Bicuspid Aortic Valve in Infants, Children, and Adolescents: A Review for Primary Care Providers

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EDUCATION GAPS

Bicuspid aortic valve is the most common congenital heart defect in children, adolescents, and adults. Primary care providers play an important role in screening, referral, and follow-up of these patients and should be aware of the family screening guidelines, sports participation recommendations, and periodic follow-up requirements for adequate surveillance of the complications that arise from bicuspid aortic valve.

OBJECTIVES *After reading this article, readers should be able to:*

1. Describe the epidemiology and anatomy of bicuspid aortic valve (BAV).
2. Understand the clinical presentation and diagnosis of BAV in infants, children, and adolescents.
3. Identify the various complications of BAV disease.
4. Discuss the management and follow-up requirements for BAV.
5. Analyze the family screening and sports participation guidelines for patients with BAV.

Bicuspid aortic valve (BAV) is the most common congenital heart defect in children, adolescents, and adults. (1) It is a heterogeneous disease that affects both the aortic valve and the aorta. It can lead to many complications, including aortic valve stenosis, regurgitation, or endocarditis. (2)(3) It also can lead to dilation of the aorta, predisposing individuals to a significantly higher risk of aortic aneurysm and dissection. (4) Although most individuals with BAV present with these long-term complications during adulthood, a considerable number of patients may also present during childhood and adolescence with early-onset disease; that may require interventions in up to 12% to 15% of the patients. (5)(6) Therefore, patients with BAV require lifelong follow-up and surveillance. BAV has multiple implications in terms of sports participation and family screening, making it an important subject for primary care providers. This article reviews the anatomy, genetics, presentation, diagnosis, and management of BAV in infants, children, and adolescents.

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ABBREVIATIONS

AHA American Heart Association
BAV bicuspid aortic valve
TTE transthoracic echocardiography

EPIDEMIOLOGY

BAV was first described by Leonardo da Vinci in *Anatomica Physiologica* in 1500. The estimated incidence of BAV is 0.5% to 2% in the general population. (1) It is 3 times more prevalent in males than in females. It can occur as an isolated lesion or in association with other simple or complex congenital heart defects (Table). (5) Moreover, it also can be a clinical feature of certain genetic syndromes and connective tissue disorders (Table). The most common congenital heart defect associated with BAV is coarctation of the aorta; BAV occurs in 25% to 85% patients with coarctation of the aorta. (5)(7) The most common genetic syndrome associated with BAV is Turner syndrome; 15% to 30% patients with Turner syndrome are affected by BAV. (11)

ANATOMY

A normal aortic valve consists of 3 cusps. These cusps are named on the basis of the respective coronary arteries that arise from the corresponding sinuses, as right, left, and noncoronary cusps (Fig 1A). BAV arises from the fusion of any of these 2 cusps, leading to 2 functional cusps instead of 3 (Fig 1B). BAV can be divided into different morphologic subtypes based on the aortic valve cusps that are fused. The most common form of BAV is right and left coronary cusp fusion, present in 71%, followed by right and noncoronary cusp fusion, present in 28%; left and noncoronary cusp fusion is the rarest form, present in only 1% of the patients with BAV. (5)(17) It is imperative to determine the different types of BAV because it may provide insight into the prognosis and complications.

GENETICS AND INHERITANCE

A heritable basis for BAV is reflected by the 8% to 10% frequency of BAV or other left ventricular outflow tract obstructive lesions in first-degree relatives of patients with BAV. (18)(19)(20) The genetic underpinnings of BAV are complex and heterogeneous. They can be polygenic in individual patients. Familial disease fits an autosomal dominant inheritance pattern with incomplete penetrance. (21) BAV is also a phenotypic feature of Turner syndrome (45,XO), present in almost 15% to 30% of patients, an incidence 30 to 60 times greater than that in healthy females (46,XX). (11) Therefore, loss of genes on the X chromosome may be a predisposing factor for BAV. (22) Some genes (syndromes) associated with BAV include *TGFBR1-2* (Loeys-Dietz syndrome), *NOTCH1, ACTA2* (familial thoracic aortic aneurysm and dissection), *FBN1* (Marfan syndrome), *KCNJ2* (Andersen-Tawil syndrome), *GATA6, GATA5, EGFR, SMAD6,* and *ROBO4*. (22) Currently there is no specific genetic testing available for BAV. Some of these genes are included on clinical testing panels for generic congenital heart disease and all can be screened for in patients who undergo whole exome sequencing. However, no dedicated, high-yield genetic testing platform is currently available specifically for BAV. Currently, presence of a genetic mutation does not necessarily confer a risk of worsening aortic stenosis. However, longitudinal outcome studies are required to determine whether certain BAV-associated genes confer increased risk of aortic valve dysfunction or dilation of the aorta.

