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KJC 2

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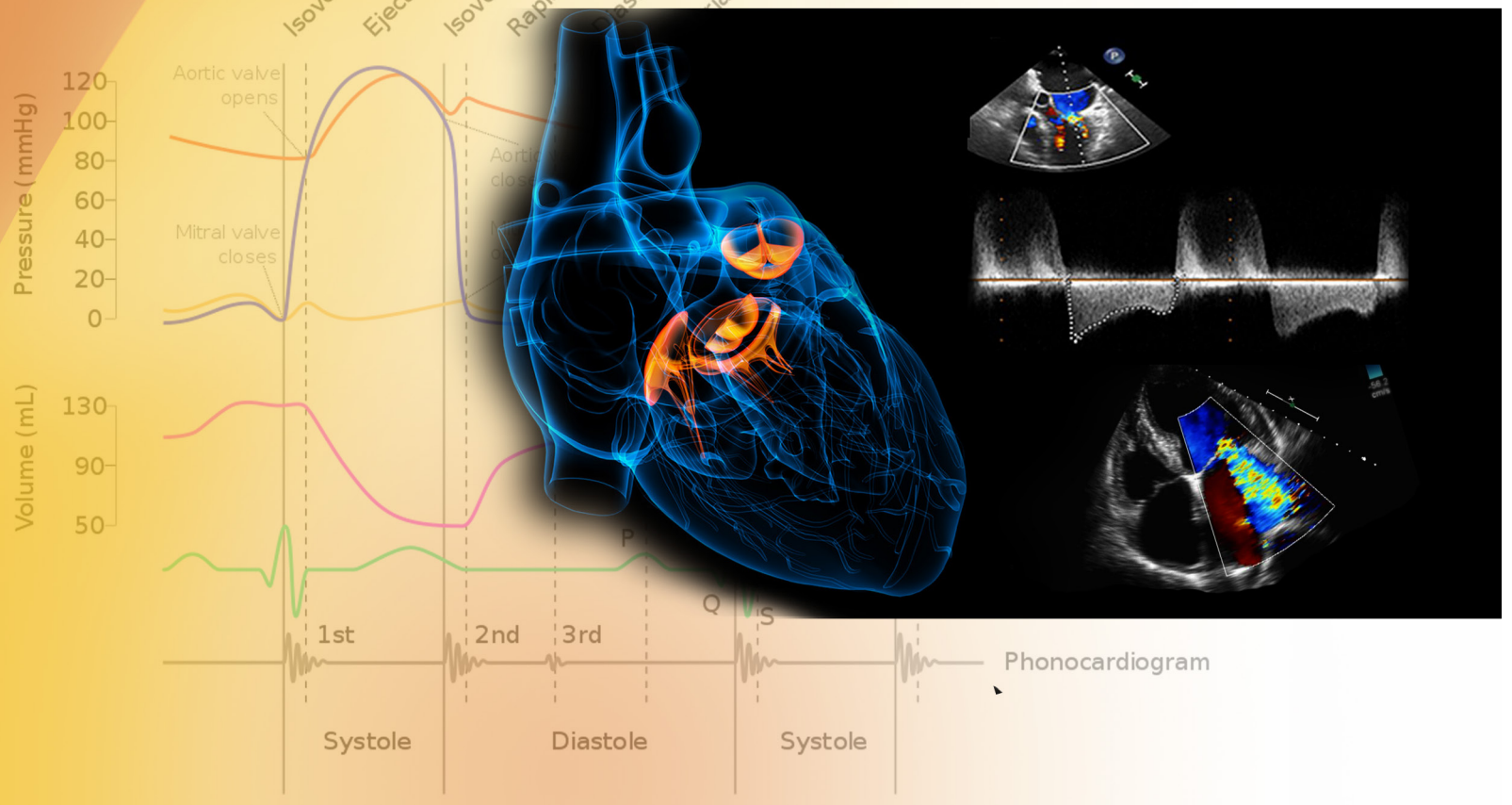

Focussed topic: **Valvular Heart Diseases**

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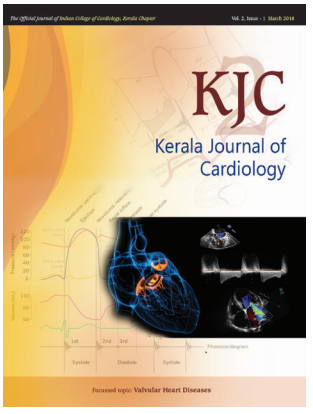

The Dream continues…!

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"We couldn't find the sports car of our dreams, so we built it ourselves"
– Ferdinand Porsche

Dear Teachers and Friends,

From the very beginning, it was well known to us that, there was no dearth of good quality journals in cardiology. But for an average student in cardiology or a young cardiologist, the immense information provided by these journals and the explosion of knowledge/ advancements in the field of cardiology, appeared more disheartening than appealing. Journals provided voluminous information of no or minimal consequences to many and they could feel as lost at sea. The Kerala journal of cardiology (KJC) was conceived to address this particular aspect and provide a customised platform to the target audience and feed them only what really mattered. The original idea of KJC is to stay focussed on a particular topic of interest and find the best teachers/ experts in the field to explain; so that the readers get all the relevant information at one place.

The reception given to the launch issue of KJC (KJC 1) was overwhelming and we thank everyone for the appreciation and encouragement. Sure; that adds more to our responsibility to bring out our best in subsequent editions. We know, it is easier to launch a journal, but sustaining it needs unending passion, hard work and perseverance. We sincerely hope we will be able to keep promises and live up to expectations in the future editions of KJC as well. This edition of KJC is named as KJC 2 and hereafter future editions of KJC will be named as KJC 3, KJC 4 and so on. We feel this will help the reader to refer to a particular topic and the concerned issue of KJC with ease.

We were fortunate to have the best teachers in the field for KJC 1, which focussed on 'congenital heart diseases'. This edition, in its "**Diamonds**" section, focuses on **'Valvular heart diseases'**. We are proud to bring this issue with four master teachers on board, discussing the various aspects of valvular heart diseases. As mentioned in previous edition, the target audience of KJC 2 will be fellows in training and young cardiologists; and of course all those who are young at heart!

Dr C G Bahuleyan, former professor and head of the department of cardiology, Medical College, Thiruvananthapuram handles the first chapter in Diamonds section of KJC 2. He is discussing various aspects of jugular venous pressure and jugular venous pulse. We know, Jugular venous pulse is a clinical sign which confuses senior physicians and students alike. The term 'JVP' remains intriguing, perplexing, terrifying…..especially in examination hall. Dr C G Bahuleyan discusses the basics as well as all the relevant information required to interpret JVP. He stays away from rare causes and clinically irrelevant aspects of the topic. A master teacher he is, he knows how students make blunders in examination hall by declaring rarer causes first!

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The second chapter of KJC 2 deals with clinical approach to valvular heart diseases. For most fellows in training of cardiology, the 'long case' for exit examination will be valvular heart disease. **Dr George Koshy A**, professor of cardiology at Medical College, Thiruvananthapuram has simplified this topic like a fairy tale. We can feel his clarity of thought, common sense and logic in approaching individual and multivalvular lesions throughout this chapter.

Dr Sudhayakumar N, former professor and head of the department of cardiology at Medical College Kottayam explains to us the common errors committed by students in examination hall and tips to overcome them. Dr Sudhayakumar has vast experience as an examiner in cardiology and he has prepared this topic in a different format, in his impeccable style. Tips and tricks in bed side clinical evaluation and case presentation are presented as a 'direct lecture to students'. Some of the discussions of this chapter overlaps with previous chapter on 'clinical approach to valvular heart diseases'. This is done intentionally so that students get a feel of two different approaches by the same master teachers to wards a particular clinical situation.

Clinical evaluation of prosthetic valves has been considered a daunting task and an unfortunate event in exit exam! **Dr Rajan Joseph Manjuran**, former professor and head of the department of cardiology deals with this apparently difficult task. Read it to believe it, we no longer need to learn by heart which valve has loud opening click….which valve has silent closing click etc…! Dr Rajan Joseph Manjuran has simplified the topic in his inimitable way and explains the clinical findings of each prosthetic valve with hemodynamic correlation.

In addition to the four topics discussed by master teachers, "KJC 2 Diamonds" section has three more articles. 'Fluoroscopy of prosthetic valves' has been discussed by Dr Abhilash T G, consultant cardiologist at Travancore Medical College Hospital Kollam. Dr John Jose, professor of cardiology at CMC hospital, Vellore and Dr Sudhakar P, assistant professor of cardiology at CMC hospital, Vellore explain their 'Approach to low gradient severe aortic stenosis'. Dr Dilu V P, consultant cardiologist at Badr Al Samaa Medical centre, Doha, Qatar deals with 'Investigations and timing of Interventions in valvular heart diseases'.

"KJC 2 Pearls" section has four chapters. Dr Bigesh Nair, consultant cardiologist at KIMS hospital, Hyderabad presents 'Recent data of rheumatic heart disease in Kerala'. Dr Ramasubramanian, fellow in interventional cardiology at Sree Chitra Tirunal Institute For Medical Sciences and Technology, Thiruvananthapuram discusses on 'Orbital atherectomy' and Dr Hiren T Kevadiya, fellow in electrophysiology & device therapy at Sree Chitra Tirunal Institute For Medical Sciences and Technology, Thiruvananthapuram deals with 'Leadless pacemakers'. And finally, from the editorial board of KJC, Dr Sajan Ahmad Z presents his 'class room' article on 'Infective endocarditis – the peripheral signs'.

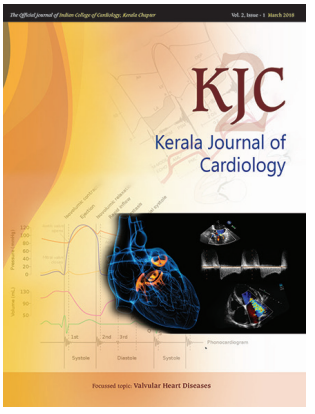
Editorial board would like to thank **Dr Ramakrishna Pillai V,** President of Indian College of Cardiology, Kerala chapter; **Dr Mangalanandan P,** Vice President of Indian College of Cardiology, Kerala chapter; and **Dr Binu S S,** Secretary of Indian College of Cardiology, Kerala chapter. KJC thrives on the unconditional support offered by them.

What started as a humble idea six months ago, is still continuing as a "mid-summer night's dream" in this month of March. May 'the KJC dream' continue in many more summers and winters to come! Expect dreams on interventional cardiology as next. Please send your articles and feedback to **abhispin@gmail.com**.

Happy dreaming

Abhilash S P
Editor in chief
on behalf of editorial board of KJC

KJC Diamonds



Jugular Venous Pulse and Pressure

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INTRODUCTION

In current clinical practice, physicians generally have become less enthusiastic in eliciting bedside clinical signs. This might have resulted from an impression of low clinical value of physical findings coupled with the easy availability and wide spread use of investigative modalities. In a recent online survey among 2684 practicing clinicians from different countries by Andrew T. Elder, only 70% felt the value of physical examination, 66% complained of inadequate supervision by the consultants while they were eliciting physical findings and 31% stated about lack of demonstration of physical findings by the consultants. [1]Among the various physical examinations mentioned in this survey, Jugular venous pulse (JVP) examination was rated as inadequately used and not clinically useful.

Mackenzie integrated JVP as part of cardiovascular physical examination in the year 1902. [2]JVP evaluation has great clinical value in cardiovascular examinations which can be done easily and repeatedly. The information obtained provides a reliable estimate of the central venous pressure (CVP) and hemodynamics of the right heart.[3]

JVP AND RIGHT ATRIAL PRESSURE

The internal jugular vein (IJV) which is formed by the union of inferior petrosal sinus and the sigmoid sinus at the base of the brain exits through jugular foramen. In the neck it is placed in the carotid sheath lateral to the internal and common carotid artery deep to the sternocleido mastoid muscle. The IJV joins the subclavian

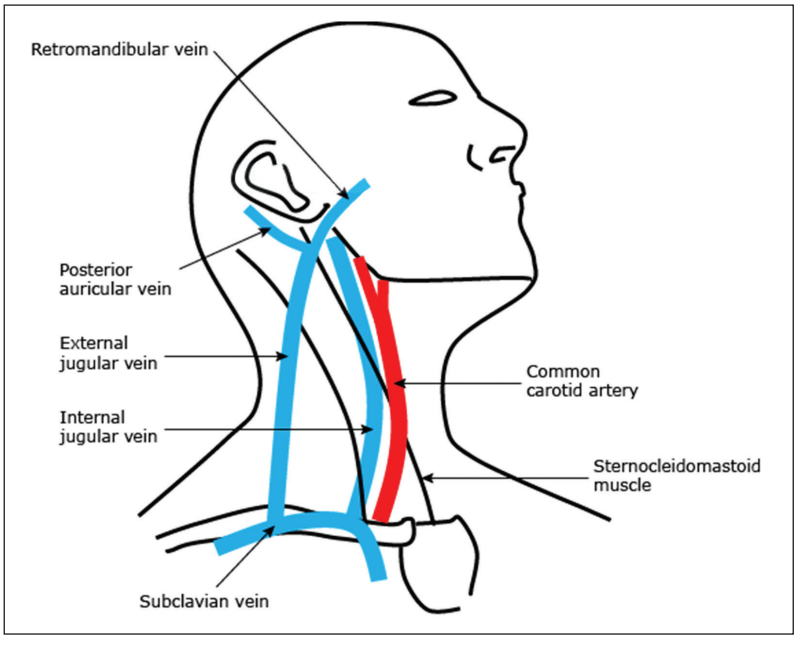

Figure 1. JVP- Anatomical points

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vein to form the right innominate vein which drain into the right atrium (RA) through the superior vena cava (SVC). The external jugular vein (EJV) formed by the union of the posterior auricular and retromandibular veins and runs down the neck within the superficial fascia obliquely across the sternocleidomastoid and drain into the subclavian vein (Figure 1). The jugular veins reflect the volume and pressure changes in the RA since they function as distensible reservoirs and conduits for the inflow of blood to the RA.[4] Abnormalities interfering with the inflow and outflow of the right heart will be reflected in the pressure and the pulse wave of the jugular veins. Elevated venous pressure can be transmitted through both IJV and EJV despite presence of interposed valves. However in view of direct continuity of the right IJV and right innominate vein with SVC the preferred vein for examination is right IJV.[5] Vinayak et al. reported the usefulness of EJV in detecting elevated RA pressure in critically ill patients in the intensive care unit with good correlation with invasive measurement.[4] Different studies showed varying level of sensitivity and specificity for the correlation of JVP with RA pressure depending upon the clinical setting, experience of the examiner, whether IJV or EJV was used and the method of correlation either invasive or non-invasive.[5-8]

The RA pressure is estimated in centimetres of water by adding the height of the jugular venous column above the sternal angle to the vertical distance from the mid RA to the sternal angle. This can be converted to millimetre of Hg by multiplying the value by 0.74 (1cm of water =0.74mm of Hg). The distance between the sternal angle and the mid RA is traditionally considered to be 5cm.[9] Imaging studies have shown that the actual distance from the sternal angle and the centre of the RA varies with patient position and body habitus. Computed tomography (CT) study suggested that 5cm could be considered when the patient is in the supine position, 8cm when the body is elevated to 30 degrees and 10cm when the upper body is elevated to 45 degree or more.[10] Good correlation between the body mass index and the distance from the sternal angle to midpoint of RA has been observed in CT study.[11] In patients with body mass index >35kg/m2 JVP seen above the medial end of the clavicle is indicative of elevated JVP. Clinical estimate of JVP has been shown to underestimate the invasively measured RA pressure which is attributed to be due to the variability of the distance between sternal angle and the centre of RA. Hence instead of considering JVP measurement as an accurate estimate of RA pressure, it is preferable to utilize it for detecting whether the RA pressure is high, normal or low. A height of the venous pulse more than 3cm from the sternal angle irrespective of the position of the patient is elevated JV with a good positive likelihood ratio (LR) of + 10.4 and a negative LR of -0.1 with a CVP of 12cm of H2O.[12] A JVP of less than 3cm above the sternal angle had an LR of +8.4 and an LR of -0.1 for a CVP <5cm of H2O.[4]

HOW TO EXAMINE JVP

Examination of JVP involves pressure measurement and pulse wave analysis. Observation is done in the supine and at varying degrees of head and upper body elevation, during phases of respiration and with manoeuvres enhancing the visibility of JVP. The right IJV is generally preferred for assessment. The left IJV is less reliable for assessing the RA pressure because the left brachiocephalic vein crosses the mediastinum and likely to be obstructed by mediastinal structures including the great vessels. The right EJV can be utilized when the right IJV cannot be adequately visualised. If the EJV is kinked in the fascia or thrombosed at the venous bulb it will not reflect the RA pressure accurately. Hence EJV is less utilized for clinical evaluation of JVP. An elevated left EJV pressure may suggest the presence of a persistent left superior vena cava.

The examiner stands on the right side of the bed as the right IJV is being evaluated. The patient lies supine on the examination table and the sternal angle (angle of Louis) is used as the reference point. Turn the head away to the left slightly and gently lift the jaw and neck upwards. Avoid too much stretch to the opposite side as this may cause stretch of the sternocleidomastoid muscle and obliterate the JVP. A tangential flash of torchlight on the skin overlying the JVP improves the visibility of both the upper level of pressure as well as the wave forms. Before measurement of JVP, the venous meniscus should be identified. The position of the patient is altered by raising the bed so as to make the meniscus clearly visible. The optimal position depends on the level of JVP. Low venous pressure is best seen in the supine position while high JVP is seen best in the sitting position. If the venous pulse is seen above the clavicle in the sitting position, the pressure is likely to be elevated[9] as the distance between the clavicle and the RA is at least 10cm. A very high JVP may not be appreciated in the supine position as the pulsation may be high up in the neck behind the mandible. In supine position, if the lower part of the earlobe is seen to pulsate, a markedly elevated JVP is suspected. In such cases, when the patient is made to sit or reclined to 45-60 degrees, the venous pulsation becomes visible.

Wood[13] showed the precise analysis of the jugular venous pulse wave forms and measurement of the venous pressure using the sternal angle as the reference point which is the junction between the manubrium and sternum at 2nd costal cartilage. JVP is measured as the vertical distance between the top of the jugular venous pulsation and the sternal angle. At bed side it is measured

by two scales, one scale held vertically from sternal angle and the other kept horizontally at upper border of blood column in IJV. The vertical distance between these two levels is the height of JVP. Bedside estimate of CVP is made in centimetres of water. It must be converted to millimetres of mercury to provide correlation with accepted haemodynamic norms. In some cases the venous pulse in the neck may not be readily visible despite changing the body positions, inspecting on the opposite side as well as using manoeuvres to enhance the JVP. In such situations, observing the collapse of the peripheral vein on the dorsum of the hand while elevating the limb will give an idea about the CVP. If the peripheral vein collapse occurs above the level of the sternal angle, the CVP is considered to be elevated. Normal wave pattern of the JVP, the time occurrence of each wave during the cardiac cycle and the mechanism of production of each wave is shown in Figure 2. The individual wave can be identified by timing it by palpating the opposite carotid artery or listening to the heart sounds simultaneously. Abnormalities of the waves can be seen in various structural, functional disorders of the heart as well as in some cardiac arrhythmias.

The JVP should be examined while patient is breathing normally (avoid examining during laboured breathing). The JVP will usually decrease with inspiration. The finding of either no decrease or increase during inspiration is known as 'Kussmaul's sign' The abdomino jugular test (hepatojugular reflux) or passive leg raising can elevate the JVP. The hepato jugular reflux can be done by applying firm and consistent pressure over the right upper quadrant of the abdomen with right palm for at least 10 seconds. If the JVP gets elevated more than 3cm and remains for at least 15 seconds during spontaneous respiration, the testis considered positive. A positive test has an LR of +8.0 for elevated right and left heart filling pressures.[14,15] Breath holding or performing Valsalva manoeuvre by the patient should be avoided since the venous pressure may be falsely elevated.

CLINICAL VALUE OF JVP EXAMINATION

Any clinical situation which interferes with RA or RV filling can cause rise in RA pressure and hence elevation in the JVP. Pulmonary hypertension resulting from any cause can lead to right ventricular hypertrophy and restriction to RV filling. This leads to high RA pressure and elevated JVP. In clinical practice, elevated JVP is seen commonly in the setting of heart failure. Elevation of the mean JVP without venous pulsation is indicative of SVC obstruction. JVP is also elevated in conditions with increased intrathoracic pressure as in the case of positive pressure ventilation, massive pleural effusion or pneumothorax.

