The impact of surgical repair on left ventricular outflow tract in atrioventricular septal defect with common atrioventricular valve orifice

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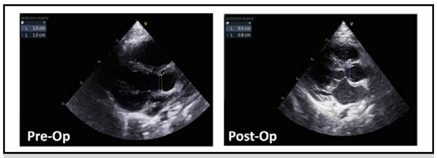
ABSTRACT

Objective: Although a narrow left ventricular outflow tract in atrioventricular septal defect is related to its intrinsic morphology, the contribution from the repair technique remains to be quantified.

Methods: A total of 108 patients with an atrioventricular septal defect with a common atrioventricular valve orifice were divided into 2 groups: 2-patch (N = 67) and modified 1-patch (N = 41) repair. The left ventricular outflow tract morphometric was analyzed by quantifying the degree of disproportion between subaortic and aortic annular dimensions (disproportionate morphometrics ratio was defined as ≤ 0.9). Z-scores (median, interquartile range) were further analyzed in a subset of 80 patients with immediate preoperative and postoperative echocardiography. A total of 44 subjects with ventricular septal defects served as controls.

Results: Before repair, 13 patients (12%) with an atrioventricular septal defect had disproportionate morphometrics (vs 6 [14%] ventricular septal defect $P = .79$), but the subaortic Z-score (−0.53, −1.07 to 0.06) was lower than the ventricular septal defect (0.07, −0.57 to 1.17; $P < .001$). After repair, both 2-patch (8 [12%] preoperatively vs 25 [37%] postoperatively; $P = .001$) and modified 1-patch (5 [12%] vs 21 [51%], $P < .001$) procedures showed a greater degree of disproportionate morphometrics. Both 2-patch (postoperatively −0.73, −1.56 to 0.08 vs preoperatively −0.43, −0.98 to 0.28; $P = .011$) and modified 1-patch (−1.42, −2.63 to −0.78 vs −0.70, −1.18 to −0.25; $P = .001$) procedures also demonstrated lower subaortic Z-scores postrepair. The postrepair subaortic Z-scores were lower in the modified 1-patch group (−1.42 [−2.63 to −0.78]) compared with the 2-patch group (−0.73 [−1.56 to 0.08]; $P = .004$). Low postrepair subaortic Z-scores (<−2) were observed in 12 patients (41%) in the modified 1-patch group and 6 patients (12%) in the 2-patch group ($P = .004$).

Conclusions: Surgical correction resulted in greater disproportionate morphometrics seen immediately postrepair. The impact on the left ventricular outflow tract was observed in all repair techniques, with a greater burden seen after modified 1-patch repair. (JTCVS Open 2023;14:385-95)



Surgical repair further altered LVOT morphometrics in AVSD with a complete AV valve orifice.

CENTRAL MESSAGE

Our findings suggest that surgical repair has a further effect on the LVOT in AVSD with a common AV valve orifice, adding to the burden on a native outflow tract that is already intrinsically narrow.

PERSPECTIVE

Before repair, the majority of patients with AVSD had proportionate LVOT morphometry. After repair, there were greater disproportionate morphometry and lower subaortic Z-scores, with a greater burden seen after modified 1-patch repair. The LVOT in the control VSD group was unaffected by surgical repair. The clinical implications from this morphometric study remain to be further evaluated.

See Commentary on page 396.

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Abbreviations and Acronyms

AV = atrioventricular
AVSD = atrioventricular septal defect
CI = confidence interval
IQR = interquartile range
LV = left ventricular
LVOT = left ventricular outflow tract
VSD = ventricular septal defect

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A satisfactory long-term survival of 80% to 90% at 15 to 20 years has been reported after atrioventricular septal defect (AVSD) repair.[1,2] Although contemporary early surgical outcome is excellent with a mortality risk of approximately 3%, the need for reintervention subjects patients to late mortality risk.[1,3] Therefore, a continual quest to reduce the need of late reinterventions is necessary. One of these important late issues after repair is left ventricular outflow tract (LVOT) obstruction in AVSD, and its mechanism is still poorly understood beyond goose-neck deformity. Relief of obstruction can be challenging because of the mechanism that is often multifactorial and complex, and its recurrent nature. Also, surgical relief of obstruction can be suboptimal.

The presence of the common atrioventricular (AV) junction displaces the aortic valve anteriorly and contributes to the elongation of the outflow tract. The morphological characteristics of AVSD along with additional intrinsic anatomic factors, such as attachment of superior bridging leaflet in the outflow tract, have been shown to contribute to a narrow subaortic area.[4-12] Quantitative assessments from various groups, including ours, further demonstrate abnormal morphometrics of the LVOT.[8,13,14] Our previous findings showed that the left ventricular (LV) outflow is not just narrow, as classically described, but there is significant disproportion between the subaortic and aortic annulus areas with a high prevalence early postrepair. This study further clarifies the influence of surgical repair on LVOT in AVSD with a common AV valve orifice.

PATIENTS AND METHODS

This study was based at the Royal Hospital for Children Glasgow, which serves as the Scottish Paediatric Cardiac Services for all regional National Health Service Scotland Health Boards.

Patients

All consecutive patients undergoing surgical repair for AVSD between January 2008 and November 2021 were identified from the institutional database (HeartSuite, Version 7.6.26). The diagnosis of complete AVSD was defined on the basis of Society of Thoracic Surgeons European Association for Cardiothoracic Surgery Congenital Heart Surgery Nomenclature and Database Project criteria, that is, the presence of a common atrioventricular junction with the common AV valve orifice.[15,16] A total of 109 patients who fulfilled these criteria on preoperative echocardiography and intraoperative descriptions were reviewed. After excluding 1 subject who had suboptimal echocardiographic pictures, 108 patients with complete AVSD formed the study cohort and were divided into 2 groups: 2-patch ($n = 67$) and modified 1-patch ($n = 41$) repair. The study cohort had balanced ventricles without other major anomalies such as tetralogy of Fallot or double outlet right ventricle. Forty-four age- and weight-matched patients who underwent ventricular septal defect (VSD) repair without other major cardiac anomalies were included in the control group ($n = 44$) (Table 1).

Operative Techniques

In the 2-patch technique, the VSD was closed with fixed autologous pericardium or prosthetic patch material (Gore-Tex or bovine), and the ASD primum was closed with untreated autologous pericardium. In the modified single-patch technique, an untreated autologous pericardium was routinely used with multiple interrupted sutures from the ventricular septal crest to the bridging leaflets and then to the autologous pericardium as described by Nunn.[17] The left AV valve cleft was routinely repaired in all patients. Any accessory attachments to the LVOT were not routinely divided in any group. The native superior bridging leaflet was not usually divided in any repair.

