BMJ Best Practice

Pulmonary stenosis

Straight to the point of care

Last updated: Jun 28, 2024

Table of Contents

Summary

Pulmonary stenosis is mostly congenital.

Symptoms range from none to profound cyanosis and the potential for sudden death.

Systolic ejection murmur is present and is loudest over left upper sternal border.

Cyanotic patients are treated with oxygen and prostaglandin E1 prior to diagnostic testing.

The diagnosis is confirmed and severity classified by echocardiography.

Mild pulmonary stenosis is a benign condition requiring sequential cardiac follow-up but no therapy.

Percutaneous balloon pulmonary valvuloplasty (PBPV) is indicated in moderate to severe/critical lesions.

Surgical valvotomy is reserved for treatment failure and contraindication to PBPV.

Definition

Pulmonary stenosis (PS) obstructs the blood flow from the right ventricle (RV) into the pulmonary bed, resulting in a pressure gradient greater than 10 mmHg across the pulmonary valve during systole. In most cases PS is found at the level of the valve, but it can also occur below the level of the valve or distally in the pulmonary arteries. PS is commonly associated with other forms of congenital heart disease.[1] [2] The increased subpulmonary ventricular pressure may lead to hypertrophy of the RV proportional to the degree of stenosis. Clinical symptoms range from none in mild PS to profound cyanosis and the potential for sudden death in critical PS.

Epidemiology

Pulmonary stenosis (PS) is estimated to occur in 7% to 12% of all patients with congenital heart disease.[3] In people with Noonan syndrome, the isolated PS is frequently caused by a dysplastic pulmonary valve and has an incidence of up to 27%.[1] Compared with white people, black people have an increased rate of peripheral PS (5.35 vs. 2.45 per 10,000 live births) and a statistical trend towards a higher incidence of valvular PS (4.48 vs. 3.46 per 10,000 live births).

Aetiology

The majority of cases are congenital. Possible embryological explanations for pulmonary stenosis (PS) vary from a malformation of the bulbus cordis to fetal endocarditis.[4] [5] Most often, there is a typical dome-shaped pulmonary valve with a narrow central opening but a preserved mobile valve base. A dysplastic pulmonary valve, with poorly mobile cusps and myxomatous thickening, is less common (15% to 20%; even less in untreated adults) and frequently part of Noonan syndrome. In adults, a stenotic pulmonary valve may calcify late in life.

A genetic abnormality is another possible aetiology, as PS is frequently associated with genetic conditions such as Noonan syndrome, Noonan syndrome with multiple lentigines (previously known as LEOPARD syndrome), Williams syndrome, or Alagille's syndrome.[6] [7]

Acquired PS is a rare condition associated with carcinoid syndrome, infectious endocarditis, myocardial tumours, and external compression. Carcinoid heart disease is caused by plaque formation on the endocardial surfaces of the right atrium and of the right valves, resulting in thickened and immobile valve leaflets.

Pathophysiology

The main pathophysiological consequence of PS is RV strain and an increase in RV pressure. The cellular effect on the RV depends on the timing of obstruction.[8] If the obstruction is present in a fetus or neonate, the myocardial response is hyperplasia of myocytes and an increase in vascularity. However, if the obstruction develops within mature myocardium, there is an increase in myocyte size (hypertrophy) without an increase in capillary network.

Mild to moderate obstruction will in general be haemodynamically well tolerated and is not associated with cyanosis or cardiac symptoms. In the severe form of PS, clinical symptoms such as dyspnoea, exercise intolerance, cyanosis, and syncope may occur. The right ventricular will eventually fail as the myocardium becomes unable to support the enhanced work load imposed by the stenosis, and patients develop jugular venous distension, peripheral oedema, pleural effusion, ascites, and hepatomegaly.

Critical PS may occur in neonates if the right ventricular outflow tract obstruction caused by the stenotic valve is so severe that it leads to cyanosis. The major source of pulmonary blood flow in severely obstructed patients is through the ductus arteriosus. Once the ductus arteriosus begins to close, blood flow will be insufficient and the neonate will become hypoxaemic.[9]

If there is no atrial or ventricular level shunt, sudden death may ensue due to compromised cardiac output.[2] Fetal and perinatal factors, including the specific physiology of PS that leads to decreased oxygen

and nutrient delivery to the brain, can critically impact neurodevelopmental, warranting early and targeted interventions.[7]

Classification

Clinical classifications

Anatomical location of obstruction:

1. Valvular
2. Subvalvular (intracavitary/infundibular)
3. Supravalvular
4. Peripheral (branch).

Aetiology

1. Congenital
2. Acquired.

Case history

Case history #1

A full-term 3.3 kg newborn girl is found to have a systolic ejection murmur shortly after birth. She is clinically asymptomatic and fully saturated while breathing room air. She has no dysmorphic features.

Case history #2

A 7-year-old boy with a normal karyotype and dysmorphic features such as webbing of neck, short stature, and pectus carinatum is incidentally found to have a prominent main pulmonary artery and cardiomegaly on chest x-ray for respiratory complaints.

Other presentations

Pulmonary stenosis (PS) may also present as critical PS in neonates. Critical PS is associated with severe right ventricular outflow obstruction and right-to-left shunting of blood at the atrial level, resulting in cyanosis. The systolic murmur may be variable, is usually prominent, but may be surprisingly soft if the cardiac output is limited and there is limited blood flow across the stenotic valve. PS may also rarely be associated with other systemic diseases including intracardiac tumours, neurofibromatosis, and extrinsic compression lesions (neoplasms).

Approach

Although patients are often asymptomatic, a clinical diagnosis can be made via the classical auscultatory findings and confirmed with echocardiography. It is common for patients to survive into adulthood even if valvuloplasty is not performed. However, with age the valve may undergo fibrous thickening and, rarely, calcification, which progressively reduces valve motility, leading to increased outlet obstruction and the appearance of symptoms. The risk of progression is highest during infancy.[12]

History and examination

Most patients present with mild to moderate disease and are asymptomatic. A history may reveal the presence of risk factors including black ancestry, or rare causes such as a family history of Noonan syndrome, Noonan syndrome with multiple lentigines (previously known as LEOPARD syndrome), Alagille's syndrome, Williams' syndrome, maternal rubella exposure during first trimester of pregnancy, rheumatic fever, endocarditis, or carcinoid syndrome. Severe pulmonary stenosis (PS) presents with exertional dyspnoea, fatigue, chest pain, or syncope with exertion. Exertional dyspnoea and fatigue develop due to reduced pulmonary blood flow and right-sided heart failure. Syncope results from reduced pulmonary blood flow, which can decrease cardiac output due to limited pulmonary venous return. It occurs in patients without a right-to-left shunt, inspiring the phrase 'better blue than grey'. Infants with severe or critical disease may present with failure to thrive.

Physical examination findings include:

- Prominence of the jugular venous A wave.
- Right ventricular (RV) heave noted in the left parasternal and xiphoid region and a systolic thrill noted on palpation along the left upper sternal border; both are signs of severe to critical disease.
- A long and harsh systolic ejection murmur with or without a systolic ejection click, usually at the left upper sternal border. Splitting of S2 may also be present. The loudness of murmur is not always related to severity, but the length of murmur, the splitting and intensity of S2, and the timing of ejection click (the earlier, the more stenotic) are related to severity. In severe and critical PS there is usually a long and harsh murmur peaking later in systole. However, in critical PS, the murmur may be soft due to poor cardiac output. The presence of a lower left parasternal systolic murmur suggests associated tricuspid regurgitation. A decrescendo diastolic murmur suggests pulmonary regurgitation.

