

Selective conduction differences in children with isolated bicuspid aortic valve

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ABSTRACT

Objective: Bicuspid aortic valve (BAV) is one of the most common congenital heart defects, yet the electrocardiographic features of isolated BAV in children have not been well characterized. We aimed to evaluate electrocardiographic parameters in pediatric patients with isolated BAV and to investigate whether early electrical changes are detectable before overt valve dysfunction.

Materials and Methods: In this retrospective case-control study, 30 children with isolated and hemodynamically uncomplicated BAV were compared with 32 age- and sex-matched healthy controls. Via 12-lead surface electrocardiography, P wave parameters, QT and QTc intervals, QRS duration, axis measurements, and the QRS-T angle were assessed by two blinded investigators. For the ECG parameters, correction for multiple comparisons was applied with the Benjamini-Hochberg method.

Results: The study included 30 children with BAV and 32 controls; median age was 142.5 versus 141.5 months, and male sex was present in 70.0% versus 75.0%, respectively. After correction for multiple comparisons, only the minimum duration of the P wave ($q=0.005$) and the dispersion of the P wave ($q=0.008$) showed significant differences between the groups; P minimum duration was higher and P wave dispersion was lower in the BAV group. No difference was found between the groups in the PR interval, QRS duration, the parameters of repolarization, and axis measurements. In the BAV group, aortic Z-scores were higher despite preserved systolic function of the left ventricle, and the left ventricular mass index did not reach statistical significance ($p=0.058$).

Conclusion: Isolated pediatric BAV is associated with selective electrocardiographic changes at the level of atrial conduction, in the absence of a hemodynamic burden, while ventricular conduction and repolarization are not affected at this stage.

Keywords: Bicuspid aortic valve, cardiology, electrocardiography, heart conduction system, heart valve disease, pediatrics

Introduction

Bicuspid aortic valve (BAV) is one of the most common congenital heart defects. In the general population, the proportion is between 0.5% and 2%, and in cohorts of newborns it has been reported at roughly 0.7–0.8% (1). The anomaly may be present in isolation, or it may coexist with other congenital heart defects such as coarctation of the aorta or ventricular septal defect, and it is frequently associated with anomalies of the aorta (2). In morphological terms, BAV is characterized by the presence of two functional leaflets in place of the normal tricuspid arrangement, and several systems of classification have been described on the basis of the fusion patterns of the leaflets (3). The etiology of BAV is multifactorial and carries a clear genetic component. Cells of the neural crest have been shown to take part both in the development of the aortic valve and in the maturation of the cardiac conduction system (4). Such a shared embryologic origin raises the possibility that structural anomalies of the

valve and disturbances of electrical conduction may coexist during early life (5).

Many children with isolated BAV are asymptomatic. Although the condition is considered benign in the early period, the natural course of valve dysfunction and of changes in the aorta may begin well before becoming clinically apparent (6). In clinical practice, BAV is associated with progressive forms of valve dysfunction, including aortic stenosis and aortic regurgitation, with aortopathy, and, as a consequence, with left ventricular hypertrophy, heart failure, and a need for surgery in a considerable proportion of patients (7). In spite of its clinical importance, early markers that are associated with adverse outcomes in BAV are difficult to identify. Current strategies for follow-up are based largely on imaging (8). Electrocardiography (ECG) is a widely available, non-invasive, and easily applied tool, yet its place in the surveillance of BAV is not well defined, and the method is not included in routine follow-up within current guidelines. Given the shared developmental origin of

the aortic valve and the cardiac conduction system, together with the scarcity of data from early life, an evaluation of electrocardiographic features in pediatric patients with BAV may provide information of value with regard to subclinical cardiac remodeling and the stratification of risk. We therefore set out to evaluate electrocardiographic parameters in children with bicuspid aortic valve and to investigate possible electrical changes that may be detectable in the early period, before overt valve dysfunction has developed.