Echocardiographic Analysis

LVOT morphometrics were analyzed using EchoPAC suite software (GE Healthcare) as described in our previous study:[14] (1) aortic valve (a, mm) annulus: the dimension taken from the hinge-to-hinge point of the nadirs of the aortic valve leaflets, that is, the echocardiographic aortic annulus; (2) subaortic area (s, mm) dimension: the narrowest point below the aortic annulus and above the left AV valve hinge point and subvalvular apparatus; and (3) subaortic/annulus ratio to quantify the degree of disproportion between these 2 areas. A disproportionate morphometrics ratio was defined as 0.9 or less.

Measurements were performed using echocardiographic images at the following time points: (1) preoperative echocardiography (median 5 days, interquartile range [IQR], 2-15 before AVSD repair) and (2) early postoperative echocardiography within 3 months postrepair (median 5 days, IQR, 1-11).

The mean of 3 repeated measurements was obtained from the long parasternal view that provided the most optimal measurement. Measurements were repeated by a second observer to obtain interobserver variability ($N = 47$). All observers were blinded to the AVSD repair technique.

Z-Scores Analysis

The Z-scores for the above measurements were obtained in a subset of 80 patients with AVSD with immediate preoperative (median 3 days, IQR,

TABLE 1. Basic demographic and clinical details between atrioventricular septal defect and control cohorts in 2-patch and modified single-patch repair

No. of patients	AVSD 108	VSD 44	P value	Difference (95% CI)
Gender (female) (N, %)	67 (62.0%)	22 (50.0%)	.18	0.12 (−0.05 to 0.29)
Age (months) at repair (median, IQR)	4.18 (3.26-5.35)	3.20 (2.54-4.68)	.028	0.70 (0.07-1.30)
Weight (kg) at repair (median, IQR)	4.79 (4.13-5.46)	4.68 (3.87-5.70)	.55	0.12 (−0.30 to 0.54)
Trisomy 21 (N, %)	85 (78.7%)	5 (11.4%)	<.001	0.67 (0.55-0.79)
Previous cardiac surgery (N, %)	7 (6.5%)	0 (0%)	.006	0.06 (0.02-0.11)
Early (30-d) mortality (N, %)	3 (2.8%)	0 (0%)	.08	0.03 (−0.003 to 0.059)
No. of patients	**2-patch 67**	**Modified single-patch 41**	***P* value**	**Difference (95% CI)**
Gender (female) (N, %)	39 (58.2%)	28 (68%)	.29	−0.10 (−0.29 to 0.08)
Age (months) at repair (median, IQR)	4.17 (3.20-5.27)	4.37 (3.30-5.50)	.38	−0.27 (−0.93 to 0.37)
Weight (kg) at repair (median, IQR)	4.75 (4.18-5.30)	4.85 (4.00-5.75)	.26	−0.23 (−0.65 to 0.20)
Trisomy 21 (N, %)	56 (83.6%)	29 (71%)	.13	0.13 (−0.04 to 0.29)
Previous cardiac surgery (N, %)	4 (6.0%)	3 (7.3%)	.79	−0.01 (−0.11 to 0.08)
Pulmonary artery band (N, %)	2 (3.0%)	1 (2.4%)	.86	0.01 (−0.06 to 0.07)
Coarctation repair (N, %)	2 (3.0%)	2 (4.9%)	.63	−0.02 (−0.10 to 0.06)
Other surgery	0 (0%)	0 (0%)	1.00	0.00 (0.00-0.00)
Early (30-d) mortality (N, %)	2 (3.0%)	1 (2.4%)	.86	0.01 (−0.06 to 0.07)

AVSD, Atrioventricular septal defect; *VSD*, ventricular septal defect; *CI*, confidence interval; *IQR*, interquartile range.

1-8) and postoperative (median 5 days, IQR, 1-7) echocardiography within 21 days of surgery. These Z-scores were determined on the basis of the operative weight from an online calculator (Cardiac Valve Z-score, Parameter[z]) based on Cincinnati Children's Hospital data.[18] A low Z-score was defined as less than –2. In the absence of data for subaortic Z-scores, a 1:1 relationship of the aortic to the subaortic dimension was assumed.

Statistical Analysis

All statistical analyses were performed with Minitab software, version 18.1 (Minitab Inc) and SPSS Statistics (Release 27.0.0, IBM-SPSS Inc). Continuous variables were analyzed using the Mann–Whitney *U* test or Kruskal–Wallis test; categorical variables were analyzed using the Z-test for 2 proportions. Paired data sets were compared with the Wilcoxon signed-rank test or the McNemar test where appropriate. An intraclass correlation coefficient (r) for continuous variability was used to assess interobserver variability for measured parameters of aortic annulus and subaortic area, where r greater than 0.7 confirmed good reproducibility.[19]

RESULTS

Interobserver Variability

Interobserver variability for measured parameters was as follows: aortic annulus, r = 0.94 and subaortic area, r = 0.92.

Prerepair Morphometric Analysis

In both the AVSD group (n = 108) and VSD control group (n = 44), most patients maintained a 1:1 relationship between the aortic annulus and the subaortic area (median ratio 1.00 [1.00-1.00]; difference: 0.00, confidence interval [CI], 0.00-0.00, $P = .37$) before surgical repair. A total of 13 patients (12%) with AVSD had a disproportionate subaortic area: annulus morphometrics (vs 6, 14% in control, difference: −0.02, CI, −0.14 to 0.10, $P = .79$). However, when compared with VSD controls (n = 44), the AVSD group (n = 80) had lower z-scores at both the aortic annulus (median −0.46 vs 0.22; difference: −0.74, CI, –1.17 to −0.37, $P < .001$) and the subaortic areas (median −0.53 vs 0.07; difference: −0.75, CI, −1.17 to –0.37, $P < .001$) (Figure 1).

Presurgical Versus Postsurgical Repair Morphometrics in Atrioventricular Septal Defect and Ventricular Septal Defect

In the VSD group, paired analysis demonstrates that the majority of VSD control patients maintained a proportionate subaortic/aortic annulus dimensions postrepair (median ratio 1.00 vs 1.00 prerepair; median difference: 0.0004, CI, 0.00 to –0.03, $P = .18$) (Figure 2). There was a small percentage of patients with VSD with disproportionate subaortic/aortic annular dimensions postoperatively (8 [18%] vs 6 [14%] prerepair; difference: −0.045, CI, −0.19 to 0.10, $P = .73$).