PRESENTATION

BAV includes a spectrum of abnormalities ranging from aortic valve dysfunction to dilation of the aorta (aortopathy). It can present in a variety of ways at different ages (Fig 2). The most common presentation of BAV is auscultation of a murmur or a systolic click. Most children with BAV are completely asymptomatic and may be diagnosed incidentally or as a result of echocardiography performed for family screening. Rarely, patients with BAV may be symptomatic at initial presentation. Neonates with BAV may present with critical aortic valve stenosis and may require urgent aortic valve intervention to relieve the obstruction. Similarly, older children or adolescents can be symptomatic depending on the degree of aortic valve dysfunction. BAV also can be diagnosed indirectly during evaluation for other congenital heart defects, including coarctation of the aorta, hypoplastic left heart syndrome, or Shone complex (a

Table. Prevalence of BAV in Other Congenital Heart Defects and Genetic Syndromes

	PREVALENCE OF BAV, %	REF. NO.
Congenital heart defects		
Coarctation of the aorta	25–85	5, 7
Interrupted aortic arch	36	5
Supravalvular aortic stenosis	27.5–38	8, 9, 10
Hypoplastic left heart syndrome	24.5	5
Ventricular septal defect	3.8	5
Genetic syndromes		
Turner syndrome	15–30	11
Williams syndrome	5–12	12, 13
Marfan syndrome	4.7	14
Loeys-Dietz syndrome	8	15
Ehlers-Danlos syndrome	1	16

BAV=bicuspid aortic valve.

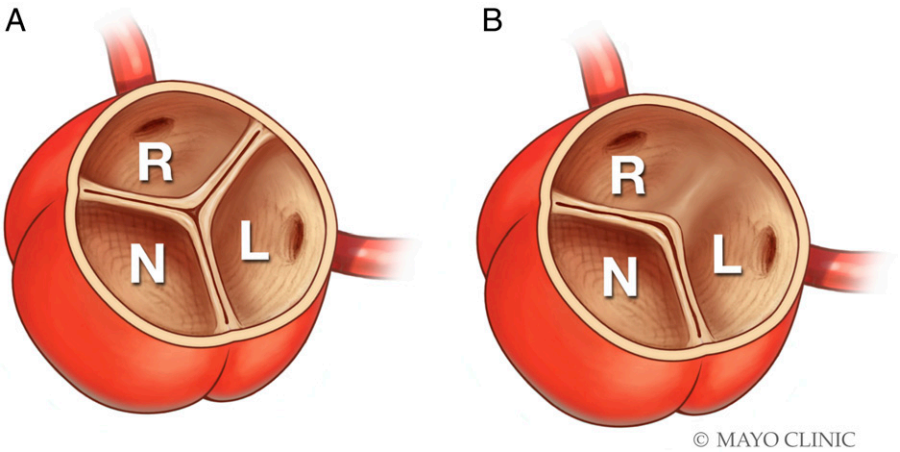


Figure 1. A. Normal aortic valve with 3 cusps labeled right (R), left (L), and noncoronary (N). B. Bicuspid aortic valve with fusion of the R and L coronary cusps, leading to 2 functional cusps.

combination of multiple left-sided heart obstructive defects, such as supravalvar mitral ring, parachute mitral valve, subaortic stenosis, BAV, and coarctation of the aorta). (17)(23) Similarly, BAV can be found during screening echocardiography performed in certain genetic syndromes and connective tissue disorders that are strongly associated with BAV, including Turner, Williams, Loeys-Dietz, Marfan, or Ehlers-Danlos syndromes. (17)

CLINICAL DIAGNOSIS

Most patients with BAV are clinically asymptomatic. Clinical suspicion of BAV in an asymptomatic individual is usually on the basis of family history and abnormal auscultatory findings on the physical examination. Children with BAV can have multiple auscultatory findings depending on the status of their valve function.

a. Normally functioning BAV: These patients may have only an ejection systolic click, which is an extra heart sound after S1 heard best at the apex. The ejection click can be differentiated from a split S1 (normal variant) by lack of variability with breathing and is heard best at the apex. They also may have a soft ejection systolic murmur. (24)
b. Stenotic BAV: These patients may have a systolic crescendo-decrescendo ejection murmur loudest at the right upper sternal border radiating toward the sternal notch and carotids, intensity varying with the degree of stenosis. An ejection systolic click may precede the murmur but is absent in severe aortic stenosis. Patients may also have a systolic thrill and increased apical impulse.
c. Regurgitant BAV: These patients may have an early high-pitched diastolic decrescendo murmur radiating from the right upper chest toward the left lower sternal border. In older children, murmur can be heard best by asking the patient to sit and lean forward with the breath held in full expiration. Murmur is accentuated by maneuvers that increase afterload, such as the handgrip maneuver. Patients with severe aortic regurgitation may have bounding pulses and a wide pulse pressure.

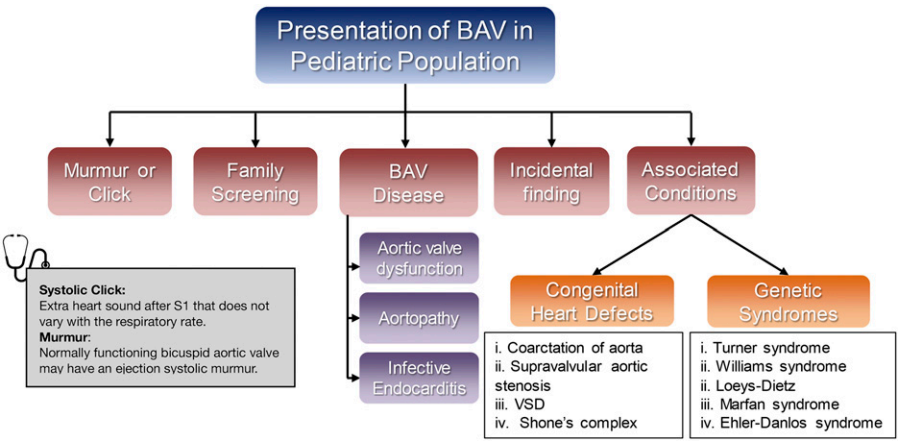


Figure 2. Flow sheet of the presentation of bicuspid aortic valve (BAV) in the pediatric population. VSD=ventricular septal defect.