HEART FAILURE (HF)

Physical findings have low sensitivity in diagnosing HF. Among the various findings, a raised JVP has a

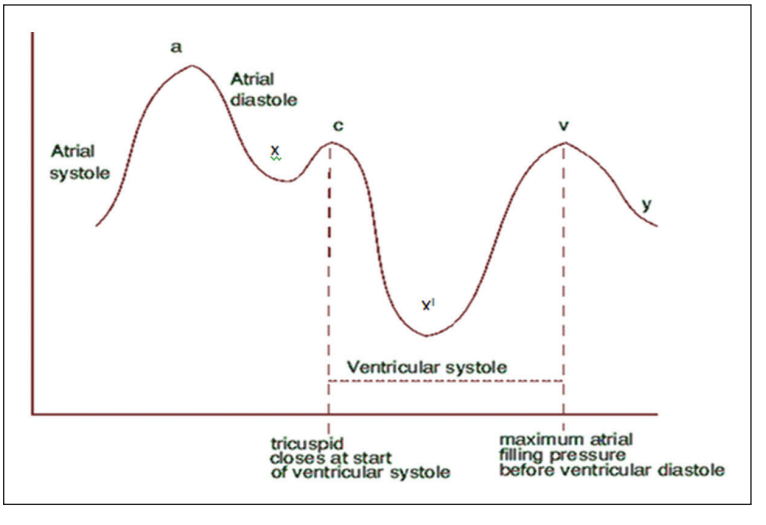


Figure 2 . JVP Wave form

'a'- wave: Right atrial contraction.
x- descent: Reflects the fall in RA pressure after 'a' wave peak during atrial relaxation.
c –wave: Represents transmitted carotid artery pulsation and upward bulging of closed tricuspid valve into RA during isovolumic systole. (Not clinically appreciated easily)
x'- descent: Caused by atrial diastolic suction created by ventricular systole, pulling tricuspid valve downwards. In normal individuals x' descent is the predominant wave form of JVP.
v- wave: Represents atrial filling at end of ventricular systole and follows just after second heart sound. Normally 'v' wave is smaller than 'a' wave because of normally compliant RA. But in atrial septal defect (ASD) 'a' wave equals to 'v' wave.
y- descent: Reflects the fall in RA pressure after tricuspid valve opening.

diagnostic value independent of other clinical and echocardiographic findings. JVP will be elevated in both systolic and diastolic HF and it has independent prognostic value in symptomatic HF.[16] Elevated JVP shows changes based on the response of the patient to the anti-heart failure treatment and this change can be utilized to assess the progress of the patient at bedside.

In patients with right ventricular hypertrophy and diastolic heart failure the 'a' wave will be prominent and with the onset of tricuspid regurgitation, the 'v' wave will become prominent and exaggerated. In cases with atrial fibrillation, the 'a' wave will be absent and JVP will appear monophasic with prominent 'v' wave.

CONSTRICTIVE PERICARDITIS

Constrictive pericarditis (CP), restrictive cardiomyopathy, right heart failure secondary to pulmonary hypertension or right ventricular myocardial infarction all will display elevated JVP. It is not easy to distinguish these conditions from the wave pattern alone. In CP the 'y' descent is prominent and sharp which represents rapid passive filling during early diastole that abruptly stops by the stiff, thickened pericardium (Figure. 3). Elevated JVP has been reported in as many as 93% of patients with surgically confirmed constrictive pericarditis.[17] The 'x' and 'y'troughs are more prominent than the 'a' and 'v' peaks and the inspiratory decline in venous pressure is confined to the depth of the 'y' descent. JVP may be normal in mild or early CP. In occult CP the increase in JVP is brought out only after volume expansion. Although Kussmauls' sign is frequently present in CP, it will not distinguish from patients with severe tricuspid valve disease or right heart failure.

CARDIAC TAMPONADE

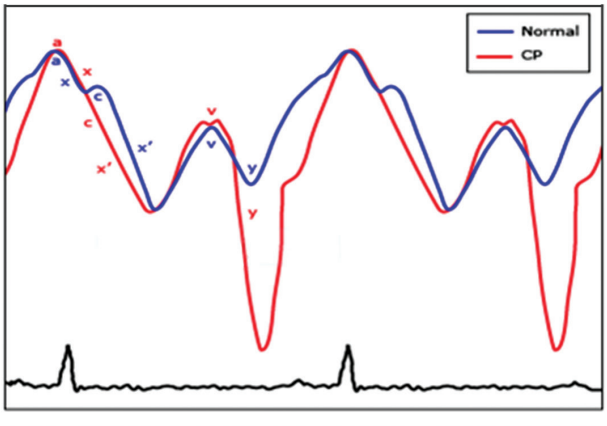
JVP is almost always markedly elevated, may be associated with venous distension in the forehead and scalp. The 'x' descent is preserved or even accentuated, the 'y' descent is attenuated or absent because of limited or absent late diastolic filling of the ventricle. Kussmaul's sign is not usually seen.

SEVERE TRICUSPID REGURGITATION (TR)

JVP is elevated with distinct 'C-V' (regurgitant) wave due to systolic regurgitation into the RA. The jugular vein is usually pulsatile and may be confused with carotid arterial pulse. Kussmaul's sign is usually present. A systolic thrill may be felt over the jugular vein in some patients with severe regurgitation. In acute severe TR, the prominent 'v' wave shows sharp upstroke, ill sustained peak and rapid decline, because of the reduced compliance of the non-dilated RA. Tricuspid stenosis is characterised by an elevated JVP with prominent presystolic 'a' wave. The 'y' descent is slow and barely appreciated. Kussmaul's sign may be seen.

PULMONARY ARTERIAL HYPERTENSION (PAH)

In cases of PAH due to left heart disease or any other causes will be associated with prominent 'a' wave in the JVP because of powerful atrial contraction to fill the



The normal jugular venous pulse waveform is represented in blue. In comparison, the jugular venous pulse waveform in a patient with constrictive pericarditis (CP) is shown in red. Note the sharp, prominent y descent in CP, which represents rapid passive filling during early diastole that abruptly stops when the ventricular volume reaches the maximal capacity allowed by the stiff, thickened pericardium.

Figure 3. Jugular Venous Pulse in constictive pericarditis

hypertrophied RV. When the RV failure ensues the JVP gets elevated with prominent 'a' wave and with onset of TR, 'v' wave also becomes prominent.

JVP IN STRUCTURAL DISORDERS OF HEART

JVP examination also helps in the diagnosis of various valvular and congenital disorders of the heart. In Eisenmenger syndrome JVP is usually normal when the shunt is distal to the tricuspid valve. In other cases a prominent 'a' wave is seen due to RA contraction that generates a high pressure to fill the hypertrophied RV. In Lutembacher syndrome when the mitral stenosis is severe, the JVP will show a prominent 'a' wave even in the absence of PAH. In ventricular septal defect with LV to RA shunt, the neck vein may show a prominent 'v' wave. The commonly observed abnormalities in JVP and associated conditions are given in Table 1.

SUMMARY:

- JVP evaluation has great clinical value in cardio vascular system examination and can be done easily and repeatedly.
- It provides reliable estimate of central venous pressure and right heart haemodynamics.
- Right IJV is preferred over EJV as it is in direct continuation with right atrium.
- Clinically measured JVP has shown to underestimate RA pressure due to variable distance from sternal angle (angle of Louis) to the midpoint of RA. Hence instead of considering to reflect accurate RA pressure JVP could be utilised to detect whether RA pressure is high, normal or low.

Table 1. JVP abnormalities and clinical conditions

SL No.	JVP character	Conditions
1	Elevated JVP with normal wave form	• Right Herat Failure • Fluid overload • Bradycardia
2	Elevated JVP with absent pulsations	• SVC obstruction
3	Prominent 'a' wave	• Tricuspid stenosis • Pulmonary stenosis • Pulmonary hypertension
4	Cannon wave (It is a very prominent 'a' wave due to atrial contraction occuring during ventricular systole - so please note cannon wave is a *systolic* wave)	Regular • Junctional rhythm • AVNRT
		Irregular • Complete heart block • Single chamber pacing • Ventricular extra systole • Ventricular tachycardia
5	Absent 'a' wave	• Atrial fibrillation
6	Prominent 'x' descent	• Cardiac tamponade
7	Prominent 'v' wave	• Tricuspid Regurgitation
8	Prominent 'y' descent	• Constrictive Pericarditis
9	Slow 'y' descent	• Tricuspid stenosis
10	Absent or attenuated 'y' descent	• Cardiac tamponade

- Sternal angle still remains the reference point and it is 5cm from midpoint of right atrium in supine position.

- Top of pulsating column > 3 cm from angle of Louis in any position is considered elevated with positive likely hood ration (LR) of 10.4.

- Bedside estimate of CVP is measured in centimetres of water which must be converted to millimetres of mercury to get the RA pressure

- Elevated JVP has been shown to have independent prognostic value in symptomatic HF.

- Despite the wide availability of investigative facilities, examination of JVP provides the clinicians important information that help in the diagnosis and prognosis of cardiac patients.

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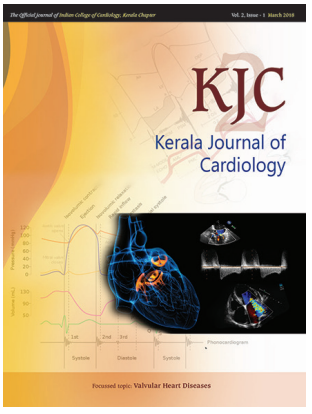

Clinical Evaluation of Valvular Heart Diseases

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Clinical examination in medicine is an art which is fast becoming extinct due to a variety of reasons. Though a plethora of investigations are now available for cardiovascular evaluation, one should not forget that the foundation on which the diagnosis and individual patient management are made still depends on a properly elicited history and physical examination. Gross errors can happen when this basic fact is forgotten. Correct diagnosis and assessment of valvular lesions require a detailed history, meticulous clinical examination and proper interpretation of appropriate investigations (Chest X ray, ECG and Echo Doppler evaluation).

Though Rheumatic fever and chronic rheumatic heart disease have come down in prevalence in the western world, they continue to be a major contributor for cardiovascular morbidity and mortality in the developing countries, including India. However, recent studies from India have also demonstrated a similar declining trend in the prevalence of chronic rheumatic heart disease. ICMR had conducted three school based surveys over a 40 year period between 1970 and 2010. The first survey (1972 to 1975) done in 5 cities which included Alleppey showed a national prevalence of 5.3 per 1000. The prevalence rate at Alleppey was 2.2 per 1000. The third and largest study (2010) involving 176904 school children showed an average national prevalence of only 0.9 per 1000 school children. Echo cardiographic studies have shown higher prevalence because of detection of "silent cases" of rheumatic valvular involvement. Rheumatic heart disease most often affects the mitral valve. Isolated aortic valve disease especially aortic stenosis is seldom related to rheumatic etiology.

History

The most important symptoms are dyspnoea, chest pain, palpitations, syncope, oedema and fatigue. Dyspnoea can be due to a variety of causes including anaemia, respiratory problems and renal diseases. Mild dyspnoea on exertion can be due to obesity or physical deconditioning. But history of paroxysmal nocturnal dyspnoea, if present is specific for left heart disease. Effort related angina is a feature of LVOT obstruction, obstructive coronary artery disease or pulmonary hypertension. Regular palpitations related to effort point to volume overload situations like MR and AR. Irregular palpitations at rest may point to atrial fibrillation. Effort related syncope is a feature of LVOT obstruction (fixed obstruction like valvular AS or dynamic obstruction – hypertrophic cardiomyopathy), severe PAH (especially idiopathic PAH), other significant obstructive

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lesions, significant bradyarrhythmias or infrequently arrhythmias like Catecholaminergic Polymorphic VT (CPVT). Fatigue is very often a non specific symptom very often related to non cardiac factors including depression. But effort related fatigue can be related to low cardiac output – chronic severe MR or significant right heart disease with fixed cardiac output. Oedema and increase in the abdominal girth due to ascites suggest right heart failure. Odema without significant left heart symptoms could be a feature of constrictive pericarditis.

GENERAL EXAMINATION

Apart from the routine, the following factors should be specifically looked for and evaluated in a patient with valvular heart disease.

1. Markers of rheumatic fever like subtle choreiform movements, subcutaneous nodules and erythema marginatum. Examination of the joints for any evidence of inflammation.

2. Markers of infective endocarditis

3. Markers of connective tissue diseases like Marfan syndrome.

4. Thyroid enlargement and clinical assessment of the thyroid status

5. Peripheral signs of AR. (Table 1)

INDIVIDUAL VALVULAR LESIONS

MITRAL STENOSIS (MS)

Etiology of MS is nearly always rheumatic. Less frequent causes include congenital lesions, mitral annular calcification, connective tissue disorders and storage disorders. Mitral annular calcification, a disease of the elderly usually leads to mitral regurgitation and often co-exists with calcific aortic valve disease and degenerative involvement of the conduction system. Congenital mitral stenosis and LV inflow obstruction – Parachute mitral valve, anomalous mitral arcade, supravalvular mitral ring and cor tri atriatuum usually present in childhood.

Approximately 50% of patients with rheumatic MS have a history of acute rheumatic fever in childhood. In the remaining half, it is believed to be secondary to sub clinical carditis. Carditis is very frequent when rheumatic fever occurs in children below the age of 5 years and is unusual with first attack of rheumatic fever occurring later in adult life. It is interesting to note that though pan carditis is known to occur in acute rheumatic fever, clinically significant myocarditis is unusual. Endocarditis mainly manifests as MR in isolation or with AR. Isolated aortic valve involvement without MR is uncommon and raises doubt about the etiology. MR is contributed by valvulitis, chorditis and annulitis. The natural history of MR is variable. 70% of

Table 1: Peripheral signs of AR

Corrigan sign	Prominent carotid pulsations
Alfred de Musset sign	Head nodding with heart beat
Landolfi sign	Change in pupil size with heart beat
Muller sign	Uvula pulsation
Rosenbach sign	Liver pulsations
Gerhardt sign	Spleen pulsations
Quincke sign	Digital capillary pulsations
Pistol shot sound	Systolic booming sound over femoral arteries
Traube sign	Systolic and diastolic booming sound over femoral artery
Duroziez sign	Systolic murmur on proximal compression and diastolic murmur on distal compression over femoral arteries
Hill sign	Lower limb systolic BP exceeding upper limb systolic BP by more than 20 mm Hg,
Corrigan Pulse	High volume collapsing pulse (water hammer pulse)
Becker sign	Retinal artery pulsations

mild MR tend to disappear on follow up whereas only around one third of severe MR who presented with heart failure are likely to have a normal heart at the end of 10 years. Most if not all mitral stenosis cases had significant MR (clinical or subclinical) to begin with and over the years, the severity of MR came down and they developed progressive commissural fusion culminating in significant obstructive lesion. There is striking difference in the natural history and rate of progression of MS in the tropical countries compared to the western world. In the developed countries, it takes more than 5 years for MS to develop and it takes another 5 to 10 years to progress to a symptomatic status. In tropical countries, the entire latent period between acute rheumatic fever and severe MS can be shorter than 5 years. Though less frequent in India now, "Juvenile MS" is a major problem in many African countries.

The pathological hallmark of rheumatic MS is commissural fusion leading to narrowing of the orifice. Chordal and cuspal fusion can also contribute to the narrowing but seldom exist without commissural fusion. Normal mitral valve area is 4 to 6 sq cms in an adult. Significant diastolic tran- mitral gradient and an audible murmur develop when the orifice is reduced to less than 2.5 sq cms. MV area less than 1 sq cm per square metre surface area is considered severe MS and will ordinarily require intervention. MS leads to increase in LA pressure and pulmonary venous hypertension. Normal LA pressure is 8 to 12 mm Hg. In severe cases of MS, LA pressures will be more than 25 mm Hg. This leads to passive pulmonary arterial hypertension (PAH). PAH in MS is also contributed by reactive pulmonary hypertension (pre capillary, 'second stenosis') and obliterative PAH (in long standing cases).

History

Gradually progressive dyspnoea on exertion is the most common symptom in MS. As the commissural fusion and narrowing of the MV orifice gradually develop over a span of several years, the symptoms are also usually slowly progressive. This reflects pulmonary venous hypertension and the increased effort required for the inflation of the alveoli due to capillary and venous engorgement. Exertion leads to enhanced venous return, increase in the cardiac output and reduction of the diastolic filling period. When pulmonary capillary pressure exceeds 25 mm Hg, transudation of fluid occur into the interstitium (interstitial pulmonary oedema) and later into the alveoli (alveolar pulmonary oedema). Paroxysmal Nocturnal Dyspnoea (PND) is a very important symptom and usually is indicative of severe disease. Though not included in the NYHA classification, most of the patients with PND will have marked restriction of ordinary activity and come under NYHA class III. Orthopnea indicates severe and advanced disease. Hemoptysis in MS can be due to multiple factors – Rupture of broncho pulmonary veins due to pulmonary venous hypertension (pulmonary apoplexy), pulmonary oedema (including the pink frothy sputum classically described with PND), lower respiratory tract infection and pulmonary infarction (in long standing cases usually with AF).

Table 2: Differential diagnosis of apical mid diastolic murmur

	MS	MDM – flow murmur	Austin Flint murmur	Carey Coombs murmur
Location	Apical	Apical	Localized to apex	Localized to apex
Pitch	Low pitched rough rumbling	Low to medium pitched	Low to medium pitched	Low to medium pitched
Length	Long with pre systolic accentuation	Short and decrescendo	Mid diastoic and pre systolic	Mid diastolic decrescendo
Apex beat	Tapping. No cardiomegaly	Forceful apex Cardiomegaly.	Forceful apex Cardiomegaly	Forceful apex. Cardiomegaly variable
Thrill	Common	Can occur	Uncommon	Never
S1	Loud	Soft or normal	Soft	Soft
S2	P2 loud	Widely split	Narrow split	Variable. Loud P2
S3	Absent. OS audible	Invariable	Only with LV dysfunction	Invariable. MR murmur invariable. Usually with tachycardia
Setting	Chronic RHD	Moderate to severe MR or VSD, PDA	Chronic severe AR	Acute Rheumatic fever with carditis

Atrial Fibrillation is a common arrhythmia in patients with severe MS. It is related not only to the severity of MS but also to the age of the individual and the initial age of rheumatic fever and the number of recurrences and the severity and extent of carditis during the previous episodes. AF is uncommon in Juvenile MS even when it is severe but is common in elderly with milder degree of MS. Majority of MS patients above the age of 50 years are in AF (almost 80%) and this predisposes to thrombo embolic episodes. 80% of patients with MS who develop stroke are in AF. Development of AF leads to significant deterioration of the functional class in MS patients due to increase in the LA pressure. This is primarily related to the reduction in the duration of the diastolic filling period due to the increase in the heart rate and also due to the lack of mechanical atrial contribution to left ventricular filling. An individual can become symptomatic for the first time with the onset of AF. Acute pulmonary oedema can occur in a comparatively mildly symptomatic person. Paroxysmal AF could be the reason for the variation in the symptomatic status in some individuals on different occasions. Fast irregular palpitations if present certainly suggest development of AF but may not be present in all patients. As the disease progresses, PAH tends to become progressively severe and patient tends to develop right ventricular failure and secondary tricuspid regurgitation. Fatigue becomes an important symptom and can be more disabling than dyspnoea on exertion. Pedal oedema, abdominal distension and other evidence of right heart failure will become evident.

Pregnancy is poorly tolerated by patients with significant MS. Increase in heart rate, blood volume and cardiac output lead to increase in LA pressure and pulmonary venous hypertension. Dyspnoea and even acute pulmonary oedema can occur for the first time during pregnancy. Symptoms usually will be prominent by the mid second trimester, when the hemodynamic abnormalities are pronounced. Severe MS is a contraindication for pregnancy and should be identified and corrected before becoming pregnant.

Table 3: Interval for the sounds following the Aortic valve closure

A2 P2 split in expiration	< 30 msec (single sound)
A2 P2 split in inspiration	40-50 msec
Wide split S2	>60 msec
A2 – OS interval	40 -120 msec
A2 – Pericardial knock	100-120 msec
A2- Tumour plop	120-140 msec
A2- S3 interval (pathological)	120-160 msec
A2-S3 interval (physiological in children)	120-200 msec
S4-S1 interval	Same as PR interval (120 -200 msec)

Physical findings and Assessment of Severity of MS

Cardiomegaly is not a feature of isolated MS. It can occur with pulmonary hypertension, RV systolic dysfunction and TR. The apex beat may be sometimes displaced laterally in some post op cases. (post -closed mtral valvotomy with left antero lateral thoracotomy).

Severe MS is suggested by

1. Presence of significant symptoms especially Class III and above and or presence of PND. Orthopnea and right heart symptoms indicate severe disease.

2. Presence of severe PAH is usually correlated with severe disease. Though passive pulmonary hypertension is invariably present in all patients with MS, reactive and obliterative pulmonary hypertension indicates severe disease (characterised by prominent parasternal heave, easily palpable second heart sound, palpable pulmonary artery pulsations, pulmonary ejection click, early diastolic murmur of pulmonary regurgitation (Graham Steel murmur) and secondary tricuspid reurgitation murmur. “a” wave in the JVP will be prominent and evidence of right heart failure including elevated mean JVP, pedal oedema and hepatomegaly may also be evident. Significant TR leads to obliteration of the x descent, positive systolic wave (CV wave), tall V wave and prominent y descent. In AF, “a” wave disappears.

3. Short A2 – OS interval. This interval represents the isovolumic relaxation period. A2 – OS interval less than 70 msec suggests severe MS

4. Length of the mid diastolic murmur. This is especially reliable in the presence of AF than in sinus rhythm. The cycle length is variable in AF. In a long cycle, if the diastolic murmur is extending into most of the diastole, it is correlated with severe MS.

5. AF. Presence of AF is not very reliable in assessing the severity of MS. AF is very often related to the age of the patient and need not be suggestive of severity of mitral valve disease.