In the AVSD group, paired analysis showed that more patients had significantly higher disproportionate

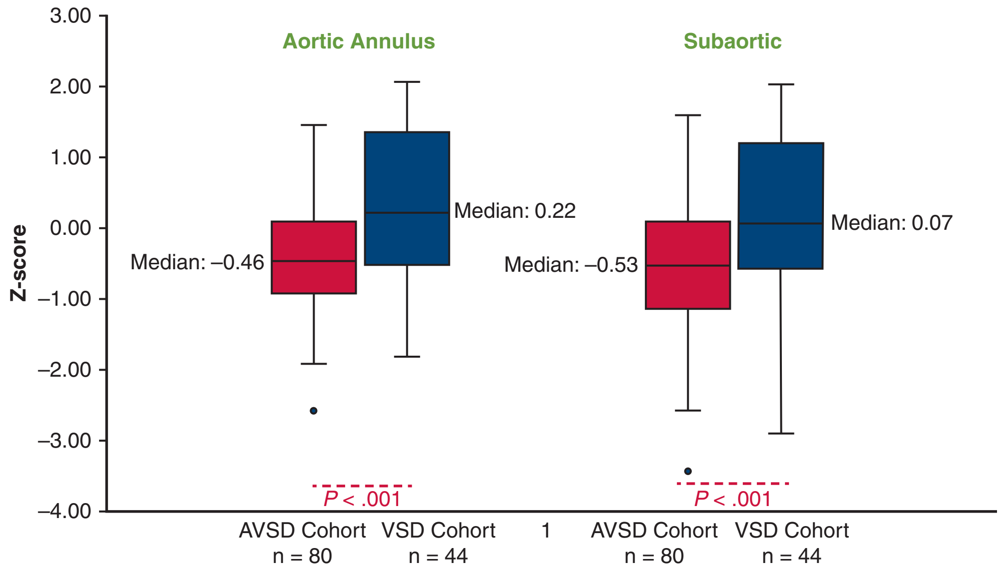

FIGURE 1. Prerepair, the median z-score of the aortic annulus is lower in the AVSD cohort compared with the VSD cohort (−0.46 vs 0.22; P < .001). The median z-score of the subaortic area is also lower in the AVSD cohort compared with the VSD cohort (−0.53 vs 0.07; P < .001). Box-and-whisker plot definition: *Lower* and *upper borders* of the box represent the *lower* and *upper* quartiles (25th percentile and 75th percentile, respectively). The *middle horizontal line* represents the median. The *lower* and *upper* whiskers represent the minimum and maximum values of nonoutliers. Extra *dots* represent outliers. *AVSD*, Atrioventricular septal defect; *VSD*, ventricular septal defect.

subaortic/aortic annular dimensions after surgical repair (median ratio 0.95 vs 1.00 prerepair; median difference: 0.06, CI, 0.04-0.08, P < .001) (Figure 2). A total of 46 patients with AVSD (43%) (vs 13 [12%] prerepair; difference: −0.31, CI, −0.42 to −0.19, P < .001) had disproportionate LVOT morphometrics postoperatively.

When compared with the VSD control cohort (n = 44), which had no significant difference in the postoperative subaortic z-score (median 0.03 vs 0.07 preoperatively; median difference: 0.00, CI, −0.13 to −0.31, P = .40), the AVSD group had significantly lower subaortic z-scores after surgical repair (median −0.92 vs −0.53 preoperatively; median difference: 0.53, CI, 0.29-0.81; P < .001) (Figure 2, *B*). There was no significant difference in the aortic annulus z-score post-AVSD repair (median −0.43 vs −0.46 prerepair; median difference 0.00, CI, −0.14 to 0.09; P = .56) or VSD repair (median 0.28 vs 0.22 prerepair; median difference 0.00; CI, −0.15 to 0.29; P = .83).

Although there were significant reductions in subaortic dimensions postoperatively in the AVSD cohort, a large proportion of patients still maintained an adequate z-score of greater than −2 (62 [78%] vs 75 [94%] prerepair; difference: −0.16; CI, −0.28 to −0.05; P = .004). However, most patients maintained adequate aortic annulus z-scores postoperatively with no statistical difference when compared with the prerepair cohort (99% vs 95% postrepair; P = .38). In comparison, patients in the VSD control cohort maintained subaortic z-scores of normal limits above −2 postrepair (41 [93%] vs 42 [95%] prerepair; estimated difference: −0.02, CI, −0.09 to −0.04, P = 1.00).

Prerepair Versus Postrepair Morphometrics in Atrioventricular Septal Defect Based on Repair Techniques

We analyzed the morphometric changes in each individual repair group. Postrepair, both the 2-patch (median 0.96 vs 1.00 prerepair; median difference: 0.05, CI, 0.02-0.07; P < .001) and modified single-patch technique (median 0.89 vs 1.00 prerepair; median difference: 0.07, CI, 0.04-0.14; P < .001) showed a greater degree of disproportionate subaortic/aortic annulus dimensions (Figure 3). In each group, more patients had disproportionate morphometrics postrepair: 8 (12%) preoperatively versus 25 (37%) (estimated difference: −0.25, CI, −0.40 to −0.11, P = .001) in the 2-patch group and 5 (12%) preoperatively versus 21 (51%) postoperatively (estimated difference: −0.39, CI, −0.59 to −0.19, P < .001) in the modified 1-patch group.

Lower median subaortic z-scores were observed after surgical repair in both the 2-patch cohort and modified single-patch cohort. When compared with prerepair z-scores, 6 patients (12%) had low subaortic z-scores after 2-patch repair (vs prerepair 2, 4%; P = .29) with lower median subaortic z-scores (−0.73, vs −0.43 prerepair; median difference: 0.36, CI, 0.00-0.58; P = .011) (Figure 4). In the modified single-patch cohort, 12 patients (41%) had low subaortic Z-score postrepair (vs preoperatively, 3 [10%]; P = .012) with lower median z-scores (−1.42 vs −0.70 prerepair; median difference: 0.86, CI, 0.33-1.47; P = .001) (Figure 4). There was no statistically significant difference in the aortic annulus z-scores postrepair in both 2-patch