Materials and Methods

As a retrospective case-control study, the present work was carried out at the pediatric cardiology clinic of Necmettin Erbakan University Faculty of Medicine. Medical records of 57 patients aged 0 to 18 years who had received a diagnosis of bicuspid aortic valve (BAV) by echocardiographic examination between January 2024 and December 2025 were reviewed in a retrospective manner. In order to evaluate an isolated and hemodynamically uncomplicated BAV phenotype, the following were set as criteria for exclusion: aortic stenosis, mild or greater aortic regurgitation, dilatation of the aortic root or of the ascending aorta, and the presence of additional cardiac anomalies. Dilatation of the aorta was defined as a Z-score of 2 or above at any level of the aortic annulus, the sinus of Valsalva, the sinotubular junction, or the ascending aorta, indexed to age and body surface area. After the application of these criteria, patients were excluded because of aortic stenosis (n=9), aortic regurgitation (n=20), aortic dilatation (n=12), or additional cardiac abnormalities, including ventricular septal defect and mitral regurgitation (n=3). These exclusion categories were not mutually exclusive; therefore, more than one reason for exclusion was present in some patients, and the numbers cited above do not sum to the total number of excluded patients. Trace or trivial aortic regurgitation was not considered hemodynamically significant and was therefore not used as a basis for exclusion. Following the application of all criteria, 30 patients with isolated BAV were included in the final analysis.

The control group consisted of 32 healthy children of similar age and sex who had presented to our hospital during the same period and who had no known cardiac disease. In total, the final population of the study comprised 30 BAV patients and 32 controls, for a total of 62 participants.

Electrocardiographic assessment

A 12-lead surface electrocardiogram (ECG) was recorded at rest for all of the participants, at a paper speed of 25 mm/s and with a standard calibration of 10 mm/mV. Recordings were obtained with a three-channel, 12-lead GE MAC 2000 ECG system (GE Healthcare, Chicago, IL, USA). All of the ECG measurements were performed manually on the original printouts by two independent investigators who were blinded to the assignment of the groups, with the aid of a digital caliper. For each of the parameters, at least three consecutive complexes were evaluated and the values were averaged. With regard to the P wave parameters, the maximum duration of the P wave (P max), the minimum duration of the P wave (P min), and the dispersion of the P wave (P max minus P min) were measured. P max was defined as the longest P wave duration recorded

across all of the leads. P min was the shortest. With regard to the parameters of ventricular repolarization, QT maximum (QT max), QT minimum (QT min), and QT dispersion (QTd, equal to QT max minus QT min) were calculated. The QT interval was defined as the interval from the onset of the QRS complex to the point at which the T wave returned to the isoelectric line, and it was assessed across all of the leads. Heart-rate-corrected QT (QTc) was calculated with the Bazett formula ($QTc = QT / \text{square root of RR}$) (9). The PR interval and the QRS duration were also measured. The frontal-plane P axis, QRS axis, and T axis were determined on the surface ECG by means of standard electrocardiographic methods; the QRS-T angle was calculated as the angular difference between the QRS axis and the T axis. In order to assess the reproducibility of the measurements, intraobserver and interobserver agreement were evaluated in a randomly selected subset of 20 cases, through the use of the intraclass correlation coefficient (ICC).

Echocardiographic assessment

Echocardiographic examinations were performed using a Siemens Acuson Juniper ultrasound system (Siemens Healthineers, Erlangen, Germany). M-mode, two-dimensional, and color Doppler imaging methods were used for standard echocardiographic assessment. All of the measurements were made by an experienced pediatric cardiologist who was blinded to the assignment of the groups. Dimensions of the left ventricle and thicknesses of the walls were measured in M-mode. The parasternal long-axis view was used for all of these measurements. Ejection fraction (EF) and shortening fraction (SF) of the left ventricle were calculated with the Teichholz method (10). Mass of the left ventricle was calculated with the Devereux formula, and the left ventricular mass index (LVMI, g/m²) was obtained by dividing the mass by the body surface area (11). Relative wall thickness (RWT) was calculated as 2 times the thickness of the posterior wall divided by the internal diameter of the left ventricle at end-diastole. Morphology of the BAV was assessed on transthoracic echocardiography through the parasternal short-axis views, and the phenotype of the valve, including the number of raphe and the pattern of leaflet fusion, was classified according to the system described by Sievers and Schmidtke. Under this classification, a morphology with two symmetric leaflets and no raphe was designated Type 0; a morphology with a single raphe, Type 1; and a morphology with two raphe, Type 2. Among the Type 1 cases, the pattern of fusion was recorded as right-left coronary leaflet fusion (RL), right-noncoronary leaflet fusion (RN), or left-noncoronary leaflet fusion (LN) (12). Dimensions of the aortic root, including the aortic annulus, the sinus of Valsalva, the sinotubular junction, and the ascending aorta, were measured from the parasternal long-axis view. Each of the measurements was converted to a Z-score indexed to age and body surface area, with the use of the Colan Z-score system based on reference data from Boston Children's Hospital (13).

