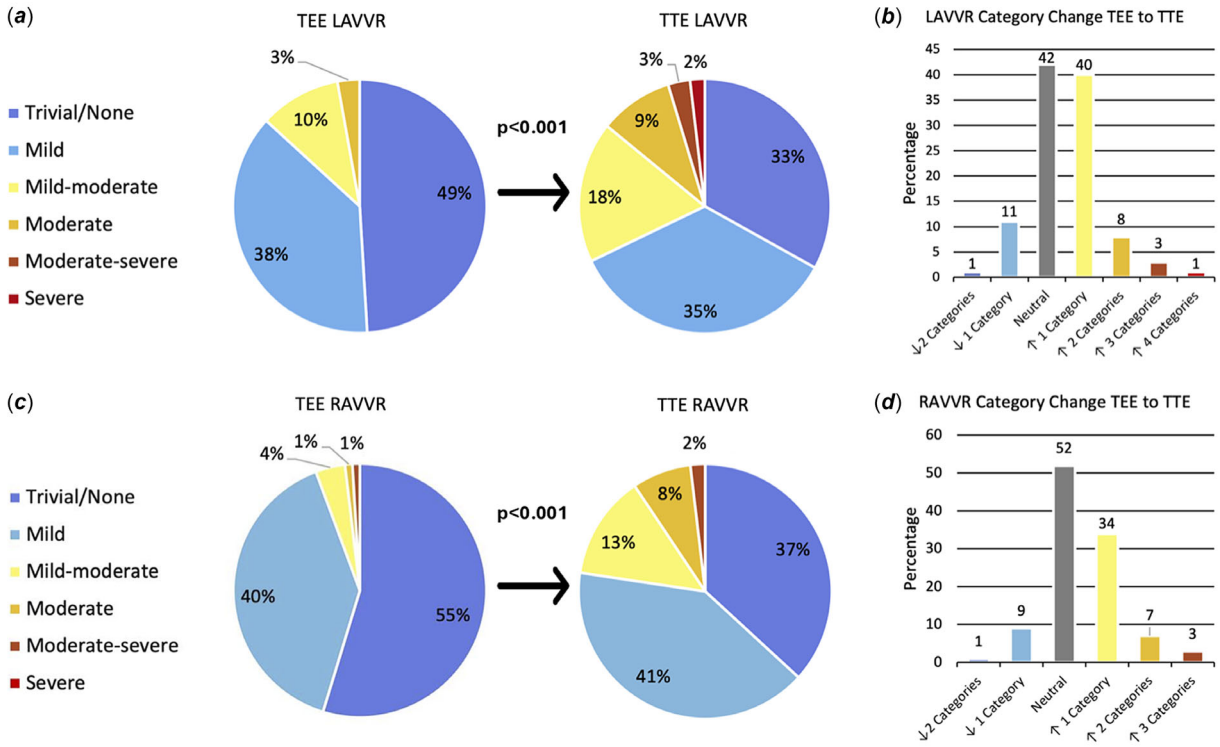

Figure 1. Comparison of atrioventricular valve regurgitation between transthoracic and transesophageal echocardiogram (Blinded analysis). Key: TEE = transesophageal echocardiogram; TTE = transthoracic echocardiogram; RAVVR = right atrioventricular valve regurgitation; LAVVR = left atrioventricular valve regurgitation.

valve regurgitation ($k = 0.4$ and 0.5 on transthoracic and transesophageal echocardiograms respectively) with 96% agreement on greater than moderate atrioventricular valve regurgitation across all studies. In regard to right atrioventricular valve regurgitation on transthoracic echocardiogram, there was moderate agreement amongst the two blinded readers ($k = 0.6$). On transesophageal echocardiogram, there was 100% agreement in scores using a cut-off of moderate or greater; hence kappa was unable to be calculated.

Out of the 15 patients with moderate or greater left atrioventricular valve regurgitation on transthoracic echocardiogram, 10 progressed clinically and did not need any additional medical or surgical management, 1 needed medical management for depressed function and subsequently improved, and 4 were brought back to the operating room. Of those patients who did get re-operation on the left atrioventricular valve, the sutures in the cleft were intact but there was either a secondary cleft that was repaired or in one case there was a tear in the leaflet remote from the original cleft closure.