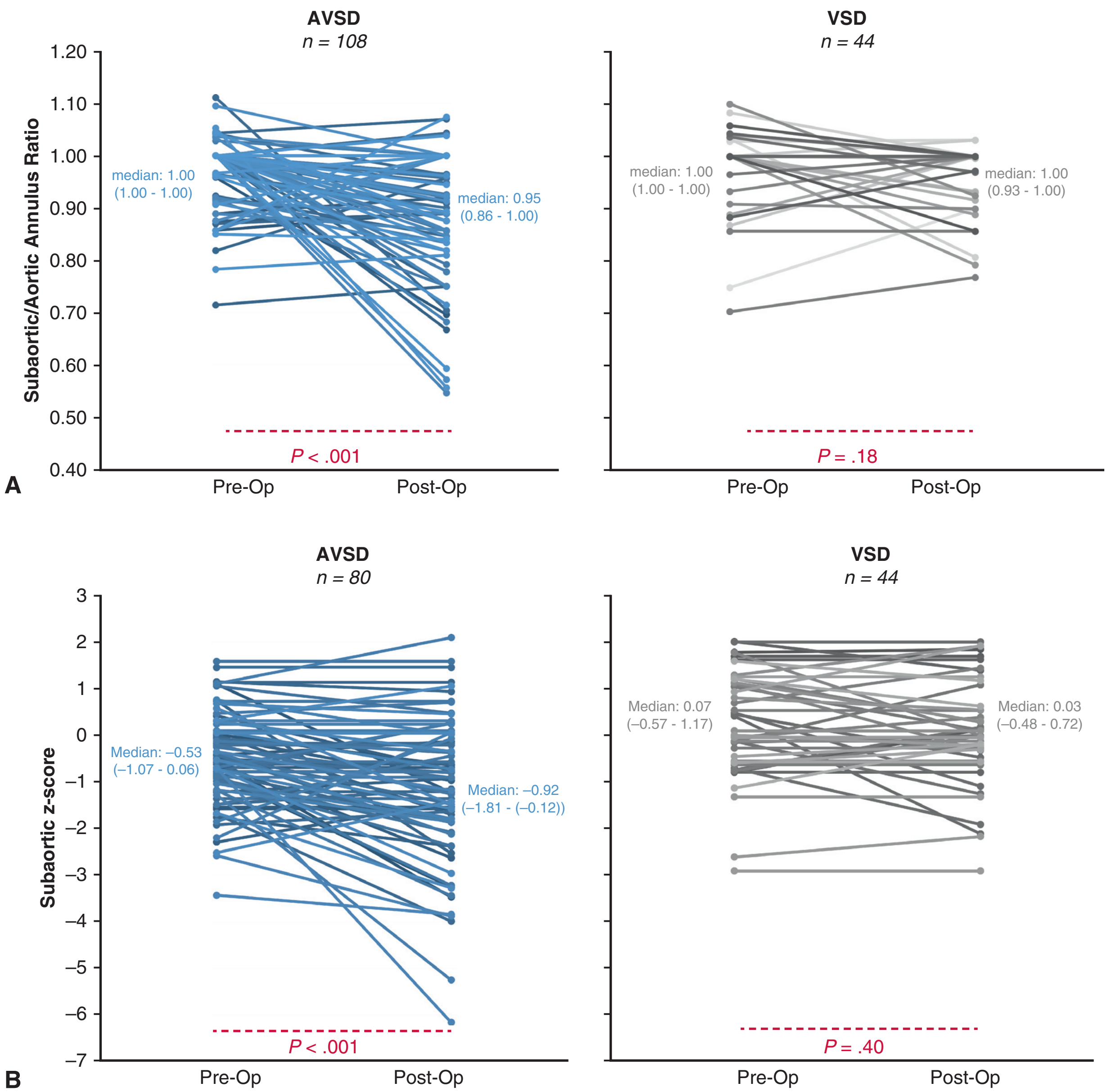

FIGURE 2. A, In paired analysis, more patients with AVSD had significantly higher disproportionate subaortic/aortic annular dimensions after surgical repair (median 0.95 vs 1.00 in VSD cohort; *P* < .001). B, The AVSD cohort (n = 80) had significantly *lower* subaortic z-scores after surgical repair (median −0.92 vs −0.53 preoperatively; *P* < .001). The VSD control cohort (n = 44) had no significant difference in the postoperative subaortic z-score (median 0.03 vs 0.07 preoperatively; *P* = .40). *AVSD*, Atrioventricular septal defect; *VSD*, ventricular septal defect.

(−0.22, vs −0.43 prerepair; *P* = .36) and modified single-patch techniques (−0.53 vs −0.57 prerepair; *P* = .94).

Postrepair Morphometric Analysis Between 2-Patch Versus Modified Single-Patch Technique

We assessed the influence of surgical technique on the LVOT morphometrics post-AVSD repair. The modified single-patch technique had lower subaortic z-scores postsurgical repair (−1.42, vs −0.73 2-patch technique; difference: 0.95 CI, 0.31-1.68; *P* = .004) (Figure 5). The number of patients with low postrepair subaortic Z-scores (<−2) was also higher in the modified single-patch cohort (12, 41% vs 6, 12% in 2-patch technique; difference −0.30; CI, −0.50 to −0.10; *P* = .004).

Left Ventricular Outflow Tract Obstruction

Reoperation to relieve LVOT obstruction was required in 4 patients (3.7%) at a mean of 6.8 years (range, 3.2-11.7) after the initial AVSD repair. Reoperation rates for LVOT obstruction were not significant between the surgical repair

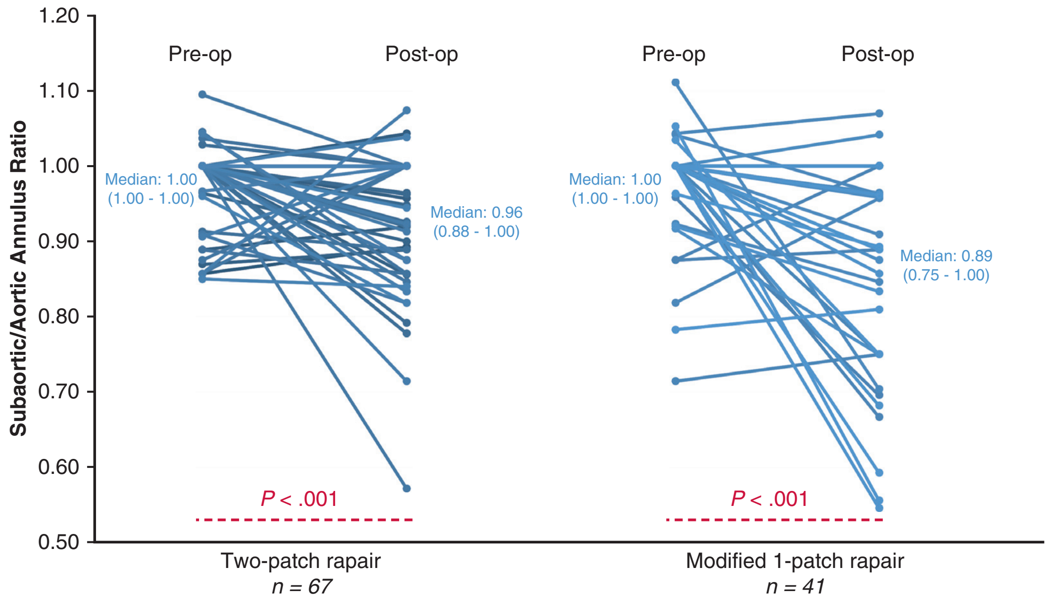

FIGURE 3. Postsurgical repair, there was a greater degree of disproportionate subaortic/aortic annulus dimensions in both the 2-patch technique (median 0.96 vs 1.00 prepair; $P < .001$) and modified single-patch techniques (median 0.89 vs 1.00 prepair; $P < .001$).

techniques (3, 4.5% 2-patch vs 1, 2.4% modified single-patch; $P = .56$).