The pliability of the valve is indicated by the loudness, pitch and “crispness”of the opening snap. Widely

Table 4: Stages of MS

Stage	Definition	Valve anatomy	Hemodynamics	Consequences	Symptoms
A	At risk for MS	Commissural fusion, diastolic doming.	Normal	None	None
B	Progressive MS	MVA >1.5 sq cm	Diastolic pressure half time < 150 msec	Mild to moderate LA dilatation. Normal pulmonary pressure at rest	None
C	Asymptomatic severe MS	MVA <1.5 sq cm. <1 sq cm with very severe MS	Diastolic pressure half time >150 msec. >220 msec with very severe MS	Severe LA dilatation. PASP >30 mm Hg	None
D	Symptomatic severe MS	MVA <1.5 sq cm. <1 sq cm with very severe MS	Diastolic pressure half time >150 msec.>220 msec with very severe MS	Severe LA dilatation. PASP >30 mm Hg	Deareased exercise tolerance. Exertional dyspnoea

audible high pitched crisp opening snap indicates pliable anterior mitral leaflet whereas localized soft dull opening snap suggest a non pliable valve unsuitable for a percutaneous procedure. Presystolic accentuation of the mid diastolic murmur in a patient with MS and sinus rhythm is due to the augmentation of the trans-mitral flow and gradient due to mechanical atrial contraction. In patients in AF, the presytolic component of the mid diastolic murmur is often absent. Even if the pre systolic component is retained, the accentuation will be seldom retained. Presence of pre systolic accentuation for the mid diastolic murmur if present suggests a pliable valve. The pre isovolumic contraction period is prolonged in MS due to the high LA pressure and because the stiffness of the mitral valve has to be overcome. The LV has to build up a higher pressure to exceed the LA pressure and hence the cross over point is delayed. This is reflected as a pronged Q-S1 interval. There is continuing flow from the LA to LV during this very early ventricular systole – pre isovolumic contraction phase. As the mitral valve orifice is being reduced by LV contraction, the velocity of forward flow increases as long as the pressure is higher in the LA than in the LV. A calcified non pliable valve will not lead to an augmentation of the diastolic gradient as it cannot freely float up during the pre isovolumic phase. The A2-OS interval and the Q-S1 intervals are variable in AF. It is decided by the preceding cycle length. If the preceding cycle length is short, LA pressures will be high and hence the A2-OS interval will be short for the subsequent cycle. Q-S1(Q-M1) minus A2- OS interval is called Well's index and is fairly constant for the varying cycle lengths in AF.

Opening snap should be differentiated from pulmonary component of S2 as well as LVS3. The A2-OS interval does not vary appreciably with the phases of respiration. OS is a higher pitched sound and is better audible at the apex or midway between apex and left sternal border. The split of the second heart sound is best appreciated over the upper left sternal border. The split widens during inspiration and narrows or become single during expiration. The LVS3 is a localized low pitched sound better appreciated over the apex in left lateral position and is often palpable.

MITRAL REGURGITATION (MR)

The two common etiological factors for MR are chronic rheumatic heart disease and Myxomatous degeneration of the mitral valve. Other etiologies include congenital, acute rheumatic fever, ischaemic (papillary muscle dysfunction), mitral annular calcification, infective endocarditis and various connective tissue disorders. Hypertrophic cardiomyopathy with obstruction is associated with subaortic obstruction and MR. Restrictive cardiomyopathy – left ventricular endomyocardial fibrosis is frequent in the state of Kerala.

The symptoms in chronic MR are decided by the severity of the lesion, the rapidity with which it develops, the compliance characteristics of the LA and the left ventricular function. Chronic severe MR developing gradually over long span of time in the presence of a compliant LA is well tolerated. The only two symptoms are palpitations due to volume overload of the LV and exertional fatigue due to reduced effective forward stroke volume. In such patients onset of dyspnoea on exertion indicates onset of left ventricular dysfunction. Unless surgical correction is done without delay, the deterioration may be fast and irreversible. But in those patients with less compliant LA, especially if MR had occurred relatively rapidly over a shorter span of time, the LA pressure tend to increase and they present with dyspnoea on exertion. The symptoms

may simulate predominant rheumatic mitral stenosis. In the third group of patients with non compliant LA, the LA pressure tend to rise fast and in some of these individuals reactive pulmonary hypertension set in early and can go into right heart failure. It is fairly common to find chronic rheumatic heart disease patients presenting with right heart failure but on evaluation are found to have normal LV systolic function. Acute MR is a clinical syndrome where patients present with severe MR over a short span of time into LA which is not prepared to accept the volume load. LV also does not have the compensatory mechanisms activated to accommodate the volume overload. The LA pressure steeply increases and the patient can go into acute pulmonary oedema. Classical example will be chordal rupure leading to flail mitral leaflet and acute severe MR in the background of myxomatous degeneration of the MV. Chordal rupure can also occur in acute rheumatic fever, infective endocarditis, acute myocardial infarction or following trauma.

Sudden onset of dyspnoea in a patient with MR may suggest chordal rupture, rheumatic reactivation, infective endocarditis or development of atrial fibrillation. Possibility of progression of coronary artery disease should also be considered in those above the age of 40 years especially in the presence of atherosclerotic risk factors. Symptomatic deterioration with onset of AF is due to the increase in heart rate and more number of "v waves" in LA per minute, contributing to the increase in the mean LA pressure.

Clinical Assessment of Severity

AF is a common arrhythmia in patients above the age of 50 years. The pulse in chronic severe MR is described as pseudo collapsing. The pulse volume is normal or low, as the effective forward stroke volume is reduced. Abrupt ejection into the low pressure LA is responsible for the abnormal character of the pulse. The apex beat may be shifted down and out with a forceful or hyper dynamic character indicative of LV volume overload situation. The palpating finger over the apex is elevated above the plane of the adjacent ribs but will be confined to not more than initial half of systole. A systolic thrill may be palpable over the apex. A third heart sound can also be palpable. The diastolic flow murmur of severe MR being medium pitched can produce an apical thrill and occurs after the palpable third heart sound. A late para sternal lift is a feature of chronic severe MR. It is because of the forceful posteriorly directed jet into LA. This should be differentiated from left parasternal heave of right ventricular hypertrophy. Left parasternal heave is defined as the sustained lift of the lower left costo chondral junctions, present throughout systole. The pulmonary artery pulsations as well the pulmonary valve closure may be palpable with pulmonary arterial hypertension.

Auscultation usually reveals reduced intensity of first heart sound. First heart sound can be loud in combined lesions with both MR and MS. First heart sound can also be loud in mitral valve prolapse with redundant mitral leaflets similar to loud aortic valve closure sound in a functionally normal bicuspid aortic valve. Also, non ejection click can fuse with the first heart sound if the prolapse occurs early in systole. This will be more apparent in the standing posture, when S1 – Non ejection click interval tend to narrow down. Left ventricular third heart sound is a low pitched sound better heard with the bell of the stethoscope, lightly applied to the chest wall. The second heart sound is characteristically widely split in chronic severe MR, because of earlier aortic valve closure due to reduced left ventricular ejection time. Loud pulmonic valve closure sound and pulmonary ejection click suggest pulmonary arterial hypertension.

The intensity of the pan systolic murmur over the apex may not have direct relation with the severity of MR. The MR murmur of rheumatic etiology and mitral valve prolapse tend to be loud whereas the murmur in myocardial disease like dilated cardiomyopathy or related to coronary artery disease tend to be less loud. The murmur related to paravalvular leak of a mitral prosthetic valve may be so soft that it can be completely missed on clinical examination. Presence of left ventricular third heart sound and mitral mid diastolic flow murmur indicates severe MR. This murmur is low pitched and decrescendo and may be associated with a thrill.

Fourth heart sound is an atrial sound recorded from the ventricle. Left ventricular fourth heart sound is not a feature of chronic severe MR. It is especially absent in rheumatic MR due to two reasons – LV tend to be compliant and atrial contribution to ventricular filling may not be required. LA is often damaged due to previous episodes of rheumatic carditis and long standing atrial distension related to chronic severe MR. These fibrotic changes in the LA can prevent it from generating forceful atrial contraction. Till the onset of systolic dysfunction, LV filling pressures will be normal. Loud LV S4 can be audible in hypertrophic cardiomyopathy and in those with underlying coronary artery disease. LV S4 is also a very important finding in acute MR. Marked increase in the LV filling pressure leads to atrial dilatation and subsequent forceful atrial contraction (Frank Starling mechanism).

Severe MR is suggested by cardiomegaly, forceful apex beat, late parasternal lift, LVS3, widely split S2, mitral mid diastolic flow murmur and evidence of pulmonary

Table 5: Stages of Chronic Primary MR

Grade	Definition	Valve anatomy	Hemodynamics	Consequences	Symptoms
A	At risk for MR	Mild MVP. Mild valve thickening	No MR. Mild MR	None	None
B	Progressive MR	Severe MVP with normal coaptation. RHD with loss of central coaptation. Previous IE	Central jet MR 20-40% LA or late systolic eccentric jet. VC < 7mm. RV <60 ml. RF <50%. ERO <0.4. Angio grade 1-2.	Mild LA dilatation Normal LV Normal PA pressure	None
C	Asymptomatic Severe MR	Severe MVPor RHD with loss of coaptation. Previous IE	Central jet MR >40%. VC >7 mm. RV >60 ml. RF >50%. ERO >0.4. Angio grade 3-4.	Moderate to severe LA dilatation. LV dilatation. PAH at rest or with exercise. C1: LVEF >60% LVESD <40 mm C2: LVEF <60%. LVESD >40 mm	None
D	Symptomatic Severe MR	Severe MVP/ RHD with loss of coaptation. Flail MV.	Same as above	Moderate or severe LA dilatation. LV dilatation. PAH present	Decreased exercise tolerance. Exertional dyspnoea.

arterial hypertension. AF does not have a direct relation to severity but more often occur in those with severe MR. Similar to MS, the threshold for AF reduces with advancing age. With the onset of left ventricular dysfunction which delays A2, the previously widely split second heart sound can become closer. Also, pulmonary arterial hypertension can reduce the pulmonary hang-out time which can lead to narrowing of the split of the second heart sound.

Cardiac enlargement out of proportion to clinically assessed MR should suggest primary myocardial disease associated with LV dysfunction and functional MR due to annular dilatation and non coaptation of the valve leaflets. This is often observed in dilated cardiomyopathy and coronary artery disease. Loud and prominent murmurs are often absent in contrast to MR of rheumatic etiology or mitral valve prolapse.

Acute MR is a medical emergency usually presenting as acute pulmonary oedema. The LA pressure tracing will demonstrate a very prominent v wave due to the direct transmission of LV systolic pressures into LA. Evidence of heart failure will be evident. The S1 tends to be soft and S4 will be loud and often palpable. S3 is invariable and P2 will be loud. The MR murmur can have a late systolic decrescendo character due to the reduced gradient at end systole due to high LA pressures.

Mitral Valve Prolapse (MVP)

This is the commonest cause for MR in the western world and the most common cardiac lesion predisposing to infective endocarditis. The unique dynamic auscultatory findings help in differentiating MVP-MR from rheumatic etiology for MR. The patient should be examined in the supine, left lateral and standing positions. Examination during squatting, isometric handgrip and strain phase of Valsalva maneuver are also helpful. The most important finding is the non ejection click and the late systolic murmur. Late systolic murmur is defined as one which starts after a gap from the first heart sound and reaches upto the second heart sound. Late systolic murmurs can be short or long. The S1 – non ejection click interval and the occurrence of the late systolic murmur are dependent on the preload, afterload and contractility. Any maneuver that decreases LV volume results in early occurrence of prolapse. This includes reduction in venous return (preload), reduction of impedance to LV emptying (afterload), tachycardia and augmentation of LV contractility. Increase in venous return, increase in impedance to LV emptying, reduction of myocardial contractility and bradycardia tend to delay the onset of mitral valve prolapse. The S1- non ejection click interval will be delayed. LV size decreases with sudden standing and during the strain phase of Valsalva maneuver. Both these lead to reduced S1- non ejection click interval and longer MR murmur. Passive leg raising, squatting and isometric hand grip delay the click and the onset of the murmur.

AORTIC REGURGITATION (AR)

Aortic regurgitation occurs when the aortic valve leaflets are not able to coapt and close the aortic orifice incompletely during diastole. This can be due to abnormalities of the valve leaflets, dilatation of the aortic root or a combination of both. In the adult, rheumatic heart disease, infective endocarditis and annulo aortic ectasia (aortic root dilatation) related to connective tissue disorders are important causes for severe AR. Para prosthetic valve leaks are also emerging as an important etiological factor. VSD with aortic valve prolapse leading to AR is probably the commonest cause in a child. Biscupid aortic valve and systemic hypertension are common causes for mild AR. Biscuspid aortic valve with aortic valve prolapse and aortic root dilatation due to the accompanying aortopathy can produce severe AR and can sometimes present acutely. Marfan syndrome is known to produce aortic root dilatation and AR. The underlying pathology of cystic medial necrosis can lead to aortic dissection which itself can produce or worsen AR. Syphilis, Ankylosing spondylitis and Rheumatoid arthritis are encountered less frequently as an etiological factor.

Chronic severe AR leads to diastolic overload of the LV, which undergoes dilatation and hypertrophy. Increase in stroke volume leads to higher cardiac output, systolic hypertension and wide pulse pressure. The hemodynamic abnormalities include increase in LV diastolic volume, increase in LVEDP, increase in LV systolic pressure and eccentric LV hypertrophy. The intra myocardial wall stress in AR is increased to a much higher extent than chronic severe MR. The major hemodynamic abnormality in chronic severe MR is increase in preload whereas in chronic severe AR, it is a combination of increase in preload and afterload. The main symptom of the patient with chronic severe AR is palpitations. Dyspnoea on exertion usually occurs very late in the natural history and often indicates the onset of left ventricular dysfunction. If dyspnoea occurs early in the clinical course of AR, one must consider associated mitral valve disease or acute AR. Associated coronary artery disease should also be considered especially with concomitant atherosclerotic risk factors.

Myocardial ischaemia can occur in severe AR. Myocardial oxygen requirement is increased by increased wall tension and LVH. Fall in diastolic blood pressure can reduce the coronary perfusion especially in the presence of slow heart rate. Nocturnal angina is known to occur in patients with chronic severe AR. It can occur even in patients who may not have exertional angina.

Assessment of Severity

Pulse is characteristically collapsing or bisferiens in severe AR. Both the character abnormalities frequently co exist. Bisferiens pulse can also occur in combination lesions in which AR is the more dominant lesion than AS and also classically in hypertrophic cardiomyopathy with obstruction. The pulse pressure is wide due to high systolic pressure and low diastolic pressure. In children and young adults, the systolic blood pressure is seldom very high since the vasculature is highly compliant. The diastolic blood pressure tends to be low. But in the elderly, the increase in stroke volume leads to significant increase in the systolic blood pressure because of the less compliant remodelled vasculature. The wide pulse pressure is due to the combination of central and

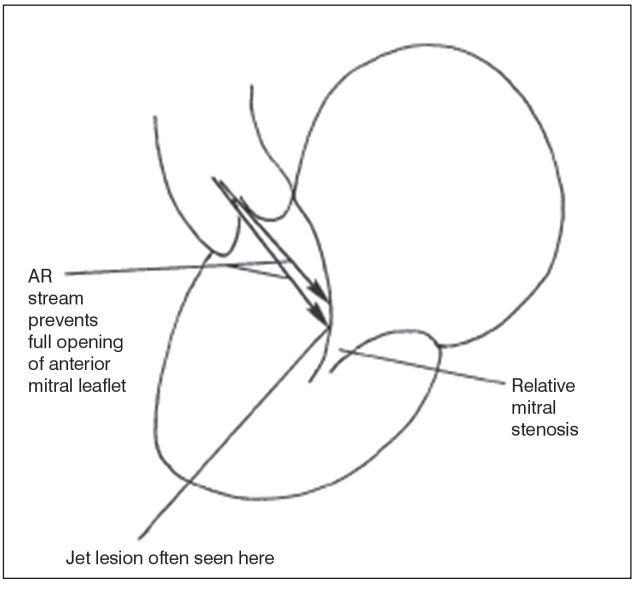
Table 6: Stages of Chronic AR

Stage	Definition	Valve anatomy	Hemodynamics	Consequences	Symptoms
A	At risk of AR	BAV, AV sclerosis, Annuloaortic ectasia. RF/RHD, IE	No AR or trace AR	None	None
B	Progressive AR	Mild to moderate calcification or structural abnormalities	Mild to Moderate AR	Normal LV or mild dilatation. Normal LV systolic function	None
C	Asymptomatic severe AR	Calcific aortic valve disease with more significant structural abnormalities	Severe AR. Jet width >60% LVOT. VC >6 mm. RV >60 ml. RF >50%. ERO >0.3. Angio grade 3-4.	C1: LVEF >50%. LVESV <50 mm C2: LVEF<50%. LVESV >50 mm.	None
D	Symptomatic severe AR	Calcific aortic valve. Significant structural abnormalities	Severe AR. Same as above	Moderate to severe LV dilatation. LVEF >50%, 40-50% or <40%	DOE, angina or HF symptoms

peripheral run off, which is responsible for the several peripheral signs described in severe AR. (Table 1)

The apex beat is shifted down and out and has a forceful character. But it may not have the classical features of a pure volume overload LV impulse like chronic severe MR. Pulsations may be palpable in the second right intercostal space due to the dilated aortic root. A systolic thrill may be palpable over the carotids (carotid shudder). Unlike mitral valve disease, AF and evidence of significant pulmonary arterial hypertension are uncommon. The first heart sound is usually normal. It can be soft with the onset of left ventricular dysfunction and in the presence of a prolonged PR interval. Longer LV ejection time delays aortic valve closure. Low systemic vascular resistance due to chronic severe AR can delay the aortic hangout interval and can also rarely contribute to delayed aortic valve closure. Second heart sound is usually closely split. A2 is soft in valvular AR because of the damaged leaflets. But A2 can be normal or even loud in annulo aortic ectasia where the leaflets are usually normal. The classical example is the loud ringing second heart sound (tambour sound) described in syphitic AR.

Unlike the situation in severe MR, presence of left ventricular third heart sound indicates LV dysfunction. One has to be careful in attributing an audible LVS3 in a child or young adult to LV dysfunction because of the likelihood of a physiological third heart sound. But presence of an LV S3 in an older adult or elderly nearly always indicates LV dysfunction. Aortic ejection clicks can be audible with congenital bicuspid aortic valve and in the presence of a dilated aortic root. The characteristic murmur of AR is a high pitched, soft, blowing, decrescendo early diastolic murmur best heard along the left sternal border. It is better heard with the patient sitting up, leaning forward and breath held in expiration. It is better appreciated with the diaphragm of the stethoscope. Faint early diastolic murmurs can be accentuated by increasing the peripheral resistance – squatting, isometric hand grip and administration of a vasopressor drug like phenylephrine. A soft AR murmur can disappear during pregnancy because of the fall in peripheral resistance. In the presence of dilated aortic root and ascending aorta and when marked atherosclerotic tortuosity pushes the ascending aorta anteriorly and to the right, the early diastolic murmur can be better audible along the right sternal border than the left sternal border.



Mechanism of Austin Flint murmur in AR.

Austin Flint murmur is an apical diastolic rumble audible in severe AR. (Figure 1) It is due to the AR jet impinging on the septal surface of the anterior mitral leaflet and pushing it up, creating a relative mitral stenosis. It has a mid diastolic and a pre systolic component. Unlike the diastolic murmur of organic MS, presystolic accentuation does not usually happen. LV dysfunction leads to premature closure of the mitral valve and the Austin Flint murmur gets truncated. Elevation of the LV diastolic pressure by the regurgitant jet can exceed the LA pressure. This can produce diastolic MR in pre systole. This also can possibly contribute to the Austin Flint murmur. Onset of LV dysfunction should be clinically suspected in the presence of reduction in the intensity of first heart sound, audible third heart sound and when the pre systolic component of the Austin Flint murmur disappears. Ejection of enhanced stroke volume across the aortic valve produces a mid systolic murmur in the aortic area and over the left sternal border. Chronic severe AR even in the absence or organic AS can occasionally produce a thrill in a thin -chested individual.

Severe AR is suggested by high volume collapsing pulse, cardiomegaly, forceful apex beat, narrowly split second heart sound, long early diastolic murmur and presence of Austin Flint murmur. Presence of peripheral signs indicate significant “run- off” and wide pulse pressure suggesting severe AR. Significant symptoms, left ventricular dysfunction and pulmonary hypertension are correlated with severe AR.

AORTIC STENOSIS (AS)

Rheumatic heart disease is an important cause for AS in the middle aged and elderly. It usually co exists with significant mitral valve disease and or AR. Isolated Aortic stenosis is seldom due to rheumatic etiology. Congenital bicuspid aortic valve is seldom stenotic at birth. In the common variety, the left and

right coronary cusps are fused and lead to fish mouth opening. Over the years, degenerative changes and calcification set in and is responsible for the reduction in the aortic valve area. Usually this happens beyond the third decade. Degenerative disease affecting a trileaflet aortic valve is the commonest cause for AS in the elderly. This more often happens in individuals with some structural abnormality of the valve like congenital cuspal inequality. Aortic sclerosis slowly develops which in some individuals progresses to severe AS. Unlike rheumatic etiology, commissural fusion is not a feature of bicuspid aortic valve and degenerative calcific AS. Mild to moderate AS is likely to progress over the years and such individuals require regular follow up. This is in contrast to mild to moderate pulmonic valve stenosis which remains stable and is unlikely to progress over the years

Almost half of patients with severe AS are asymptomatic. Because many of these elderly individuals are sedentary, functional assessment of the symptoms may be difficult. The three important symptoms of patients with severe AS are effort related greying of vision (near syncope and syncope), effort angina and dyspnoea on exertion. As many of the middle aged and elderly have multiple atherosclerotic risk factors, associated coronary artery disease is common which may also contribute to the symptoms. Natural history series have demonstrated that the average survival after the onset of angina is 5 years and that after syncope is 2 to 3 years. The survival is less than 2 years after the onset of dyspnoea due to LV systolic dysfunction. But it is important to remember that some patients can have long standing mild dyspnoea on exertion due to LVH and diastolic dysfunction. But a distinct deterioration in the symptomatic status is often correlated with the onset of LV systolic dysfunction.