Statistical analysis

Statistical analyses were performed with SPSS version 24.0 (IBM Corp., Armonk, NY, USA). Normality of the continuous variables was assessed by the Shapiro-Wilk test together with visual inspection. Given that the size of the sample was limited and that a considerable proportion of the variables did not follow

a normal distribution, continuous variables were presented as median and interquartile range (IQR). Categorical variables were expressed as count and as percentage. For comparisons between the BAV and control groups, the Mann-Whitney U test was used for continuous variables and Fisher's exact test for categorical variables. All of the tests were two-sided. Significance was set at p below 0.050. Because the primary aim of the study was the evaluation of electrophysiological parameters in the BAV patients, correction for multiple comparisons was applied only to the ECG parameters. For this purpose, the rate of false discovery (FDR) was controlled with the Benjamini-Hochberg method, and q values below 0.050 were considered significant. Echocardiographic parameters were presented as secondary and descriptive findings; those analyses were regarded as exploratory. In the LVMI subgroup analyses, each group was split at its own median LVMI value into high and low subgroup, and comparisons were made with the Mann-Whitney U test. Such an approach was preferred because the use of a fixed threshold is limited in the pediatric population, where LVMI varies considerably with age and with body surface area. Reproducibility of the ECG measurements was assessed in a randomly selected subset of 20 cases by means of the intraclass correlation coefficient (ICC). An ICC below 0.50 was interpreted as poor agreement, 0.50 to 0.75 as moderate, 0.75 to 0.90 as good, and above 0.90 as excellent.

Results

A total of 62 subjects were included in the study, of whom 30 were patients with bicuspid aortic valve (BAV) and 32 were healthy controls. Demographic and basic clinical characteristics of the two groups are summarized in Table I. Between the BAV and control groups, no statistically significant difference was found with regard to age, sex distribution, weight, height, body surface area, or heart (Table I). In the BAV group, the median age at the time of diagnosis stood at 96.5 months (IQR: 36.3–119.0). With regard to the morphology of the valve, the most frequently encountered

Table I: Demographic characteristics and valve morphology of the bicuspid aortic valve and control groups

Variable	BAV	Control	p
Number of patients	30	32	-
Age (months)*	142.5 (113.8–179.2)	141.5 (99.8–186.5)	0.756
Weight (kg)*	42.0 (30.0–54.0)	46.5 (26.8–60.2)	0.597
Height (cm)*	153.5 (137.5–163.0)	155.0 (133.8–168.0)	0.972
Body surface area (m ²)*	1.37 (1.06–1.56)	1.42 (0.99–1.69)	0.678
Heart rate (beats/min)	84.0 (75.0–97.0)	80.5 (69.0–89.8)	0.262
Male sex†	21 (70.0)	24 (75)	0.884
Age at diagnosis (months)*	96.5 [36.3–119.0]	-	NA
BAV morphology		-	NA
Type 0	11 (36.7)	-	NA
Type 1 RL	15 (50.0)	-	NA
Type 1 RN	3 (10.0)	-	NA
Type 1 LN	1 (3.3)	-	NA

*: median (IQR) (Mann-Whitney U test), †: n(%) (Fisher's exact test), **BAV**: bicuspid aortic valve