DISCUSSION

Despite significant improvement of early postrepair mortality in the current era, the risk of reoperation persists long term with an impact on late survival.[1,3] This study provides morphometric evidence of impact from surgical repair on the LVOT in AVSD with a common atrioventricular valve orifice. Our previous study, which set out to define postrepair LVOT morphometrics, demonstrated a high prevalence of abnormal morphometrics in both complete and partial AVSD with subset analysis in complete AVSD showing an association between the repair technique and the LVOT morphometrics. This raised an important question of whether there were any impacts from surgical repair in addition to intrinsic anatomy alone, especially in patients with a common AV valve orifice.[14] The findings from this study

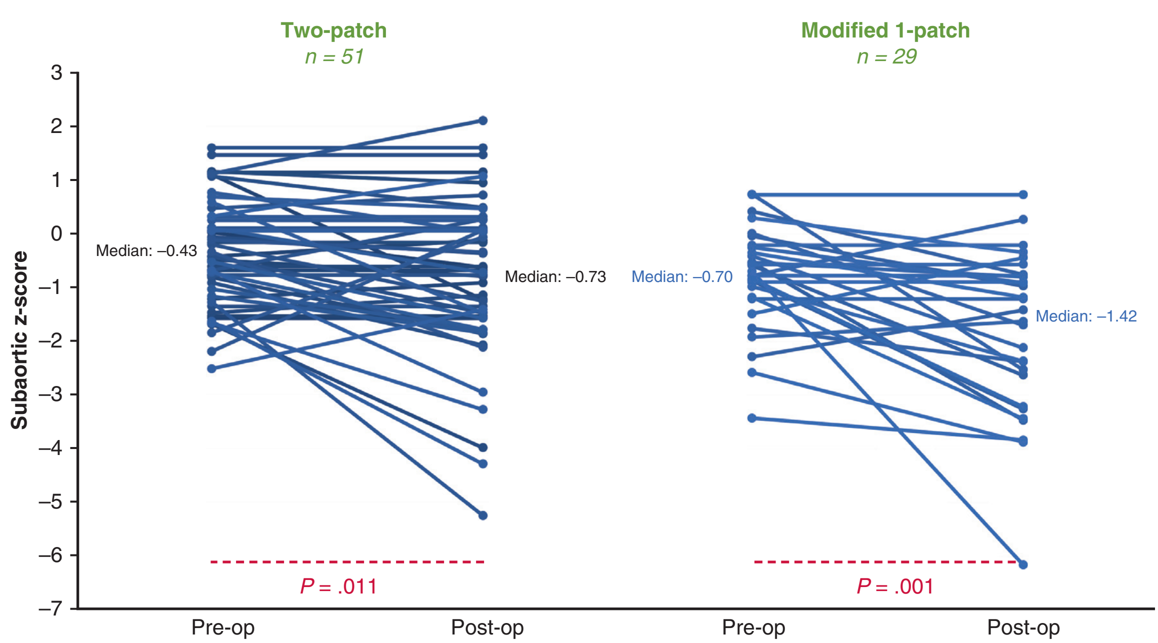

FIGURE 4. Lower median subaortic z-scores were observed after surgical repair in both the 2-patch cohort (−0.76 vs −0.46 prerepair; $P = .006$) and modified single-patch cohorts (−1.42 vs −0.70 prerepair; $P = .001$).

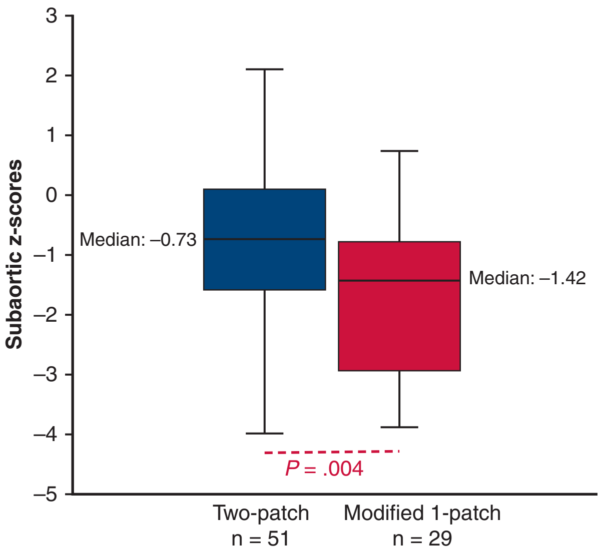

FIGURE 5. Postrepair subaortic z-scores were lower in the modified 1-patch cohort (−1.42 vs −0.76 in the 2-patch repair cohort; $P = 007$). Box-and-whisker plot definition: *Lower* and *upper borders* of the box represent the *lower* and *upper* quartiles (25th percentile and 75th percentile, respectively). The *middle horizontal line* represents the median. The *lower* and *upper* whiskers represent the minimum and maximum values of nonoutliers. Extra *dots* represent outliers.

concurred with the fact that the native LVOT is smaller in AVSD when compared with VSD before surgery; however, significant derangements of LV morphometrics were further observed immediately after repair for AVSD with a common AV valve orifice (Figure 6). The patients with VSD had preserved LV outflow morphometrics after surgery (Video Abstract).

The native outflow in the left heart of patients with AVSD is an area that fascinates morphologists and surgeons alike. An elongated long outflow tract may not necessarily result in a narrower subaortic area; therefore, additional intrinsic anatomic substrates must be present. These include the anterolateral muscle bundle, attachment of the superior bridging leaflet in the outflow tract, scooped out ventricular septum, and left deviation of the anterior ventricular septum.[3,11-16,18,20] These anatomic factors contribute to both elongated and narrow subaortic areas, which result from a complex multifactorial mechanism. Our morphometric analysis adds to the current understanding of the LVOT in AVSD as follows: (1) In addition to a narrower subaortic area, the aortic annulus in AVSD is also significantly smaller than in the control group; (2) the majority still maintain adequate Z-scores in aortic and subaortic areas; and (3) a proportionate relationship between aortic annulus and subaortic dimensions is maintained before repair. Unlike patients with congenital aortic valve disease or Shone's complex, a "smallish" aortic annulus is not a previously known feature associated with AVSD. The aortic annulus in AVSD is likely a reflection of its in utero developmental growth in proportion to its subaortic area. This may have an implication in the surgical approach for patients with AVSD who require aortic valve surgery later in life.

After repair, the subaortic-aortic areas became disproportionate in a significant number of patients, with a further decline in Z-scores primarily in the subaortic area, an observation that was made in the AVSD group only, but not in the VSD control group. There were approximately 10% of disproportionate LVOTs, whether AVSD or VSD prerepair, but affected 40% postrepair in AVSD. There was also a significant decrease in absolute subaortic dimensions and Z-score values after AVSD repair (Figure 7). Early LVOT obstruction is not normally seen postrepair. Presumably, more than three-quarters of the patients still maintained an adequate Z-score postrepair. In contrast, none of the patients with VSD had low Z-scores before or after surgery.