Rarely, children with BAV can be symptomatic. Symptoms of BAV are a manifestation of its complications and usually are evident only in severe disease. Patients with clinically significant aortic valve stenosis or regurgitation may present with failure to thrive, fatigue, dyspnea, and chest pain on exertion depending on their age. Clinical findings in symptomatic infants, children, and adolescents according to age are listed in Figure 3.

For patients suspected of having BAV, it is important to look for findings of associated congenital heart lesions and genetic syndromes. For instance, BAV commonly is associated with coarctation of the aorta. Coarctation of the aorta results in upper extremity hypertension, delayed femoral pulses or a systolic murmur heard prominently at the left interscapular region. Similarly, Turner syndrome is strongly associated with BAV and coarctation of the aorta. In females with BAV and coarctation of the aorta it is important to identify any physical manifestation of Turner syndrome, such as short stature, primary amenorrhea, a broad chest, wide-spaced nipples, and cubitus valgus. It has been proposed that karyotyping for Turner syndrome should be performed in all girls with coarctation of the aorta due to its high prevalence (5.3%–12.6%) and absence of classic findings in mosaicism. (25)(26)

INVESTIGATIONS

Diagnosis of BAV is confirmed by transthoracic echocardiography (TTE) with high sensitivity and specificity of 92% and 96%, respectively. (27)(28)(29) The parasternal short-axis view is used for visualization of the aortic valve cusps and the morphology of fusion (Fig 4 and Video 1). TTE also can quantitate aortic valve dysfunction in terms of degree of stenosis or regurgitation (Video 2). Moreover, left ventricular wall thickness and chamber size can be determined, and both can progressively enlarge in patients with aortic stenosis and aortic regurgitation. In addition, TTE is used to assess the diameter of the aorta and the degree of aortic dilatation at various levels. The degree of aortic dilatation in the pediatric and adolescent population is determined based on the *Z* score formatted to body surface area. Cross-sectional imaging with computed tomographic angiography and magnetic resonance angiography can provide incremental information in patients when there is a concern that intervention may be warranted (Fig 5). Once fully grown,

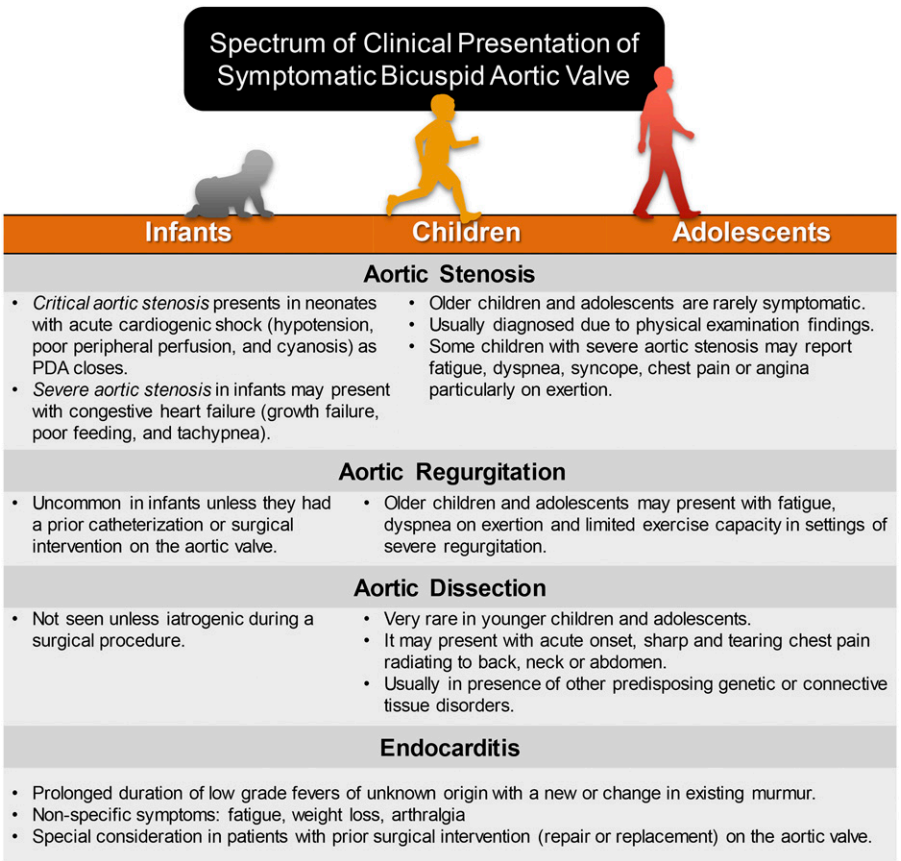


Figure 3. The clinical presentations of various complications in patients with bicuspid aortic valve. PDA=patent ductus arteriosus.

adolescents should have alternate imaging such as computed tomographic angiography or preferably magnetic resonance angiography (due to lack of radiation) to assess the entire aorta and compare it with the TTE measurements.

COMPLICATIONS, PROGRESSION, AND THEIR MANAGEMENT

BAV disease is a spectrum ranging from a normally functioning aortic valve with normal dimensions of the aorta to significant valve dysfunction and aortic aneurysm formation (Fig 6). BAV can lead to 3 major complications: aortic valve disease (stenosis or regurgitation), aortopathy/dilation of the aorta, and endocarditis of the valve. (30) Clinical findings of the various complications are listed in Figure 3. The incidence of primary cardiac events in children and adolescents with BAV due to these complications is very low. (30)(31) Most interventions for patients with BAV are performed for valve stenosis and include balloon angioplasty, surgical valve repair, or replacement. (6) Primary aortic dissection is an extremely rare event in children and usually is associated with other predisposing factors. A detailed description of BAV complications is provided later herein.