Table II: Comparison of electrocardiographic parameters between the bicuspid aortic valve and control groups

Variable	BAV*	Control*	p	FDR q
Number of patients	30	32	-	-
PR (ms)	126.0 (117.0–135.0)	130.0 (119.5–140.0)	0.212	0.353
P max (ms)	86.0 (81.0–91.5)	88.0 (84.0–98.0)	0.326	0.478
P min (ms)	55.5 (51.0–60.8)	47.0 (41.0–52.0)	<0.001	0.005
P dispersion (ms)	33.0 (26.3–36.5)	39.5 (32.8–48.0)	0.001	0.008
QT max (ms)	362.0 (343.0–376.0)	363.0 (351.2–376.0)	0.746	0.746
QT min (ms)	313.0 (298.5–325.5)	311.0 (298.5–320.0)	0.382	0.478
QTd (ms)	41.0 (35.0–52.8)	50.0 (41.5–58.0)	0.033	0.123
QTc max (ms)	424.0 (412.5–437.0)	417.0 (402.2–427.2)	0.116	0.267
QTc min (ms)	373.5 (360.3–384.0)	363.5 (346.8–375.2)	0.013	0.067
QTc dispersion (ms)	51.0 (41.0–64.5)	59.5 (47.5–64.5)	0.128	0.267
QRS duration (ms)	82.0 (75.0–89.0)	80.0 (71.5–86.0)	0.708	0.746
P axis	45.0 (36.0–64.0)	44.0 (26.0–56.2)	0.356	0.478
QRS axis	65.0 (53.0–84.5)	72.5 (66.8–82.2)	0.101	0.267
T axis	45.0 (33.0–53.5)	46.5 (39.8–55.5)	0.143	0.267
QRS-T angle	23.0 (7.0–33.0)	28.0 (14.8–36.2)	0.418	0.482

*: median (IQR) (Mann-Whitney U test), **BAV**: bicuspid aortic valve, **QTd**: QT dispersion, **QTc**: heart-rate-corrected QT, **ms**: millisecond, Correction for multiple comparisons was applied with the Benjamini-Hochberg method for control of the false discovery rate (FDR).

Table III: Comparison of echocardiographic parameters between the bicuspid aortic valve and control groups

Variable	BAV*	Control*	p
Number of patients	30	32	-
Ejection fraction (%)	70.0 (68.5–72.0)	71.0 (68.8–74.0)	0.269
Shortening fraction (%)	39.0 (38.0–41.0)	40.0 (38.0–42.0)	0.187
Aortic annulus (mm)	17.0 (15.5–19.5)	16.0 (14.0–18.2)	0.399
Aortic annulus Z-score	-0.29 (-1.14–0.62)	-1.3 (-1.8– -0.3)	0.011
Sinus of Valsalva (mm)	23.0 (19.0–25.3)	22.0 (17.8–24.2)	0.611
Sinus of Valsalva Z-score	-0.86 (-1.83– -0.15)	-1.3 (-2.4– -0.6)	0.082
Sinotubular junction (mm)	18.0 (16.0–21.4)	17.8 (15.8–19.4)	0.380
Sinotubular junction Z-score	-0.29 (-1.74–0.79)	-1.6 (-2.5– -1.0)	0.004
Ascending aorta (mm)	21.1 (19.0–24.0)	20.0 (18.8–22.6)	0.221
Ascending aorta Z-score	0.64 (-0.48–1.29)	-0.1 (-0.5–0.4)	0.033
IVSd (mm)	8.0 (6.5–8.0)	7.0 (6.0–8.0)	0.397
LVEDd (mm)	42.0 (38.5–48.0)	41.5 (35.8–48.0)	0.597
LVEDs (mm)	25.0 (23.5–27.0)	24.5 (20.0–28.0)	0.596
LVPWd (mm)	8.0 (6.0–8.5)	7.0 (6.0–8.0)	0.298
LVEDd Z-score	-0.03 (-0.77–0.73)	-0.5 (-1.0–0.3)	0.207
LVEDs Z-score	-0.71 (-1.17– -0.05)	-0.8 (-1.7– -0.1)	0.272
Left ventricular mass (g)	97.4 (66.6–127.6)	95.7 (54.3–117.4)	0.554
Left ventricular mass index (g/m ²)	71.5 (65.6–87.3)	65.5 (58.3–71.6)	0.058
Relative wall thickness	0.35 (0.32–0.41)	0.34 (0.31–0.38)	0.507