Although we showed an objective observation of increasing derangement of LVOT geometry post-AVSD repair, the precise mechanism remains speculative. It is possible that surgical repair results in either or both

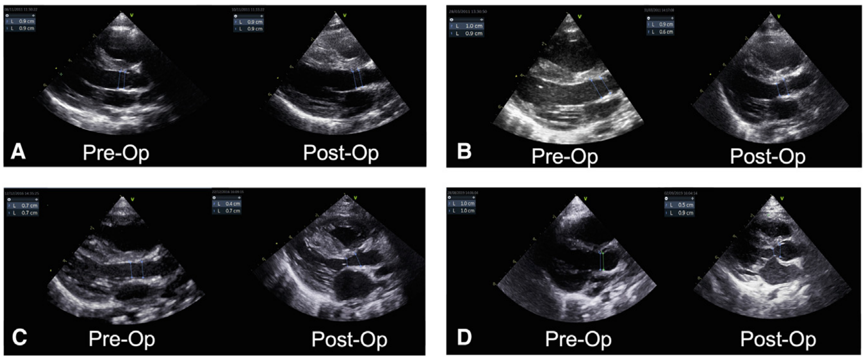

FIGURE 6. Examples of morphometric changes in the LVOT immediately after surgical repair in patients with AVSD. A, No change in LVOT morphometrics postsurgical repair. B, Mild degree of disproportionate LVOT morphometrics after surgical repair. C and D, More severe disproportionate LVOT morphometrics immediately after AVSD repair.

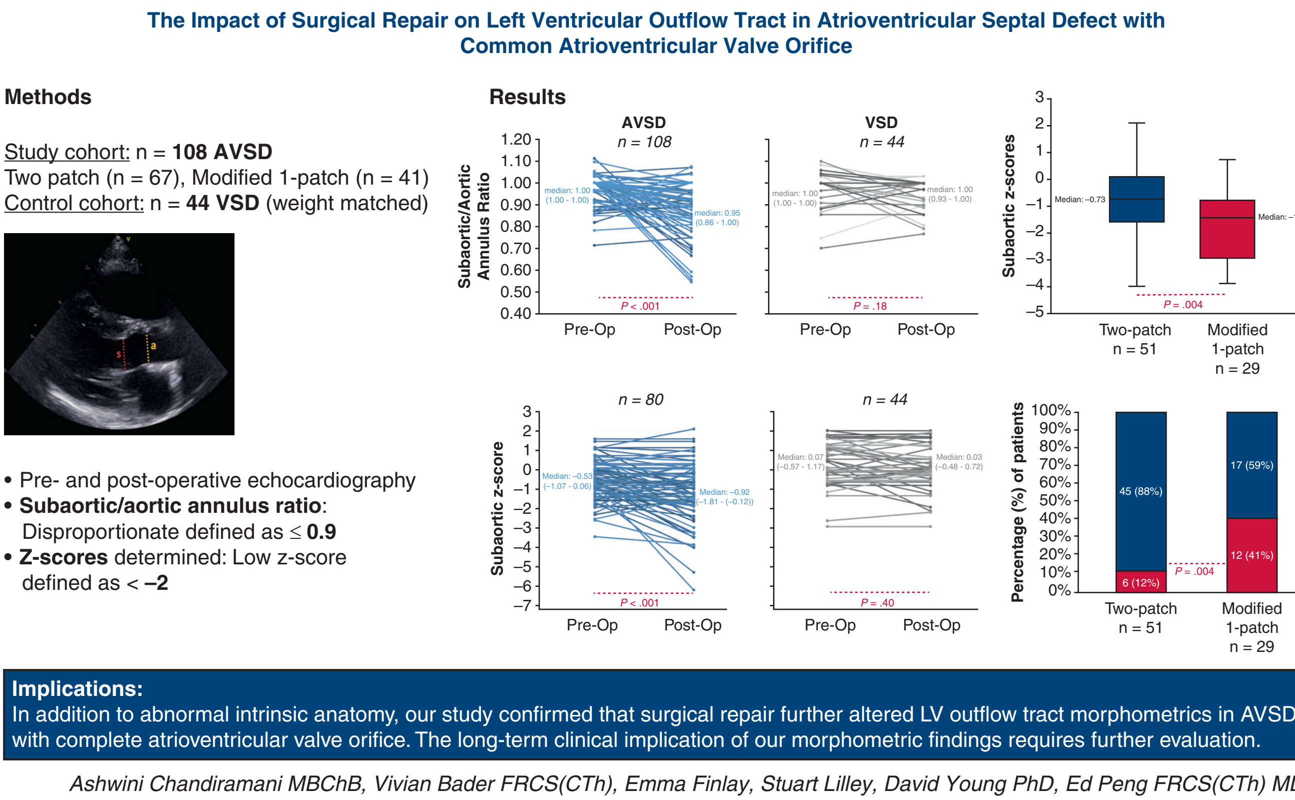

FIGURE 7. In addition to abnormal intrinsic anatomy, this study confirmed that surgical repair further altered LVOT morphometrics in AVSD with a common AV valve orifice. The findings were observed in all surgical techniques with a greater burden seen in the modified 1-patch group. *AVSD*, Atrioventricular septal defect; *VSD*, ventricular septal defect.

(1) upward tethering of septal crest or (2) downward tethering of bridging leaflets that encroach on the outflow tract. Although septal tethering may occur in the VSD group, as shown in several control patients (Figure 2), 2 important factors render the LVOT in VSD control less vulnerable to surgical effect; first, the native LVOT in VSD is more capacious compared with that of AVSD, and second, the size of the VSD in control group is smaller than the usually large inlet defect in AVSD.

The degree of derangement in LVOT morphometrics appeared to be seen with a greater burden after the modified 1-patch technique compared with the more commonly used 2-patch repair. Although there was a higher proportion of patients in the 2-patch group with a low z-score (<2) postrepair (12% vs 4%), this did not reach statistical significance. Nevertheless, the 2-patch group had a significantly lower median z-score and greater disproportionate morphometrics postrepair, which confirmed that the technique also affects the LVOT. In modified 1-patch repair, popularly known as the "Nunn technique," the bridging leaflets are tethered to the ventricular septal crest by the VSD patch; thus, there is a risk of further narrowing of the LVOT. The shape of the ventricular scoop also has been implicated, and those with an anterior superior extension of the VSD will have further narrowing of the LVOT, and this will have a bearing on the use of the modified 1-patch technique.[20] The concern that the modified 1-patch technique may affect the outflow tract remains a subject of debate.[11,17,21-23] Although our study showed evidence of a significantly narrower subaortic area after modified 1-patch repair, the incidence of late LVOT obstruction is not statistically different in both groups, which concur with a recent study by Fong and colleagues.[24] The overall incidence of significant late LVOT obstruction is still small, and this study may not be powered enough to detect a significant difference in clinical incidence. In our unit in which both 2- and modified 1-patch techniques are used, the latter tends to be used when the size of the inlet VSD is smaller; therefore, this may impact the outflow tract less than when the same technique is used in those with a large inlet VSD. Although both surgical groups have a common AV valve orifice, we may not be comparing like to like because of the difference in ventricular scoop shape, which is influenced by its depth and extension into the outflow tract of the left heart. Nonetheless, a narrower LVOT was found to be associated with a deeper ventricular scoop, in which the 2-patch technique would be more commonly applied.[20]

Therefore, the finding of narrower LVOT in modified 1-patch technique may suggest an important impact from this technique despite its use in patients with a shallower ventricular scoop.