Normal aortic valve area is 3 to 4 square cm. Clinically significant AS manifests when the valve area is reduced to less than 2 square cm. Aortic valve area less than 1 square cm or less than 0.6 square cm per square meter surface area is considered severe AS. Area less than 0.75 square cm (less than 0.5 square cm/square meter surface area) is considered critical AS.

Hemodynamic abnormalities in AS are low stroke volume and elevated LV systolic and diastolic pressures. The diastolic pressures are elevated because of the concentric LVH and diastolic dysfunction leading to sympathetic vasoconstriction. Later systolic dysfunction tend to develop because of excessive afterload, decreased LV contractility, myocardial fibrosis and accompanying ischaemia. Even in cases without evident LV dysfunction, LV will not be able to increase the cardiac output in relation to exercise. Severe AS carries a significant risk of arrhythmias and sudden cardiac death. Those with high systolic gradients, marked LVH, myocardial fibrosis and myocardial ischemia are at higher risk of sudden cardiac death (SCD). SCD is comparatively less in those who are totally asymptomatic.

Clinical Features and Assessment of Severity

The pulse in severe AS is classically described as parvus (low volume) et tardus (slow rising). This character abnormality is best appreciated over the carotids. The pulse pressure is narrow. In children and young adults, the systolic blood pressure tends to be low. But in elderly with severe calcific AS, it is not uncommon to have systolic blood pressure above 160 mm Hg. This is a reflection of the inelasticity of the aorta and the non compliant vasculature. Apex beat is characteristically described as heaving – the palpating finger is elevated above the plane of the adjacent ribs and is sustained for more than half of systole. Significant cardiomegaly does not occur. LV is not dilated but has concentric hypertrophy.

A presystolic expansion (equivalent of palpable S4) may be felt over the apex in the left lateral position. A systolic thrill may be felt over the upper right sternal border or left sternal border. The thrill is better appreciated in expiration with the patient sitting up in the leaning forward position. Presence of a thrill is usually correlated with a systolic gradient exceeding 40 mm Hg in an adult and 25 mm Hg in children. Thrill may be palpable over the carotids (carotid shudder).

First heart sound can be normal or may be reduced in intensity. The second heart sound may be paradoxically split because of delayed aortic valve closure related to prolonged left ventricular ejection time. During paradoxical split, the split is wider and better appreciated during expiration. The aortic valve closure sound can be muffled especially if the valve is calcified. Audible left ventricular fourth heart sound in children or young adults with aortic stenosis indicates severe obstruction. But an audible LVS4 does not have the same significance in elderly with aortic stenosis. Audible S4 is common in people above the age of 60 years, especially in the presence of systemic hypertension and or coronary artery disease. But palpable S4 in any age is considered abnormal. Presence of LVS4 in a person under the age of 40 years indicates a peak gradient of at least 50 mm Hg. An aortic ejection click which is constant (non phasic) and heard over the base as well as sometimes over the apex indicates non calcified valve and may be audible in congenital AS in children and young adults. As

Table 7: Stages of Valvular AS

Stage	Definition	Valve anatomy	Hemodynamics	Consequences	Symptoms
A	At risk of AS	BAV, AVsclerosis	V max < 2m/sec	None	None
B	Progressive AS	Mild to moderate leaflet calcification or mild restricted opening	Mild AS: V max 2-2.9. Mean gradient <20 Moderate AS: V max 3-3.9. Grad: 20-39	Normal LVEF with or without mild diastolic dysfunction	None
C	Asymptomatic severe AS	Significant structural abnormalities	V max >4. Mean gradient > 40.AVA <1. Very severe AS: V max > 5. Mean grad >60.	Normal LVEF. LVH with diastolic dysfunction	None
C1	C1: No LV dysfunction				
C2	C2. With LV dysfunction		V max >4 Grad >40	LVEF: <50%	None
D	Symptomatic Severe AS	Severe structural abnormalities with calcification			DOE, angina, syncope or HF symptoms
D1	High gradient		V max > 4. Mean grad >40.AVA <1	LVH, diastolic dysfunction. PAH may be present.	
D2	Low flow, low gradient, low EF		V max <4. Mean grad <40.AVA <1 with DSE.	LVEF: <50%	
D3	Paradoxical LF, LG, Normal EF		V max <4. Mean grad <40. AVA <1. SVI <35.	Small LV cavity. LVH. Low SV. Restrictive filling. EF >50%	

the valve leaflets get calcified, loud ejection clicks are unusual beyond the age of 40 years even with bicuspid aortic valves. Aortic ejection clicks are usually absent in rheumatic AS. Left ventricular third heart sound can develop with the onset of LV dysfunction.

The turbulent flow across the stenotic aortic valve produces a harsh crescendo decrescendo ejection systolic murmur maximally audible over the aortic area or left sternal border. The murmur of severe AS is described as rasping, grunting and coarse. It is characteristically conducted to both carotids. The later the peak of the crescendo and the longer the duration of the murmur, the more severe the stenosis. The high frequency components of the ejection systolic murmur selectively tend to radiate to the apex and may sound musical or cooing simulating the murmur of MR. This is called the Gallavardin phenomenon. This is especially common in elderly patients with calcific aortic stenosis. This is less frequent in rheumatic AS because the commissural fusion may prevent the leaflets from vibrating and producing pure frequencies. The murmur of severe AS can become short and soft with the onset of LV dysfunction because of the marked reduction in stroke volume.

Severe AS is indicated by slow rising, low volume pulse, narrow pulse pressure, heaving apex with palpable presystolic expansion over the apex, palpable thrill over upper right sternal and or left sternal border, soft S1, Paradoxically split S2 with a muffled aortic component and an audible LVS4 over apex. The harsh ejection systolic murmur will be long and late peaking. Evidence of pulmonary hypertension and heart failure are indicators of severe lesion. But associated mitral valve disease should be ruled out.

TRICUSPID STENOSIS (TS)

Normal tricuspid orifice measures 5 to 7 square cm. TV area less than 1 square cm indicates severe TS. Rheumatic TS almost always occur with mitral valve disease and associated aortic valve disease. Pathology is similar to rheumatic MS – commissural fusion often associated with subvalvular pathology. Carcinoid disease and congenital causes including Ebstein malformation of the tricuspid valve are the other two etiological factors.

The left heart symptoms related to mitral valve disease (dyspnoea on exertion, PND, hemoptysis, pulmonary oedema) will be attenuated by the more proximal

stenotic lesion. The clinical picture will be dominated by low cardiac output and systemic venous congestion. Fatigue, pedal oedema and abdominal distension are the usual symptoms. AF is common. Physical examination will reveal low volume pulse. JVP will be elevated and "a" waves will be prominent and the Y descent will be slow because of the slow emptying of blood from RA to RV. Auscultation over the lower left sternal border will reveal a mid diastolic murmur, characteristically increasing with inspiration (Carvallo's sign). Unlike MS, loud mid diastolic murmurs are unusual. Most of the patients will be in AF and a faint mid diastolic murmur over the left sternal border can be picked up during inspiration on careful auscultation. In patients in sinus rhythm, pre systolic expansion of the liver may be possible. A high index of suspicion is required to diagnose organic tricuspid valve disease.

TRICUSPID REGURGITATION (TR)

Primary organic disease of the tricuspid valve leading to inadequate closure of the tricuspid orifice is rare. It can occur in rheumatic heart disease in association with mitral and often aortic valve disease. Ebstein anomaly, carcinoid heart disease and infective endocarditis are other causes. Right ventricular endomyocardial fibrosis, a form of restrictive cardiomyopathy can also lead to low pressure TR. Isolated TR encountered in clinical practice is almost always secondary to pulmonary arterial hypertension, annular dilatation and right ventricular dysfunction. In hypertensive TR, the systolic pressure is reflected into the RA which is often markedly dilated. AF is a common arrhythmia. Pedal oedema and ascites are the usual symptoms. JVP shows obliterated x descent, prominent CV wave (systolic wave), tall V waves and prominent y descent. Findings of PAH will be evident. Murmur due to secondary TR (high pressure TR) is a high pitched pan systolic murmur maximally audible over the lower left sternal border characteristically increasing with inspiration. It may be accompanied by RVS3 and a mid diastolic flow murmur. Sometimes in severe pure MS with severe PAH and right ventricular dysfunction, the TR murmur may be widely audible including the lower left sternal border and the apex which is formed by the RV. Because the LV is displaced more posteriorly and because of the reduced forward flow across the mitral valve, the mitral mid diastolic murmur may be totally inaudible (silent MS). The TR murmur may be mistaken for MR. The inspiratory augmentation of the murmur and the other findings of severe PAH and TR helps in the differentiation. The inspiratory augmentation will be reduced or lost with the onset of significant right ventricular dysfunction. Systolic hepatic pulsations are observed with severe TR. The murmur of primary TR (low pressure TR) tends to be low to medium pitched. It is often soft and has a late systolic decrescendo due to equalisation of pressures between RV and RA. Inspiratory augmentation is usually less striking. In conditions like RVEMF and RV infarction, the murmur may be soft or inaudible.

PULMONARY STENOSIS (PS)

Right ventricular outflow tract obstruction can be valvular, supra valvular and subvalvular / infundibular. As an isolated anomaly, "mobile dome-shaped" pulmonary valve stenosis is the most common type of right ventricular outflow tract obstruction. Different types of physical appearances/ facies are described in PS. Round bloated facies is known to occur in infants with mobile dome shaped PS. Noonan syndrome, Congenital Rubella Syndrome, William syndrome and Alagille syndrome are well known to be associated with RVOT obstruction. The pulmonary valve in Noonan syndrome is usually dysplastic – three thickened immobile cusps without commissural fusion and a non dilated pulmonary trunk. The predominant site of obstruction in the other three syndromes is usually in the pulmonary artery and the branches (supra valvular or peripheral PS).

The "a" wave in the JVP tends to be prominent in significant PS. The height of "a" wave increases progressively as the stenosis increases. Moderate to severe PS with intact inter ventricular septum is associated with left para sternal heave. Systolic thrill is sometimes palpable in moderate to severe PS. It is maximal in the second left intercostal space with radiation upward and to the left because the intra pulmonary jet is directed upward and towards the left pulmonary artery. Pulmonary ejection click coincides with abrupt superior movement of the mobile dome shaped pulmonary valve. It is phasic and better audible during expiration. Ejection sounds are absent with immobile dysplastic valves. The S1 – EC interval varies inversely with the degree of stenosis. It is decided by the pressure difference between the right atrial "a" wave and the pulmonary artery diastolic pressure. Pre systolic opening of the pulmonary valve is possible in very severe PS, when the right atrial "a" wave exceeds the pulmonary artery diastolic pressure. The severity of RVOT obstruction decides the duration of right ventricular ejection and the length of the ejection systolic murmur. With mild PS, the systolic murmur tends to be symmetric and ends before the aortic component of the second heart sound. The split of the second heart sound will be near normal and the intensity of P2 will be preserved. With moderate PS, the murmur ends at the aortic component of the second heart sound. The second sound tends to be widely split with reduced intensity of P2. With severe PS, the murmur tends to be longer, late peaking and extending beyond A2, which is often

inaudible. The Second sound will be widely split with muffled P2. With very severe PS, the murmur has an asymmetric kite –shape (late peaking) reaching upto a delayed inaudible P2. A2 will also be inaudible as the loud murmur extends well beyond that. Audible S4 is correlated with severe PS.

PULMONARY REGURGITATION (PR)

PR is usually secondary to pulmonary hypertension. Congenital pulmonary valve regurgitation is uncommon leading to low pressure PR. Post operative Tetralogy of Fallot with trans - annular patch is a frequently encountered etiological factor. An impulse will be usually palpable in the second and third left intercostals space close to the sternum. Parasternal pulsations are usually seen but sustained left parasternal heave is unusual. The diastolic murmur of low pressure PR is low to medium frequency, is crescendo decrescendo and starts slightly after the pulmonary valve closure sound. It is usually short in duration because of equalisation of pressures in mid to late diastole. The murmur is occasionally louder in inspiration and is often associated with a thrill. A pulmonary mid systolic ejection murmur is usually present. The second heart sound is normally split or shows wide variable split and P2 is soft or even inaudible. The murmur sounds very much like a mid diastolic murmur. In contrast, the murmur of PR related to pulmonary hypertension tends to be higher pitched and starts immediately after the pulmonary valve closure sound. The P2 is loud and often palpable. Constant vascular pulmonary ejection click is almost invariable. Left parasternal heave due to systolic overload of the right ventricle is seen in those with intact inter ventricular septum. As the diastolic gradient between pulmonary artery and right ventricle persists throughout diastole, the murmur tends to be long and even pan diastolic. The murmur of hypertensive PR classically has a decrescendo character and does not show respiratory variation.

MULTI VALVULAR LESIONS

The commonest etiology with multi valvular lesions is rheumatic heart disease. The mitral valve is almost always involved followed by aortic valve involvement. Clinically significant tricuspid valve involvement is uncommon and pulmonary valve is usually not involved. Calcific aortic valve disease can co- exist with mitral annular calcification and MR. Connective tissue diseases can produce AR due to annuloaortic ectasia and MR due to myxomatous degeneration of mitral leaflets and MR. Carcinoid heart disease is known to produce right sided valve involvement. Infective endocarditis can sometimes involve both mitral and aortic valves because of the extension of the infective process. Rarely congenital LV outflow obstruction can co-exist with mitral inflow obstruction. The clinical findings of organic tricuspid valve involvement are usually subtle and can be easily missed unless very specifically looked for. The faint systolic murmur of organic TR and the short murmur of organic TS will be audible only on deep inspiration or passive leg raising. It will be difficult to pick up these murmurs when the loud left sided murmurs are easily audible over the precordium.

MS and MR

These two lesions frequently co exist. The etiology is almost always rheumatic heart disease. Mitral Annular Calcification leads to predominantly MR but can also produce some degree of stenosis. It usually occurs in elderly individuals. Congenital mitral valve disease is infrequently encountered in children. Increase in the mitral inflow in MR can exaggerate the clinical features of associated MS. One should find out if the early diastolic sound is an opening snap or an LVS3. Classically opening snap is a loud high pitched widely audible crisp sound. Usually it is audible with maximum intensity midway between apex and left sternal border. LVS3 is a low pitched sound best appreciated in the left lateral position with the bell of the stethoscope. It is very often localized and may be palpable. Presence of a third heart sound practically rules out any significant MS. The mid diastolic murmur heard in chronic severe MR follows the LVS3 and is decrescendo and does not have a pre systolic component. First heart sound tends to be loud in MS but is often soft in MR. S1 can sometimes be loud in mitral valve prolapse because of the fusion of S1 with an early non ejection click. Significant MR in the presence of MS is suggested by the presence of LV type of forceful apex beat (shifted down and out) and pan systolic murmur over the apex. Widely split second heart sound may suggest significant MR.

MS and AR

MS being the proximal lesion can affect the assessment of AR. As a general statement, the severity of AR can be under estimated. Around one third of patients with severe MS and pulmonary arterial hypertension have reduced pre load to the LV and hence reduced cardiac output. In such patients the pulse pressure tends to be less wide and the peripheral signs of AR may be less than expected. In a patient with AR, associated MS is suggested by presence of AF, loud S1, presence of opening snap, diastolic thrill over the apex, presence of pre systolic accentuation for the mid diastolic murmur and evidence of pulmonary arterial hypertension. Opening snap may be soft or even inaudible in MS patients who have associated significant AR. This is because of the AR jet impinging on the ventricular side

of the anterior mitral leaflet. Auscultatory findings of MS can be attenuated by severe AR because of the elevated LV diastolic pressure and consequent reduction in the trans-mitral gradient. The A2-OS interval may be wider even with severe MS.

MS and AS

Here, the distal lesion can interfere with the assessment of the proximal lesion. LVH associated with AS elevates the LV diastolic pressure and hence the trans-mitral gradient comes down. The MS severity tends to be under estimated. The A2 – OS interval may be wide and the mid diastolic murmur may be shorter and softer even with severe MS. MS associated with severe PAH and reduced cardiac output can under estimate the severity of AS. The ejection systolic murmur can be shorter and softer even with severe AS. Because of the LV inflow obstruction LVS4 cannot be heard even with severe AS.

AS and AR

In presence of chronic severe AR, associated significant organic AS is suggested by heaving apex and a long late peaking ejection systolic murmur. Though Bisferiens character for the pulse can occur in mixed lesions, it is uncommon with dominant AS. Though a systolic thrill over the upper right sternal border or left sternal border can exist in relation to the flow murmur of severe AR in thin individuals, it is uncommon. Presence of a systolic thrill ordinarily indicates associated organic AS. The peripheral signs of AR may be less evident and there can be systolic decapitation of blood pressure. It is uncommon to have a systolic BP exceeding 130 mm Hg in a child or young adult with severe organic AS. But in the elderly this is not reliable as the systolic BP can remain high because of the inelastic aorta ant the reduced compliance of the vasculature.

AS and MR

This is probably the worst hemodynamic combination. Severe AS increases the LV systolic pressure and hence the gradient between LV and LA. The MR worsens and tends to be progressive. The regurgitant fraction increases and the forward stroke volume come down. Findings of MR will be accentuated and the findings of AS will be attenuated. Severe MR is suggested by cardiac enlargement, LVS3, mitral mid diastolic flow murmur and a widely split second heart sound. Evidence of AF and PAH favour MR. AS leads to narrowly or paradoxically split second heart sound. Whenever the clinical findings suggest a combination of LVOT murmur and MR, one should consider hypertrophic cardiomyopathy with obstruction. The systolic anterior motion of the anterior mitral leaflet is responsible for the dynamic LVOT gradient as well as the MR. Dynamic auscultation is especially useful in this situation. Standing, strain phase of Valsalva maneuver and isometric hand grip tend to increase the murmur of hypertrophic cardiomyopathy with obstruction.

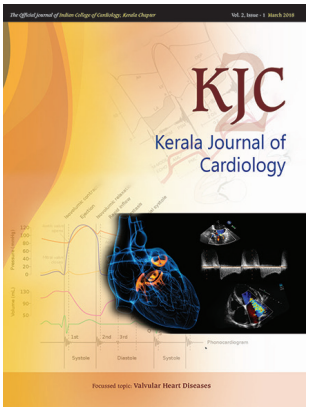
AR and MR

There is significant volume overload of the LV due to two regurgitant lesions. The LV systolic pressures are high due to AR. This tends to worsen MR because of the high gradient between LV and LA. Hence findings of MR will be accentuated by AR. The forward stroke volume into aorta is reduced because of MR. This can lead to systolic decapitation of the blood pressure. The peripheral signs of AR may be attenuated. The second heart sound is widely split by MR whereas the split becomes narrow in the presence of significant AR. LVS3 indicates significant MR and may not indicate LV dysfunction. Mitral mid diastolic murmur can occur due to both MR as well as AR. In MR, it is related to the increased flow across the mitral valve and in AR, it is related to the Austin Flint murmur. Mitral mid diastolic flow murmur is decrescendo whereas Austin Flint murmur classically has both mid diastolic and pre systolic components. Presence of AF and significant PAH suggest significant MR.

Tricuspid Valve Disease and Left Sided Lesions

Both TS and TR lead to reduction in LA volume and pressures. The left heart symptoms can come down with the onset of significant organic tricuspid valve disease. The trans -mitral gradient comes down and MS tend to be underestimated. Low cardiac output due the proximal tricuspid valve disease can attenuate the findings of AS and lead to under estimation of the severity of AR. Even with severe AS, the ejection systolic murmur tends to become short and soft.

Proper analysis of a detailed history coupled with a meticulous clinical examination very often help in arriving at a reasonable and accurate diagnosis. The investigations should be interpreted with this background information.



Valvular Heart Disease in Examination Hall - Errors Committed and Tips to Overcome

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Editor's Note: ***This article is prepared like a direct speech to the exam going students; to learn from the master as it is; raw, untouched and nothing lost in transit!***

Postgraduate student in the examination hall – are you disciplined and meticulous or as casual as in the ward? Till the case is allotted you plan to be very systematic; but once you start the case evaluation you can become as casual as in the ward! Examination is not at all different from the case discussion done in the ward; hence be systematic in your 3 years of clinical posting. The case presentation format is same as that for MBBS examination – meticulous history elicitation, proper complete physical examination and **intelligent contemplation** – but in a better language and mode. Your body language is also important – be confident; but overconfidence can turn out to be negative. Examiners are also a heterogeneous group of individuals with different views and attitude (an intelligent student assesses that and responds appropriately). Try to assess whether the examiner agrees with you; try to get away from difficult areas at the earliest (e. JVP, dynamic auscultation, valsalva etc.)

How to respond to a question? Study the question first and answer to the point (and not the reverse by giving the explanation first and then the precise answer) For example, you have got an early diastolic sound in mitral area and examiner asks what it is – say either S3 or opening snap rather than telling that because it is low/ high pitched, it is localised, better heard with diaphragm etc. I feel it is _. (Avoid using the terms like "I feel"). Many questions are simple and straight forward; but some are difficult and confusing – analyse as follows – is the question familiar or not? is the topic familiar or not?