*: median (IQR) (Mann-Whitney U test), **BAV**: bicuspid aortic valve, **IVSd**: end-diastolic interventricular septal thickness, **LVEDd**: end-diastolic left ventricular diameter, **LVEDs**: end-systolic left ventricular diameter, **LVPWd**: end-diastolic left ventricular posterior wall thickness.

type was Type 1 RL, which was observed in 50.0% of the patients, followed by Type 0 at 36.7%, Type 1 RN at 10.0%, and Type 1 LN at 3.3%.

Electrocardiographic parameters of the BAV and control groups are compared in Table II. With regard to atrial conduction, the duration of P min in the BAV group was found to be higher than

Table IV: Comparison of electrocardiographic parameters according to LVMI subgroups

Variable	BAV group			Control group		
	High LVMI	Low LVMI	p	High LVMI	Low LVMI	p
Number of patients	15	15	-	16	16	-
Heart rate (beats/min)*	77.0 (72.5–91.0)	86.0 (82.0–101.5)	0.164	69.0 (63.5–82.2)	90.0 (79.2–102.8)	<0.001
PR (ms)*	126.0 (120.0–135.0)	124.0 (115.0–133.0)	0.589	137.0 (129.5–146.5)	121.0 (114.5–134.5)	0.003
QT max (ms)*	370.0 (352.0–376.0)	345.0 (341.0–368.0)	0.158	368.0 (361.5–384.5)	353.0 (325.0–367.0)	0.010
QT min (ms)*	315.0 (310.0–331.5)	312.0 (294.5–318.0)	0.350	316.0 (308.8–337.2)	304.0 (286.5–315.2)	0.027
QTc max (ms)*	424.0 (404.5–441.0)	433.0 (415.0–435.5)	0.633	408.0 (386.2–425.2)	423.5 (412.0–433.0)	0.045
QRS duration (ms)*	84.0 (80.0–94.0)	74.0 (72.0–82.0)	0.003	85.0 (80.0–91.0)	75.0 (68.0–81.0)	0.005

*: median (IQR) (Mann-Whitney U test), **LVMI**: left ventricular mass index, **QTc**: heart-rate-corrected QT

that in the control group [55.5 (51.0–60.8) vs. 47.0 (41.0–52.0), $p<0.001$], whereas the dispersion of the P wave was lower in the BAV group than in the controls [33.0 (26.3–36.5) vs. 39.5 (32.8–48.0), $p=0.001$]. In the unadjusted analysis, both QTd and QTc min also showed significant differences between the groups, with p values of 0.033 and 0.013, respectively. After correction for multiple comparisons by means of the Benjamini-Hochberg method for the false discovery rate, however, only P min and P wave dispersion retained their statistical significance, at q values of 0.005 and 0.008.

Echocardiographic findings of the BAV and control groups are presented in Table III. No significant difference was found between the groups with regard to ejection fraction or shortening fraction, both of which reflect systolic function of the left ventricle. In terms of the absolute values, the aortic root measurements were also similar between the two groups. By contrast, certain aortic Z-scores that had been standardized for body surface area were higher in the BAV group. In particular, the Z-score of the aortic annulus, the Z-score of the sinotubular junction, and the Z-score of the ascending aorta were all significantly higher in the BAV group than in the control group [–0.29 (–1.14–0.62) vs. –1.3 (–1.8– –0.3), $p=0.011$; –0.29 (–1.74–0.79) vs. –1.6 (–2.5– –1.0), $p=0.004$ and 0.64 (–0.48–1.29) vs. –0.1 (–0.5–0.4), $p=0.033$ respectively]. For the sinus of Valsalva Z-score, no significant difference was found between the groups. The left ventricular mass index was numerically higher in the BAV group, but the difference did not reach statistical significance (71.5 [65.6–87.3] g/m² vs 65.5 [58.3–71.6] g/m², $p=0.058$). No significant difference was observed with regard to relative wall thickness, left ventricular dimensions, or wall thicknesses. Given these findings, it is evident that while systolic function and the geometry of the left ventricle were largely preserved in the isolated BAV group, early structural differences at the level of the aortic Z-scores may already be present.