- Signs of right-sided heart failure, which may be seen in severe disease and are always seen in critical disease. These include jugular venous distension, peripheral oedema, ascites, hepatomegaly, and dullness to percussion of the chest (due to a pleural effusion).
- Cyanosis, a feature of critical PS produced by right-to-left shunting through an associated septal defect or a patent foramen ovale. It is detected in the lips and fingers.

Rarely, dysmorphic features may be identified, suggesting the presence of a syndrome associated with PS. These include:

- Noonan syndrome: features include typical facies of down-slanting or wide-set eyes, low-set or abnormally shaped ears, and sagging eyelids (ptosis); growth retardation; delayed puberty with undescended testicles; pectus excavatum; and a webbed and short-appearing neck. See Noonan syndrome .
- Noonan syndrome with multiple lentigines: features include growth retardation, lentigines, ocular hypertelorism, abnormal genitalia (usually cryptorchidism or unilateral testis), and retarded growth.

- Williams' syndrome: features include microcephaly (30%); typical facies of short upturned nose, flat nasal bridge, long philtrum, flat malar area, wide mouth, full lips, dental malocclusion/widely spaced teeth, micrognathia, stellate irides, and peri-orbital fullness; hypoplastic nails, lax skin; joint hyperelasticity, hallux valgus, contractures, kyphoscoliosis, and lordosis.
- Alagille's syndrome: features include growth retardation and typical facies of a broadened forehead, pointed chin, and elongated nose with bulbous tip.

First line investigations

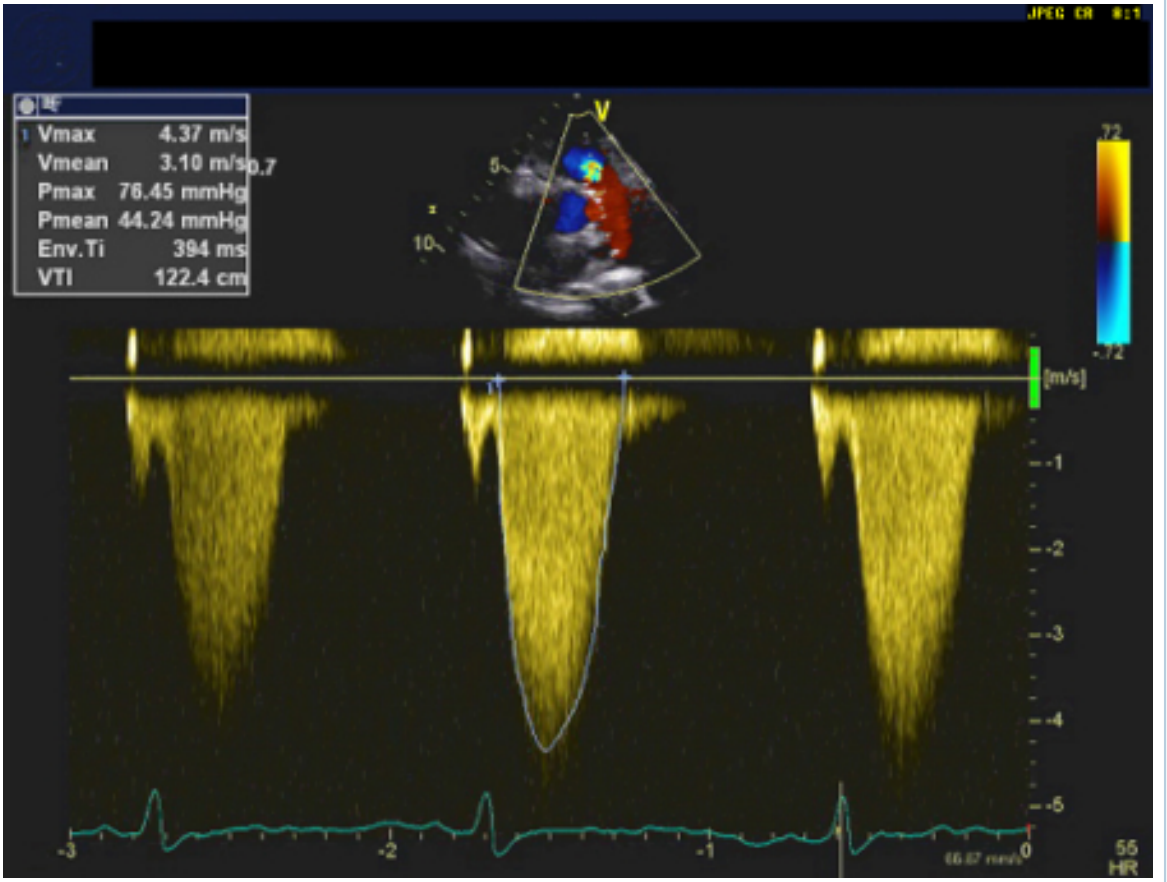
A standard 12-lead ECG is routinely performed to identify cardiac anomalies that may be associated with congenital heart disease or valve disease.[13] [14] [15] ECG findings are typically normal in patients with mild PS. Right axis deviation is commonly seen in moderate to severe PS.[2] Right bundle branch block is usually seen; the exception is patients with Noonan syndrome, who have left bundle branch block.

Chest x-ray is also routinely performed in patients with known or suspected valve disease or congenital heart disease.[14][15] Findings may be normal or show a prominent main pulmonary artery. In severe PS, marked cardiomegaly, right atrial and ventricular enlargement, and decreased pulmonary vascularity may be seen.

The investigation of choice is a two-dimensional echocardiogram with Doppler assessment.[13][15] This enables visualisation of pulmonary valve stenosis, confirming the diagnosis, and classifies the severity by measuring the transvalvular gradient. A transthoracic echocardiogram is usually performed first-line; a transoesophageal echocardiogram may provide complementary information in adult or adolescent patients.[13] [15] [16]

The severity of right ventricular outflow tract (RVOT) obstruction is classified as follows:[13]

- Mild: peak gradient is <36 mmHg and peak velocity is <3 m/s
- Moderate: peak gradient is 36-64 mmHg and peak velocity is 3-4 m/s
- Severe: peak gradient is >64 mmHg and peak velocity is >4 m/s; mean gradient is >35 mmHg.



Continuous wave doppler demonstrating severe pulmonary stenosis on transthoracic echocardiogram

Used with permission by National University Heart Centre, Singapore

Other investigations

Diagnostic cardiac catheterisation may be required in some patients to more precisely confirm the extent, severity, and level of RVOT obstruction.[13] [14] [15]

Critical pulmonary stenosis may occur in neonates if the RVOT obstruction caused by the stenotic valve is so severe that it leads to cyanosis. The major source of pulmonary blood flow in severely obstructed patients is through the ductus arteriosus. Once the ductus arteriosus begins to close, blood flow will be insufficient and the neonate will become hypoxaemic.[9]

If cyanosis is present, additional investigations that are required include pulse oximetry (revealing low arterial oxygen saturation), a full blood count (reveals an elevated haemoglobin and haematocrit if there is a right-to-left shunt, reflecting erythrocytosis), and arterial blood gases (which reveal low PaO_2).