- Question familiar, topic familiar – answer is likely to be correct
- Question unfamiliar, topic familiar – try to derive the answer (an intelligent student can)
- Question familiar, topic unfamiliar – you are likely to be wrong
- Question unfamiliar, topic unfamiliar – don't open your mouth- answer will be a blunder- say "not sure Sir"

Quite often you get the diagnosis well before (tip!); use it intelligently – not for making the diagnosis. Examiners are interested in your clinical skill only – ability to elicit proper history, pick up salient clinical findings and to analyse the data to make a proper working diagnosis / differential diagnosis. When asked about differential diagnosis, don't put all the possibilities under the sun; be precise and to the point. Don't go for a very rare but glamorous diagnosis; consider common entities first. Usually the examiners make a clinical assessment of the case and formulate their own differential diagnosis which may not be the correct one at the end (many times students are right in this aspect).

May I quote some of my personal experiences as examiner

Examiners' diagnosis	Student's diagnosis
Hypertrophic obstructive cardiomyopathy	LV pseudoaneurysm (without history)
Large VSD with hyperdynamic PAH	Tricuspid atresia, VSD , PAH

In both situations, students' diagnoses were the right ones!

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Case of mitral stenosis, s/p PTMC, restenosis, mitral regurgitation; patient had an early diastolic murmur and midsystolic murmur in the base; what we (examiners) expected was a diagnosis of aortic regurgitation with discussion on how to differentiate it from pulmonary regurgitation. To our surprise the candidate's diagnosis was rheumatic pulmonary stenosis + regurgitation which turned out to be right on echocardiographic evaluation! (Don't under assess the IQ of the examiners- they do know you receive tips).

What are the problems faced during discussion of valvular heart diseases? I may discuss the sequence in which examination is conducted usually. Long case needs detailed presentation. History , discussion about the history, complete physical findings with discussion and asking to demonstrate some findings (like JVP), diagnosis and differential diagnosis, ECG, radiology, echocardiogram(may be asked to do the echo), further advanced non-invasive and invasive evaluation, management and prognosis. For short cases there are 2 formats. Diagnosis first and then justify or salient findings first followed by diagnosis. Many a times a brief history elicitation can be done within the time permitted. In both situations importance is given to clinical findings.

ILLUSTRATION OF A LONG CASE

History presentation

No doubt that a detailed history should be elicited ; but relevant data is to be presented in a standard format; don't stretch it too much by including unnecessary statements like – "according to patient" or "went to this doctor who told him... relative told to consult X who did all these things and said...."like that; instead be very precise. Usual problem that a candidate encounters is inclusion of unnecessary data in the present illness. Symptoms which are related to the active illness and has a continuity should be included. For a better understanding I may take one case for illustration.

30 year old farmer; history suggestive of rheumatic fever at 15 years age, on regular penicillin prophylaxis for 5 years ; stopped on own; asymptomatic for next 10 years; recurrence of rheumatic fever 5 years ago followed by progressive dyspnea; now in NYHA IV; irregular palpitation x 1 year and edema legs x 3 months.

In this situation the initial episode of rheumatic fever has to be described in detail as past history. Data from the recurrence 5 years ago onwards shall be the presenting complaints.

I may discuss the presenting complaints as follows:

This 30 year old gentleman working as manual labourer in paddy field has presented with symptoms of migratory polyarthritis 5 years ago followed by progressive dyspnea – from NYHA class II to class IV – with episodes of orthopnea and paroxysmal nocturnal dyspnea; palpitation of irregular nature for the last 1 year and now having edema legs for the last 3 months

History in detail.. This young man who was taking penicillin prophylaxis for a diagnosis of rheumatic fever made at the age of 15 years stopped it on his own after 5 years and was remaining asymptomatic for the next 10 years. 5 years ago he developed .. (describe in detail regarding the episode of recurrence with mention regarding presence of symptoms of carditis). Along with this / after a period of... he started experiencing the symptom of dyspnea; to begin with it was brought on by..(describe the activity which produced the symptom in detail) and say .."he was in NYHA class II". Then put the progression of the symptom like – progressed to class III over the next ....years and further to the present class IV for the last 1 year; mention presence or absence of orthopnea/ paroxysmal nocturnal dyspnea (PND) / hemoptysis etc.

Then present in detail the symptom of palpitation (usually incomplete) – on exertion / at rest ; paroxysmal (yes/no); regular / irregular; fast / slow; is it the rate or force which is uncomfortable/ worsening of existing symptom or associated new symptoms / any evidence of embolic manifestations. Same for edema also.. distribution / unilateral or bilateral / symmetric or asymmetric/ painful or not / associated symptoms like oliguria, abdominal distension, puffiness of face, worsening of cardiac symptoms etc. Important negative data also has to be presented

Past history – positive or negative data related to the present entity has to be discussed first; not diabetes/ hypertension/ dyslipidemia in this case. In the current case episode of rheumatic fever at 15 years age should be discussed in detail (available data); don't say "there was a history of rheumatic fever".

Note: a) Proper sequence of events b) Relevant negative data; complete but not too long and boring c) Use only generic names of drugs

Questions to be anticipated

- NYHA / Ross classification; is orthopnea / PND included?
- Mechanism of orthopnea / PND / edema
- Hemoptysis in mitral stenosis

After history presentation you will be asked to summarise. Many times the complete data will be presented again irritating the examiner. Summarise in minimum words, the maximum relevant data in proper sequence. In this case it may be as .. "30 yr old manual labourer with h/o rheumatic fever at 15 years and on regular penicliin prophylaxis for 5 years only developed recurrence of rheumatic fever by the age of 25 years. After this he developed progressive dyspnea – progressing from class II to IV over the next 4 years with episodes of PND and orthopnea. For the last one year he has irregular palpitations and he has edema for the last 3 months".

Discussion about symptoms

Rather than jumping to anatomical diagnosis, discuss how to explain the symptoms on physiologic basis. In the case illustrated, rather than telling it is mitral valve disease, explain the altered physiology – "dyspnea in this case indicates pulmonary venous congestion; it is chronic and progressive; now it is severe and pulmonary capillary pressure is likely to be more than 25 mm Hg. Commonest situation is chronic left atrial hypertension (anticipate the question – other conditions of pulmonary venous hypertension) and is due to mitral valve disease. Irregular palpitation indicates development of atrial fibrillation and dependent edema suggests systemic venous congestion".

Questions

- Can it be aortic valve disease? .. chronic severe left atrial hypertension is less common in aortic valve disease ; it occurs secondary to LV dysfunction after which prolonged survival is unusual (anticipate the question on natural history of valvular heart disease - read literature well about this aspect). Atrial fibrillation is also less common in isolated aortic valve disease early in natural history. In RHD mitral valve involvement is the commonest (read - valvular involvement in rheumatic fever and RHD; why mitral valve is more affected than aortic; why tricuspid and pulmonary are rarely affected)
- Differential diagnosis of left atrial hypertension
- Diagnosis from history

Physical examination

Almost always it starts like – "moderately built and nourished; conscious and cooperative". Describe the stature and status based on the clinical entity. For a neurologic or medical case it could begin with "conscious and cooperative" but not in a CVS case like this. In this case it can be as "Young gentleman with a height of ... cm , weight of .. kg and body mass index of .. kg/m2. He is tachypnoeic but comfortable in supine position". Dysmorphic features if any have to be presented in detail. You can also say "no external manifestations of rheumatic fever / endocarditis"

Pulse – perfect complete presentation is a must. Irregularity in atrial fibrillation (AF) can be missed if the ventricular response is slow (usually chronic cases will be on digoxin and / or betablockers and hence heart rate will be slow and you are likely to miss AF. At slow heart rate, the cardiac cycles are relatively long and hence the irregularity may not be striking enough to be appreciated in contrast to a fast rate. Pulse volume – better to put as normal / high / low rather than good volume (make sure that the findings are congruous – pulse volume and character should match with the blood pressure also). Character – don't say "no special character"; either normal or the specific abnormality. Look for all peripheral pulses; any asymmetry, check the blood pressure in all the 4 limbs and look for bruit in major vessels. Sometimes you may be asked to draw the pulse pattern of the patient (later JVP and hemodynamic tracings also). Almost always the answers have been quite disappointing. Include one timer in drawing (ECG) and minimum two full cardiac cycles (learn to draw the pulse, JVP and cardiac cycle pressure tracings during your training period monitored by the faculty; multiple attempts are needed to have a reasonable outcome)

Blood pressure (BP) – Always record in right arm and one leg; all 4 limbs in specific clinical situations. Upper and lower limb comparison should be on palpatory systolic pressure (lower limb pressure is usually recorded as the palpatory one in distal vessel, except in children). Supine and standing blood pressure has to be recorded in hypertensive people and also in those who had syncope / presyncope.

How to mention blood pressure in aortic regurgitation? As the Korotkoff sounds are overlapping with pistol shot sounds, muffling is taken as the diastolic value (also in children and in hyperdynamic circulatory states). Some examiners want it like 140 / 50 /0 (I am not in favour of this as the sounds don't disappear even at zero). I mentioned earlier that examiners are a heterogenous group – so go with the examiners; don't try to contradict them; you can put your views softly – if it's right, internal is supposed to support you – not otherwise.

Jugular venous pressue (JVP) – rather than presenting as JVP; present it as jugular venous pressure and jugular venous pulse separately. Mention the pressure and wave form. It is better to describe the A and V waves and also the descents than saying "the waves are normal". *In which position?* Instead of telling either 45 degree or upright position, discuss both with emphasis on

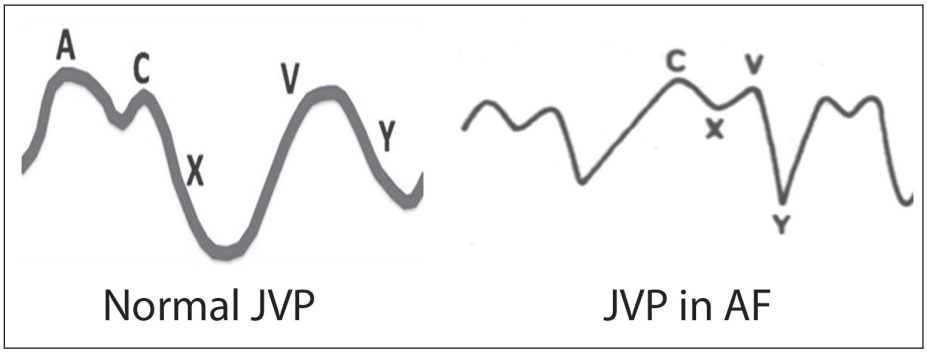


Figure 1
Normal JVP and JVP in AF

current recommendations (Read the data to support it). *Description of wave form* – usually is biased with the diagnosis you make, you may present the findings to suit that. As mentioned earlier many a times the heart rate will be slow in AF and you may consider it as sinus rhythm and present JVP as having 'a' wave also. *JVP in atrial fibrillation* – how many waves? Usual answer is only one wave. Draw a normal JVP pattern and take away the A wave; see how many waves – still there will be 2 waves (2 descents are still there; so there has to be 2 ascents and hence 2 waves – don't argue with the examiner on this issue) See Figure 1.

Questions

- Which is the most prominent event in normal JVP (ans: X descent)
- Mechanism of X descents
- Conditions with equal a & v waves

Many times the examiner may raise some doubt (may not be genuine) about your findings and may ask you "would you like to verify?. Grab the opportunity and re examine. Need not change your initial observation, if you are confident. Either you might have gone wrong in your interpretation or many a times it is to assess whether you know the proper method of examination of JVP. In a patient with valvular heart disease and right heart failure, carefully look for the sharpness of Y descent to rule out tricuspid stenosis.

Precordium – combine inspection and palpation ; apex beat can be mentioned at the end of other inspection findings like-"apex beat seen and felt in ..". Don't try to modify the character of the apex beat to suit to the final diagnosis; put it the way you really got it. Percussion is useful to assess the right atrial enlargement and situs. The precordial examination gives the following informations

- Cardiomegaly – yes / no ; if yes which chamber is contributing
- Apex – ? LV / RV type (discuss with your faculty regarding the method)
- Left parasternal heave (LPH) / epigastric pulsations – suggest RVH / RV enlargement; in RVH parasternal heave is localised and less impressive compared to RV enlargement; ? need for grading of LPH
- Pulmonary area – ? pulmonary artery dilated / PAH+
- Suprasternum – for aorta
- Right atrial enlargement by percussion

Thus before auscultation you get an idea of the radiology of heart.

Auscultation – is only fine tuning of the assessment made so far and to pick up additional soft findings, as by now we have got information about the cardiac rhythm, systemic and pulmonary venous pressure, systemic and pulmonary arterial pressure, cardiac output and cardiac anatomy.

Usual errors – not systematic ; anticipating the findings based on the diagnosis you have made. Instead be systematic and follow an order (should be mitral > tricuspid > pulmonary > aortic); S1 > S2 > additional sounds (prioritize based on the clinical diagnosis; in the case illustrated, opening snap, S3 and pulmonary clicks are important) > murmurs. Seldom students make a proper presentation of S2- 3 points should always to be included – split / variation with respiration / intensity of components. Sequence of presentation of murmurs – murmur / murmurs related to the dominant valve involvement shall be presented first followed by the other valve murmurs. For example, in the case illustrated, mitral murmurs have to be presented before aortic; if mitral stenosis is dominant start with that > mitral regurgitation murmur (if present) > aortic murmur. Perfect and complete description of the murmur has to be presented. For example, murmur of MS – "low pitched, rough, rumbling, mid diastolic murmur with/ without presystolic accentuation heard over the apex best with bell of stethoscope with patient in left lateral position during expiration". Another common statement made is in the description of the murmur of AS where the description goes like ".....the murmur is heard best in sitting up leaning forward position, breath held in expiration". This statement is applicable only for the murmur of AR.

S2 – OS interval- extremely difficult to assess clinically; I have heard some students saying " S2 – OS is about 60 ms" – that is too much! Just say whether it is relatively long or short.

Do a complete examination of respiratory system and abdomen (concentrate on hepatic pulsation) and relevant neurologic examination (Don't attempt to test muscle power for every CVS case!)

Questions

- S3 vs OS ; S3 vs pericardial knock
- Draw the diastolic sounds in proper temporal sequence and the various timings
- When to say P2 is loud (palpable in pulmonary area, louder than a normal A2 , P2 heard over apex)
- Wide split – ? fixed or varying .. examine in standing position; varying split will narrow.
- S1 intensity during atrial fibrillation in mitral stenosis (can have differences of opinion; as the left atrial pressure is remaining high in all cycles, variation in the position of leaflets at end diastole doesn't happen and hence S1 intensity can be constant)
- MDM heard over apex ..is it mitral stenosis or flow rumble of mitral regurgitation? (OS, loud S1, diastolic thrill and presystolic murmur favour stenosis; flow rumble is confined to mid diastole)
- Can presystolic accentuation of mitral stenosis murmur occur in AF (find out the answer and mechanism)
- Is there organic tricuspid valve disease (gross CHF/ non response to treatment/ evidence of tricuspid stenosis)
- certain patients with severe mitral stenosis are less symptomatic – explain (severe PAH / RHF / tricuspid valve disease / associated atrial septal defect – all decompress left atrium)
- EDM in this case – is it AR / PR?

You have to concentrate on

- BP.. wide pulse pressure for significant AR
- JVP – height ; wave form especially V and Y descents
- Apex – for LV enlargement ; if present – MR vs AR ; if pulse pressure is normal consider MR and vice versa
- Intensity of S1 – if loud – mitral stenosis ; if soft – mitral regurgitation or calcified valve

Significant cardiomegaly with normal pulse pressure – likely to be dominant mitral regurgitation. No or minimal cardiomegaly – mitral stenosis is likely to be dominant.

What is the likely diagnosis in the above case?

Format of presenting the diagnosis is very important. It could be as follows (short forms to be avoided as far as possible).

- Group / etiologic entity (eg. rheumatic / congenital / coronary atherosclerotic etc.)
- Anatomic diagnosis (with severity when clear)
- Complications primarily related to the entity (eg. pulmonary hypertension)
- Cardiac failure (yes / no)
- Rhythm status
- NYHA class
- Comorbid conditions – relevant to the present issue > others

If assessment of severity is difficult, don't mention it; wait for discussion – eg. severity of pulmonary hypertension / tricuspid regurgitation when they are not severe; severity of mitral regurgitation in presence of severe aortic regurgitation. Similarly "moderate severity' should be used with caution.

In the given long case it shall be as follows:

Rhuematic Heart Disease – mitral stenosis (severe), mitral regurgitation (mild) - probably pliable valve- aortic regurgitation (mild) - Pulmonary venous and arterial hypertension - Tricuspid regurgitation - Atrial fibrillation with controlled heart rate - Congestive heart failure - NYHA IV.

Illustration of a short case (case of aortic valve disease)

Two approaches - 1. diagnosis & justification 2. Clinical findings and then diagnosis.

Diagnosis (format same as long case)

Valvular heart disease – probably congenital bicuspid aortic valve - Aortic stenosis (severe), aortic regurgitation (mild) - No pulmonary hypertension - Sinus rhythm - Not in heart failure / NYHA II - Type 2 diabetes mellitus - dyslipidemia.

Justification

Aortic stenosis .. symptoms .... / slow rising pulse / narrow pulse pressure / heaving apex / LV S4 / delayed A2 / prominent midsystolic murmur in aortic area. (anticipate the questions on symptoms, pulse, significance of S4 , S2 etc.; detailed assessment of AS).

Why severe?.. above data + late peaking of murmur

Aortic regurgitation .. early diatolic murmur.. ; why mild? .. narrow / normal pulse pressure ; short murmur (Questions – length of murmur vs severity; assessment of severity of AS in presence of AR, why bicuspid aortic valve? can it be tricuspid / can it be rheumatic?)

Mitral regurgitation (MR)

Isolated severe MR is easy; symptomatology is same as in mitral stenosis. LV type cardiomegaly , typical MR murmur, LV S3 and mitral MDM. Be careful about S2 ; don't anticipate the nature of split as it will be modified by severity of MR, LV function, PA pressure and RV function. Do dynamic auscultation in any case of MR, unless the patient is in CHF. If there is left parasternal heave / pulsation, try to differentiate whether it is due to RVH / LA expansion (anticipate question on this).

Aortic regurgitation (AR)

Isolated severe AR is also relatively easy; usual issues are

- ? valvular vs vascular
- S2 in AR
- MDM ..? Austin Flint vs mitral stenosis (loud S1,OS,thrill,presystolic accentuation, presence of AF, severe PAH - in that sequence - favour mitral stenosis)
- ? mechanism of Austin Flint murmur
- ? significance of S3 / S4 in AR
- Aortic midsystolic murmur – flow murmur vs aortic stenosis (thrill, length and peaking of murmur, sustained apex are the useful data)
- ? acute vs chronic AR

Aortic stenosis (AS)

Isolated AS is rare; usually will have AR also. If rheumatic, multivalvular.

- ? etiology (young people- -congenital ; mulltivalvular – rheumatic ; elderly – degenerative)
- ? severity (symptoms, tardive pulse, narrow pulse pressure, heaving apex, delayed soft A2, long mumur, late peaking – in that sequence will be better); many times student start with late peaking- honestly speaking, is it easy to pick up? Usually you make the assessment of severity and then stretch the peak accordingly!
- Ejection click – before the examiner asks, you have to present it as constant click (anticipate the questions on click)
- ECG in AS .. assessment of severity
- LVH in ECG - - AS vs AR (QRS voltage is maximum in AR as it has both increase in muscle mass and cavity diameter – Brody effect ie. voltage is correlated with the amount of blood in the cavity -, deep narrow Q waves etc; in AS voltage criteria is unimpressive but more of ST T changes, widening of QRS, smaller septal q waves).

Tricuspid valve lesions

Isolated tricuspid valve lesions are rare (likely to be Ebstein's anomaly / RV EMF) and usually seen with multivalvular disease. Dynamic auscultation is a must; concentrate on hepatic pulsation also. Address the following issues (tricuspid valve and RV function are getting more attention now; hence read the literature well).

- ? hypertensive vs normotensive
- ? organic vs functional
- ? severity
- Assessment of RV function
- Indications for surgery
- ? presence of tricuspid stenosis

Multivalvular lesion

Seldom isolated valvular lesion is kept for post graduate examination; hence a discussion on the influence of one lesion on another is given below.

MS + MR

Commonest lesion in RHD; usually one lesion dominates. MS doesn't significantly influence the hemodynamics and clinical finding of MR (S3 will be absent); however MR can enhance the features of MS. In either situation the symptomatology, pulmonary hemodynamics and its sequelae will be determined by the left atrial pressure.

When to diagnose MS in a case of severe MR? – presence of diastolic thrill , loud S1 , OS and presystolic mumrmur.

MS + AR

Very common combination; mild AR will not modify the features of MS and vice versa. Usually the proximal lesion modifies the hemodynamics of distal lesion. Severe MS reduces the LV diastolic volume and hence the LV stroke volume; so there can be decapitation of the aortic systolic pressure. However the regurgitant parameters are not modified; no alteration in diastolic pressure and peripheral signs and hence assessment of severity of AR may not be difficult. Severe AR doesn't alter the hemodynamics of MS; the usual question is how to diagnose MS in a case of severe AR when you hear a mid diastolic murmur over the apex.

Question : What happens to OS – presence and timing – in a patient with MS having significant AR (draw the LV, LA, aortic pressure tracing and find out the answer).

MS + AS

Severe MS reduces the LV preload and hence can further attenuate the stroke volume, thus enhancing the symptoms of AS. Pulse pressure further narrows; the midsystolic murmur gets attenuated but not the peaking pattern. ? influence of AS on MS - draw the LV, LA, aortic pressure tracing and try to solve (see Figure 2).