Aortic Valve Disease

Aortic Stenosis. Fusion of the aortic valve cusps in BAV can lead to abnormal valve opening and a decrease in the effective valve orifice, causing aortic stenosis. It can be present at birth or develop progressively over time. Critical congenital aortic stenosis presents in a neonate or in early infancy with symptoms of acute-onset heart failure, leading to cardiogenic shock, usually after spontaneous closure of the patent ductus arteriosus. These infants require urgent aortic valve interventions with either catheter-based balloon valvuloplasty (described later herein) or surgical intervention. The choice of intervention is influenced by valve morphology, severity of left ventricular dysfunction, and institutional preference. Older infants and children may develop progressive aortic valve stenosis, which can lead to left ventricular hypertrophy, and these patients may require intervention before adulthood. (6)

Aortic Regurgitation. Abnormal coaptation of the aortic valve cusps may lead to primary aortic valve regurgitation. Moreover, regurgitation also can develop progressively secondary to previous aortic valve interventions, including balloon valvuloplasty and surgical valvotomy. Significant aortic valve regurgitation can lead to left ventricular dilation

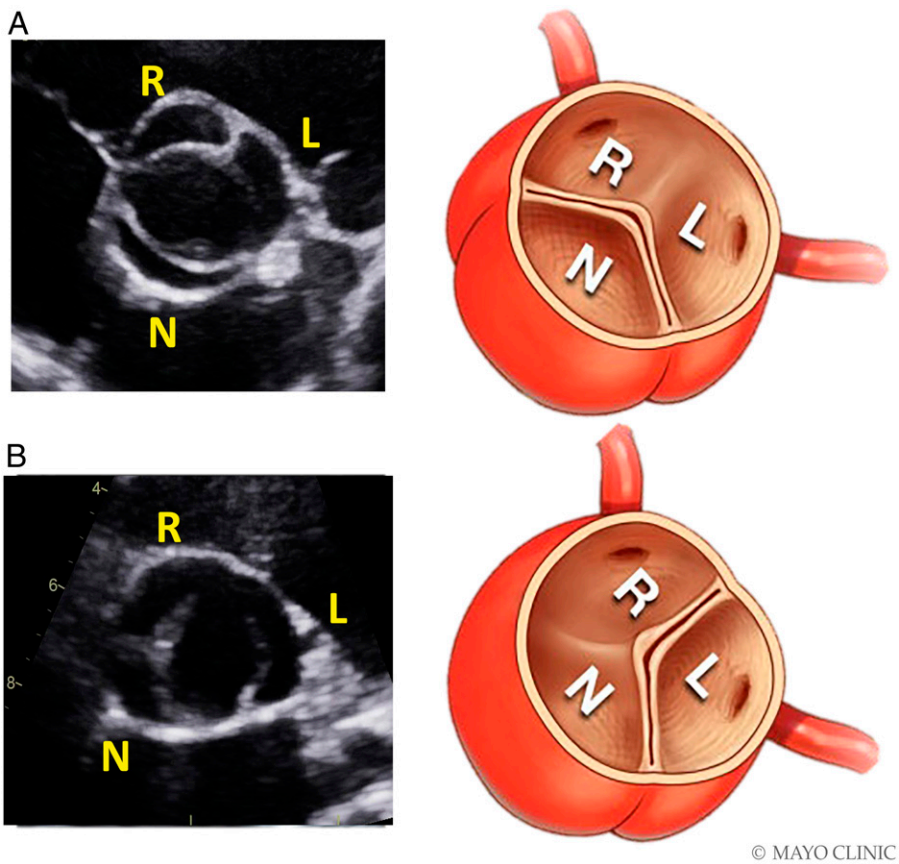


Figure 4. Parasternal short-axis views to evaluate valve morphology. A. Fusion between the right (R) and left (L) coronary cusps. B. Fusion between the R and noncoronary (N) cusps.

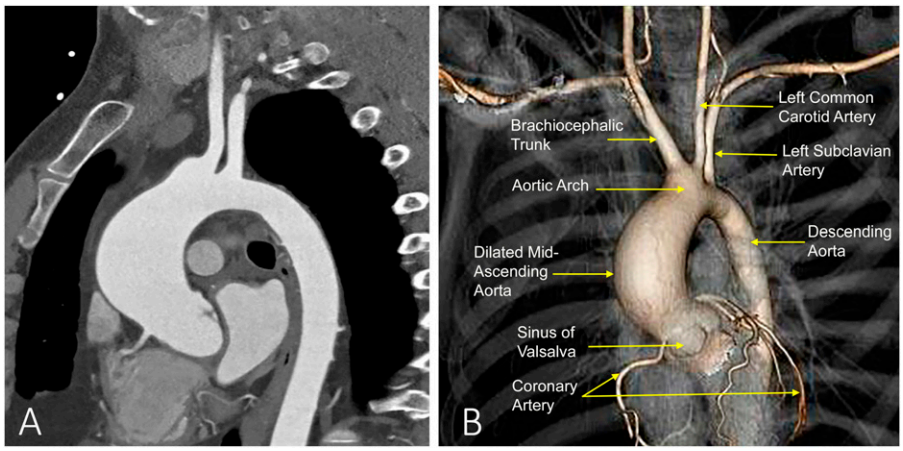


Figure 5. Dilation of the aorta in a patient with bicuspid aortic valve. A. Computed tomographic angiogram demonstrating ascending aortic dilation in a patient with bicuspid aortic valve. B. Three-dimensional reconstruction of the dilated ascending aorta in a patient with bicuspid aortic valve.

and decline in the ejection fraction over time, causing exercise intolerance and symptoms of heart failure. Symptoms of exercise intolerance or heart failure are indications for intervention.