Imaging modalities such as cardiac magnetic resonance imaging or cardiac computed tomography are not first-line investigations but can support procedural planning and may be requested by the cardiac interventionist and/or surgeon.[13] [15]

Exercise stress testing may be used to objectively assess symptoms if considering intervention.[13] [14]

History and exam

Key diagnostic factors

pathological systolic ejection murmur with or without a systolic click (common)

- Usually loudest on auscultation over left upper sternal border.
- Loudness of murmur is not always related to severity, but length of murmur, splitting and intensity of S2, and timing of ejection click (the earlier, the more stenotic) is related to severity of PS.
- In severe/critical PS there is usually a long and harsh murmur peaking later in systole; however, in critical PS, the murmur may be soft due to poor cardiac output.
-

Other diagnostic factors

rheumatic fever (uncommon)

- Risk very low as pulmonary valve rarely involved.

dyspnoea (uncommon)

- With/without exertion in severe PS.
- Develops due to limited pulmonary blood flow and right heart failure.

fatigue (uncommon)

- With exertion in severe PS.
- Develops due to limited pulmonary blood flow and right heart failure.

chest pain (uncommon)

- With exertion in severe PS.

syncope (uncommon)

- With exertion in severe PS.
- Results from reduced pulmonary blood flow, which can decrease cardiac output due to limited pulmonary venous return.
- Occurs in patients without a right-to-left shunt (who have inspired the phrase 'better blue than grey'); requires urgent referral for PS treatment.

dysmorphic features of Noonan syndrome (uncommon)

- Growth retardation; typical facies: down-slanting or wide-set eyes, low-set or abnormally shaped ears, sagging eyelids (ptosis); delayed puberty with undescended testicles; pectus excavatum; webbed and short-appearing neck.

dysmorphic features of Noonan syndrome with multiple lentigines (uncommon)

- Growth retardation; lentigines; ocular hypertelorism, abnormal genitalia (usually cryptorchidism or unilateral testis); retarded growth.

dysmorphic features of Williams syndrome (uncommon)

- Microcephaly (30%); typical facies: short upturned nose, flat nasal bridge, long philtrum, flat malar area, wide mouth, full lips, dental malocclusion/widely spaced teeth, micrognathia, stellate irides, peri-orbital fullness; hypoplastic nails, lax skin; musculoskeletal: joint hyperelasticity, hallux valgus, contractures, kyphoscoliosis, lordosis.

dysmorphic features of Alagille's syndrome (uncommon)

- Growth retardation; typical facies: broadened forehead, pointed chin, and elongated nose with bulbous tip.

failure to thrive (uncommon)

- Infants with severe or critical disease may present with failure to thrive.

cyanosis (uncommon)

- Detected in lips and fingers.
- Only present in patients with a right-to-left shunt at the atrial level via an atrial septal defect.
- Exaggerated by limited blood flow to the pulmonary vascular bed.
- May occur at any age but is most frequent in newborns with critical or severe PS; not reliable for assessment of severity.

signs of right heart failure (uncommon)

- Jugular venous distension, peripheral oedema, pleural effusion, ascites, and hepatomegaly.

right ventricular heave (uncommon)

- Noted in the left parasternal and xiphoid region in severe or critical PS.

systolic thrill (uncommon)

- Noted on palpation along the left upper sternal border in severe or critical PS.

Risk factors

Strong

Noonan syndrome

- Up to 27% have isolated PS, often due to dysplastic pulmonary valve.[1]

Noonan syndrome with multiple lentigines

- Frequent finding but usually mild and asymptomatic.

Alagille syndrome

- About 85% have peripheral PS.

Williams syndrome

- About 50% have significant cardiac lesion, including severe PS, supravalvar aortic stenosis, or mitral valve regurgitation.

congenital rubella syndrome

- Occasional finding; other cardiac defects include septal defects and patent ductus arteriosus.

Weak

black ethnicity

- Increased rate of peripheral PS (5.35 versus 2.45 per 10,000 live births) and a statistical trend towards a higher incidence of valvar PS (4.48 versus 3.46 per 10,000 live births) compared with white people.[10]

carcinoid syndrome

- About 50% of patients with carcinoid syndrome have some cardiac involvement of the right-sided valves; half of these have some degree of PS.[11]

infectious endocarditis

- PS is an occasional finding.

myocardial tumours

- PS is an occasional finding.

external compression

- PS is an occasional finding if there is compression from an external lesion such as a neoplasm.

Investigations

1st test to order

Test	Result
ECG • A standard 12-lead ECG is routinely performed to identify cardiac anomalies that may be associated with congenital heart disease or valve disease.[13] [14] [15]	**mild PS: typically normal or mild right axis deviation; moderate PS: right axis deviation (abnormal for age) and RV conduction delay (abnormal for age); severe/critical PS: extreme right axis deviation, R wave large for age, right atrial enlargement with tall and peaked P wave in lead II and in precordial leads V1 to V3**
chest x-ray • Routinely performed in patients with known or suspected valve disease.[14] [15]	**usually normal; may show prominent main pulmonary artery shadow; marked cardiomegaly, right atrial and ventricular enlargement, and decreased pulmonary vascularity may be seen in severe disease**
echocardiography with Doppler assessment • Two-dimensional echocardiography with Doppler interrogation is the investigation of choice.[13] [15] • It confirms diagnosis by visualising pulmonary valve and stenosis and classifies severity by measuring transvalvular gradient. • A transthoracic echocardiogram is usually performed first-line; a transoesophageal echocardiogram may provide complementary information in adult or adolescent patients.[13] [15][16]	**abnormal morphology of valve; increased transvalvular gradient across pulmonary valve during systole (>10 mmHg).**

Other tests to consider

Test	Result
diagnostic cardiac catheterisation • May be required in some patients to more precisely confirm the extent, severity, and level of right ventricular outflow tract obstruction.[13] [14] [15] • Required to differentiate critical pulmonary stenosis from pulmonary atresia with intact ventricular septum.[9]	**thickened and doming of valve in fluoroscopy and contrast angiography; increased transvalvular gradient (10 mmHg) measured by direct pullback or simultaneous measurement with double lumen catheters**
Hb and Hct • Required if cyanosis is present.	**increased in cyanosis caused by right-to-left shunt, leading to erythrocytosis**
pulse oximetry • Required if cyanosis is present.	**low arterial oxygen saturation (SaO_2) in central cyanosis**
arterial blood gas • Required if cyanosis is present.	**low PaO_2 in central cyanosis**
cardiac MRI • Not a first-line investigation but can support procedural planning and may be requested by the cardiac interventionist and/or surgeon.[13] [15]	**additional information relating to the level of right ventricular outflow tract obstruction, right ventricular volumes, pulmonary annulus, outflow tract and artery dimensions, and differential pulmonary blood flow**
cardiac CT • Not a first-line investigation but can support procedural planning and may be requested by the cardiac interventionist and/or surgeon.[13] [15]	**may show reduced functional capacity**
exercise stress testing • May be used to objectively assess symptoms if considering intervention.[13] [14]	**may show reduced functional capacity**

Differentials

Condition	Differentiating signs / symptoms	Differentiating tests
Innocent murmur	• Asymptomatic. • On auscultation, systolic murmur, usually softer and shorter compared with PS, no ejection click.	• Echocardiography with colour Doppler: normal cardiac and physiology.
Straight back syndrome	• On auscultation, no ejection click but systolic right ventricular (RV) outflow track murmur along left upper sternal border.	• Echocardiography with colour Doppler: normal cardiac anatomy and physiology. • Lateral chest x-ray: abnormally straight spinal curve.
Idiopathic dilation of pulmonary artery	• On auscultation, softer systolic murmur.	• Echocardiography with colour Doppler: morphologically normal pulmonary valve, dilated pulmonary artery.
Pulmonary artery stenosis	• On auscultation, mid-to-late systolic murmur, radiating to the back and lateral lung fields, no ejection click.	• Echocardiography: stenotic pulmonary artery.
Aortic valve stenosis	• On auscultation, systolic ejection murmur in upper right sternal border, radiating into carotids and left ventricular apex.	• Echocardiography with colour Doppler: stenotic aortic valve.
Atrial septal defect (ASD)	• On auscultation, systolic RV outflow track murmur of functional PS, wide and fixed splitting of S2, no ejection click.	• Echocardiography: morphologically normal pulmonary valve but abnormal findings of atrial septum; colour Doppler: left-to-right shunting.
Ventricular septal defect	• On auscultation, pansystolic regurgitant murmur typically at lower sternal border; can be difficult to distinguish from PS murmur.	• Echocardiography with colour Doppler: left-to-right interventricular septal blood flow.
Ebstein's anomaly	• Active pre-cordium; on auscultation, softer systolic murmur at lower left sternal border, sometimes 'quadruple' rhythm.	• Chest x-ray: cardiomegaly, decreased pulmonary vascular markings. • ECG: reduced voltage, right bundle branch block, right atrial enlargement; echo: apically displaced septal