Study Limitations

This is not a prospective study. Echocardiograms were reviewed retrospectively and may be affected by quality. The measurement of the LVOT may be affected by the angle of the echocardiographic view. Multiple views were examined and measured. Some differences in the measurements are subtle (~1 mm in difference). Whether that translates into clinical significance is unknown. We did not include Rastelli classification in this study because it is not routinely recorded in operative notes. We did not use the single-patch technique; therefore, it was not included in this study.

CONCLUSIONS

This morphometric study in AVSD with a common AV valve orifice confirmed further derangements of LVOT morphometrics immediately after surgical repair. The findings suggest that surgical repair has a further effect on LVOT, adding to the burden on a native LVOT, which is already narrowed by various anatomic factors. The findings were observed in all surgical techniques with a greater burden seen in the modified 1-patch group. A larger prospective, randomized, multicenter trial may be necessary to further evaluate the clinical implications of the findings from this morphometric study.

Webcast

You can watch a Webcast of this AATS meeting presentation by going to: https://www.aats.org/resources/1489.

Conflict of Interest Statement

The authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

References

1. Ginde S, Lam J, Hill GD, Cohen S, Woods RK, Mitchell ME, et al. Long-term outcomes after surgical repair of complete atrioventricular septal defect. *J Thorac Cardiovasc Surg*. 2015;150:369-74. https://doi.org/10.1016/j.jtcvs.2015.05.011
2. Hoohenkerk GJF, Bruggemans EF, Rijlaarsdam M, Schoof PH, Koolbergen DR, Hazekamp MG. More than 30 years' experience with surgical correction of atrioventricular septal defects. *Ann Thorac Surg*. 2010;90:1554-61. https://doi.org/10.1016/j.athoracsur.2010.06.008
3. St Louis JD, Jodhka U, Jacobs JP, He X, Hill KD, Pasquali SK, et al. Contemporary outcomes of complete atrioventricular septal defect repair: analysis of the Society of Thoracic Surgeons Congenital Heart Surgery Database. *J Thorac Cardiovasc Surg*. 2014;148:2526-31. https://doi.org/10.1016/j.jtcvs.2014.05.095
4. Draulans-Noë HAY, Wenink ACG. Anterolateral muscle bundle of the left ventricle in atrioventricular septal defect: left ventricular outflow tract and subaortic stenosis. *Pediatr Cardiol*. 1991;12:83-8. https://doi.org/10.1007/BF02238408
5. Piccoli GP, Ho SY, Wilkinson JL, Macartney FJ, Gerlis LM, Anderson RH. Left-sided obstructive lesions in atrioventricular septal defects: an anatomic study. *J Thorac Cardiovasc Surg*. 1982;83:453-60.
6. Van Arsdell GS, Williams WG, Boutin C, Trusler GA, Coles JG, Rebeyka IM, et al. Subaortic stenosis in the spectrum of atrioventricular septal defects. *J Thorac Cardiovasc Surg*. 1995;110:1534-42. https://doi.org/10.1016/S0022-5223(95)70077-3
7. Shiokawa Y, Becker AE. The left ventricular outflow tract in atrioventricular septal defect revisited: surgical considerations regarding preservation of aortic valve integrity in the perspective of anatomic observations. *J Thorac Cardiovasc Surg*. 1997;114:586-93. https://doi.org/10.1016/S0022-5223(97)70048-5
8. Suzuki K, Ho SY, Anderson RH, Becker AE, Neches WH, Devine WA, et al. Morphometric analysis of atrioventricular septal defect with common valve orifice. *J Am Coll Cardiol*. 1998;31:217-23. https://doi.org/10.1016/S0735-1097(97)00456-7
9. Sellers RD, Lillehei CW, Edwards JE. Subaortic stenosis caused by anomalies of the atrioventricular valves. *J Thorac Cardiovasc Surg*. 1964;48:289-302.
10. Chang CI, Becker AE. Surgical anatomy of left ventricular outflow tract obstruction in complete atrioventricular septal defect. A concept for operative repair. *J Thorac Cardiovasc Surg*. 1987;94:897-903.
11. Overman DM. Reoperation for left ventricular outflow tract obstruction after repair of atrioventricular septal. *Semin Thorac Cardiovasc Surg Pediatr Card Surg Annu*. 2014;17:43-7. https://doi.org/10.1053/j.pcsu.2014.01.008
12. Gallo P, Hokayem NJ, D'Offizi F, D'Alessandro, Francalanci P, D'Amati G, et al. Left ventricular outflow tract obstruction in atrioventricular septal defects: a pathologic and morphometric evaluation. *Clin Cardiol*. 1991;14:513-21. https://doi.org/10.1002/clc.4960140611
13. Abarbanell GL, Morrow G, Kelleman MS, Kanter KR, Border WL, Sachdeva R. Echocardiographic predictors of left ventricular outflow tract obstruction following repair of atrioventricular septal defect. *Congenit Heart Dis*. 2016;11:554-61. https://doi.org/10.1111/chd.12370
14. Chandiramani AS, Bader V, Finlay E, Lilley S, McLean A, Peng E. The role of abnormal subaortic morphometry as a substrate for left ventricular outflow tract obstruction following atrioventricular septal defect repair. *Eur J Cardiothorac Surg*. 2022;61:545-52. https://doi.org/10.1093/ejcts/ezab397
15. Jacobs JP, Burke RP, Quintessenza JA, Mavroudis C. Congenital heart surgery nomenclature and database project: atrioventricular canal defect. *Ann Thorac Surg*. 2000;69:36-43. https://doi.org/10.1016/S0003-4975(99)01235-7
16. Jacobs JP, Jacobs ML, Mavroudis C, Chai PJ, Tchervenkov CI, Lacour-Gayet FG, et al. Atrioventricular septal defects: lessons learned about patterns of practice and outcomes from the Congenital Heart Surgery Database of the Society of Thoracic Surgeons. *World J Pediatr Congenit Heart Surg*. 2010;1:68-77. https://doi.org/10.1177/21501351 10361504
17. Nunn GR. Atrioventricular canal: modified single patch technique. *Semin Thorac Cardiovasc Surg Pediatr Card Surg Annu*. 2007;10:28-31. https://doi.org/10.1053/j.pcsu.2007.01.009
18. Zilberman MV, Khoury PR, Kimball RT. Two-dimensional echocardiographic valve measurements in healthy children: gender-specific differences. *Pediatr Cardiol*. 2005;26:356-60. https://doi.org/10.1007/s00246-004-0736-z
19. Bunting K, Steeds R, Slater L, Rogers J, Gkoutos G, Kotecha D. A practical guide to assess the reproducibility of echocardiographic measurements. *J Am Soc Echocardiogr*. 2019;32:1505-15.
20. Adachi I, Ho SY, McCarthy KP, Uemura H, Emani S, Mayer JE, Pigula FA. Ventricular scoop in atrioventricular septal defect: relevance to simplified single-patch method. *Ann Thorac Surg*. 2009;87:198-203. https://doi.org/10.1016/j.athoracsur.2008.09.033
21. Myers PO, del Nido PJ, Marx GR, et al. Improving left ventricular outflow tract obstruction repair in common atrioventricular canal defects. *Ann Thorac Surg*. 2012;94:599-605. https://doi.org/10.1016/j.athoracsur.2012.04.009