Management. It is important to console families that most interventions in neonates and small children should be considered palliative. In almost all cases, these patients will require a more definitive valve procedure(s) later in life.

Percutaneous Balloon Valvuloplasty. Balloon valvuloplasty is a percutaneous intervention performed in the cardiac catheterization laboratory for relieving aortic stenosis. It is performed by inserting a balloon-tipped catheter, usually via the femoral artery and advancing it to cross the aortic valve followed by inflation of the balloon, leading to improved opening of the valve. In neonates it may be performed from the femoral venous approach, and access to the aortic valve is provided in a prograde manner after crossing the patent foramen ovale and advancing the catheter through the left atrium and left ventricle into the ascending aorta. Carotid artery access to the aortic valve may be used in select patients. Although it has excellent immediate results in relieving stenosis, balloon valvuloplasty can cause significant aortic regurgitation. Valve restenosis is a progressive problem, and additional procedures are necessary in many patients. (32)

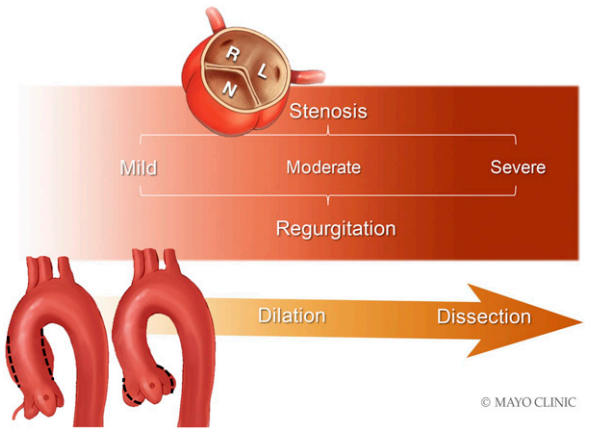


Figure 6. Spectrum of bicuspid aortic valve disease and its complications. Aortic valve stenosis and regurgitation can range from mild to severe. Aortic dilation can be present at the level of the aortic sinus or ascending aorta ranging from mild to severe. L=left, N=noncoronary, and R=right cusps.

Surgical Interventions. Various surgical interventions are available for patients with BAV. Surgical valvotomy or repair is performed in infants and children using a short incision at the fused commissure of the valve to improve the mobility of the leaflets. Other patients may be better served with the Ross procedure, in which the patient's native pulmonary valve is used as a neo-aortic autograft and a homograft is inserted into the pulmonary valve position. A benefit of the Ross procedure is that it avoids anticoagulation with warfarin and the need for frequent upsizing of the autograft. The Ross procedure is also commonly used in neonates and infants with critical or severe aortic valve disease, but the outcomes in critically ill neonates and infants are not as durable as in older children. (33) However, the Ross procedure creates "2-valve disease" in patients who were born with only aortic valve disease. In addition, the homograft in the pulmonary position will require upsizing or percutaneous valve insertion at some point. In older adolescents approaching adulthood, aortic valve replacement with a bioprosthetic or mechanical aortic valve may be performed. Mechanical aortic valve prostheses are more durable than bioprosthetic valves and theoretically need fewer repeated operations, but mechanical valves require lifelong anticoagulation and restriction from contact sports. Therefore, valve replacement needs to be individualized for each patient. An alternate approach to the Ross procedure or