Condition	Differentiating signs / symptoms	Differentiating tests
		leaflet, redundant anterior leaflet of tricuspid valve.
Tetralogy of Fallot	• Cyanosis more pronounced than in PS; usually no ejection click as stenosis lies below level of valve or is due to small pulmonary annulus.	• Chest x-ray: decreased pulmonary vascular markings, uptilted right ventricular apex. • Echocardiography with colour Doppler: aortic override, ventricular septum defect.
Pulmonary valve atresia with intact ventricular septum	• Progressive cyanosis; on auscultation, no PS murmur as all the pulmonary blood flow is via ductus arteriosus.	• Echocardiography with colour Doppler: atresia of pulmonary valve, blood flow via ductus arteriosus.

Criteria

Two-dimensional echocardiography with Doppler assessment

Severity of right ventricular outflow tract (RVOT) obstruction is defined as follows:[15]

- Mild: peak gradient is <36 mmHg and peak velocity is <3 m/s
- Moderate: peak gradient is 36-64 mmHg and peak velocity is 3-4 m/s
- Severe: peak gradient is >64 mmHg and peak velocity is >4 m/s; mean gradient is >35 mmHg.

Critical pulmonary stenosis may occur in neonates if the RVOT obstruction caused by the stenotic valve is so severe that it leads to cyanosis. The major source of pulmonary blood flow in severely obstructed patients is through the ductus arteriosus. Once the ductus arteriosus begins to close, blood flow will be insufficient and the neonate will become hypoxemic.[9]

Approach

Treatment is guided by the disease severity determined by echocardiogram. See Diagnostic criteria .

Mild disease typically requires no intervention, whereas percutaneous balloon pulmonary valvuloplasty or surgical valvuloplasty may be warranted in moderate or severe/critical disease.[13] [17] [18]

In individuals with pulmonary stenosis (PS), those undergoing cardiac surgery with cardiopulmonary bypass during infancy are at a heightened risk of developing developmental delays or disorders, necessitating vigilant follow-up. Patients presenting with chronic cyanosis without cardiopulmonary bypass in infancy also warrant close monitoring because they have an increased risk of neurodevelopmental challenges. Additionally, a subset of patients may not display conventional risk factors but still possess an elevated risk of neurodevelopmental issues due to interventions or hospitalisations related to their condition from infancy through to adolescence.[7]

Mild disease

This form of PS rarely progresses, and although requiring sequential cardiology follow-up into adulthood, requires no medical or surgical therapy.[13] [18] [19] Patients are asymptomatic and symptoms, if they appear, should not be attributed to PS but should be investigated further to elucidate the cause.

Moderate disease

In patients with moderate disease, intervention with percutaneous balloon pulmonary valvuloplasty (PBPV) is generally recommended.[13] [15] [18] Although the Second Natural History Study, which followed patients with moderate PS over 20 years, reported excellent outcomes with and without invasive treatment, most experts agree that moderate gradients will eventually progress to severe obstruction and right heart failure and warrant invasive treatment independently of symptom status.[19] Nevertheless, the utility of invasive treatment in asymptomatic patients with moderate PS remains under debate, and its use varies by institution.

US guidelines recommend PBPV as the first-line therapy for moderate or severe PS and otherwise unexplained symptoms of heart failure, cyanosis from interatrial right-to-left communication, and/or exercise intolerance.[13] European guidelines recommend intervention in the presence of one or more of the following: symptoms related to PS; decreasing right ventricular function and/or progressive tricuspid regurgitation to at least moderate; and/or right-to-left shunting via an atrial septal defect or ventricular septal defect.[15]

PBPV is determined by invasive cardiac catheterisation. It relieves right ventricular outflow tract obstruction by dilating the valve.[20] The benefits of this procedure are that it is less invasive compared with surgical valvuloplasty, does not require cardiopulmonary bypass, and significantly decreases neonatal mortality.

Surgical valvuloplasty (cutting of a constricted cardiac valve to relieve obstruction) is indicated if patients are ineligible for PBPV, for example if they have a dysplastic pulmonary valve not amenable to balloon dilation (e.g., in Noonan syndrome) or if they have multiple levels of fixed obstruction (i.e., sub- and/or supravalvar), or if PBPV has previously failed.[13]

Severe or critical disease

Prior to echocardiographic assessment, oxygen may be started in patients with cyanosis or respiratory distress. The flow should be set to a fraction of inspired oxygen (FiO_2) of 1 with a flow rate of 8 to 10 L/minute in infants. A maximum of 15 L/minute can be given in adults. Cyanotic neonates who are unresponsive to oxygen can be treated with alprostadil (prostaglandin E1). This dilates arterioles and maintains the patency of the ductus arteriosus, increasing blood flow to the lungs.[9]

Most experts agree that severe gradients will eventually progress to severe obstruction and right heart failure and warrant invasive treatment independently of symptom status.[19] All patients therefore require urgent PBPV or surgical valvuloplasty; the indications and approach are the same as for moderate disease.[9] [13] [15] [18]

Treatment algorithm overview

Please note that formulations/routes and doses may differ between drug names and brands, drug formularies, or locations. Treatment recommendations are specific to patient groups: see disclaimer

Acute (summary)		
mild disease		
	1st	**observation**
moderate disease		
	1st	**percutaneous balloon pulmonary valvuloplasty**
	2nd	**surgical valvuloplasty**
severe to critical disease		
without respiratory distress or cyanosis	**1st**	**percutaneous balloon pulmonary valvuloplasty**
	2nd	**surgical valvuloplasty**
with respiratory distress or cyanosis	**1st**	**supplemental oxygen ± alprostadil**
	plus	**percutaneous balloon pulmonary valvuloplasty**
	2nd	**surgical valvuloplasty**

Treatment algorithm

Please note that formulations/routes and doses may differ between drug names and brands, drug formularies, or locations. Treatment recommendations are specific to patient groups: see disclaimer

Acute

mild disease

1st **observation**

» This form is asymptomatic and rarely progresses. It requires only sequential cardiology follow-up into adulthood.[13] [17] [18]

moderate disease

1st **percutaneous balloon pulmonary valvuloplasty**

» In patients with moderate disease, intervention with percutaneous balloon pulmonary valvuloplasty (PBPV) is generally recommended.[13] [15] [18] Most experts agree that moderate gradients will eventually progress to severe obstruction and right heart failure and warrant invasive treatment independently of symptom status.[19] Nevertheless, the utility of invasive treatment in asymptomatic patients with moderate PS remains under debate, and its use varies by institution.

» US guidelines recommend PBPV as the first-line therapy for moderate or severe PS and otherwise unexplained symptoms of heart failure, cyanosis from interatrial right-to-left communication, and/or exercise intolerance.[13] European guidelines recommend intervention in the presence of one or more of the following: symptoms related to PS; decreasing right ventricular function and/or progressive tricuspid regurgitation to at least moderate; and/or right-to-left shunting via an atrial septal defect or ventricular septal defect.[15]

» The benefits of PBPV are that it is less invasive compared with surgical valvuloplasty, does not require cardiopulmonary bypass, and significantly decreases neonatal mortality.