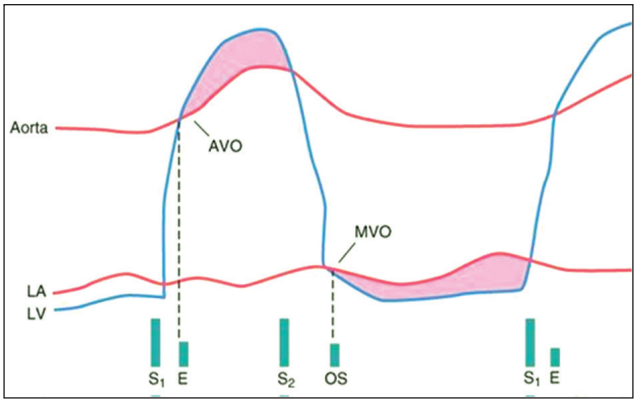


Figure 2. Hemodynamic tracing in AS vs MS. Due to impaired relaxation, the isovolumetric time gets prolonged thereby delaying the OS; A2 – OS interval gets prolonged (same physiology occurs in the presence of any condition which impairs relaxation eg. hypertension, myocardial ischemia, ventricular hypertrophy). Other situations producing a long A2 – OS interval in severe MS are PAH, RV failure, tricuspid valve disease , atrial septal defect and hypovolemia – all will decompress the LA resulting in reduction in the LV inflow gradient.

MR+ AR

In presence of severe AR, the LV systolic pressure is high and hence the MR gets accentuated. The forward stroke volume to aorta comes down leading to decapitation of systolic blood pressure. The following changes can occur.

- Hemodynamics and the murmur of MR get accentuated
- Pulse, BP – systolic decapitation of BP; however diastolic BP, pulse character, peripheral signs and murmur of AR are not modified
- A2 - delayed by AR ; earlier by MR
- Echocardiographic findings of MR get exaggerated by AR; not vice versa.

MR + AS

As both occur in the same phase of cardiac cycle, one influences the other strongly. As the LV systolic pressure rises the MR gets aggravated; the regurgitant fraction of MR reduces the forward stroke volume in AS.

- Pulse volume becomes lower but character is not altered
- Very strong apex beat
- S2 - early A2 of MR vs delayed A2 of AS
- MR murmur accentuated ; AS murmur attenuated
- Echo – exaggeration of MR data ; attenuation of LV > aorta gradient

Influence of tricuspid valve disease

Significant tricuspid valve disease reduces the RV stroke volume to pulmonary circuit thereby reducing the left atrial and left ventricular input, thus decompressing the left heart. The left atrial pressure decreases and hence the symptoms and findings of MS come down (under assessment of severity of MS clinically). The reduction in LV preload will exaggerate the symptoms of AS; the auscultatory findings become less impressive.

Other major factors which influence the hemodynamics and clinical findings of valvular lesions are left and right ventricular function, pulmonary artery hypertension, systemic hypertension and cardiac rhythm apart from noncardiac factors like hyperdynamic circulatory states, volume status, renal function etc.

After the case discussion investigation, management and prognosis will be discussed.

Investigations

To start with ECG or Chest Xray (funny question - ? which first – I am not sure; but for dominant mitral valve disease I may prefer Chest X ray and for aortic valve disease ECG)

ECG .. Read systematically – rate and rhythm > P wave analysis > PR (normal, constant or varying) > QRS – duration , axis, LVH, RVH, Q waves- > ST > T > QTc. Common error made in examination is axis calculation – hence get trained in the axis calculation; QTc is also missed frequently. You should clearly know the criteria for atrial abnormality and ventricular hypertrophy, digitalis effect vs toxicity etc.

Chest Xray .. read systematically unless intervened by the examiner (See Figure 3)

- Technique – proper or not
- CT ratio
- Left border (aortic knuckle> PA > hump along left border below PA > rest of left border)
- Right border (RA / SVC / asc. aorta / azygos vein)
- Look for implants / devices, left atrium, calcifications etc.
- MPA / RPA/ LPA / pulmonary vascularity (upper lobe vessels)

- Features of transudation (peribronchial cuffing, hilar haziness, pulmonary edema, effusions)
- Kerley lines

You may be asked about the hemodynamic status also from X ray

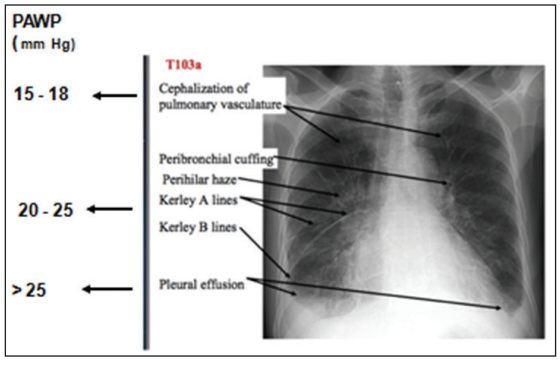


Figure 3

Echocardiogram.. Start in the standard systematic approach; many a time students start straight away to prove the final diagnosis. What the examiners are trying to assess is whether you are doing it properly or not. Knowledge about instrumentation is extremely important.

Management

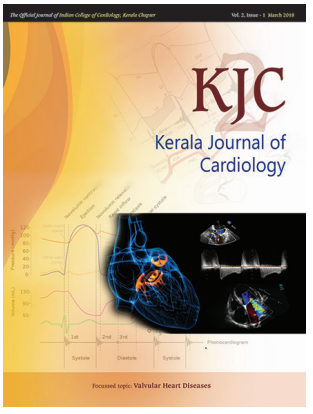
Non pharmacological > pharmacological > intervention > surgery – in that sequence; quite often you go for the definitive procedure without discussing the medical management. You should not forget to discuss rheumatic fever and endocarditis prophylaxis in relevant situations.

Suggested areas of reading

- Rheumatic fever with recent updates
- Natural history data
- Articles on restensois after mitral valvotomy
- Recent recommendations on valvular heart disease
- Indications and timing of surgery
- (Have a discussion in your department and modify the above views, content and format accordingly)

Abbreviations

A2 – aortic component of S2; AF – atrial fibrillation; AR – aortic regurgitation ; AS – aortic stenosis; BP – blood pressure; JVP – jugular venous pressure / pulse; LV- left ventricle ; LA – left atrium; MDM – mid diastolic murmur; MR – mitral regurgitation; MS – mitral stenosis; OS – opening snap; PA – pulmonary artery; PAH – pulmonary artery hypertension; PND – paroxysmal nocturnal dyspnea; PTMC – percutaneous transmitral commissurotomy; RA – right atrium; RV- right ventricle; RVH – right ventricular hypertrophy; S1 – first heart sound; S2 – second heart sound; S3 – third heart sound; S4 – fourth heart sound; SVC – superior vena cava



Clinical Assessment of Prosthetic Valve Function

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INTRODUCTION

Commonest surgical procedure for valve malfunction is valve replacement. Patients with significant valve disease with normal or near normal left ventricular function improve significantly following valve replacement. Prosthetic valves have distinct auscultatory findings which help to assess the function of these valves. The auscultatory findings differ depending on the type of prosthetic valve. Prosthetic valve malfunction caused by thrombosis, pannus formation, regurgitation or dehiscence can be recognized by proper clinical examination.

Types of Prosthetic Valves

- Caged ball valve. Eg. Starr- Edwards
- Single tilting disc valve. Eg. Bjork- Shiley, Chitra valve, Medtronik-Hall Valve
- Bileaflet Tilting disc valve. Eg. St. Jude bileaflet valve
- Tissue valve or Bioprosthetic valve. Eg. Hancock, Carpentier – Edwards
- Homografts – Preserved Human Aortic valve

Each type of valve has distinct auscultatoy findings.

CLINICAL ASSESSMENT OF PROSTHETIC VALVE FUNCTION

The clinical assessment can be classified into:

- Symptom assessment
- Clinical Examination

SYMPTOM ASSESSMENT

Patients of significant valve disease improve in functional class following valve replacement except in patients with significant left ventricular dysfunction. After the initial post operative period, failure of improvement in symptoms of patients of valve replacement points towards prosthetic valve malfunction or surgical complication. Again after an initial improvement in cardiac function, any deterioration in the functional status must alert the physician of the possibility of valve malfunction or a complication like atrial fibrillation which resulted in clinical deterioration. Very often initial symptom of progressive valve malfunction may be missed unless careful attention is paid to proper clinical examination of the patient. Sometimes serious prosthetic valve malfunction may remain asymptomatic. Other associated complications like systemic and pulmonary embolism, atrial fibrillation, haemolysis, anaemia, infective endocarditis or infections especially chest infections should be specifically sought for in a prosthetic valve patient.

CLINICAL EXAMINATION

The examination findings differ among prosthetic valves.

Caged – ball valve (eg.Starr-Edwards)

Caged- ball valves are characterized by metallic closing and opening noises. These correspond to the closing movement of the ball which seats on to the ring of the

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valve and opening process when the ball falls on to the metallic cage. Both the noises are high pitched, metallic, loud noises which can be easily distinguished from normal heart sounds.[1] The opening noise is louder than the closing noise because in the opening motion the ball comes to strike the metallic cage while in closing motion the ball seats onto the cloth covered metallic ring.

Mitral caged ball valve

The mitral prosthetic valve has been studied by various workers.[2-4] The metallic opening sound (OS) is louder than the closing sound (CS) of the valve. The OS, which corresponds to the opening snap of the mitral stenosis, is audible 0.07 to 0.11second after A_2 and is best audible at the apex.[2] The A_2- OS interval does not vary significantly from beat to beat even in patients of atrial fibrillation.[3] However a long R-R interval by decompressing the left atrium can decrease the intensity of OS in the succeeding beat.[4] Narrowing of A_2–OS interval to less than 0.05 second indicate prosthetic valve obstruction or severe regurgitation. Delay in A_2–OS interval is suggestive of interference with the opening motion of the poppet.[5] Sometimes multiple opening sounds could be audible. It is due to the multiple excursions of the poppet related to the blood flow and indicates well functioning caged ball prosthesis.

The CS of the caged ball prosthetic valve produces a metallic noise which corresponds to first heart sound. It occurs 0.06 to 0.08 second after the onset of QRS complex.[6] In caged ball the OS is louder than the CS.[1] The CS may diminish with prolonged PR interval.

A mid systolic murmur is very often audible in the left sternal border which is caused by the projecting rigid cage of the caged ball onto the left ventricular (LV) outflow. Presence of diastolic murmur in caged ball prosthetic valve indicates valve malfunction.[7]

Aortic caged ball valve

The opening of the caged ball aortic prosthetic valve produces a metallic sound. The interval between S1 and aortic OS is approximately 0.07 second.[6] Multiple opening sounds may be audible due to the movement of the poppet.[8] The aortic OS may be heard all over the precordium. It may be best audible at the apex or the left parasternal region.

The CS of the aortic prosthetic valve is also heard as a loud metallic noise. However CS is less loud than OS. Reduction in intensity of OS compared to CS of the aortic prosthetic valve indicates valve dysfunction.[9] However the presence of loud OS does not exclude prosthetic valve dysfunction.

Ejection systolic murmur can be heard at the aortic area with radiation to carotids. Sometimes carotid shudder may be palpated.[2] Diastolic murmurs are not audible in aortic caged ball prosthesis. Presence of a diastolic murmur indicates valve dysfunction.

Single Tilting Disc Valve

The tilting disc valve does not produce a loud OS because as the disc swings open it does not strike against any metallic/ resonant part.[10] However a metallic CS will be audible. Absence of metallic CS indicates valve malfunction.[11] In general tilting disc valve sounds are less loud than caged-ball valve sounds.[1]

Mitral single tilting disc valve

The OS is not clinically audible.[1] The CS is metallic and loud and corresponds to S1.[11] The CS can decrease in intensity if the disc movement is interfered with due to thrombosis or pannus.[12] In addition to grade 2/6 Ejection systolic murmur in the parasternal region, normally functioning tilting disc prosthetic valve, may produce a mid-diastolic murmur at apex. The tilting disc valves are inherently stenotic and the opening size of the valve may be half of the size of the normal valve. This may result in turbulent flow across the valve which can be the reason for the mid-diastolic murmur.[1]

Aortic single tilting disc valve

Similar to mitral single tilting disc valve, the aortic tilting disc valve also does not produce clinically detectable OS while metallic CS is audible.[13] Reduction in intensity/metallic nature of CS of aortic prosthetic valve indicates associated prosthetic valve malfunction. An ejection systolic murmur is heard in the aortic area. Occasionally soft diastolic murmur may be audible in the normally functioning tilting disc prosthetic valve.[14] On the contrary, even in presence of severe valve malfunction with regurgitation, no diastolic murmur may be audible.[1]

Bileaflet Tilting Disc Valve

Auscultatory findings of bileaflet tilting disc valve are similar to single tilting disc valve except that diastolic murmur is not normally audible in bileaflet tilting disc valve at aortic position.[1] (Table 1)

Tissue Valves or Bioprosthetic Valves

Tissue valve can produce a CS similar to normal valves both in aortic and mitral positions. The aortic bioprosthetic valve will have a systolic ejection murmur at the base of the heart which can radiate to the carotids.

The mitral bioprosthetic valve will have OS best audible at the apex in one half of the patients.[15] This is a high pitched event. Apical diastolic murmur can be heard in majority of the patients with mitral bioprosthetic valve and is independent of valve size.[16] There can be a mid systolic murmur in one half to two thirds of patients with mitral bioprosthetic valve. The murmur production may be due to the resonating properties of the valve cusps or due to the flexible resonating stents.[17] Any alteration in the murmur character indicates prosthetic valve dysfunction.[1] In aortic bioprosthetic valve, OS is not audible. A grade 2/6 mid systolic murmur can be audible in the left sternal border while no diastolic murmur is audible[1]. Presence of diastolic murmur indicates valve malfunction in aortic bioprosthesis.

Homograft

The homograft prosthetic valve sounds are similar to normal heart sounds. Homografts are not associated with murmurs. Presence of diastolic murmur indicates valve dysfunction.

PROSTHETIC VALVE – RECOGNITION OF COMPLICATIONS

The common complications leading to prosthetic valve malfunction are

- Valve thrombosis
- Pannus formation
- Valve dehiscence
- Infective endocarditis
- Paravalvular leak
- Structural failure of the valve

Valve Thrombosis

The prosthetic valve thrombosis can cause symptoms depending on the size of thrombus. Large thrombus can lead to cardiovascular collapse or acute pulmonary edema.[18] In patients of prosthetic valve with acute deterioration of clinical status, valve thrombosis must be suspected. Caged-ball valves are more prone to valve thrombosis.[19] In patients with prosthetic valve,

Table 1: Acoustic characteristics of various prosthetic valves - Normal and abnormal

Prosthetic valve	Mitral position		Aortic position	
	Normal	Abnormal	Normal	Abnormal
Caged-ball valve	• Metallic OS and CS • OS>CS • 2/6 Ejection systolic murmur • No diastolic murmur	• Loss of metallic sound • OS<CS • Diastolic murmur • Pansystolic murmur	• Metallic OS and CS • OS>CS • 2/6 Ejection Systolic Murmur • No diastolic murmur	• Loss of metallic sound • OS<CS • Aortic diastolic murmur • Change in loudness of ejection systolic murmur
Single tilting disc valve	• Metallic CS • No metallic OS • 2/6 Ejection systolic murmur • Mid–diastolic rumble	• Loss of metallic CS • Pansystolic murmur	• Metallic CS • OS may be heard • CS>OS • Occasional diastolic murmur	• Loss of metallic sound • Change in loudness of ejection systolic murmur • Early diastolic murmur
Bileaflet tilting valve	• Metallic CS • No metallic OS • CS>OS • Mid–diastolic murmur	• Loss of metallic CS • Pansystolic murmur	• Metallic CS • OS may be audible • CS>OS • 2/6 Ejection systolic murmur	• Loss of metallic sound • Diastolic murmur • Change in loudness of ejection systolic murmur
Bioprosthetic valve	• Normal heart sounds • OS may be heard • 2/6 Ejection systolic murmur • Mid–diastolic rumble	• Pansystolic murmur • Prolonged diastolic murmur	• Normal heart sounds • 2/6 Ejection systolic murmur • No diastolic murmur	• Diastolic murmur • Change in loudness of ejection murmur
Homograft			• Normal heart sounds • No murmur	• Diastolic murmur

OS=Opening Sound CS=Closing Sound

embolic episodes indicate valve thrombus formation. Physical findings of prosthetic valve thrombosis are decreased intensity and loss of metallic nature of one or both sounds. In caged – ball prosthetic valve, if the CS is louder than OS, it indicates valve malfunction and possibility of valve thrombosis must be considered. This is due to decreased movement of poppet or disc.[20] Failure of the valve to close properly can result in valve regurgitation murmurs. However significant prosthetic valve regurgitation can occur even without murmurs.[1]

Pannus Formation

It is an insidious process. Pannus can cause prosthetic valve malfunction leading to valve stenosis.[21] Pannus can co-exist with thrombus. Alteration in the prosthetic valve sounds and new murmurs are features of pannus.

Valve Dehiscence

Valve dehiscence can result in prosthetic valve malfunction. Disappearance of OS[20] and development of regurgitation murmurs are features of valve dehiscence.

Infective Endocarditis

Infective endocarditis of the prosthetic valve can lead to valve dehiscence. Valve regurgitation murmurs can occur.[22]

Paravalvular Leak

Paravalvular leak unless severe can remain asymptomatic. Even in presence of paravalvular regurgitation, no murmur may be detected on clinical examination.[1] However, presence of pansystolic murmur in mitral prosthesis and early diastolic murmur in aortic prosthesis suggest paravalvular leak. Most often investigations like transthoracic echo-doppler will be needed to confirm the diagnosis.[21]

Structural Failure of the Valve

Single disc valve with 70° opening angle has been shown to have risk of strut fracture. Strut fracture results in acute dyspnea and cardiovascular collapse.[20] This is due to disc embolization and acute mitral regurgitation.

Bioprosthetic valves (heterograft) and homograft can develop structural failure.[23,24] These patients develop gradual increase in dyspnea. Bioprosthetic valve regurgitation/stenosis can be diagnosed by the presence of new onset murmurs.[20]

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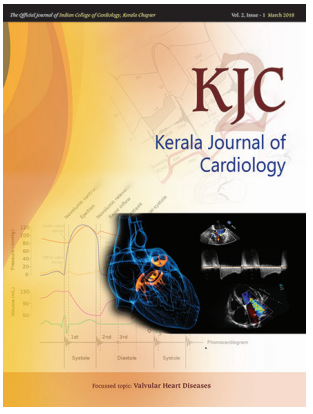

Fluoroscopy of Prosthetic Heart Valves

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The first successful orthotopic valve replacement in the mitral position was done by Starr on September 21, 1960, which was followed by Harken's implantation of a prosthesis in the aortic position. Since then there has been significant improvement in surgical techniques and valve design. Prosthetic valve thrombosis is a potentially life-threatening complication of heart valve replacement. Prosthetic valve thrombosis incidence was reported to be 0.03% in bioprosthetic valves, 0.5% to 8% in mechanical valves in the mitral and aortic positions respectively, and as high as 20% in mechanical tricuspid valves. Establishing the exact cause of prosthetic heart valve (PHV) dysfunction is essential to determine the appropriate treatment strategy. It requires a comprehensive approach that integrates several parameters of valve morphology and function assessed with 2D/3D transthoracic (TTE) and trans-esophageal (TEE) echocardiography, Cinefluoroscpy, CT and occasionally MRI to appropriately detect and quantitate PHV dysfunction. This article explains the use of cineflouroscopy in assessment of prosthetic valve function. (Tables 1 & 2)

Table 1. Types of prosthetic heart valves
Biological
Stented • Porcine bioprosthesis • Pericardial bioprosthesis Stentless • Porcine bioprosthesis • Pericardial bioprosthesis • Aortic homograft • Pulmonary autograft (Ross procedure)
Sutureless
Transcatheter
Mechanical • Bileaflet • Single tilting disk • Caged ball

Table 2. Uses of cine fluoroscopy in prosthetic valves
Identification of type of implanted device
Evaluation of valve function • Valve leaves mobility • Valve ring motion
Evaluation of Structural integrity of valve • Strut fracture • Migration of parts of valve
Monitoring the effect of thrombolysis in Prosthetic valve thrombosis

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A. IDENTIFICATION OF TYPE OF IMPLANTED DEVICE

Identification of prosthetic valve in chest X-ray

In chest X-ray PA view, the aortic valve should lie above, and the mitral valve below an imaginary line passing from the right cardio-phrenic angle to the inferior aspect of the left hilum (fig.1).

On the lateral view the aortic valve lies above, and the mitral valve below an imaginary line passing from the carina to the cardiac apex (Figure 1 & 2).

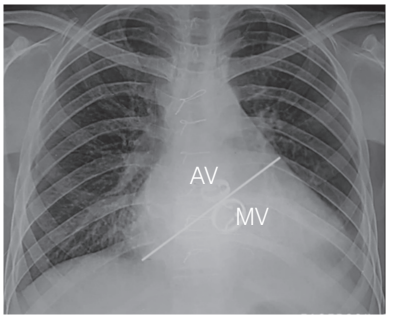


Figure-1

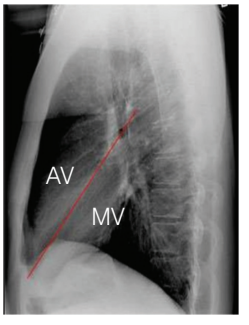


Figure-2

Other methods suggested for CXR PA view are:

Valve orientation method- Mitral valve appears more vertical and aortic valve appears more horizontal and uncertain if it lies in between (Figure 3).