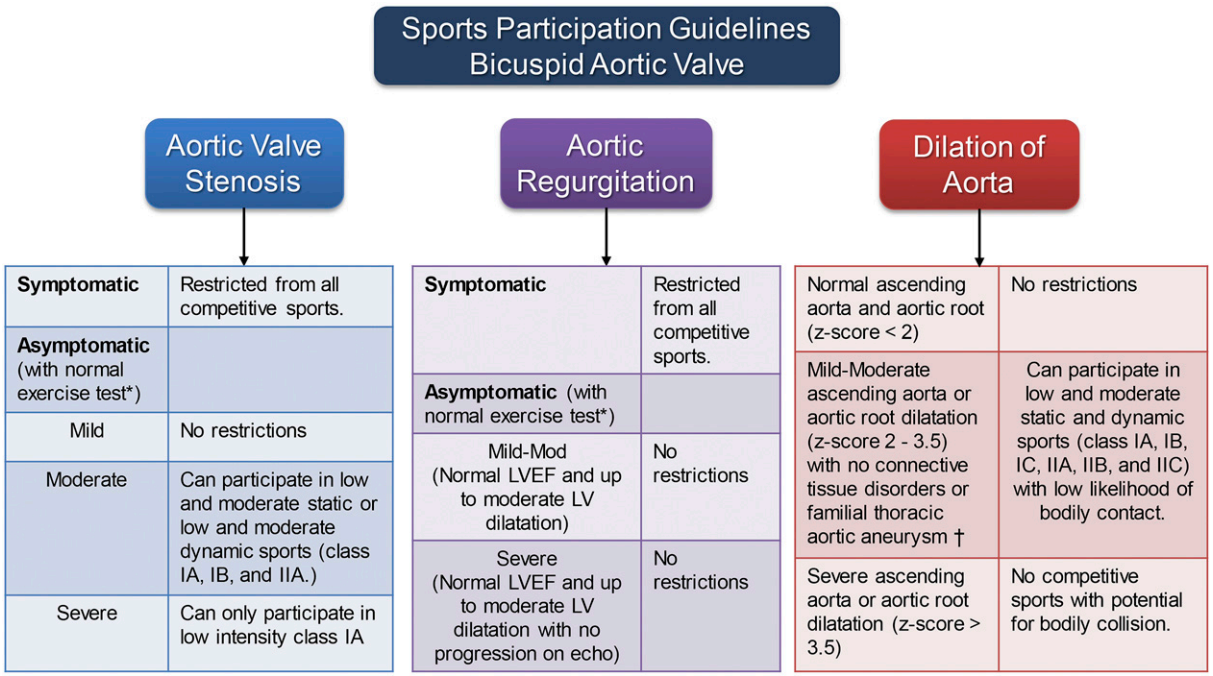


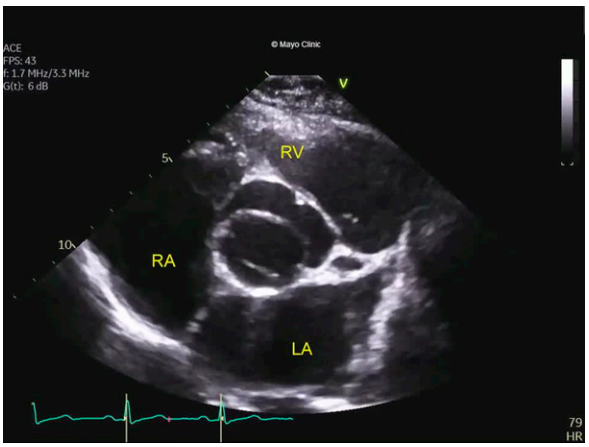
Figure 7. Summary of sports participation guidelines by the American College of Cardiology and the American Heart Association for patients with bicuspid aortic valve. For a detailed review of sports classification, the guideline statement should be reviewed. *A normal exercise test should be at least comparable with the level of activity achieved in competition and the training regimen. †The presence of connective tissue disorders or familial thoracic aortic aneurysm will affect the sports participation depending on the type of disorder. LV=left ventricle, LVEF=left ventricular ejection fraction.

primary aortic valve replacement with prosthesis may be the Ozaki operation. The Ozaki operation involves excision of the diseased native aortic cusps and creation of new cusps from autologous pericardium. (34)

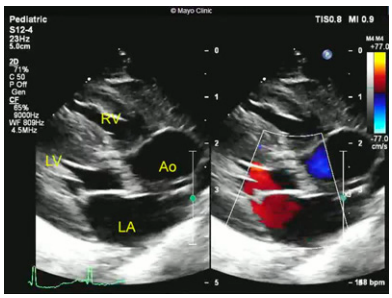
Aortopathy

Aortopathy, or abnormal dilation of the aorta, is another major complication of BAV. The mechanism of this aortopathy is multifactorial, including genetic, cellular, and molecular mechanisms. Cystic medial necrosis of the aortic wall, association with connective tissue disorders, and sheer wall stress on the aorta from abnormal hemodynamic flow patterns of blood across the abnormal aortic valve contribute to aortic dilation. Although aortic dilation is common in children with BAV, it rarely causes aortic dissection during childhood or adolescence unless there are other concomitant connective tissue disorders or syndromes, such as Marfan syndrome, type IV Ehlers-Danlos syndrome, Loeys-Dietz syndrome, or Turner syndrome, and/or predisposing risk factors, such as hypertension or significant dilation of the aorta (>50–55 mm). Children with BAV who have a dilated aorta should be evaluated regularly, with echocardiography performed at least every 2 to 3 years to monitor the degree and rate of aortic dilation and the status of the aortic valve.

Management. Medical management of aortic dilation in patients with BAV may include β-blockers, angiotensin-converting enzyme inhibitors, and angiotensin receptor blockers. Currently there is no evidence regarding the role of these medications in patients with BAV, and data have been extrapolated from patients with Marfan syndrome and dilated aortas. (35) Therefore, a significant variation in practice



Video 1. Parasternal short-axis view at the level of the aortic valve demonstrating bicuspid aortic valve with fusion of the right and left aortic valve cusps with no stenosis. The fused right and left cusps form a larger cusp, resulting in orifice eccentricity. LA=left atrium, RA=right atrium, RV=right ventricle.



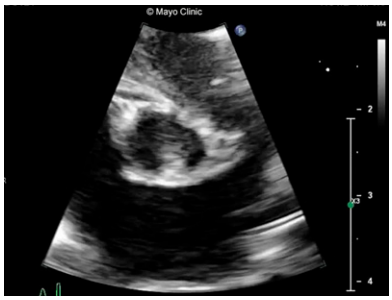
Video 2. Two-dimensional transthoracic echocardiograms of a neonate with bicuspid aortic valve and severe aortic valve stenosis. A. Parasternal long-axis view demonstrating a thickened aortic valve with severe stenosis (demonstrated by the aliasing of color flow across the aortic valve in systole) and mild regurgitation (demonstrated by the blue regurgitation jets as the aortic valve closes in diastole). Left ventricular hypertrophy is present secondary to the aortic valve stenosis. Aortic dilation is also visible at the level of the mid-ascending aorta. B. Parasternal short-axis view at the level of the aortic valve demonstrating severely thickened bicuspid aortic valve with fusion (raphe) of the right and noncoronary cusps and partial fusion of the right and left cusps. C. Parasternal short-axis view at the level of the aortic valve after surgical valvotomy clearly demonstrating bicuspid aortic valve with fusion (raphe) of the right and noncoronary cusps. Ao=ascending aorta, LA=left atrium, LV=left ventricle, RV=right ventricle.

exists among pediatric cardiologists, and medical management is individualized to every patient based on the benefits, tolerance, and adverse effects of these medications. However, hypertension in patients with BAV should be aggressively treated because hypertension is a risk factor for aortic dilation.