2nd **surgical valvuloplasty**

» Surgical valvuloplasty (cutting of a constricted cardiac valve to relieve obstruction) is indicated if patients are ineligible for percutaneous balloon pulmonary valvuloplasty (PBPV), for example if they have a dysplastic pulmonary valve not amenable to balloon dilation (e.g., in Noonan syndrome) or if they have multiple levels of fixed

Acute

obstruction (i.e., sub- and/or supravalvar), or if PBPV has previously failed.[13]

»

severe to critical disease

without respiratory distress or cyanosis

1st **percutaneous balloon pulmonary valvuloplasty**

» Most experts agree that severe gradients will eventually progress to severe obstruction and right heart failure and warrant invasive treatment independently of symptom status.[19] Critical disease requires urgent treatment.

» US guidelines recommend PBPV as the first-line therapy for moderate or severe PS and otherwise unexplained symptoms of heart failure, cyanosis from interatrial right-to-left communication, and/or exercise intolerance.[13] European guidelines recommend intervention in the presence of one or more of the following: symptoms related to PS; decreasing right ventricular function and/or progressive tricuspid regurgitation to at least moderate; and/or right-to-left shunting via an atrial septal defect or ventricular septal defect.[15]

» The benefits of PBPV are that it is less invasive compared with surgical valvuloplasty, does not require cardiopulmonary bypass, and significantly decreases neonatal mortality.

2nd **surgical valvuloplasty**

» Surgical valvuloplasty (cutting of a constricted cardiac valve to relieve obstruction) is indicated if patients are ineligible for percutaneous balloon pulmonary valvuloplasty (PBPV), for example if they have a dysplastic pulmonary valve not amenable to balloon dilation (e.g., in Noonan syndrome) or if they have multiple levels of fixed obstruction (i.e., sub- and/or supravalvar), or if PBPV has previously failed.[13]

»

with respiratory distress or cyanosis

1st **supplemental oxygen ± alprostadil**

Primary options

» alprostadil: 0.05 to 0.1 micrograms/kg/minute intravenous infusion, maximum 0.4 micrograms/kg/minute

» Fraction of inspired oxygen (FiO_2) of 1 at a flow rate of 8 to 10 L/minute in infants, up to 15 L/minute in adults. Adjusted as necessary for

Acute

pulse oximetry saturations of 92% to 96% in term infants/adults and 88% to 92% in preterm infants.

» Cyanotic neonates who are unresponsive to oxygen can be treated with alprostadil (prostaglandin E1). This dilates arterioles and maintains patency of ductus arteriosus increasing blood flow to the lungs.[9] Maximal effect seen in 30 minutes. Doses above 0.03 micrograms/kg/min do not offer any clinical advantage once patency of the ductus arteriosus has been established. Alprostadil is usually continued until 24 hour post-balloon or surgical valvuloplasty.

plus **percutaneous balloon pulmonary valvuloplasty**

Treatment recommended for ALL patients in selected patient group

» Most experts agree that severe gradients will eventually progress to severe obstruction and right heart failure and warrant invasive treatment independently of symptom status.[13] Critical disease requires urgent treatment.

» US guidelines recommend PBPV as the first-line therapy for moderate or severe PS and otherwise unexplained symptoms of heart failure, cyanosis from interatrial right-to-left communication, and/or exercise intolerance.[13] European guidelines recommend intervention in the presence of one or more of the following: symptoms related to PS; decreasing right ventricular function and/or progressive tricuspid regurgitation to at least moderate; and/or right-to-left shunting via an atrial septal defect or ventricular septal defect.[15]

» The benefits of PBPV are that it is less invasive compared with surgical valvuloplasty, does not require cardiopulmonary bypass, and significantly decreases neonatal mortality.

2nd **surgical valvuloplasty**

» Surgical valvuloplasty (cutting of a constricted cardiac valve to relieve obstruction) is indicated if patients are ineligible for percutaneous balloon pulmonary valvuloplasty (PBPV), for example if they have a dysplastic pulmonary valve not amenable to balloon dilation (e.g., in Noonan syndrome) or if they have multiple levels of fixed obstruction (i.e., sub- and/or supravalvar), or if PBPV has previously failed.[13]

Patient discussions

In general, patients with mild or residual pulmonary stenosis (PS) following intervention do not need to restrict physical activities. Patients with moderate PS should avoid high-intensity exercise and static sports such as climbing or gymnastics. Patients with severe PS should participate in low-intensity exercise only.[15]

Transition from paediatric to adult care warrants development of a healthcare transition programme. This should emphasise the importance of patient self-management, support patients in improving their medical knowledge, and be sensitive to the presence of intellectual disability, mental health conditions, or other comorbidities.[25]

FOLLOW UP

Monitoring

Monitoring

Patients with mild PS do not require therapy but need to be monitored in an outpatient setting for progression of disease. While mild PS is thought of as a static lesion, studies using colour echocardiography suggest that infancy is the highest risk period for progression.[12] Therefore, patients need to be monitored annually until 4 years of age, after which clinical visits can range from every 3 to 5 years into adulthood. Less frequent follow-up may be appropriate for adult patients.[14]

Given the potential neurodevelopmental impacts associated with PS, incorporating comprehensive genetic evaluation and neurodevelopmental surveillance into the routine monitoring protocol is crucial, especially for patients who have undergone cardiac surgery or present with risk factors for developmental delays. This ensures a comprehensive approach to care that addresses all aspects of the patient's well-being.[7]

Clinical visits should consist of history, physical examination, ECG, echocardiography, and an exercise test when indicated.[13]

For those who have undergone an interventional procedure, follow-up will depend on the severity of stenosis after dilation. In general, there will be visits at 6 to 12 months, 5 years, and then every 10 years post-intervention.

Complications

Complications	Timeframe	Likelihood
vascular lacerations due to valvuloplasty	**short term**	**low**
Early complication of valvuloplasty; may require surgical intervention.		
tearing of pulmonary valve annulus due to valvuloplasty	**short term**	**low**
Early complication of valvuloplasty; may require surgical intervention.		
arrhythmias due to valvuloplasty	**short term**	**low**
Early complication of valvuloplasty; management will depend on type and severity.		
'suicide' RV (dynamic infundibular stenosis post-balloon or surgical valvuloplasty)	**short term**	**low**
Dynamic stenosis due to continued vigorous contraction of the RV previously needed to overcome the PS. Recognised immediately post-procedure due to persistent obstruction to pulmonary outflow. May require medical therapy with a beta-blocker or continuation of alprostadil for a short period of time post-intervention, usually less than 2 weeks.		
pulmonary valve insufficiency post-valvuloplasty	**variable**	**high**
Invariably, relief of the valvular stenosis results in incompetency of the pulmonary valve. This is due to stretching of the annulus and failure of the leaflets to coapt. The resulting regurgitation can be mild, moderate, or severe and requires ongoing evaluation by a cardiologist, with the frequency of evaluation dependent on the severity of the regurgitation. In general, pulmonary insufficiency is well tolerated over a long time period.		
right heart failure	**variable**	**medium**
In severe PS, the right ventricle (RV) will eventually fail as the myocardium becomes unable to support the enhanced work load imposed by the PS. Patients present with symptoms of exercise intolerance, increasing dyspnoea, jugular venous distension, peripheral oedema, pleural effusion, ascites, and hepatomegaly. These signs and symptoms indicate that the condition has progressed to critical PS and warrant immediate referral to a (paediatric) cardiologist. Although initial management with digoxin and loop diuretics will be directed at the heart failure, urgent PS treatment (percutaneous balloon valvuloplasty or surgery) is required for definitive therapy and to prevent permanent damage to the RV.		

