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Repair of complete atrioventricular canal defects: Early and midterm results and comparison of the left anterior leaflet augmentation technique with traditional technics

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Abstract

Background: Complete atrioventricular septal defects (CAVSD) include a variable spectrum of congenital malformations with different forms of clinical findings. We examined early and midterm outcomes, the need for reoperation, postoperative residual AV valve regurgitation, and other risk factors after various CAVSD repairs.

Methods: Between 2014 and 2018, we have performed 89 isolated CAVSD repairs. We retrospectively reviewed the patients' medical records. Patients were divided into three groups according to their repair techniques modified one patch repair (MP) ($n = 16$); two patch repair (TP) ($n = 49$); and left anterior leaflet augmentation (ALA) technique ($n = 24$).

Results: Eighty patients (89.8%) survived hospital discharge. Early mortality rates were three (18.8%) in the group MP, five (10.2%) in the group TP, and one (4.2%) in the group ALA. Thirteen patients died during the follow-up period. Late mortality rates were three (18.8%) in the group MP, four (16.6%) in the group ALA, and six (12.2%) in the group TP. The mean follow-up time was 35.9 ± 22.97 months (range: 0.3–77 months). The morbidity and mortality results were similar between-group TP and ALA but worse in the MP group. Low body weight (<4 kg) and younger age at surgery (<4 months) were found to be risk factors on mortality by univariate and multivariate analysis. Surgical technic was not found to be an independent risk factor.

Conclusion: In our series, TP and ALA techniques had satisfactory results in early and midterm periods. Younger age and small bodyweight might increase early mortality and the need for reoperation.

KEYWORDS

anterior leaflet augmentation, complete atrioventricular septal defects, congenital cardiac surgery, modified one patch, two patch

Abbreviations: ACC, aortic cross-clamp; ALA, anterior leaflet augmentation; AV, atrioventricular; AVVR, AV valve regurgitation; BSA, body surface area; CAVSD, complete atrioventricular septal defects; CI, confidence interval; CPB, cardiopulmonary bypass; CRRT, continues renal replacement therapy; ECLS, extra corporeal life support; LVOT, left ventricular outflow; MP, modified one patch repair; OR, odds ratio; SE, standard error; TEE, transesophageal echocardiography; TP, two patch repair.

1 | INTRODUCTION

Complete atrioventricular septal defect (CAVSD) is congenital heart disease, including a spectrum of atrioventricular (AV) septum and AV valve anomalies. Since C. Walton Lillehei performed the first successful surgical repair of a CAVSD in 1955, a lot of distance has been covered in terms of early mortality and reoperation.[1] Previous studies showed that overall early mortality is about 10%.[2–4] However, despite satisfactory results, up to 10% of cases may require reoperation for AV valve regurgitation (AVVR), residual VSD, or left ventricular outflow (LVOT) tract obstruction.[4–6] Modified one patch (MP) and two patch (TP) have been the most commonly used techniques. An alternative method described by Poirier and called augmentation of left-sided anterior bridging leaflets (left anterior leaflet augmentation [ALA]) had gained some acceptance.[7,8] This technique may be used during the first operation or reoperation. Advantages of this technique are providing a better exposure, may decrease the possibility of LVOT obstruction, and completing valve repair with less tension, therefore, reducing the possibility of residual AV valve leakage. We recently started to use this technique besides traditional MP and TP techniques.

In this study, we compared the early and midterm results and the need for reoperation of these three techniques. We assessed estimated survival rates, risk factors associated with mortality and reoperation.

2 | MATERIAL AND METHODS

2.1 | Patient population

We retrospectively scanned archives of patients who had undergone complete surgical repair for CAVSD between January 2014 and June 2018 in the institution's surgical database. A total of 101 patients were selected. Patients with partial, intermediate type AVSD, and unbalanced forms of AVSD who undergone single ventricle palliation were excluded. Patients with associated pathologies requiring additional intervention like tetralogy of Fallot and valvar or subvalvular pulmonary stenosis were excluded. The remaining 89 patients were divided into 3 groups according to the applied surgical technique to determine the impact of surgical techniques on early and midterm outcomes. We compared three different surgical technics to identify mortality, reoperations after surgery, and other factors like age at repair, weight, Down Syndrome, body surface area (BSA), Aristotle Basic Score, and Aristotle Comprehensive Score, and preoperative echocardiographic findings. Surgical techniques were chosen by the individual patient's anatomy and the surgeon's discretion. The surgical strategy applied as the MP technique 16 (18%) patients, TP technic 49 (55%) patients, and ALA 24 (27%) patients. Complete cleft closure was done in all three techniques.

The study protocol was approved by the same hospital's ethical committee (dated 8/6/2018 and report no. 201828).