Mitral	Aortic	Uncertain
		

Figure -3

Valve orifice shape method - If the valve orifice appears en face then it is mitral, if in profile it is aortic and uncertain if in projects in between (Figure 4).

Mitral	Aortic	Uncertain
		

Figure- 4

Direction of blood flow - Perceived direction of blood flow across valve method- If the perceived direction of blood flow appears to be across the valve toward the cardiac apex then it is mitral, if it is towards the ascending aorta then it is aortic, otherwise the position is uncertain (Figure 5).

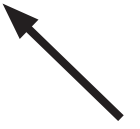
Mitral	Aortic	Uncertain
		?

Figure-5

Identification of type of implanted device in fluoroscopy - Each model of prosthetic valve has unique radiological properties and it may help to identify the valve when no previous records are available.

MECHANICAL HEART VALVES

Caged ball heart valves - Starr Edwards valve

They consist of a silastic occluder housed in a wire cage with three or four struts. The base ring and cage are radio opaque. The silastic ball is impregnated with barium to make it slightly radio opaque. The cage is made up of three struts in valves for aortic position and four struts in valves for mitral position (Figure 6).

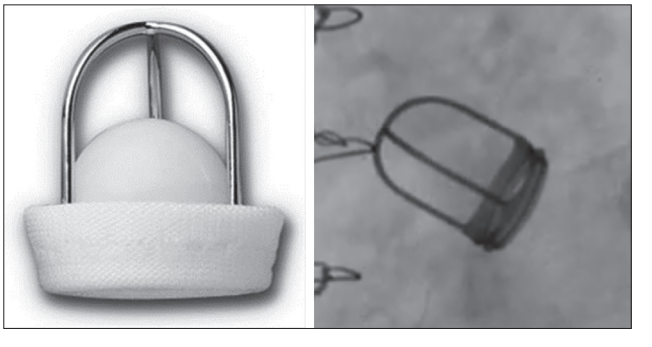


Figure -6

Tilting disc valves

Bjork-Shiley Prosthesis- The base ring is radiopaque and emerging from the base ring are two eccentrically placed "U" shaped structures which are of unequal size. The disc is radiolucent in some models or has an outer radiopaque ring in other models (Figure 7).

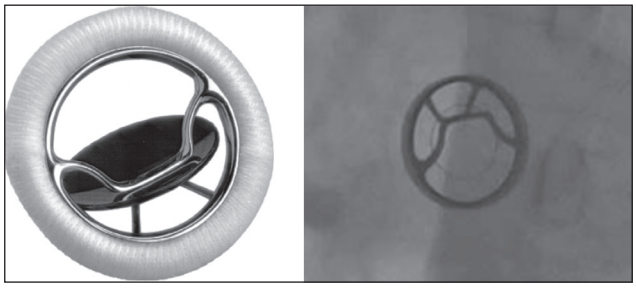


Figure-7

Medtronic- hall valve - The base ring is radiopaque and has a characteristic curved central strut (Figure 8).

Figure-8

TTK Chitra valve - The base ring is made up of cobalt chromium alloy (HAYNESS 25) and is radio opaque. The disc is made from ultra high molecular weight poly ethylene and is radiolucent (Figure 9).

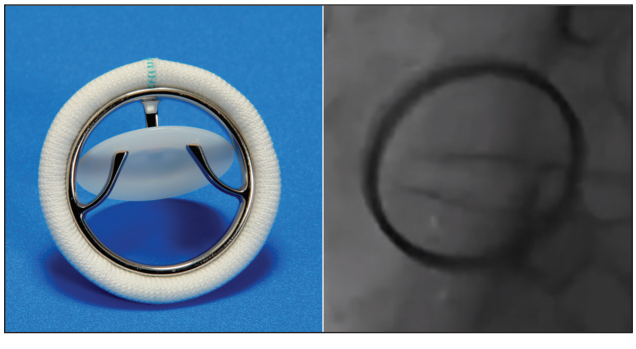


Figure-9

Bileaflet valves

St. Jude Medical Valve - The base ring is radiolucent. When viewed on edge, the discs are radiopaque (Figure 10).

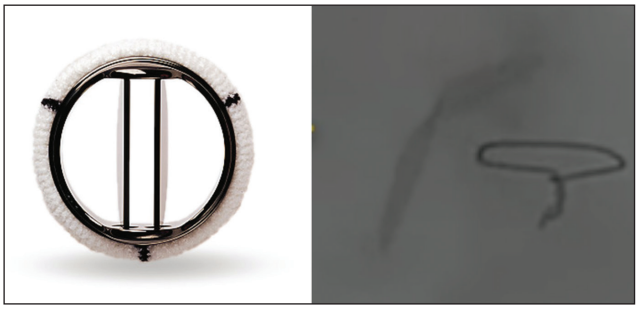


Figure-10

Carbomedics sorin bileaflet valve - Both the base ring and discs are radiopaque (Figure 11).

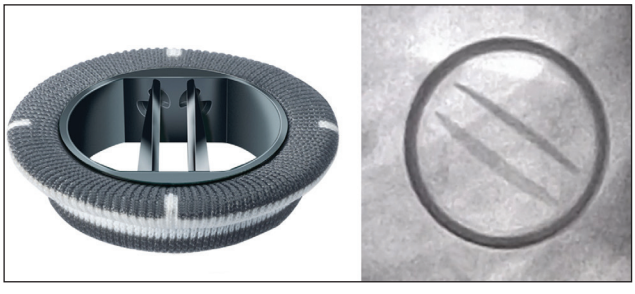


Figure-11

Bioprosthetic heart valves

Carpentier-Edwards Supraannular Bioprosthesis-(Aortic position) - Continuous narrow wireform outlines each of the three stents and that portion of the base ring between stents (Figure 12).

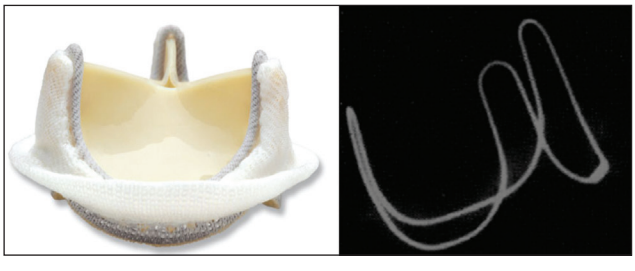


Figure-12

Carpentier-Edwards Pericardial Valve Bioprosthesis (mitral position:) - The base ring is marked by a flattened circular ring with three holes. In addition, a narrow wireform outlines each of the three stents and the base ring between the stents (Figure 13)

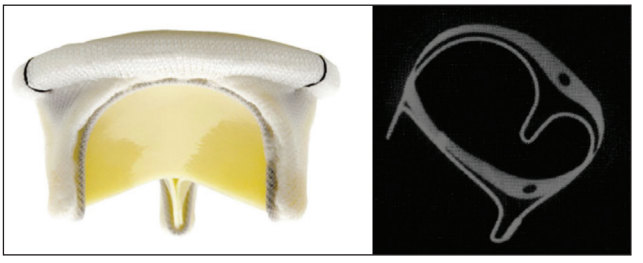


Figure-13

Medtronic Hancock II Pericardial Heart Valve - The base ring is narrow, circular wirelike form. Three tiny circular rings mark the distal external aspects of the three stents (Figure 14).

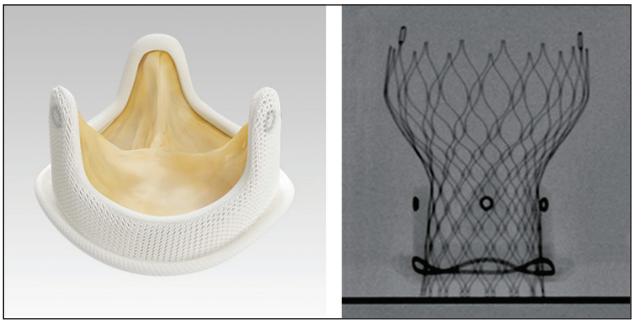


Figure-14- X ray image shows a core valve within Hancock II valve

Trans catheter aortic valves

Core valve (Medtronic) - The multilevel frame made of nitinol is radiopaque. The 3 valve leaflets and a skirt, made from a single layer of porcine pericardium is radiolucent (Figure 15).

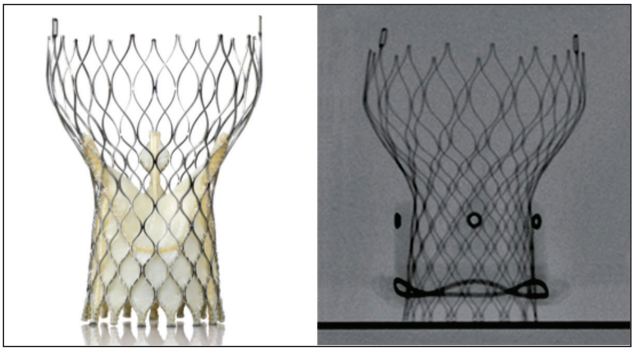


Figure- 15

Edward sapien 3 - The cobalt-chromium frame is radiopaque, trileaflet bovine pericardial tissue valve, and polyethylene terephthalate (PET) fabric skirt are radioluscent (Figure 16).

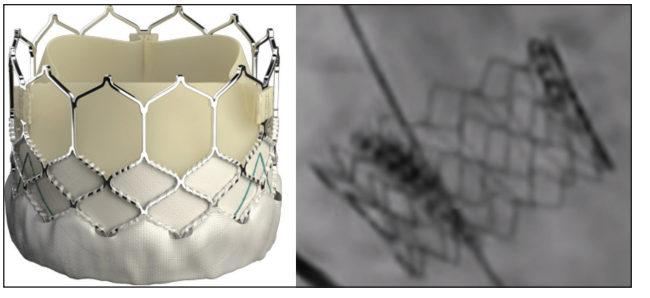


Figure 16

B. EVALUATION OF PROSTHETIC VALVE FUNCTION

Using cinefluoroscopy prosthetic valve dysfunction can be easily detected , especially in patients with bileaflet prosthetic valves where the disks can be directly visualized, and opening and closing angles measured. Persistent restriction of leaflet motion with calculated opening angle greater than the mean value suggest prosthetic valve obstruction. Increased mobility of the valve ring suggest dehiscence although a higher degree of dehiscence is required to be detected by cine fluoroscopy.

Calculation of Opening and Closing Angle

Patient in supine position

Views

Normal motion varies with each valve model and with each patient, a baseline fluoroscopic examination will be helpful for future reference. Since the rotational orientation during the placement of the prosthetic valves differs, view that can correctly visualize the valves vary from patient to patient. Aortic prosthesis may be visualized better in RAO caudal and LAO cranial angles, whereas RAO cranial position is more appropriate for visualization of mitral prosthesis.

European Association of Cardiovascular Imaging Recommendations for the imaging assessment of prosthetic heart valves suggest three views for optimal evaluation of prosthetic valve function.

1. **Posteroanterior view** - 0 and lateral 90 view to assess the in-situ orientation of valve

2. **'In profile' projection** - with the radiographic beam parallel to both the valve ring plane and the tilting axis of disc , allowing calculation of opening and closing angles

3. **The 'en face' projection** - with the radiographic beam parallel to the valve outflow tract which is utilized only for mitral prostheses.

Cinefluoroscopy provides a better evaluation of the motion of discs in the aortic position than echocardiography

Opening and closing angles

Single disc valves - the opening angle is defined as the angle between the housing and the disc at its fully open position (Figure 17). (Table 3)

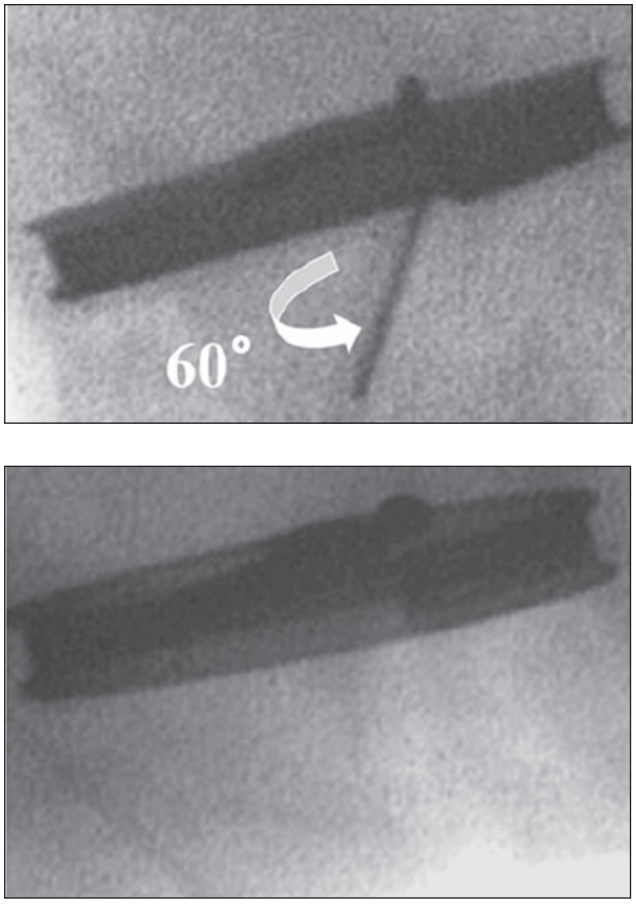


Figure-17

Bileaflet disc valves - the angle between the leaflets in the fully open and closed position (Figure 18).

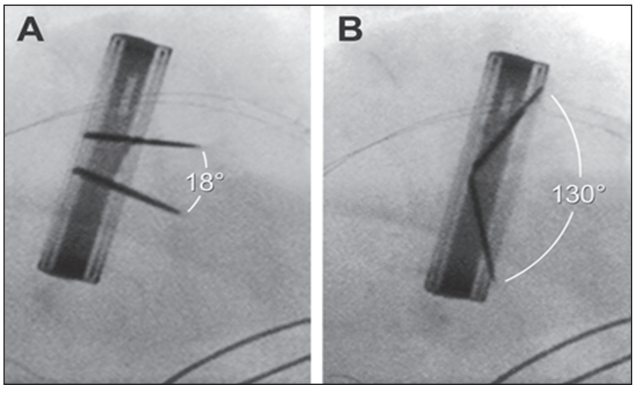


Figure-18

Table-3 Normal opening and closing angles of prosthetic valves

Valve	Opening angle	Closing angle
Carbomedics	$<24^0$	$>130^0$
Edwards duromedic	$<29^0$	$>148^0$
Sorin Bicarbon	$<24^0$	$>135^0$
St Jude medical	$<13^0$	$>120^0$
Medtronic Hall (single disc)	$70\text{-}75^0$	

Use of cinefluoroscopy in bioprosthetic valves

The utility of cinefluoroscopy is limited in patients with bioprosthetic valves. The detection of calcium on the leaflets of a tissue valve is diagnostic of degeneration but does not allow assessment of its hemodynamic impact.

Evaluation of valve ring motion

The dehiscence of prosthetic aortic valve is an uncommon complication, which may result from endocarditis, aortic aneurysm, and severe calcification or defective collagen. This results in paravalvular regurgitation. Fluoroscopy will demonstrate rocking and tilting of the base ring of the prosthesis. Tilting or rocking of more than 10° in the case of the mitral valve and more than 6° in the case of aortic valve is highly suggestive of dehiscence. Interruption must be continuous for at least 40% of the circumference of the base ring before abnormal rocking will be appreciated in cinefluoroscopy. Doppler echocardiography can identify earlier stages of valve dehiscence than fluoroscopy.

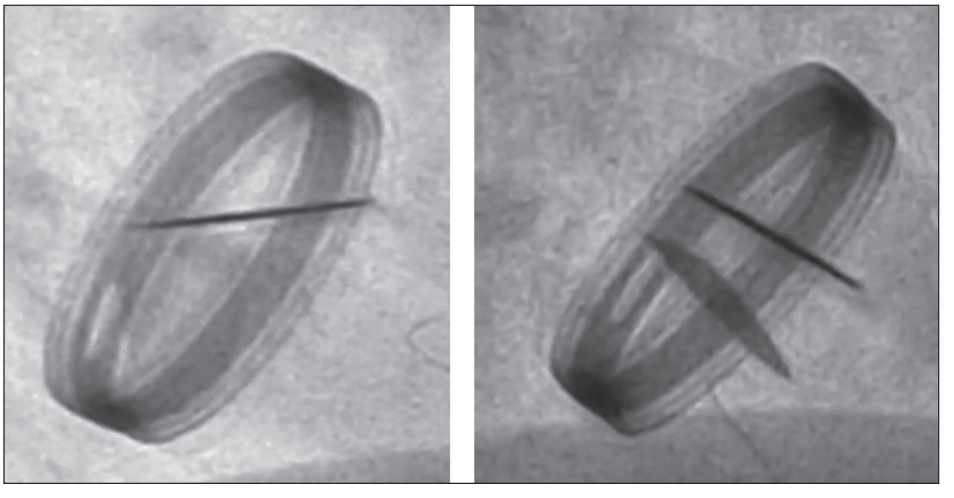
C. EVALUATION OF STRUCTURAL INTEGRITY OF VALVE

Cinefluoroscopy helps in identification of structural failure of the prosthetic valve like ball variance, poppet embolization, strut fracture and embolization of discs.

D. MONITORING THE EFFECT OF THROMBOLYSIS IN PROSTHETIC VALVE THROMBOSIS

Cinefluoroscopy is complementary to echocardiography in early diagnosis and monitoring of prosthetic valve thrombosis. A non-obstructive prosthetic valve thrombosis can be missed by 2D imaging when Doppler parameters are within normal limits and clinical features are subtle. Fluoroscopy can identify early stages of prosthetic valve thrombosis before increase in Doppler gradient. Improvement in valve leaflet mobility and normalization of opening angle helps to assess the effectiveness of thrombolysis. There are case reports demonstrating restriction of valve leaflet mobility even after normalization of Doppler gradient, which became normal after repeat doses of thrombolysis. So a pretreatment and post treatment fluoroscopy will help to assess the therapeutic benefit of thrombolysis in patients with prosthetic valve thrombosis.

To summarize, cinefluoroscopy is a noninvasive, readily available, method for detecting prosthetic valve dysfunction, especially of mechanical prosthetic heart valves. The information obtained from cinefluoroscopy is complementary to that obtained from 2D and 3D Echocardiography in diagnosing and monitoring the treatment of valve dysfunction in patients with mechanical heart valves. Fluoroscopy should always form part of diagnostic work up of patients with prosthetic heart valves dysfunction.



Stuck leaflet of bileaflet valve After thrombolysis

Figure -19

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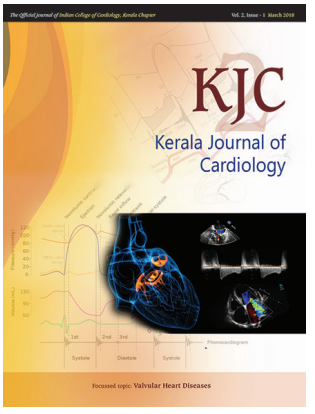
FOCUSSED REVIEW



Approach to Low-Gradient Severe Aortic Stenosis

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CASE SCENARIO

I am 79 years old…..I have high blood sugars & high blood pressures…. I' been using inhalers for the last 3 years…..I had a heart attack 6 months back.

And I had a stroke 2 years ago…. I also had angioplasty of my left leg blood vessels 1 year ago.

I am on insulin, I take aspirin and some drugs for high blood pressure. Nowadays, I have some difficulty doing my daily activities.

GRAND ROUNDS

Mrs. XX has aortic stenosis on clinical examination ECG shows left ventricular hypertrophy, on ECHO she has a mean gradient of 28 mmHg across the aortic valve. Valve area on continuity equation is 0.9 cm2. Left ventricular Ejection fraction is 60%. I think she has moderate…..er…..severe… mmo..moderate aortic stenosis

The simplest explanation is almost always somebody screwed up!

If not, call the TAVI guys!

'If it doesn't fit you must not quit' - Johnny Cochran

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What is Low-Gradient Severe As? How Common is it? What is its Relevance?

Hemodynamically severe valvular aortic stenosis (AS) is defined as a peak aortic jet velocity ≥4 m/s, a mean transvalvular pressure gradient ≥40 mmHg, and/or an aortic valve area (AVA) <1.0 cm^2 on echocardiography[1]. The fulfilment of all three criteria essentially confirms the presence of severe AS; however, discordant findings occur in a significant proportion of patients both with and without left ventricular systolic dysfunction. Up to 50% of severe AS patients are diagnosed to have low-gradient severe AS, i.e. a small AVA (<1.0 cm2) consistent with severe AS but a low-gradient (mean transvalvular pressure gradient <40 mmHg) consistent with non severe AS. Converse discordance (non severe range AVA, severe range mean gradient) occurs in less than 10%.

Since the pressure gradient is directly related to the squared function of transvalvular flow rate, even a modest decrease in flow rate can result in a significant reduction in gradient and an underestimation of stenosis severity. Low-flow low-gradient AS may occur with reduced LV ejection fraction (classical low-flow) or preserved LV ejection fraction (paradoxical low-flow). Additionally, there exists a subset of low-gradient severe AS patients with a normal flow (stroke volume index >35 mL/m^2), referred to as normal-flow, low-gradient AS. [2-4]

Thus, all cases of severe AS can be grouped into one of the following hemodynamic variants:

1) High gradient AS with either preserved LV function or LV dysfunction

2) Low-flow low-gradient AS with severe LV dysfunction [*Classical low-flow, low-gradient AS*]

3) Low-flow low-gradient AS with preserved LV function [*paradoxical low-flow, low-gradient AS*] and

4) Normal-flow low-gradient AS with preserved LV function.