FOLLOW UP

Complications	Timeframe	Likelihood
sudden death	**variable**	**low**
Occurs due to limited pulmonary blood flow with either profound cyanosis or low cardiac output and right heart failure.		
cardiac perforation due to valvuloplasty	**variable**	**low**
Major complication requiring surgical intervention, occurring in around 0.1%.[22]		
tricuspid insufficiency post-valvuloplasty	**variable**	**low**
Major complication requiring surgical intervention, occurring in around 0.2%.[22]		
death post-valvuloplasty	**variable**	**low**
Major complication, occurring in around 0.2%.[22]		

Prognosis

Mild pulmonary stenosis (PS)

Survival in untreated patients is equivalent to that of the general population.[21]

While mild PS is thought of as a static lesion, modern studies using colour echocardiography suggest that infancy is the highest-risk period for progression.[12]

Moderate/severe/critical PS

Critical PS is fatal in the neonate without intervention.[9]

Percutaneous valvuloplasty produces excellent short- and long-term results in reducing the pulmonary valve obstruction.[22] Data from more than 26 institutions within the Valvuloplasty and Angioplasty of Congenital Anomalies (VACA) Registry resulted in an overall acute decrease in peak systolic gradients from 71 to 28 mmHg.[23]

Long-term results of 860 patients followed up for 14 years after balloon valvuloplasty showed that 4 out of 5 were free from clinically significant PS.[22] For neonates with critical PS, the rate of technical success for this procedure is about 90%, with a 5% complication rate. The freedom from re-intervention rate (surgical or catheterisation) has been estimated to be 79%. The study identified the following independent risk factors for suboptimal outcome: higher initial pulmonary valvular gradient, high early residual gradient, dysplastic valve, and younger age at intervention.

In a study on patients with non-dysplastic valves, surgical valvuloplasty decreased the mean pressure gradient significantly more compared with balloon valvuloplasty.[24] In addition, surgical valvuloplasty was associated with fewer re-interventions but a longer hospital stay and led more frequently to moderate pulmonary valve insufficiency following the intervention.

Diagnostic guidelines

Europe

Guidelines for the management of adult congenital heart disease (previously grown-up congenital heart disease) (http://www.escardio.org/Guidelines/Clinical-Practice-Guidelines)

Published by: European Society of Cardiology **Last published:** 2020

North America

ACR appropriateness criteria: congenital or acquired heart disease (https://www.acr.org/Clinical-Resources/Clinical-Tools-and-Reference/Appropriateness-Criteria)

Published by: American College of Radiology **Last published:** 2023

AHA/ACC guideline for the management of patients with valvular heart disease (https://professional.heart.org/en/guidelines-and-statements)

Published by: American Heart Association; American College of Cardiology **Last published:** 2020

AHA/ACC 2018 guidelines for the management of adults with congenital heart disease (https://professional.heart.org/en/guidelines-and-statements)

Published by: American Heart Association; American College of Cardiology **Last published:** 2018

Treatment guidelines

United Kingdom

Prophylaxis against infective endocarditis: antimicrobial prophylaxis against infective endocarditis in adults and children undergoing interventional procedures (https://www.nice.org.uk/guidance/CG64)

Published by: National Institute for Health and Care Excellence **Last published:** 2016

Balloon dilatation of pulmonary valve stenosis (https://www.nice.org.uk/guidance/ipg67)

Published by: National Institute for Health and Care Excellence **Last published:** 2004

Balloon dilatation with or without stenting for pulmonary artery or non-valvar right ventricular outflow tract obstruction in children (https://www.nice.org.uk/guidance/ipg76)

Published by: National Institute for Health and Care Excellence **Last published:** 2004

Europe

Guidelines for the management of adult congenital heart disease (previously grown-up congenital heart disease) (http://www.escardio.org/Guidelines/Clinical-Practice-Guidelines)

Published by: European Society of Cardiology **Last published:** 2020

Management of cardiovascular diseases during pregnancy (http://www.escardio.org/Guidelines/Clinical-Practice-Guidelines)

Published by: European Society of Cardiology **Last published:** 2018

North America

Guidelines for cardiovascular intervention in adults with congenital heart disease (https://ccs.ca/guidelines-and-position-statement-library)

Published by: Canadian Cardiovascular Society **Last published:** 2022

AHA/ACC guideline for the management of patients with valvular heart disease (https://professional.heart.org/en/guidelines-and-statements)

Published by: American Heart Association; American College of Cardiology **Last published:** 2020

AHA/ACC 2018 guidelines for the management of adults with congenital heart disease (https://professional.heart.org/en/guidelines-and-statements)

Published by: American Heart Association; American College of Cardiology **Last published:** 2018

Management of pregnancy in patients with complex congenital heart disease (https://professional.heart.org/en/guidelines-and-statements)

Published by: American Heart Association **Last published:** 2017

Asia

Guideline on management and re-interventional therapy in patients with congenital heart disease long-term after initial repair (https://www.j-circ.or.jp/english/cj/jcs-guidelines)

Published by: Japanese Circulation Society **Last published:** 2022

Key articles

- Stout KK, Daniels CJ, Aboulhosn JA, et al. 2018 AHA/ACC guideline for the management of adults with congenital heart disease: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. J Am Coll Cardiol. 2018 Aug 10 [Epub ahead of print]. Full text (https://www.ahajournals.org/doi/10.1161/CIR.0000000000000603) Abstract (http://www.ncbi.nlm.nih.gov/pubmed/30121239?tool=bestpractice.bmj.com)

- Otto CM, Nishimura RA, Bonow RO, et al. 2020 ACC/AHA guideline for the management of patients with valvular heart disease: executive summary: a report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines. Circulation. 2021 Feb 2;143(5):e35-71. Full text (https://www.ahajournals.org/doi/10.1161/CIR.0000000000000923) Abstract (http://www.ncbi.nlm.nih.gov/pubmed/33332149?tool=bestpractice.bmj.com)

- European Society of Cardiology. 2020 ESC guidelines for the management of adult congenital heart disease (previously grown-up congenital heart disease). Aug 2020 [internet publication]. Full text (https://www.escardio.org/Guidelines/Clinical-Practice-Guidelines/Grown-Up-Congenital-Heart-Disease-Management-of)

References

1. Burch M, Sharland M, Shinebourne E, et al. Cardiologic abnormalities in Noonan syndrome: phenotypic diagnosis and echocardiographic assessment of 118 patients. J Am Coll Cardiol. 1993 Oct;22(4):1189-92. Full text (http://www.sciencedirect.com/science/article/pii/0735109793904365?via%3Dihub) Abstract (http://www.ncbi.nlm.nih.gov/pubmed/8409059?tool=bestpractice.bmj.com)

2. Ruckdeschel E, Kim YY. Pulmonary valve stenosis in the adult patient: pathophysiology, diagnosis and management. Heart. 2019 Mar;105(5):414-22. Full text (https://www.doi.org/10.1136/heartjnl-2017-312743) Abstract (http://www.ncbi.nlm.nih.gov/pubmed/30337335?tool=bestpractice.bmj.com)

3. Marchini F, Meossi S, Passarini G, et al. Pulmonary valve stenosis: from diagnosis to current management techniques and future prospects. Vasc Health Risk Manag. 2023;19:379-90. Full text (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10320808) Abstract (http://www.ncbi.nlm.nih.gov/pubmed/37416511?tool=bestpractice.bmj.com)

4. Keith A. The Hunterian lectures on malformations of the heart. Lancet. 1909;2:359.

5. Oka M, Angrist GM. Mechanism of cardiac valvular fusion and stenosis. Am Heart J. 1967;74:37-47.

6. Pierpont ME, Basson CT, Benson DW Jr, et al. Genetic basis for congenital heart defects: current knowledge. A scientific statement from the American Heart Association Congenital Cardiac Defects Committee, Council on Cardiovascular Disease in the Young: endorsed by the American Academy of Pediatrics. Circulation. 2007;115:3015-3038. Full text (http://circ.ahajournals.org/content/115/23/3015.full)

REFERENCES

7. Sood E, Newburger JW, Anixt JS, et al. Neurodevelopmental outcomes for individuals with congenital heart disease: updates in neuroprotection, risk-stratification, evaluation, and management: a scientific statement from the American Heart Association. Circulation. 2024 Mar 26;149(13):e997-1022. Full text (https://www.ahajournals.org/doi/full/10.1161/CIR.0000000000001211) Abstract (http://www.ncbi.nlm.nih.gov/pubmed/38385268?tool=bestpractice.bmj.com)

8. Garson A, Bricker JT, Fisher DJ, eds. The science and practice of pediatric cardiology. 2nd ed. Baltimore, MD: Lippincott, Williams & Wilkins; 1998 (Vol 1):1207-56.