2.2 | Surgical techniques

The total repair was performed through a median sternotomy. Standard cardiopulmonary bypass (CPB) was instituted by bicaval and aortic cannulation with mild-to-moderate hypothermia. Following cross-clamping the aorta, cold antegrade blood cardioplegia was administered with intermittent doses given every 20 min. We performed operations with blood cardioplegia for the first 50 patients (56%) until 2016. After that, we switched our protocol to Del Nido cardioplegia every 60 min for the last 49 patients (44%). We also used Del Nido cardioplegia during saline testing of the valve competency to avoid the washing effect. After administration of cold blood cardioplegia, a medial right atriotomy is performed. This incision was extended to the right AV groove to facilitate the exposure. The vent is placed into the left atrium. First, a saline test was made through into the common AV valve. By floating the common AV valve, the common AV valve's midportion (zone of opposition) point marked with a 6.0 prolene suture. Pledgeted sutures are placed on the right side of the ventricular septum without dividing the common superior and inferior bridging leaflets. These sutures are passed through the projected midpoint of the dividing line between the common AV valve leaflets. After passing the suture through the AV valve tissue, sutures passed through a patch of the glutaraldehyde-treated autologous pericardium (glutaraldehyde concentration: 0.5% for 3 min). Interrupted 6-0 prolene sutures were used to closing the cleft. Finally, the pericardial patch was used to close the atrial component of the defect. The right atrium was closed with running prolene sutures, and the right and left sides of the heart were deaired. The patients were always weaned from CPB on 0.5 μg/kg/min of milrinone. Dopamine and/or adrenaline were used depending on the cardiac output.

The TP technique was done by first closing the VSD with a Dacron patch. The VSD patch was placed under the bridging leaflets and sutured to the ventricular septum. Sutures were passed through the patch's superior edge and through the bridging leaflets at the zone of division between the right and left components of the common AV valve. These sutures were passed through a glutaraldehyde-treated autologous pericardium to close the atrial septal defect. The cleft of the new left AV valve was closed before completion of the atrial septal defect closure.

The superior and inferior bridging leaflets and their short secondary attachments were divided. The superior and/or inferior bridging leaflets are then incised along their junction with the anulus. A pericardial patch shaped like a crescent is inserted to augment the anterior left AV valve leaflet (Figure 1). Complete cleft closure was accomplished without any tension, and more space was created for LVOT to avoid obstruction.

2.3 | Outcomes

Primary outcomes for this study to determine the early and midterm mortality rates. Analysis of risk factors associated with residual or recurrent AVVR, residual VSD, LVOT obstruction such as low body weight, early age at repair, and surgical technic. Early death was defined as death

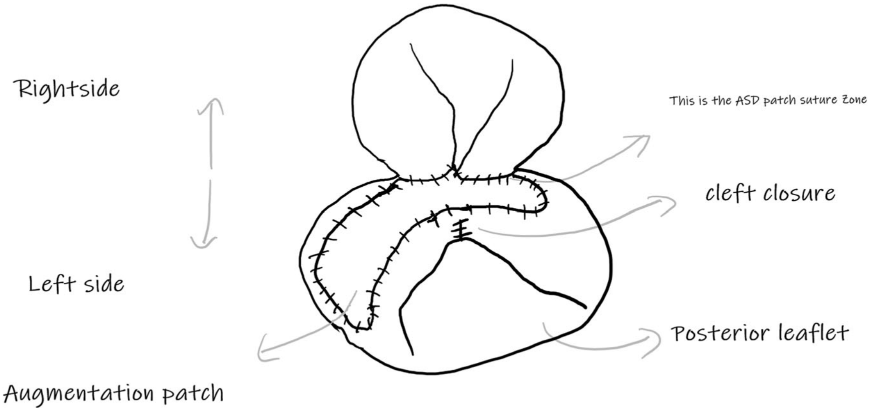

FIGURE 1 Schematic picture of augmentation of anterior right AV leaflet. AV, atrioventricular

TABLE 1 Patients' characteristics and preoperative echocardiographic findings

	MP (*n* = 16)	TP (*n* = 49)	ALA (*n* = 24)	*p* value
Gender (female/male)	11/5	27/22	12/12	.49
Age at repair (months)	8.78 ± 8.99	5.69 ± 2.71	6.66 ± 3.58	.07
Weight (kg)	5.86 ± 1.95	6.04 ± 7.84	5.74 ± 1.18	.98
BSA (m^2)	0.31 ± 0.079	0.29 ± 0.05	0.30 ± 0.046	.42
Down syndrome (*n*; %)	12 (75)	44 (89.79)	23 (95.8)	.1
ABC	8.5 ± 1.28	8.24 ± 2.48	8.61 ± 1.20	.74
ACC	9.64 ± 2.13	8.98 ± 3.16	9.55 ± 1.38	.55
Preoperative Left AVVR (*n*; %)				
Less than mild	7 (43.7)	27 (55.1)	16 (66.7)	
More than moderate	9 (56.3)	22 (44.9)	8 (33.3)	.35
Preoperative Right AVVR (*n*; %)				
Less than mild	6 (37.5)	19 (38.8)	12 (50)	
More than moderate	10 (62.5)	30 (61.2)	12 (50)	.62

Note: Data are described as mean ± standard deviation or *n* (%).

Abbreviations: ABC, Aristotle Basic complexity Score; ACC, Aristotle Comprehensive complexity Score; AVVR, atrio-ventricular valve regurgitation; BSA, body surface area; SD, standard deviation.

before hospital discharge or death within 1 month from surgery. Reoperations described surgical intervention for AVVR, residual VSD closure, and LVOT obstruction. Preoperative and postoperative AVVR was classified as less than mild and more than moderate. Reinterventions for bleeding or cardiac tamponade were not included for reoperation. We sought to determine the covariates on the possibility of mortality and reoperation with binary logistic regression. Postoperative junctional and atrial arrhythmias were evaluated together. Extra corporeal life support (ECLS), septicemia, permanent pacemaker implantation, and Continuous renal replacement therapy (CRRT) (either peritoneal dialysis or hemodialysis) were determined as major adverse events. Our literature research showed that the mean hospital stay is about 14 days after CAVSD repair. Therefore, we identified prolonged hospitalization for more than 14 days. We sought to determine the covariates on the possibility of prolonged hospitalization with binary logistic regression. All patients followed-up between 1 and 77 (mean follow-up time was 35.9 ± 22.97) months.