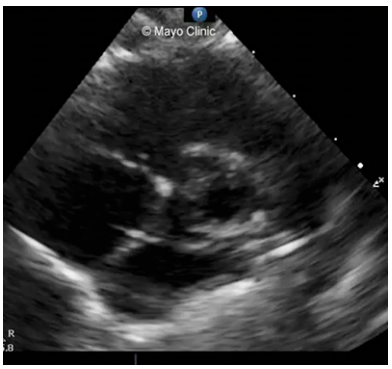
Surgical management consists of replacement of the aortic root or ascending aorta with or without valve replacement. Valve-sparing aortic root replacement may be more difficult in patients with BAV than in those with a normal 3-cusp valve.

Endocarditis

Native aortic valve endocarditis is a relatively rare entity, estimated to be approximately 0.16% per year in unoperated children and adolescents, but it can lead to significant morbidity and mortality. (36) Patients with BAV are at higher risk for infective endocarditis of the native aortic valve than



Video 2. (Continued.)



Video 2. (Continued.)

are individuals with normal 3-cusp aortic valve. (37) Patients who have had previous aortic valve surgery (particularly valve replacement) are at even higher risk for endocarditis than patients with native aortic valve without intervention. (38) Current endocarditis prophylaxis guidelines consider BAV as an intermediate-risk condition, and endocarditis prophylaxis is not recommended for patients with BAV before dental procedures or invasive procedures of the respiratory tract. (39) However, patients with BAV with a previous episode of endocarditis or those who have a history of aortic valve surgery or intervention require endocarditis prophylaxis depending on the type of intervention and prosthetic material used. Endocarditis must be excluded in any patient with BAV (including those who have had aortic valve surgery) who presents with fever of unknown origin or an embolic event. Evaluation of these patients should include blood cultures, inflammatory markers (C-reactive protein and erythrocyte sedimentation rate), and imaging such as echocardiography early in the disease course depending on the clinical suspicion.

LONG-TERM MANAGEMENT AND CONSIDERATIONS FOR PRIMARY CARE PROVIDERS

1. Pediatric Cardiology Follow-up: Patients with BAV require lifelong follow-up with a cardiologist. Most patients with a normally functioning BAV have periodic follow-up, every 2 to 3 years, with repeated echocardiography for surveillance of the aortic valve function and dilation of the aorta. Patients with significant aortic valve stenosis, regurgitation, or significant aortic dilation may require more frequent follow-up.
2. Primary Care Provider Follow-up: All patients with BAV should have annual follow-up with their primary care providers. Any change in the murmur or new symptoms

of atypical chest pain, palpitations with activity, increased fatigue, and decreased exercise tolerance should prompt an expedited follow-up with the cardiologist. Blood pressure should be obtained during every health maintenance visit, with special attention to hypertension. In patients with hypertension, upper and lower extremity blood pressures should be obtained because BAV is associated with coarctation of the aorta. In those with repaired coarctation, hypertension may signal an important re-coarctation but may also be present in patients with no residual narrowing. Moreover, hypertension is a risk factor associated with aortic dilation and should be treated aggressively. (40)(41)

3. Family Screening: Echocardiographic screening is recommended by the American Heart Association (AHA) in all first-degree relatives of patients with BAV because it may occur in up to 10% of asymptomatic family members. (42) It is important to screen parents and older siblings because most complications of BAV usually manifest after early childhood.
4. Sports Participation: The AHA and the American College of Cardiology have published guidelines for sports participation in athletes with BAV. Suggestions for sports restriction are based on symptoms and degree of aortic valve stenosis, regurgitation or aortic dilation, and presence of additional connective tissue disorders or syndromes. (43) Most experts suggest avoidance of heavy isometric exercises, heavy weight lifting, and contact sports in patients with significant aortic dilation due to concern for aortic dissection. Figure 7 summarizes major sports participation recommendations by the American College of Cardiology and the AHA. For detailed recommendations, the scientific statement by the AHA and the American College of Cardiology on eligibility and disqualification recommendations for competitive athletes with cardiovascular abnormalities should be consulted (http://www.acc.org/education-and-meetings/image-and-slide-gallery/media-detail?id=FB92803045D249AE91B715650DD0EBE4). (43)(44)(45) Most of the AHA guideline recommendations have a level of evidence rated as "C" and are not supported with rigorous evidence-based data. Because symptoms and complications of aortic valve disease or aortopathy are rare in children and adolescents, decisions regarding sports participation are complex. A shared decision is required by patient, family, coach, school officials, and cardiologist. In those who do compete at an elite level, an annual evaluation with imaging and perhaps exercise testing is prudent.
5. Endocarditis Prophylaxis: Although patients with BAV are at significantly higher risk for endocarditis than individuals with a normal aortic valve, it is rare to have native aortic valve endocarditis. Current guidelines do not recommend routine antibiotic prophylaxis before dental or invasive respiratory tract procedures. (39) However, patients with BAV who had a previous episode of endocarditis or those after aortic valve surgery and replacement require lifelong antibiotic prophylaxis. Optimal dental hygiene is important universally in all patients with BAV. Despite a low incidence of endocarditis, it is important to consider endocarditis in the differential diagnosis of patients with BAV who have fevers of unknown origin or any embolic phenomenon.