9. Latson LA. Critical pulmonary stenosis. J Interv Cardiol. 2001 Jun;14(3):345-50. Full text (https://pubmed.ncbi.nlm.nih.gov/12053395) Abstract (http://www.ncbi.nlm.nih.gov/pubmed/12053395?tool=bestpractice.bmj.com)

10. Botto LD, Correa A, Erickson JD. Racial and temporal variations in the prevalence of heart defects. Pediatrics. 2001 Mar;107(3):E32. Full text (http://pediatrics.aappublications.org/content/107/3/e32.full) Abstract (http://www.ncbi.nlm.nih.gov/pubmed/11230613?tool=bestpractice.bmj.com)

11. Moyssakis IE, Rallidis LS, Guida GF, et al. Incidence and evolution of carcinoid syndrome in the heart. J Heart Valve Dis. 1997 Nov;6(6):625-30. Abstract (http://www.ncbi.nlm.nih.gov/pubmed/9427132?tool=bestpractice.bmj.com)

12. Rowland DG, Hammill WW, Allen HD, et al. Natural course of isolated pulmonary valve stenosis in infants and children utilizing Doppler echocardiography. Am J Cardiol. 1997 Feb 1;79(3):344-9. Abstract (http://www.ncbi.nlm.nih.gov/pubmed/9036756?tool=bestpractice.bmj.com)

13. Stout KK, Daniels CJ, Aboulhosn JA, et al. 2018 AHA/ACC guideline for the management of adults with congenital heart disease: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. J Am Coll Cardiol. 2018 Aug 10 [Epub ahead of print]. Full text (https://www.ahajournals.org/doi/10.1161/CIR.0000000000000603) Abstract (http://www.ncbi.nlm.nih.gov/pubmed/30121239?tool=bestpractice.bmj.com)

14. Otto CM, Nishimura RA, Bonow RO, et al. 2020 ACC/AHA guideline for the management of patients with valvular heart disease: executive summary: a report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines. Circulation. 2021 Feb 2;143(5):e35-71. Full text (https://www.ahajournals.org/doi/10.1161/CIR.0000000000000923) Abstract (http://www.ncbi.nlm.nih.gov/pubmed/33332149?tool=bestpractice.bmj.com)

15. European Society of Cardiology. 2020 ESC guidelines for the management of adult congenital heart disease (previously grown-up congenital heart disease). Aug 2020 [internet publication]. Full text (https://www.escardio.org/Guidelines/Clinical-Practice-Guidelines/Grown-Up-Congenital-Heart-Disease-Management-of)

16. American College of Radiology. ACR appropriateness criteria®: congenital or acquired heart disease. 2023 [internet publication]. Full text (https://acsearch.acr.org/docs/3102389/Narrative)

17. Drossner DM, Mahle WT. A management strategy for mild valvar pulmonary stenosis. Pediatr Cardiol. 2008 May;29(3):649-52. Abstract (http://www.ncbi.nlm.nih.gov/pubmed/18193316?tool=bestpractice.bmj.com)

18. Marelli A, Beauchesne L, Colman J, et al. Canadian Cardiovascular Society 2022 guidelines for cardiovascular interventions in adults with congenital heart disease. Can J Cardiol. 2022 Jul;38(7):862-96. Full text (https://www.onlinecjc.ca/article/S0828-282X(22)00260-4/fulltext) Abstract (http://www.ncbi.nlm.nih.gov/pubmed/35460862?tool=bestpractice.bmj.com)

19. Hayes CJ, Gersony WM, Driscoll DJ, et al. Second natural history study of congenital heart defects: results of treatment of patients with pulmonary valvar stenosis. Circulation. 1993 Feb;87(suppl 2):I28-37. Abstract (http://www.ncbi.nlm.nih.gov/pubmed/8425320?tool=bestpractice.bmj.com)

20. Wash KP. Interventional paediatric cardiology. BMJ. 2003 Aug 16;327(7411):385-8. Full text (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1126797) Abstract (http://www.ncbi.nlm.nih.gov/pubmed/12919997?tool=bestpractice.bmj.com)

21. Tinker J, Howitt G, Markman P, et al. The natural history of isolated pulmonary stenosis. Br Heart J. 1965 Mar;27:151-60. Full text (http://www.ncbi.nlm.nih.gov/pmc/articles/PMC503295/pdf/brheartj00337-0001.pdf)

22. Gudausky TM, Beekman RH 3rd. Current options, and long-term results for interventional treatment of pulmonary valvar stenosis. Cardiol Young. 2006 Oct;16(5):418-27. Abstract (http://www.ncbi.nlm.nih.gov/pubmed/16984693?tool=bestpractice.bmj.com)

23. Stanger P, Cassidy SC, Girod DA, et al. Balloon pulmonary valvuloplasty: results of the Valvuloplasty and Angioplasty of Congenital Anomalies registry. Am J Cardiol. 1990 Mar 15;65(11):775-83. Abstract (http://www.ncbi.nlm.nih.gov/pubmed/2316460?tool=bestpractice.bmj.com)

24. Peterson C, Schilthuis JJ, Dodge-Khatami A, et al. Comparative long-term results of surgery versus balloon valvuloplasty for pulmonary valve stenosis in infants and children. Ann Thorac Surg. 2003 Oct;76(4):1078-82. Abstract (http://www.ncbi.nlm.nih.gov/pubmed/14529989?tool=bestpractice.bmj.com)

25. John AS, Jackson JL, Moons P, et al. Advances in managing transition to adulthood for adolescents with congenital heart disease: a practical approach to transition program design: a scientific statement from the American Heart Association. J Am Heart Assoc. 2022 Apr 5;11(7):e025278. Full text (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9075425) Abstract (http://www.ncbi.nlm.nih.gov/pubmed/35297271?tool=bestpractice.bmj.com)