2.4 | Statistical analyses

In the study, the distribution of variables was classified, and descriptive results were obtained using SPSS version 15 (Statistical Package for the Social Sciences for Windows) program. Continues variables are presented as mean ± *SD*, median with range, and categorical variables presented as frequencies and percentages of the total. Continues variables compared using non-parametric Kruskal–Wallis test and significant results compared using post hoc tests. Patient preoperative and postoperative echocardiographic AV valve findings compared using the χ^2 test. Overall survival analyses of the groups were evaluated with Kaplan–Meier curves, and differences were tested with a log-rank test. Effects of covariates on the possibility of survivals, prolonged hospitalization, and reoperation in univariate and multivariate analysis are reported as odds ratio (OR) with the 95% confidence interval (CI). Statistically significant difference was accepted with a $p < .05$.

3 | RESULTS

3.1 | Preoperative patients' characteristics

The preoperative characteristics for the 89 patients who underwent total repair for CAVSD are summarized in Table 1. There was no statistically significant difference for gender, age, weight, and BSA parameters between the three groups. Both basic and comprehensive Aristotle complexity Scores were similar, and there was no statistically significant difference.

The preoperative echocardiographic findings were also summarized in Table 1. There was no statistically significant difference between the groups in terms of preoperative AVVRs.

3.2 | Patient's operative characteristics and postoperative outcomes

The perioperative characteristics and postoperative outcomes are summarized in Table 2. There were no differences between the groups for CPB and aortic cross-clamp (ACC) time. Frequency of patients with pneumonia found 56.3% ($n = 9$) in group MP ($p = .001$). According to the post hoc test, p-value for TP and ALA group was <.001. The mean time of intensive care unit (ICU) stay for group MP was statistically significant between groups ($p < .001$). The post hoc test is significant for both TP and ALA, with the standard error of 2.07 and 2.32, respectively. The mean time of hospital stay for group MP was 34.8 ± 48.96 ($p = .003$). That is much higher than other groups like ICU stay. The post hoc test is significant for both TP and ALA with the standard error of 4.42 and 4.95, respectively. Also, we identified prolonged hospitalization (>14 days). There were 36 patients in the total cohort. We analyzed the effects of covariates on the possibility of prolonged hospitalization using univariate and multivariate binary logistic regression analysis. By univariate analysis, the severe degree of the left AVVR and MP technic were found to be significant ($p = .02$ and $p = .015$, respectively). By multivariate analysis, weight ($p = .027$), age ($p = .009$), TP ($p = .02$), and ALA technic ($p = .01$) were found to be significant. TP and ALA technics were significant to decreasing the possibility of prolonged hospitalization. Details were presented in Table 3.

Six patients switched CPB again during the first operation. Two of these patients were in group MP (12.5%), two patients were in group TP (4.2%), and two patients were in group ALA (8.3%). According to intraoperative transesophageal echocardiography (TEE) visualization, all four patients switched to CPB in the groups MP and ALA due to significant left AVVR. In the group TP, one of the patients had significant pulmonary hypertension preoperatively and had severe left AVVR after weaning CPB. The second patient was switched to CPB because of LVOT obstruction.

TABLE 2 Operative data and postoperative outcomes

	MP ($n = 16$)	TP ($n = 49$)	ALA ($n = 24$)	p value
CPB time (min)mean + SD	144.68 ± 47.27	149.69 ± 53.59	141.66 ± 33.17	.78
Aorta clamp (min)mean *SD*	107.68 ± 33.59	115.42 ± 37.39	103.08 ± 19.37	.3
ICU stays (day)	18.68 ± 21.55	7.26 ± 6.01	6.66 ± 2.86	**<.001**
Hospital stays (day)	34.8 ± 48.96	14.12 ± 7.92	13.54 ± 8.25	**.003**
Prolonged hospitalization	11/68.8%	18/36.7%	7/29.2%	**.03**
Intubation time (hour)	120.85 ± 144.58	66.18 ± 99.79	66 ± 51.17	.14
Pneumonia	9/56.3%	6/12.2%	1/4.2%	**.001**
Reoperation	3/18.8%	2/4.2%	1/4.2%	.11
Rehospitalization	4/25%	6/12.2%	1/4.2%	.15
Major adverse event	4/25%	12/24.4%	9/37.5%	.48
Septicemia	2/12.5%	3/6.12%	0	.24
PPI	1/6.3%	8/16.3%	7/29.2%	.16
ECLS	0	3/6.1%	0	.28
CRRT	3/18.7%	6/12.2%	3/12.5	.79
Dysrhythmias	3/18.8%	12/24.4%	2/8.3%	.26
Hospital mortality	3/18.8%	5/10.2%	1/4.2%	.33
Late mortality	3/18.8%	6/12.2%	4/16.6%	.42

Note: Data are described as mean ± standard deviation or n (%).

Abbreviations: CPB, cardiopulmonary bypass; CRRT, continues renal replacement therapy; ECLS, extra corporeal life support; ICU, intensive care unit; PPI, permanent pacemaker implantation.