Our analysis of the effect of the left ventricular mass index on the electrocardiographic parameters was carried out within each of the two groups separately. Because no universally accepted threshold value for LVMI covers the entire pediatric age range, both the BAV and the control groups were divided into high and low LVMI subgroups at their own median value. For the BAV group, the median stood at 71.42 g/m², with 15 patients in each of the subgroups. In the control group, the median was 65.53 g/m², and the subgroups consisted of 16 subjects each.

The results of the LVMI subgroup analysis are presented in Table IV. The only electrocardiographic parameter that differed significantly between the high and the low LVMI subgroups

within the BAV group was QRS duration, which was longer in the high-LVMI subgroup (84.0 [80.0–94.0] ms vs 74.0 [72.0–82.0] ms, $p=0.003$). All of the remaining parameters were comparable. In the control group, by contrast, the relationship between LVMI and the electrocardiographic parameters was more extensive: heart rate was lower in the high-LVMI subgroup ($p<0.001$); the PR interval was longer ($p=0.003$); QT max and QT min were both higher ($p=0.010$ and $p=0.027$); QTc max was lower ($p=0.045$); and QRS duration was longer ($p=0.005$). For both of the groups, P min, P wave dispersion, QTd, QTc min, QTc dispersion, the axis measurements, and the QRS-T angle did not differ significantly between the subgroups.

With regard to the reproducibility of the electrocardiographic measurements, both intraobserver and interobserver agreement were high across all of the parameters, with intraobserver ICC values between 0.852 and 0.995 and interobserver ICC values between 0.837 and 0.997, corresponding to a level of agreement that was generally good to excellent. Agreement was, in this respect, similarly strong for the P wave parameters that constituted the principal findings of the study. The ICC values for P min stood at 0.968 for intraobserver and 0.992 for interobserver agreement, and for P wave dispersion the corresponding values were 0.957 and 0.984. Such findings indicate that the measurements were highly reliable.

Discussion

The principal finding of the present study is that electrocardiographic differentiation in isolated and hemodynamically uncomplicated pediatric BAV does not take the form of a widespread conduction or repolarization abnormality but is instead confined, selectively, to the P wave parameters. After correction for multiple comparisons, only P minimum duration and P wave dispersion retained their significance, while the PR interval, QRS duration, QT- and QTc-based measures of repolarization, and the axis parameters did not differ between the groups. Ventricular parameters were unaffected. The observation that P minimum duration was higher and P wave dispersion was lower in the BAV group suggests that the most prominent of the electrical differences is found at the level of atrial conduction rather than at the level of ventricular conduction or repolarization.

These findings are, on the whole, consistent with the limited data in the literature, although they differ in certain respects. Bilen and colleagues, in an earlier study of adult patients

with isolated BAV, reported an increase in both the duration of the P wave and the dispersion of the P wave (14). In our study, by contrast, it was not the maximum duration but the minimum duration of the P wave that was prominent, and P wave dispersion was lower rather than higher. The direction differed. Such a pattern suggests that atrial depolarization in isolated BAV may diverge from the distribution typically seen in healthy individuals. Of note, age-related features specific to the pediatric population should be considered when interpreting the P wave parameters, since the duration and the dispersion of the P wave have been shown to vary with age in healthy children (15). In our cohort, the demographic similarity of the two groups reduces the likelihood that the observed differences are attributable to such variables. Even so, these findings should be interpreted not as direct indicators of the risk of arrhythmia but rather as markers of a limited electrophysiological differentiation.