22. Backer CL, Stewart RD, Bailliard F, Kelle AM, Webb CL, Mavroudis C. Complete atrioventricular canal: comparison of modified single-patch technique with two-patch technique. *Ann Thorac Surg*. 2007;84:2038-46. https://doi.org/10.1016/j.athoracsur.2007.04.129
23. Backer CL, Eltayeb O, Mongé MC, Wurlitzer KC, Hack MA, Boles LH, et al. Modified single patch: are we still worried about subaortic stenosis? *Ann Thorac Surg*. 2015;99:1671-6. https://doi.org/10.1016/j.athoracsur.2015.01.032
24. Fong L, Betts K, Bell D, Konstantinov I, Nicholson I, Winlaw D, et al. Complete atrioventricular septal defect repair in Australia: results over 25 years. *J Thorac Cardiovasc Surg*. 2020;159:1014-25. https://doi.org/10.1016/j.jtcvs.2019.08.005

Key Words: atrioventricular septal defect, congenital heart disease, left ventricular outflow tract

Discussion

Presenter: Dr Ashwini Chandiramani

Dr Scott Bradley *(Columbia, SC)*. Your work builds on previous work from your group, which was presented 2 years ago at the European Association, and there's a lot of interesting information in here about the LVOT in patients with complete AVSD. I have several questions for you. You presented information on the structure but not the function of the LVOT. Do you have any information on pressure gradients of these LVOTs and whether there's any correlation between the dimensions that you've measured and pressure gradients?

Dr Ashwini Chandiramani *(Aberdeen, Scotland)*. Unfortunately, I did not assess or collect the data regarding the pressure points, but that's something definitely to consider to do later in this study.

Dr Bradley. You've obviously got the echocardiograms. That would be a good next study.

Dr Chandiramani. Yes.

Dr Bradley. The next question is whether some of your findings, particularly in the modified single-patch group, may have to do with patient selection. Many surgeons, as we've heard this morning, choose between 2-patch and modified single-patch depending on the depth of the VSD. So is it possible that the relatively small size of this subaortic area after modified single-patch repair is not directly related to the repair technique itself but rather the preoperative anatomy of the patients selected for the modified single-patch repair? Do you know if your surgeons use that way of choosing repair techniques?

Dr Chandiramani. At our institution, as we've discussed, it's the surgeon's preference, but from what I've understood, if the size of the inlet VSD is smaller, the modified single-patch technique is preferred. However, as a general institution, by default, the 2-patch technique is carried out. You make a valid point that we may not be comparing like for like because the size of the VSD may be different, and the shape of the ventricular scoop may be impacted by this. As a result, a randomized, controlled trial may need to be carried out, and the size of the VSD is also something to consider when comparing the techniques as well.

Dr Bradley. Yeah, you could also probably get at it by taking a good look at your preoperative echoes in the 2 groups and [confirm?] the outflow tracts. Final question is you know the actual reoperation for LVOT obstruction in these patients is rare, approximately 5% in most series. There was a large 4-center series from Australia presented at this meeting 3 years ago, which found no difference in LVOT reoperation between a 2-patch and a modified single-patch approach even when the patients were propensity matched. Given your findings, what are your group's thoughts on why the smaller outflow tract after a modified single-patch repair is not linked to a higher risk for LVOT reoperation?

Dr Chandiramani. It could be that the size of the study group is small, and given that the incidence is not high, the study may not have high enough significance to demonstrate the impact on whether it has an impact on outflow tract obstruction. It may not be strong enough.

Dr Bradley. Yes, and dementia may not be the only thing involved. There may be other factors involved.

Dr Chandiramani. Definitely.

Dr Bradley. Reoperation in the outflow tract is a complex area.

Unidentified Speaker 1. I think maybe you should have talked about [inaudible] case is closed, but the pendulum was swinging. I want to highlight something. I've happily been [inaudible] from a unit where there was a lot of Australia patch technique that has been used. I've been confronted with difficulties in the patient when the patients are coming back, and I think it's important to highlight that point. When you have an Australian patch technique and you have to redo the head of mitral valve replacement after that for failure of the AV valve, you have to redo the AV valve. I find myself in a situation where it's impossible to do anything else that undoes the whole repair and re-create the patch years later to accommodate the size of a new valve there. Last week, I observed an LVOT obstruction relief where the [inaudible] was so stuck that I had to do a Ross procedure at the same time. So do you have experience with—I'm hesitating between the words of difficulties or disaster after the reoperation in the Australian patch technique? Sorry to share, but I think it's important to everybody.

Dr Chandiramani. Unfortunately, I don't have the surgical experiences yet. That's above my level as I am still currently a junior doctor, so I haven't developed the experience to comment on that yet.

Unidentified Speaker 1. Maybe David can comment.

Unidentified Speaker 2. I have been persistently wrong about this. Thank you for referencing that paper, "The Morphologic Specimen," for those of you who want to laugh. We're all among friends. It was my very first paper as a congenital heart fellow. I presented in this convention center on a Wednesday as the very last paper [laughter]. But to come to this, it seems to me there are issues that are immutable and not. Within your analysis, this is very elegant: You have a subcategory of patients with either technique who have better LVOTs, closer to normal LVOTs, or closer to the VSD LVOTs. Have you had a chance to look at that and say, "Let's take nature at its best"? Is there a difference between when a surgeon modifies that versus when a surgeon creates something that's closer to what nature wants to be in terms of outcome or recurrence of subaortic stenosis?

Dr Chandiramani. That is something we should look into. I will go back to the United Kingdom and take all the comments that have been given to me today and carry this forward.

Unidentified Speaker 3. The nice thing about your study is that it highlighted the need to get a detailed echo assessment of the LV outflow and do that in a serial manner as in the series from Australia, and there are many. First, I don't think that the need for reoperation is necessarily a good indicator of having at least moderate LVOT obstruction. Of course, many of the images are just obtained in a single plane and without this kind of detailed assessment. So perhaps to answer these questions going forward, we're going to need to do something prospective with a more thorough assessment protocol.