TABLE 3 Predictors of prolonged hospitalization

Variable	Univariate B	SE	OR (95% CI)	p	Multivariate B	SE	OR (95% CI)	p	
Weight	−0.012	0.152	0.988 (0.734–1.331)	.94	0.704	0.318	2.021 (1.083–3.772)	**.027**	
Age	−0.088	0.061	0.915 (0.812–1.032)	.15	−0.298	0.114	.742 (0.594–0.928)	**.009**	
Right AVVR (severe)	1.629	0.848	5.100 (0.967–26.893)	.055	1.619	0.947	5.047 (0.789–32.273)	.087	
Left AVVR (severe)	1.135	0.501	3.111 (1.166–8.301)	**.02**	0.845	0.573	2.328 (0.757–7.164)	.141	
MP	1.44	0.593	4.224 (1.321–13.507)	**.015**	–	–	–	–	
TP	−0.343	0.435	0.71 (0.303–1.663)	.430	−1.695	0.749	0.184 (0.042–0.797)	**.02**	(MP is reference category)
ALA	−0.671	0.514	0.511 (0.187–1.399)	.191	−2.151	0.830	0.116 (0.023–0.592)	**.01**	(MP is reference category)

Abbreviations: ALA, anterior leaflet augmentation; AVVR, atrio-ventricular valve regurgitation; CI, confidence interval; MP, modified one patch repair; OR, odds ratio; TP, two patch repair; SE, standard error.

There were 11 patients rehospitalized after discharge. Four (25%) patients were in the group MP, six (12.2%) patients were in the group TP, and one (4.2%) patient was in the group ALA. Two patients were rehospitalized to planning redo surgery because of severe left AVVR who operated using MP technique. One patient rehospitalized because of severe left AVVR to receive medical treatment. The last patient applied to the hospital because of fever in the group MP. Three patients rehospitalized because of severe left AVVR receive medical treatment, and the remaining three patients applied to the hospital because of noncardiac problems in the group TP. The patient in the group ALA has a severe degree of left AVVR at discharge applied to the hospital after discharge with sudden cardiac arrest.

3.3 | Hospital mortality

There was nine hospital mortality in the total cohort. Three hospital mortality were in the MP group. One of the patients with down syndrome had moderate common AV valve insufficiency in the early postoperative period. One of the patients (3 kg body weight preoperatively) has moderate right AV valve insufficiency and mild left AV valve insufficiency in the early postoperative period. The third patient had undergone a second operation due to severe left AV valve insufficiency and severe stenosis. Two of these patients died because of septicemia due to pneumonia. Five patients died in the TP group at the hospital. Four of these patients had a severe right and/or left AV valve insufficiency. The last patient died because of low cardiac output. We were unable to apply the second operation due to septicemia or poor condition. Only one patient died in the ALA group who has a severe right and left AVVR at the hospital. Six patients died (13.3%) in the early surgical-era (before 2016), and three patients died (6.8%) in the late surgical-era (after 2016).

3.4 | Predictors of hospital mortality

We analyzed the effects of covariates on the possibility of hospital mortality using univariate and multivariate binary logistic regression

TABLE 4 Predictors of hospital mortality

Variable	Univariate B	SE	OR (95% CI)	p	Multivariate B	SE	OR (95% CI)	p	
Low weight (<4 Kg)	2.015	0.845	7.5 (1.433-39.263)	**.017**	3.289	1.385	26.813 (1.777-404.589)	**.018**	
CPB	0.015	0.007	1.016 (1.002-1.029)	**.02**	0.012	0.008	1.012 (0.996-1.029)	.151	
Right AVVR (severe)	2.015	0.845	7.500 (1.433-39.263)	**.017**	1.613	1.049	5.017 (0.641-39.245)	.124	
Left AVVR (severe)	1.460	0.722	4.306 (1.045-17.735)	**.043**	1.932	0.952	6.905 (1.068-44.632)	**.042**	
Surgical era	0.743	0.742	2.103 (.491-8.996)	.316	2.101	1.657	8.172 (0.318-210.147)	.205	
MP	0.947	0.769	2.577 (.571-11.640)	.219	–	–	–	–	
TP	0.22	0.707	1.023 (.256-4.092)	.975	−0.053	1.018	.948 (0.129-6.978)	.958	(MP is reference category)
ALA	−1.172	1.089	.310 (.037-2.619)	.282	−0.976	2.288	3.788 (0.043-335.546)	.560	(MP is reference category)

Abbreviations: ALA, anterior leaflet augmentation; AVVR, Atrio-Ventricular Valve Regurgitation; CI, confidence interval; CPB, cardiopulmonary bypass; MP, modified one patch repair; OR, odds ratio; TP, two patch repair; SE, standard error.

TABLE 5 Postoperative last echocardiographic findings before discharge or death

	MP (16)	TP (49)	ALA (24)	*p* value
Left AVVR				
Less than mild (*n*; %)	5 (31%)	17 (34.7%)	10 (41.7%)	
More than moderate (*n*; %)	11 (69%)	32 (65.3%)	14 (58.3%)	.77
Right AVVR				
Less than mild (*n*; %)	8(50%)	29 (59.2%)	17 (70.8%)	
More than moderate (*n*; %)	8 (50%)	20 (40.8%)	7 (29.2%)	.4
Left AVVR				
Severe (*n*; %)	6 (37.5%)	11 (22.4%)	6 (25%)	.49
Right AVVR				
Severe (*n*; %)	2 (12.5%)	5 (10.2%)	1 (4.2%)	.6

Note: Data are described as *n* (%).