Few studies have directly related electrocardiographic findings to pediatric BAV. In a 2025 study of neonates with BAV, Stormly and colleagues reported a longer PR interval, a longer QRS duration, and a lower R wave amplitude in lead V6; however, these differences did not survive correction for multiple comparisons (16). The fact that our group of patients was older than the neonatal period and that complicated cases had been excluded may, in part, explain why the PR and QRS differences reported by Stormly and colleagues were not observed in our cohort. Together with our results, these data suggest that electrical changes in pediatric BAV may appear early but do not necessarily follow a consistent pattern. A uniform signature has not been identified.

A second important finding is that, although the systolic function of the left ventricle and the geometry of the left ventricle were largely preserved, certain aortic Z-scores were higher in the BAV group than in the control group. The left ventricular mass index was numerically higher in the BAV group but did not reach statistical significance, and this observation suggests that the electrical differences in our study cannot be explained by overt left ventricular hypertrophy or by impairment of the systolic function. Such a finding is consistent with the existing literature and indicates that early structural differences, particularly at the level of the aortic geometry, may be present in pediatric BAV before a considerable hemodynamic burden has developed (17,18). Despite the higher aortic Z-scores in the BAV group, however, the parameters of ventricular conduction and of repolarization did not show a corresponding difference. An increase in the mass of the left ventricle is, in general, associated with changes in the parameters of ventricular conduction and repolarization, yet no such changes were observed in the present study. In the literature as well, it has been reported that ventricular remodeling is limited in hemodynamically uncomplicated BAV and that electrocardiographic changes, for the most part, tend to be more closely tied to dysfunction of the valve than to the underlying structural anomaly itself (19).

The subgroup analysis further supported this pattern, although these findings should be considered exploratory given the small sample size. In the control group, LVMI was associated with several ECG parameters, whereas in the BAV

group, only QRS duration differed according to LVMI. This contrast suggests that the relationship between ventricular structure and electrical activity in children with isolated BAV may differ from the classical model of ventricular loading. Although associations between conduction parameters and structural measurements have been reported in adult BAV cohorts, this relationship may not be directly applicable to pediatric patients with isolated BAV (20). Further studies with larger cohorts are needed to clarify the structural–electrical relationship in this population.

Limitations

Several limitations of the present study should be acknowledged. The single-center design and relatively small sample may have limited study power, particularly for subgroup analyses. Because the design was retrospective and cross-sectional, selection bias cannot be excluded, and longitudinal changes in electrocardiographic findings or their relationship with clinical outcomes could not be assessed. In addition, the absence of Holter monitoring and advanced electrophysiological testing limits interpretation of the clinical significance of the observed ECG differences.

Among the strengths of the study, the inclusion of only isolated and hemodynamically uncomplicated BAV cases is particularly relevant. This approach minimized the potential confounding effects of valve dysfunction and hemodynamic burden, allowing a more direct evaluation of the early electrophysiological phenotype. The use of an age- and sex-matched control group, together with high intraobserver and interobserver agreement for ECG measurements, further supports the reliability of the findings.

Conclusion

In conclusion, the present study shows subtle but selective electrophysiological differences in children with isolated BAV in the absence of considerable hemodynamic burden. Although atrial conduction parameters appear to be altered even in hemodynamically uncomplicated BAV, the clinical significance of these findings remains uncertain. Larger longitudinal studies with detailed clinical follow-up are needed to determine whether these electrocardiographic changes have prognostic significance.

Ethics committee approval

This study was conducted in accordance with the Helsinki Declaration Principles. The study was approved by Necmettin Erbakan University (13 March 2026, reference number: 2026/6283).

Contribution of the authors

Study conception and design: US and ABP; data collection: MB, FŞ, US and TB; analysis and interpretation of results: US, MBO, and FŞ; draft manuscript preparation: US, FŞ. All authors reviewed the results and approved the final version of the article.

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Conflict of interest

The authors declare that there is no conflict of interest.

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