There were 30 (28.3%) patients in whom a residual ventricular shunt and 13 (12.2%) in whom an atrial shunt was identified on transthoracic but not transesophageal echocardiogram. All intracardiac shunts identified only on transthoracic echocardiogram were trivial or small and there were no patients in whom the defect was characterised in a larger size category than that assigned from transesophageal echocardiogram.

Discussion

Knowledge of the expected differences in atrioventricular valve function and detection rate for residual intracardiac shunts from transesophageal to transthoracic echocardiogram can help inform intraoperative decision-making. We report changes in assessment of atrioventricular valve function and detection rate for residual lesions between transesophageal and transthoracic echocardiogram. Although subtle, these differences can serve as a roadmap of expectation for patients' post-operative imaging findings and could influence decision-making to return to cardiopulmonary bypass when initial intraoperative transesophageal imaging identifies borderline atrioventricular valve function.

In our cohort, the left atrioventricular valve inflow gradient was similar between transthoracic and transesophageal echocardiogram, whereas there was a mild increase in the right atrioventricular valve inflow gradient despite a higher haematocrit at the time of transthoracic echocardiogram. Our findings can bolster confidence that assessment of left atrioventricular valve stenosis is similar between transesophageal and transthoracic echocardiogram despite technical differences between modalities and changes in haemodynamic conditions. Conversely, the increase in right atrioventricular valve inflow gradient observed in our data is likely due to a poorer angle of Doppler interrogation on transesophageal echocardiogram. Using angle correct algorithms could overcome some of this inherent limitation, but the use of such algorithms is not typically recommended, and we suspect that our practice of interrogation of the right atrioventricular valve inflow gradient by continuous wave Doppler without angle correction is consistent with most other centres. Although statistically significant, the absolute increase in inflow gradient was small and right atrioventricular valve dysfunction constitutes a much less common indication for re-intervention following atrioventricular septal defect repair.[7] Amongst our cohort, there were no reoperations on the right atrioventricular valve to date.

There was increased left and right atrioventricular valve regurgitation from transesophageal to transthoracic imaging. Our findings are in alignment with the findings detailed by

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Honjo et al[2] although our data reflect a larger sample size. Systolic blood pressure was higher at the time of transthoracic study, and increase in left atrioventricular valve regurgitation could occur in part from increased afterload. The increase in right atrioventricular valve regurgitation may be less clinically important than the degree of left atrioventricular valve regurgitation as the latter can be a predictor for re-intervention.[1] Notably, left and right atrioventricular valve regurgitation increased both on blinded review of all imaging and when evaluating clinically reported scores with a larger magnitude of increase for both atrioventricular valves noted on blinded review. This could be due to a tendency to agree with the prior reader in clinical practice. Increase in left atrioventricular valve regurgitation to greater than moderate did result in re-operation in 4 out of 15 patients.

Notably, residual shunting was more frequently identified on transthoracic echocardiogram compared to transesophageal echocardiogram. All residual shunts only identified on transthoracic imaging were haemodynamically insignificant. These data suggest that transesophageal echocardiogram in the modern era is a strong post-operative checkpoint with adequate sensitivity to detect haemodynamically significant intracardiac shunts and is consistent with a prior study by Hanna, et al.[8] This residual shunting only detected on transthoracic imaging is likely due to increased available imaging planes and time for completion of the study compared to intraoperative transesophageal studies.

Limitations of this study include the expected limitations of single-centre retrospective studies. A continuous wave Doppler through the right atrioventricular valve for inflow gradient was not available on transesophageal echocardiogram for all patients, although was present often enough to allow meaningful analysis. Given the subjective nature of atrioventricular valve regurgitation assessment in paediatric echocardiography, we collected both data from the reports to capture a centre-wide experience and completed blinded review of all echocardiograms with an assessment of interrater variability. Interrater agreement was modest, as expected given inherent subjectivity in regurgitation assessment, although consistent increases in mean regurgitation scores by both blinded review and clinical reports help bolster confidence in findings.

In conclusion, we report changes in findings and interpretation from transesophageal to transthoracic echocardiogram following atrioventricular septal defect repair, which may help inform expectations for post-operative imaging. Future investigation may seek to help establish a relationship between post-operative transesophageal findings and clinical outcomes.

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