Abbreviations: ALA, anterior leaflet augmentation; AVVR, atrioventricular valve regurgitation; MP, modified one patch repair; TP, two patch repair.

analysis. By univariate analysis, low body weight (<4 kg), CPB time, severe degree of right AVVR, and severe degree of left AVVR were found to be significant (*p* values were .017, .02, .017, and .043, respectively). By multivariable analysis, low body weight (<4 kg) and severe degree of left AVVR were found to be significant risk factors for hospital mortality (*p* values were .018 and .042, respectively). Details were presented in Table 4.

3.5 | Echocardiographic findings

We classified the patient's early postoperative echocardiographic findings (before discharge or death) as less than mild, more than a moderate, and severe degree of regurgitation in Table 5. There was no significant difference between groups for left and right AV valve insufficiency. Frequency of having more than moderate insufficiency in both left and right AV valve similar between groups but slightly better in the ALA group. The frequency of having a severe degree of regurgitation for both AV valves was higher in the MP group.

We classified the patient's echocardiographic findings, which were evaluated at the last visit in Table 6. The same comparison method was used as we did before for postoperative echocardiographic findings. There was no statistically significant difference between groups for left AV valve findings, but the frequency of having more than moderate degrees was much higher in the MP group than others. Also, the frequency of having a severe degree of left AVVR was lesser in group ALA. Right AV valve competency was better in group ALA. While no patient had a severe degree of right AVVR in the group ALA, 20% of patients had a severe degree of regurgitation in group MP. This finding was statistically significant ($p = .03$). According to post hoc tests, *p* values were .04 for both TP and ALA.

3.6 | Reoperation

There were three patients (18.8%) who had needed reoperation in group MP. Two patients reoperated due to a severe degree of both left and right AVVR before discharge. The third patient underwent reoperation due to severe left AVVR after 6 months from the first surgery and died after the second operation. One patient (4.2%) underwent a second operation in the group ALA due to a severe degree of left AVVR after 23 weeks from the first surgery but died after the second surgery. There were two patients (4.2%) in group TP who required reoperation. One patient underwent mitral valve replacement. Other patient underwent mitral and LVOT obstruction repair after 2 years from the first surgery.

We analyzed the effects of covariates on the possibility of reoperation using univariate and multivariate binary logistic regression analysis. The echocardiographic findings we used for regression were achieved the last examination before discharge. By univariate analysis, age <4 months and severe degree of left AVVR were found to be significant risk factors for reoperation (*p* values were .02 and .01, respectively). By multivariable analysis, the same factors were found to be significant for reoperation (*p* values were .03 and .02, respectively). Details were presented in Table 7.

TABLE 6 Follow up echocardiographic findings at last visit

	MP (10)	TP (38)	ALA (19)	*p* value
Left AVVR				
Less than mild (*n*; %)	5 (50%)	27 (69.2%)	13 (68.4%)	
More than moderate (*n*; %)	5 (50%)	11 (30.8%)	6 (31.6%)	.45
Right AVVR				
Less than mild (*n*; %)	8 (80%)	32 (82.1%)	19 (100%)	
More than moderate (*n*; %)	2 (20%)	6 (17.9%)	0 (0%)	.15
Left AVVR				
Severe (*n*; %)	1 (10%)	3 (7.7%)	1 (5.3%)	.89
Right AVVR				
Severe (*n*; %)	2 (20%)	1 (2.6%)	0	**.03**

Note: Data are described as *n* (%).

Abbreviations: ALA, anterior leaflet augmentation; AVVR, atrioventricular valve regurgitation; MP, modified one patch repair; TP, two patch repair.

TABLE 7 Predictors of reoperation

Variable	Univariate *B*	*SE*	OR (95% CI)	*p*	Multivariable *B*	*SE*	OR (95% CI)	*p*
Weight <5.5 kg	1.440	1.117	4.222 (0.473-37.727)	.20	0.343	1.331	1.410 (0.104–15.138)	.77
Age <4 months	2.107	0.890	8.222 (1.438–47.008)	**.02**	3.509	1.595	33.419 (1.466–761.713)	**.03**
Right AVVR (severe)	1.859	0.964	6.417 (0.970–42.464)	.054	2.650	1.439	14.159 (0.843–237.765)	.07
Left AVVR (severe)	2.893	1.127	18.056 (1.982–164.521)	**.01**	3.253	1.433	25.874 (1.559–429.535)	**.02**
MP	1.684	0.871	5.385 (0.978–29.660)	.053	–	–	–	–
TP	−0.960	0.894	0.383 (0.066–2.208)	.28	−0.922	1.298	0.398 (0.31–5.067)	.48 (MP is reference category)
ALA	−0.651	1.123	0.522 (0.058–4.710)	.56	−0.591	1.526	0.554 (0.28–11.024)	.7 (MP is reference category)

Abbreviations: ALA, anterior leaflet augmentation; AVVR, Atrio-Ventricular Valve Regurgitation; CI, confidence interval; MP, modified one patch repair; OR, odds ratio; TP, two patch repair; SE, standard error.

Freedom from reoperation at 3 and 5 years were 97% and 90% for the total cohort, respectively. Freedom from reoperation at 3 years was 100% in the TP, 95% in ALA, and 92.5% in the MP group. Freedom from reoperation at 5 years was 95% in the TP and 82% in the MP group. Freedom from reoperation of Kaplan–Meier plot was presented in Figure 4.