Images

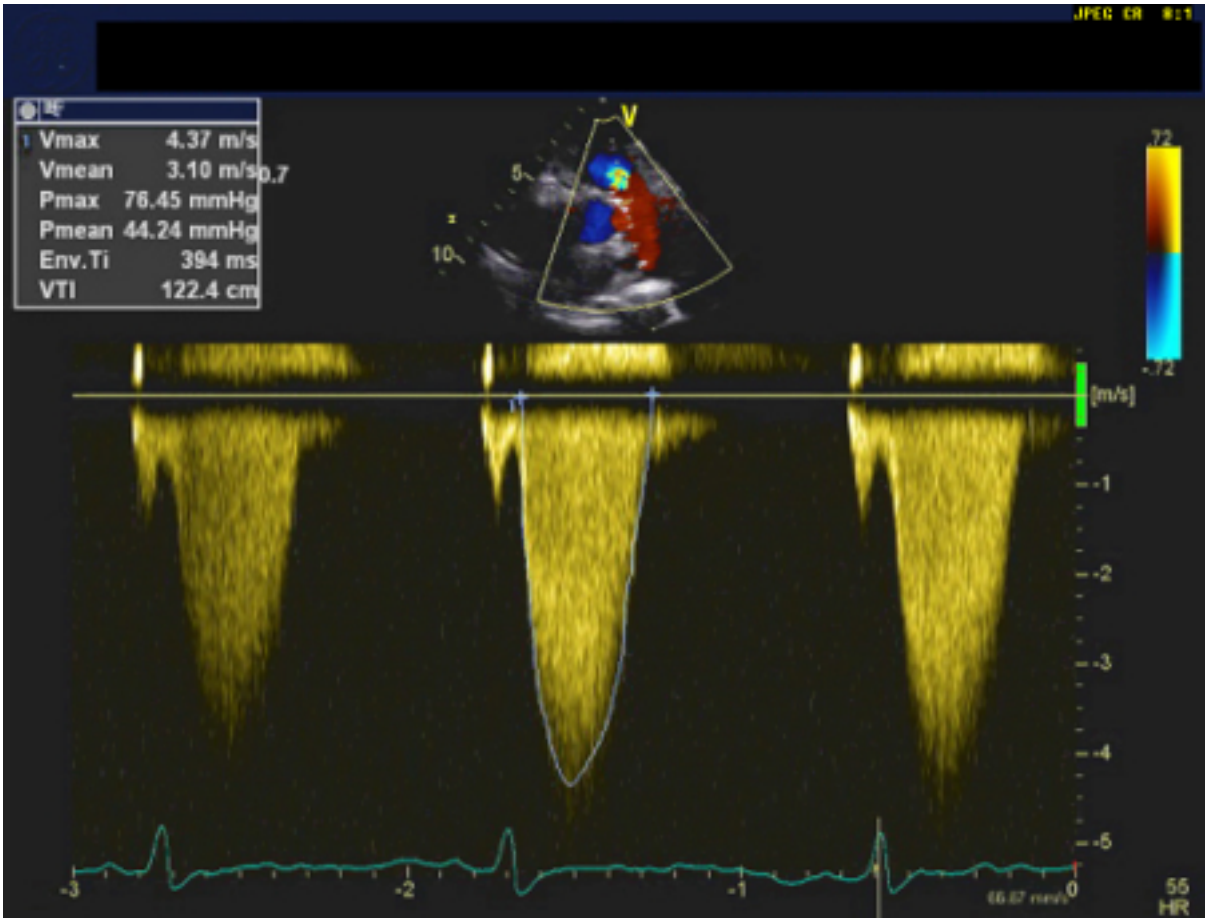


Figure 1: Continuous wave doppler demonstrating severe pulmonary stenosis on transthoracic echocardiogram

Used with permission by National University Heart Centre, Singapore

Disclaimer

BMJ Best Practice is intended for licensed medical professionals. BMJ Publishing Group Ltd (BMJ) does not advocate or endorse the use of any drug or therapy contained within this publication nor does it diagnose patients. As a medical professional you retain full responsibility for the care and treatment of your patients and you should use your own clinical judgement and expertise when using this product.

This content is not intended to cover all possible diagnosis methods, treatments, follow up, drugs and any contraindications or side effects. In addition, since such standards and practices in medicine change as new data become available, you should consult a variety of sources. We strongly recommend that you independently verify specified diagnosis, treatments and follow-up and ensure it is appropriate for your patient within your region. In addition, with respect to prescription medication, you are advised to check the product information sheet accompanying each drug to verify conditions of use and identify any changes in dosage schedule or contraindications, particularly if the drug to be administered is new, infrequently used, or has a narrow therapeutic range. You must always check that drugs referenced are licensed for the specified use and at the specified doses in your region.

Information included in BMJ Best Practice is provided on an “as is” basis without any representations, conditions or warranties that it is accurate and up to date. BMJ and its licensors and licensees assume no responsibility for any aspect of treatment administered to any patients with the aid of this information. To the fullest extent permitted by law, BMJ and its licensors and licensees shall not incur any liability, including without limitation, liability for damages, arising from the content. All conditions, warranties and other terms which might otherwise be implied by the law including, without limitation, the warranties of satisfactory quality, fitness for a particular purpose, use of reasonable care and skill and non-infringement of proprietary rights are excluded.

Where BMJ Best Practice has been translated into a language other than English, BMJ does not warrant the accuracy and reliability of the translations or the content provided by third parties (including but not limited to local regulations, clinical guidelines, terminology, drug names and drug dosages). BMJ is not responsible for any errors and omissions arising from translation and adaptation or otherwise.Where BMJ Best Practice lists drug names, it does so by recommended International Nonproprietary Names (rINNs) only. It is possible that certain drug formularies might refer to the same drugs using different names.

Please note that recommended formulations and doses may differ between drug databases drug names and brands, drug formularies, or locations. A local drug formulary should always be consulted for full prescribing information.

Treatment recommendations in BMJ Best Practice are specific to patient groups. Care is advised when selecting the integrated drug formulary as some treatment recommendations are for adults only, and external links to a paediatric formulary do not necessarily advocate use in children (and vice-versa). Always check that you have selected the correct drug formulary for your patient.

Where your version of BMJ Best Practice does not integrate with a local drug formulary, you should consult a local pharmaceutical database for comprehensive drug information including contraindications, drug interactions, and alternative dosing before prescribing.

Interpretation of numbers

Regardless of the language in which the content is displayed, numerals are displayed according to the original English-language numerical separator standard. For example 4 digit numbers shall not include a comma nor a decimal point; numbers of 5 or more digits shall include commas; and numbers stated to be less than 1 shall be depicted using decimal points. See Figure 1 below for an explanatory table.

BMJ accepts no responsibility for misinterpretation of numbers which comply with this stated numerical separator standard.

This approach is in line with the guidance of the International Bureau of Weights and Measures Service.

Figure 1 – BMJ Best Practice Numeral Style

5-digit numerals: 10,000

4-digit numerals: 1000

numerals < 1: 0.25

Our full website and application terms and conditions can be found here: Website Terms and Conditions.

Contact us

+ 44 (0) 207 111 1105
support@bmj.com

BMJ
BMA House
Tavistock Square
London
WC1H 9JR
UK

BMJ Best Practice

Contributors:

// Authors:

Jeremy Asnes, MD

Associate Professor of Pediatrics (Cardiology)
Yale Pediatric Cardiology, Yale New Haven Children's Hospital, New Haven, CT
DISCLOSURES: JA is a Principal Investigator for the Medtronic Harmony™ Transcatheter Pulmonary Valve clinical trial. JA has also been a paid consultant for Medtronic, the manufacturer of the Melody and Harmony transcatheter pulmonary valves.

Britton Keeshan, MD, MPH

Assistant Professor of Clinical Pediatrics
Yale Pediatric Cardiology, Yale New Haven Children's Hospital, New Haven, CT
DISCLOSURES: BK declares that he has no competing interests.

// Acknowledgements:

Dr Asnes and Dr Keeshan would like to gratefully acknowledge Dr Ivandito Kuntjoro, Dr Edgar Tay, Dr James Yip, Dr Kian Keong Pho, Dr Low Ting Ting, Dr Peter S. Fischbach, Dr Cyrus Samai, and Dr David M. Drossner, the previous authors of this topic.
DISCLOSURES: ET, IK, JY, KKP, LTT, PSF, CS and DD declared that they had no competing interests.

// Peer Reviewers:

John Charpie, MD, PhD

Associate Professor of Pediatrics
Medical Director, Pediatric Cardiothoracic Intensive Care Unit, University of Michigan Congenital Heart Center, Ann Arbor, MI
DISCLOSURES: JC declares that he has no competing interests.

James Gnanapragasam, MBBS, MSc, FRCP, FRCPCH

Consultant in Paediatric Cardiology
Southampton University Hospitals NHS Trust, Southampton, UK
DISCLOSURES: JG declares that he has no competing interests.