Summary

1. Bicuspid aortic valve (BAV) is the most common congenital heart defect in children, adolescents, and adults, present in 0.5% to 2% of individuals. (1)
2. Most patients with BAV are asymptomatic and are diagnosed due to a murmur or click on examination or due to family screening. Rarely, patients with BAV and severe disease are symptomatic.
3. BAV can lead to many complications, including aortic valve stenosis and/or regurgitation, endocarditis, and dilation of the aorta; 12% to 15% of pediatric patients with BAV may require intervention before adulthood. (6)
4. Based on American Heart Association guidelines, all first-degree family members of a patient with BAV should have echocardiographic screening, even if they have normal physical examination findings. (42)
5. Based on consensus, patients with BAV need regular pediatric cardiology and surveillance echocardiography follow-up. The frequency of this follow-up depends on valve function and aortic dimensions.
6. Based on consensus, patients with BAV should have annual follow-up with their primary care physician with special attention to the evaluation of hypertension.
7. Although patients with BAV are at higher risk for endocarditis, current guidelines do not recommend endocarditis prophylaxis

before routine dental procedures or high-risk invasive respiratory procedures for patients with BAV without a history of surgery or intervention on the aortic valve. (39)

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References for this article can be found at http://pedsinreview.aappublications.org/content/42/No. 5/233.

PIR QUIZ *Individual CME quizzes are available via the blue CME link under the article title in the online Table of Contents of any issue. To learn how to claim MOC points, go to: http://www.aappublications.org/content/moc-credit.*

1. A 7-year-old girl is brought to the clinic for a health supervision visit. The family recently immigrated from El Salvador with no accompanying medical records. On physical examination her weight is at the 25th percentile for age but her height is less than the 3rd percentile. Her blood pressure is 120/90 mm Hg in both upper extremities. A radiofemoral delay is noted on simultaneous palpation of the pulses. She has nonpitting edema of her lower extremities and was noted to have a broad chest and cubitus valgus. Heart examination is significant for soft ejection systolic murmur heard prominently at the left interscapular region. An ejection systolic click heard as an extra heart sound after S1 best heard at the apex that did not change with breathing was also noted. A transthoracic echocardiogram is ordered. Which of the following genetic syndromes best explains the associated clinical findings in this patient?

   A. Alagille syndrome.
   B. Down syndrome.
   C. Marfan syndrome.
   D. Noonan syndrome.
   E. Turner syndrome.

2. A 16-year-old boy is followed in your clinical practice. He has a history of bicuspid aortic valve (BAV) and aortic root enlargement seen on echocardiogram. He is followed up with repeated echocardiography every 2 years. The greatest risk for aortic dissection is expected to occur in which of the following associated scenarios?

   A. Ehlers-Danlos syndrome type III.
   B. Loeys-Dietz syndrome.
   C. Mild aortic root enlargement.
   D. Noonan syndrome.
   E. Normal blood pressure measurements.

3. A 10-year-old boy is diagnosed as having BAV in your practice. He has a normal aortic root dimension. His blood pressure is 100/70 mm Hg. He has normal growth and development and is asymptomatic. Which of the following is the most appropriate treatment plan for this patient?

   A. Angiotensin-converting enzyme-1 inhibitor.
   B. Angiotensin receptor blockade medication.
   C. No specific medication is needed.
   D. Percutaneous balloon valvuloplasty.
   E. Propranolol.

4. A 15-year-old boy with BAV is followed in your clinic. He does not have aortic root enlargement and is growing normally. He has an 18-year-old sister and an 11-year-old brother, who are both healthy and growing normally. His mother is 47 years old and healthy. His father is 50 years old and is being treated medically for hypertension. His mother has an older sister, aged 52 years, who carries a diagnosis of Marfan syndrome. A BAV screening echocardiogram is recommended for which of the following patient's family members?

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A. Both the patient's parents and his 18-year-old sister.
B. Both the patient's parents and his 2 siblings.
C. Only the patient's father because he has hypertension.
D. Only the patient's mother because she has a sister with Marfan syndrome.
E. Only the patient's 2 siblings because his parents would have displayed complications of BAV by this age.

5. A 16-year-old girl with tall stature and scoliosis is seen as a new patient in the clinic for a sport preparticipation clearance. The family recently moved to the area. Review of her records shows that she has a history of BAV. Her last echocardiogram was 3 years earlier. A follow-up echocardiography is obtained today and reveals BAV and moderate aortic root enlargement. She plays competitive basketball and soccer. In addition to starting her on β-blockers, which of the following is the most appropriate follow-up plan for this patient?

A. Continue current sports activities with no restrictions. No other follow-up is needed.
B. Follow-up echocardiography in 6 months, discontinue contact sports, and recommend heavy isometric and weight lifting exercises.
C. Follow-up echocardiogram in 6 months, refer to genetics, and in the meantime, continue current sports activity with no restrictions.
D. Restrict her from playing contact sports. No other follow-up is needed.
E. Restrict her from playing contact sports, refer her to genetics for diagnostic evaluation, and perform BAV screening of first-degree family members.