3.7 | Late mortality

There was 13 late mortality in the total cohort. Three of them were in the MP group. Two of the patients had a moderate degree of right AVVR before discharge, and one of them had pacemaker implantation. The third patient had not any of the risk factors. He died with an unknown cause at home. There was six late mortality in the TP group. All of six patients had more than a moderate degree of right and/or left AVVR. Three of them also had pacemaker implantation after the first surgery. Two of these patients had abdominal surgery due to gastrointestinal malformations. There were four patients in the ALA group. Three of these patients had a severe degree of left AVVR. We performed mitral surgery on one of these patients. He also had pacemaker implantation. He died because of pulmonary and infectious complications. The last patient had a moderate degree of right AVVR, and he died because of pulmonary complications.

3.8 | Predictors of total mortality

We analyzed the effects of covariates on the possibility of total mortality using univariate and multivariate binary logistic regression

TABLE 8 Predictors of total mortality

Variable	Univariate *B*	*SE*	OR (95% CI)	*p*	Multivariate *B*	*SE*	OR (95% CI)	*p*
Right AVVR (more than moderate)	2.180	0.570	8.850 (2.894-27.065)	**.000**	1.862	0.667	6.437 (1.741-23.799)	**.005**
Left AVVR (more than moderate)	1.696	0.545	5.455 (1.875-15.868)	**.002**	1.367	0.621	3.922 (1.162-13.242)	**.028**
Major adverse event	1.606	0.528	4.985 (1.771-14.03)	**.002**	1.441	0.621	4.225 (1.251-14.269)	**.02**
MP	0.760	0.589	2.137 (0.674-6.778)	.20	–	–	–	–
TP	−0.270	0.493	0.763 (0.291-2.004)	.58	−1.102	0.764	0.332 (0.074–1.484)	.15 (MP is reference category)
ALA	−0.717	0.860	0.743 (0.240-2.300)	.61	−1.149	0.907	0.488 (0.090–2.635)	.4 (MP is reference category)

Abbreviations: ALA, anterior leaflet augmentation; AVVR: atrio-ventricular valve regurgitation; CI, confidence interval; OR, odds ratio; SE, standard error.

analysis. By univariate analysis, more than a moderate degree of right and left AVVR and major adverse events were significant (p values were .000, .002, and .002, respectively). The same factors were significant for total mortality by multivariable analysis (p values were .005, .028, and .02, respectively). Details were presented in Table 8.

3.9 | Survival analysis

The mean follow-up time of the total cohort was 35.9 ± 22.97 months (range: 1–77 months). The 5-year survival rate was 76.8% for the total cohort. The 1-year survival rates were 75.7% in MP, 83% in TP, and 82.5% in the ALA group. The 3-year survival rates were 62.5% in MP, 76.4% in TP, and 78.5% in the ALA group. The log-rank test was not statistically significant ($p = .501$). Kaplan–Meier survival plots were presented in Figures 2 and 3.

We also analyzed the freedom from reoperation and death. The 1-year freedom from reoperation and death rates were 75% in the group MP and 83% for TP and ALA. The 3-year freedom from reoperation and death rates were 62% in MP, 76% in TP, and 78% in the ALA group. The log-rank test was not statistically significant ($p = .39$). Kaplan–Meier survival plot was presented in Figure 4.

4 | DISCUSSION

This study sought to identify the early and midterm survival and risk for reoperation in 89 patients after CAVSD repair at our institution from 2014 to 2018. The overall estimated survival rate for the study was 76.8% at 5 years.

It was emphasized in previous studies that the most important advantage of the MP technique is shortening CPB and ACC time.[9,10] In our research, we found that CPB and ACC times were similar between groups, and there was no statistically significant difference. Loomba et al. reported a meta-analysis that includes 724 patients (10 manuscripts which were chosen from 964 studies) comparing as MP and TP repair.[11] The MP repair had a mean CPB time of 107 min, and the TP repair had a mean time of 129 min (mean difference: 28.53, 95% confidence interval: 37.88–19.17). Our TP and ALA repair results were similar with this meta-analysis, but the CPB time of MP repair was higher in our study. It is seen that we cannot benefit from this advantage offered by the MP technique. Another remarkable point is that the ALA technique did not have a longer CPB time.

There are different data in the literature about ICU and hospital stay. Most studies have shown that the MP technique provides shorter hospital and ICU stay or no difference with TP technic.[10] In our research, it was observed that the mean hospital, ICU stays, and intubation times in the MP group were higher than other groups. Therefore, complications such as pneumonia and septicemia have been observed to be higher. The mean time of hospital and ICU stay were significantly higher in the MP group, but they were similar between TP and ALA repair. According to our literature research, the mean time of hospital stay was about 12–14 days.[12,13] Therefore, we determined prolonged hospitalization as the mean time of hospital stay longer than 14 days. A severe degree of AVVR and MP repair technic were significant risk factors for prolonged hospitalization by univariate analysis. On the other hand, weight and age factors were found to be significant risk factors by multivariate analysis. TP and ALA technics have been shown to reduce the risk for prolonged hospitalization.

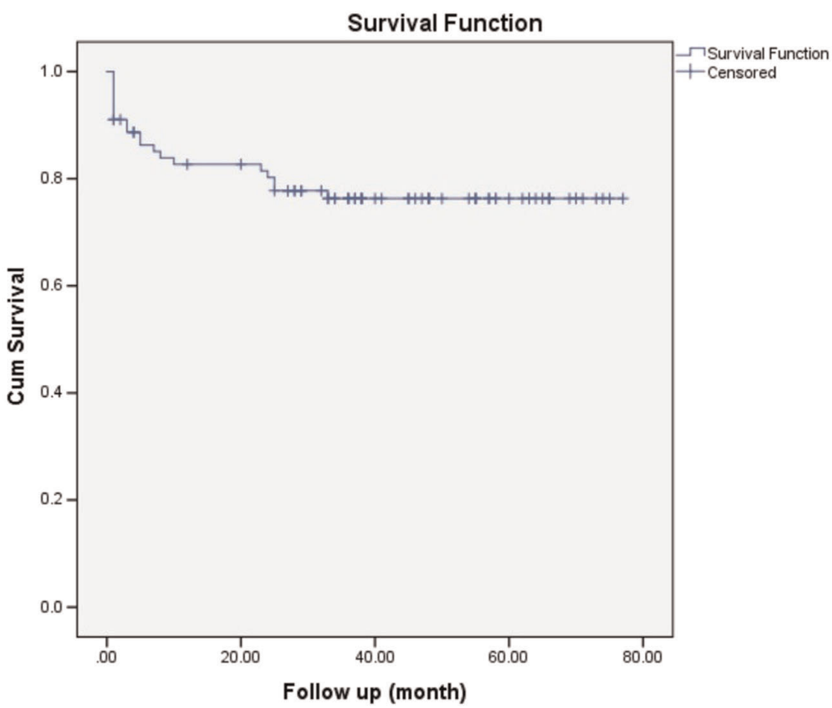

FIGURE 2 Kaplan–Meier survival plot for the total cohort

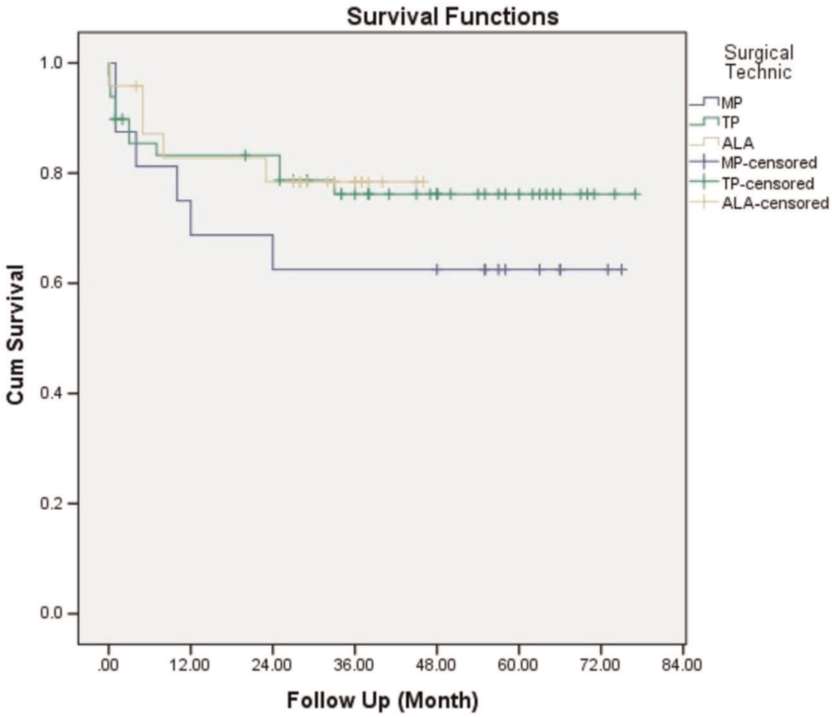

FIGURE 3 Kaplan–Meier survival plot for groups (log-rank $p = .5$)

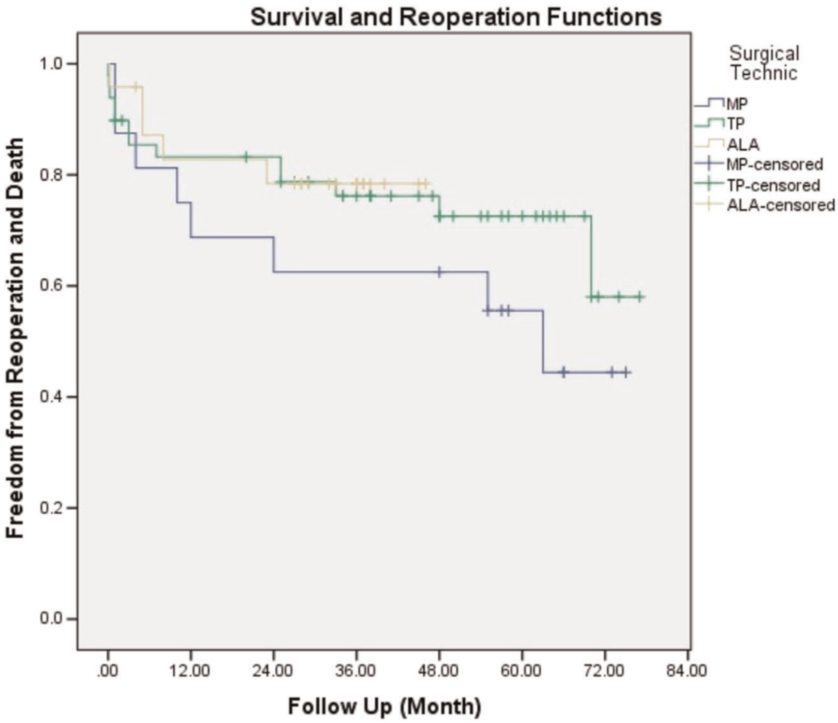

FIGURE 4 Kaplan–Meier freedom from reoperation and death plot for groups (log-rank $p = .39$)

As expected, a high degree of residual AVVR affects intubation time, ICU stays, hospital stays, and complications. Also, residual AVVR is the most common reason for reoperations.[14,15] Several studies reported that the MP technic is not a risk factor for left AVVR comparing with the TP technic.[9,10] We achieved similar results with previous studies. There was no statistically significant difference between groups for left AVVR. Although the severe degree of left AVVR rates was higher in the MP group before discharge, it was similar to other groups at the last visit. The striking point is that the severe degree of right AVVR rates was higher in the MP group at the last visit, and this finding was statistically significant ($p = .03$).

Although the hospital mortality rates were not statistically different, it was significantly less in the ALA group, and the hospital mortality rate was higher in the MP group than others. We found that CPB time is an independent risk factor on hospital mortality by univariate analysis (OR = 1.016; 95% CI: 1.002–1.029, $p = .02$).

Previous studies already reported that CPB time increases the risk of mortality.[16,17] Salis et al. reported that 30-min increments in CPB time are an independent risk factor for postoperative death (OR = 1.57, $p < .0001$).[17] We know that lower body weight increases mortality from previous studies.[3] Schleiger and colleagues reported that patient low body weight (<4 kg) is an independent risk factor for mortality and reoperation (Hazard ratio [HR] 0.289, 95% CI: 0.150–0.555, $p < .001$).[5] We also observed that the mortality rate was higher in patients under <4 kg. We found a significant difference in regression analysis for the relationship of body weight <4 kg with mortality (OR: 7.5, 95% CI: 1.433–39.263, $p = .017$). Also, severe degrees of right and left AVVR were found to be significant risk factors for hospital mortality by univariate analysis. By multivariate logistic regression analysis, low body weight (<4 kg) and severe degree of the left AVVR were significant. Hoohenkerk et al.[4] found that severe degree of left AVVR as an independent risk factor for hospital mortality by univariate analysis (OR: 4.33 (1.09–17.22) $p = .037$). However, none of the surgical technics were found to be a risk factor for hospital mortality.

We did regression analysis for total mortality as we did for hospital mortality. We sought to identify the factors: surgical technics, major adverse events, and more than a moderate degree of both AVVR. More than a moderate degree of both AVVR and major adverse events were found to be significant by both univariate and multivariate analysis. Similar to our study, Loomba et al. reported that both the MP and the TP technics were not a risk factor for mortality by binary logistic analysis.[11] Also, Wang et al. recently reported a study comparing surgical results of CAVSD patients as MP and TP technic. They emphasized that MP repair technic can be used with lower mortality and lower incidence of left AVVR.[14]

Our hospital mortality rates were similar to the recent studies' results. The total hospital mortality of this study was 10.1%. On the other hand, our mortality rates were 13.3% before 2016 and decreased to 6.8% after 2016. Late mortality rates were 13.6% after 2016% and 15.5% before 2016. Even these results were not statistically significant, and mortality rates decreased with the surgical era. There are too many research in the literature that comparing surgical results after CAVSD repair by surgical era.[3,13] Airaksinen et al. reported a study of 388 CAVSD patients comparing with the last six decades. They showed how the surgical results are improving by decades.[13] We thought that our results significantly improved with years, probably because of gaining experience. Also, leaving MP technic might contribute to this situation.

Crawford reported the incidence of reintervention to be as high as 19.7%.[18] We had six (6.7%) patients who needed reintervention. Loomba et al. found 5.95% in the MP group required reoperation and 5.12% of those in the TP group.[11] Although it was not statistically significant in our study, the reintervention rate in the MP (18.8%) group was higher than the other groups (4.2% both) in our study. Estimated 1-year freedom from reoperation and death rates was similar, but there was a significant difference at 3-years between ALA (78%) and TP (76%) comparing MP (62%) group. But none of these results were statistically significant. Residual AVVR, which was also discussed in previous studies, takes an important place in reintervention and mortality.[4,18–21] In our study, the need for reoperation in all patients originated from the left or both AVVR. Only one patient reoperated with left AVVR and significant LVOT stenosis. Our binary logistic analysis of covariates on reoperation showed that age less than 4 months and severe degree of left AVVR are independent risk factors by both univariate and multivariate analysis. Surgical technic was not found to be a risk factor. Fong et al. reported that freedom from left AV valve reintervention at 5-year was 85% for the MP group and 87% for the TP group.[19] Also, loomba et al. reported that there was no significant difference of need for reoperation for left AVVR associated with the MP and TP technic.[11]

5 | CONCLUSION

Surgical treatment of CAVSD can be performed with satisfactory results. Our study showed that patients smaller than 4 months and 4 kg have associated with poor prognosis. It is also important to avoid prolonged CPB times and major adverse events to decrease the risk of mortality. Left AVVR remains a challenging issue for reoperation and mortality. TP technique looks superior with similar CPB and ACC times compared with MP technique. Although the ALA technique has recently started to be experienced, it may use without extending the CPB time and gives satisfactory results for AV valve competency. We need more studies with a large number of patients and longer follow-up times for better results.

6 | LIMITATIONS

The main restriction of this study is that the study was retrospective and carried out in a single center with a limited number of patients.

CONFLICT OF INTERESTS

The authors declare that there are no conflict of interests.

AUTHOR CONTRIBUTIONS

Concept/Design: Serdar Basgoze, Selen Onan. *Data analysis/interpretation*: Serdar Basgoze, Okan Yildiz, Erkut Ozturk. *Drafting article*: Serdar Basgoze, Selen Onan. Statistics: Serdar Basgoze, Erkut Ozturk. *Data collection*: Serdar Basgoze, Okan Yildiz.

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