The last three subsets pose considerable diagnostic as well as therapeutic challenges because of the uncertainty about the actual stenosis severity due to AVA-gradient discrepancy. In all these three conditions, it is important to rule out measurement errors and pseudo severe AS. Classic low-flow, low-gradient AS with LV dysfunction has poor clinical outcomes when managed conservatively; therefore, it is essential to recognize this condition early and aortic valve replacement (surgical/trans-catheter) performed.[5,6] Paradoxical low-flow, low-gradient AS is a heterogeneous entity, and management decisions are even more challenging. Clinically, these patients often have considerable hypertrophy with small cavity sizes (thereby lowering the stroke volume), reduced longitudinal function and high valve-arterial impedance.[5] Paradoxical low-flow AS is associated with female gender, older age and systemic hypertension.[6] These patients have better outcomes compared with the classical low-flow low-gradient AS, and symptomatic patients have similar mortality benefit from aortic valve replacement compared with their normal flow counterparts.[7,8] The third sub type of low-gradient AS, the normal-flow low-gradient AS might be related to inherent discrepancies in the guidelines criteria for severe AS, but can occur associated with reduced aortic compliance and associated systolic hypertension. These patients tend to have a better survival compared with the other two categories of low-gradient AS.

APPROACH TO THE MANAGEMENT OF LOW-GRADIENT SEVERE AS

When do you suspect low gradient severe AS?

Low gradient severe AS is suspected when the measured aortic valve area (derived by the continuity equation) is severe and the transvalvular mean gradient is not (figure 1).

Note:

1. *In order not to miss the spectrum of low gradient severe AS, it is essential to systematically incorporate AVA measurement by continuity equation and stroke volume index during routine ECHO evaluation of an AS patient.*

2. *To avoid erroneous AVA measurements, it is imperative to follow the steps mentioned below.*

   a. *Align pulse wave Doppler parallel to LV outflow in an apical long axis or five chamber view to obtain optimal LVOT velocity signals. Position sample volume 5-10 mm below the aortic valve. Sweep speed of 100mm/s.*

   b. *Measure LVOT diameter 5mm below the aortic leaflet insertion in a zoomed parasternal long-axis image in mid-systole and from inner edge to inner edge.*

   c. *Use highest transaortic velocity measured by continuous wave Doppler interrogation performed from a multiple acoustic window interrogation (apical,right parasternal and suprasternal windows etc). Ensure continuous-wave beam is well aligned with the aortic flow jet.*

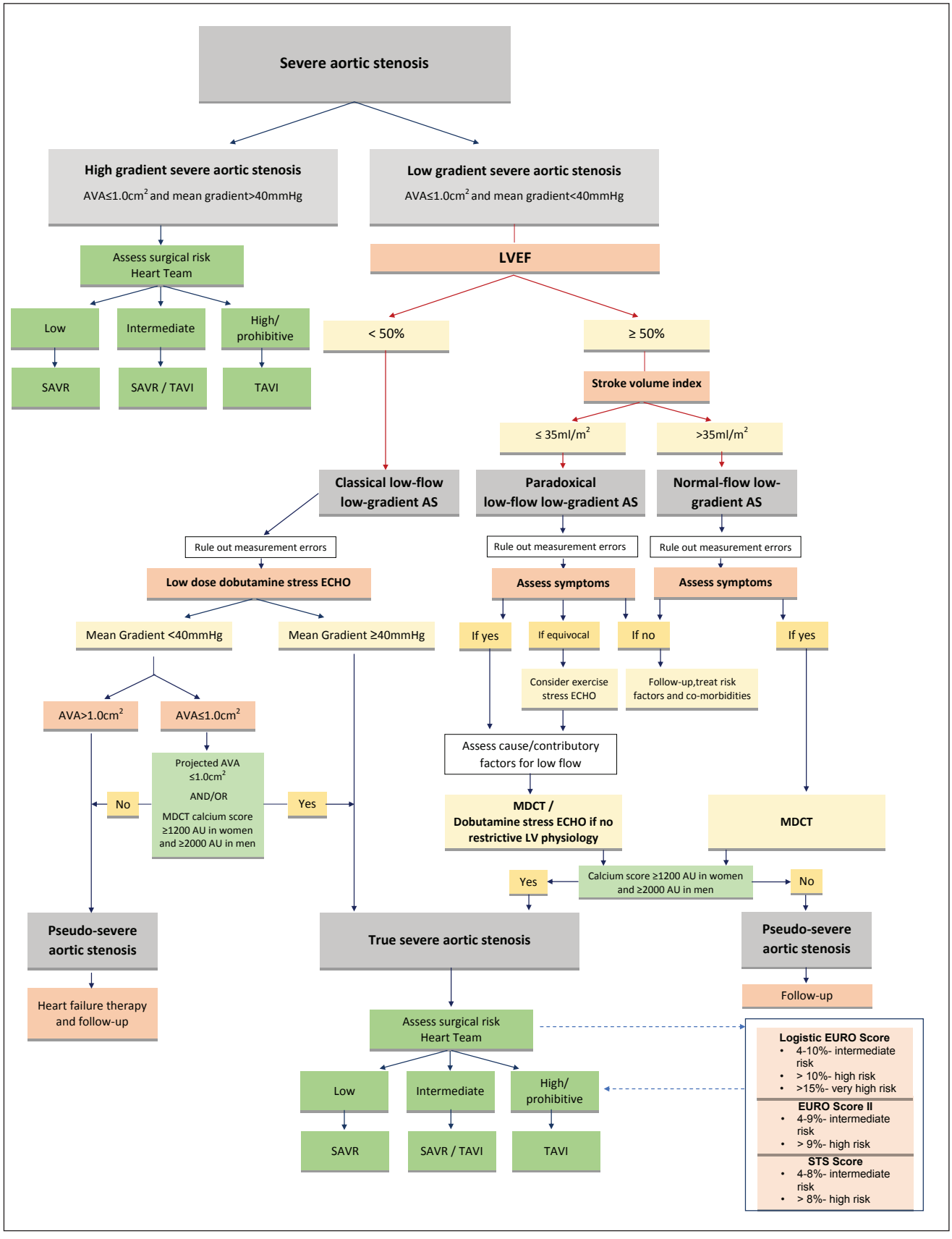

Figure 1. Clinical-hemodynamic spectrum of severe aortic stenosis - An algorithm for management
AVA, aortic valve area; MDCT, multi detector computed tomography, AS, aortic stenosis; SAVR, surgical aortic valve replacement; TAVI, transcatheter aortic valve implantation.

d. Consider indexing AVA for body surface area.

If the Doppler velocity index (ratio of LVOT to transaortic velocity) is more than 0.25 in the presence of a small AVA, consider possibility of an underestimated LVOT velocity or diameter.

Effective orifice area derived by continuity equation is usually slightly smaller than the anatomic AVA obtained by planimetry (since continuity equation method assumes LVOT to be circular).

The next step in the diagnosis is to differentiate low-flow low-gradient AS (classical type) from paradoxical/ normal-flow low-gradient AS.

CLASSICAL LOW-FLOW LOW-GRADIENT SEVERE AS

Classical low-flow low-gradient severe AS is diagnosed if the LV ejection fraction is less than 50% in a patient with low gradient AS. Low flow state in these patients is related to low stroke volume because of depressed LV systolic function. LV systolic dysfunction can be due to presence of severe AS with LV afterload mismatch (true severe AS) and/or due to presence of concomitant myocardial dysfunction, usually ischemic. In the latter case, degree of AS severity may be overestimated because of an incomplete valve opening (pseudo-severe AS).

Differentiation of true severe AS from pseudo severe AS is usually done by low dose dobutamine stress ECHO (5 ug/kg/min with 5ug increments at every[5-8] min upto 20ug/kg/min). The stenosis is considered true-severe when the mean gradient is ≥40 mmHg at any of the dobutamine stress ECHO stages. On the other hand, pseudo-severe AS is characterized by a stress mean gradient < 40 mmHg and a AVA > 1cm^2.

There is a third category of patients whose stress mean gradient remains < 40 mmHg but with a AVA < 1cm2 (figure 1). These are patients who have a modest increase in transvalvular flow during dobutamine stress ECHO. Since the mean gradient and AVA are largely dependent on flow rate, a parameter labelled as projected AVA at normal flow rate (250 ml/s) has been proposed to standardise the calculation of AVA. [9,10] If projected AVA at normal flow rate is < 1 cm^2, it indicates true severe AS and if it is > 1cm^2 it indicates pseudo severe stenosis. Projected AVA at normal flow rate can be calculated by measuring AVA and transvalvular flow rate at a minimum of two different flow rates during dobutamine stress ECHO using the equation:

Projected AVA at normal flow rate
= AVArest + VC x (250-Qrest)

where AVArest is the resting AVA, Qrest is the resting mean transvalvular flow rate and VC is the 'valve compliance' or slope of the valve area – transvalvular flow relationship. VC is calculated as (AVApeak-AVArest)/ (Qpeak-Qrest).

Multidetector computed tomography (MDCT) is a useful tool for corroborating stenosis severity (by measuring aortic valve calcification) in this third category of patients (figure 1).[11-13]

True severe low-flow low-gradient AS has poor outcomes when managed conservatively, and hence warrants interventional or surgical management (figure 1) unless life expectancy is less than one year. Associated coronary artery disease also needs to be addressed. Conservative management is preferred for patients with pseudo-severe AS. LV dyssynchrony may be present in some of the patients without LV flow reserve (lack of an increase in systolic velocity integral>20% during Dobutamine Stress Echo) and these patients may benefit from cardiac resynchronization therapy.[14]

PARADOXICAL LOW-FLOW LOW-GRADIENT SEVERE AS

Presence of normal LV systolic function does not rule out a low-flow state and hence, stroke volume or the mean transvalvular flow rate should be determined to assess low-flow state. Low-flow is defined as indexed stroke volume <35 ml/m2 or a mean transvalvular flow rate (stroke volume/systolic ejection period) <200ml/s.[3] Nearly 1/3rd of AS patients are determined to have paradoxical low-flow low-gradient AS based on the above criteria, and characterized by the presence of a small LV cavity, impaired LV diastolic filling and systolic longitudinal function.[3] For management of this group of patients, the steps given below may be followed. Step 1: Rule out measurement errors (see above box). Re-check carefully to assess whether the patient has moderate stenosis with an underestimated stroke volume index and AVA or severe stenosis with an underestimated gradient. Step 2: Assess symptoms (exercise testing if feasible). Step 3: Assess and treat contributory factors for low flow- hypertension, atrial fibrillation, mitral regurgitation, mitral stenosis, right ventricular dysfunction, and tricuspid regurgitation etc. Step 4: Confirm stenosis severity by MDCT or low dose dobutamine stress ECHO if feasible (figure 1). Dobutamine stress ECHO should not be used in patients with severe restrictive LV physiology.

Aortic valve replacement should be considered in symptomatic true-severe paradoxical low-flow low-gradient AS patients, and those with pseudo-severe AS should be managed conservatively.

NORMAL FLOW LOW-GRADIENT SEVERE AS

Normal-flow, low-gradient AS is characterized by an AVA ≤ 1.0 cm2, indexed AVA ≤ 0.6 cm2/m2, mean gradient < 40 mmHg, LVEF ≥50% and a stroke volume index > 35 mL/m2. This category might be due to inherent discrepancies in the guidelines criteria for severe AS i.e, the AVA cut-off value of 1.0 cm2 for defining AS severity does not correspond to a mean gradient of 40 mmHg but rather to a gradient of 30–35 mmHg.[15] Normal flow low-gradient AS can also occur in the context of small body size (moderate aortic stenosis with small body surface area) and prolonged ejection time (normal stroke volume index, but reduced transvalvular flow), and reduced aortic compliance and systolic hypertension (markedly reduced gradient).[3-16] Approach to the management of normal flow low-gradient AS is similar to paradoxical low-flow low-gradient AS (figure 1).

In conclusion, low gradient AS is a challenging entity with three main subtypes. Differentiating these subtypes is important from both a prognostic and therapeutic stand point. Minimizing measurement errors and differentiating true severe AS (benefit from aortic valve replacement) from pseudo severe AS (managed conservatively) are the crucial factors in the management of low gradient AS. Currently, low dose dobutamine stress ECHO and MDCT are the key modalities for proper diagnosis.

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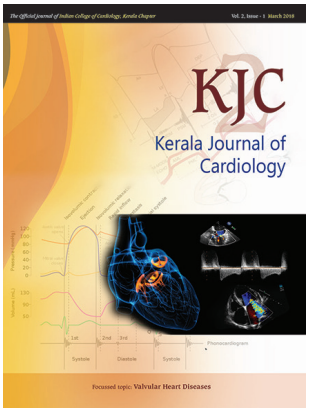

Investigations and Timing of Interventions in Valvular Heart Diseases

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The management of valvular heart disease (VHD) depends on several questions:

1. What are the symptoms (if any)? 2. What, and how severe, is the lesion? 3. How is the relevant ventricle coping?

Precise evaluation of the patient's history and symptomatic status as well as proper physical examination are crucial for the diagnosis and management of VHD. ECG and xray chest are two basic investigations for any patient with valvular heart disease. (Table 1)

Cardiac imaging is crucial for accurate determination of the nature and severity of the lesion, ventricular size and function. Echocardiography is the key technique to diagnose VHD and assess its severity and prognosis. Other non-invasive investigations such as stress testing, CMR, CT, fluoroscopy and biomarkers are complementary. CMR provides an accurate assessment of valvular function, particularly quantification of regurgitation and accurate LV mass and volumes. B-type natriuretic peptide levels may provide additional information on severity and prognosis. (Tables 2 & 3)

CHEST X-RAY (CXR) IN VALVULAR HEART DISEASE

The chest X-ray can provide useful information on ventricular size, left atrial and pulmonary artery dilatation, and pulmonary congestion/oedema. (Figures 1, 2 & 3)

LA Enlargement

Direct visualisation of the enlarged atrium

1. Double density sign(when the right side of the left atrium pushes into the adjacent lung, and becomes visible superimposed or even beyond the normal right heart border known as atrial escape)
2. Oblique measurement of greater than 7cm
3. Convex left atrial appendage (third mogul sign)

Indirect signs

1. Splaying of the carina, with the increase of the tracheal bifurcation angle to over 90 degrees
2. Posterior displacement of the left mainstem bronchus on the lateral radiograph (right and left bronchi, therefore, do not overlap, but rather form an upside down 'V', sometimes referred to as the walking man sign)
3. Superior displacement of the left mainstem bronchus on frontal view
4. Posterior displacement of a barium-filled oesophagus or nasogastric tube

RA Enlargement

5. Right atrial convexity is more than 50% of the cardiovascular height
6. Right atrial margin is more than 5.5 cm from the midline

RV Enlargement

7. Rounded left heart border
8. Uplifted cardiac apex
9. Filling of the retrosternal space(lateral view)
10. Rotation of the heart posteriorly(lateral view)

LV Enlargement

11. Left heart border is displaced leftward, inferiorly, or posteriorly
12. Rounding of the cardiac apex

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13. 'Hoffman-Rigler' sign (On a lateral chest radiograph, if the distance between the left ventricular border and the posterior border of IVC exceeds 1.8 cm, at a level 2 cm above the intersection of diaphragm and IVC).
14. 'Shmoo' sign (Refers to the appearance of a prominent, rounded left ventricle and dilated aorta on a plain AP chest radiograph giving the appearance of Shmoo, a fictional cartoon character)

CXR - Pulmonary Venous Congestion

1.Features useful for broadly assessing pulmonary oedema on a plain chest radiograph	Upper lobe pulmonary venous diversion / pulmonary venous engorgement(Stag's antler sign)
2. Features of Pulmonary interstitial oedema:	A. Peribronchial cuffing and perihilar haze B.septal lines/Kerley lines C.thickening of interlobar fissure
3.Features of pulmonary alveolar oedema:	A.Air space opacification classically in a batwing distribution. B.Air bronchograms
4.Pleural effusions and fluid in interlobar fissures (including 'vanishing' pulmonary pseudotumor)	

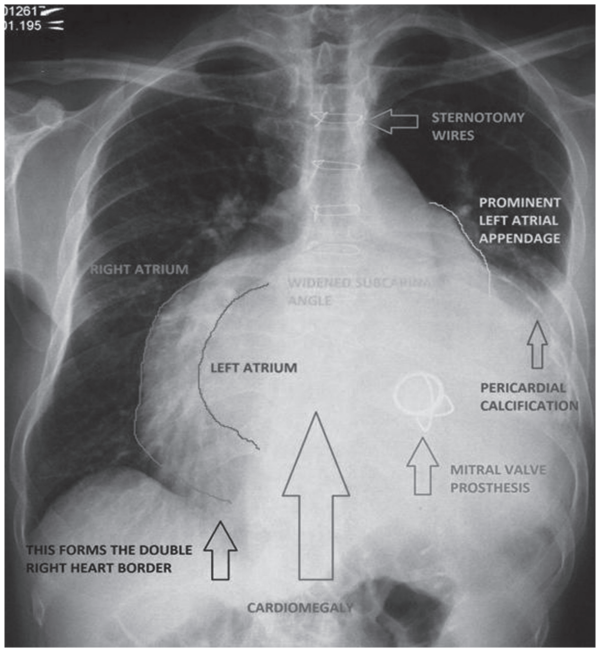


Figure 1: X-ray of post MVR patient - PA view

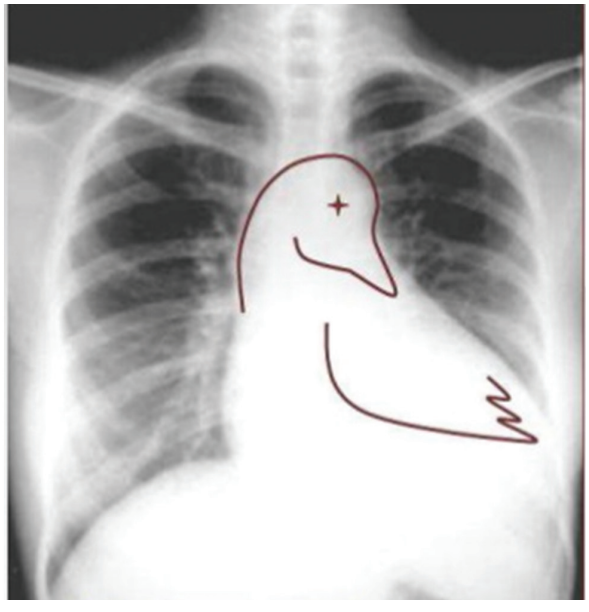


Figure 2: 'Sitting Dove' sign - Aortic regurgitation

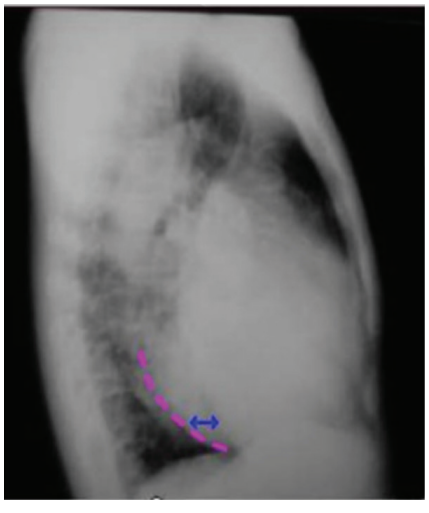


Figure 3: X-ray - Lateral view

- Posterior displacement of the posterior-inferior border of the heart.
- 'Hoffman Rigler' sign: Measured 2 cm above the intersction of diaphragm & IVC - It is positive if posterior border extends more than 1.8 cm of IVC

Table 1: Common ECG and CXR finding in valvular heart diseases

	ECG Changes	CXR findings
AS	1. LVH with secondary ST T changes in 85% 2. LA enlargement in 80% 3. AF in 10-15% 4. AV block / intraventricular block in 5%	1. Rounding of LV border and apex 2. Aortic valve and root calcification in lateral view 3. Dilated ascending aorta (particularly in BAV) 4. Cardiomegaly and pulmonary venous congestion in late stage 5. RA,RV enlargements in advanced heart failure
AR	1. Left axis deviation 2. Early LV volume overload:- prominent Q waves in L1, aVL, and V3 through V6. T wave tall and upright 3. Late phase:-total QRS amplitude increases,T wave inverted with ST depression	1. Cardiomegaly 2. The LV is enlarged laterally and inferiorly 3. Dilatation of the aortic root and aortic arch('Sitting dove' sign - Figure 2)
MS	1. LAE in 90% 2. p mitrale 3. AF 4. RV hypertrophy:- in 50% if PA pressure is 70-100 mmHg 5. R/S>1 and QRS axis > 80:- when PA pressure >100 mmHg consistently present	1. LA enlargement 2. Extreme LA enlargement indicates associated severe MR 3. RA,RV,PA dilatation with PAH 4. Kerley B lines in 30% cases with PCWP<20 and in 70% cases with PCWP>20 5. Kerley A lines in longstanding obstruction
MR	1. LAE and AF are the most common findings 2. RV Hypertrophy in 15%	1. LA,LV enlargement 2. RA,RV,PA dilatation with PAH 3. Pulmonary venous congestion in heart failure
TR	1. Incomplete RBBB 2. Q in V1 3. AF	1. Marked cardiomegaly 2. RA,RV dilatation 3. distension of azygos vein with pleural effusion

CARDIAC MAGNETIC RESONANCE(CMR)

In patients with inadequate echocardiographic quality or discrepant results, CMR should be used to assess the severity of valvular lesions (particularly regurgitant lesions),Ventricular volumes,Systolic function, abnormalities of the ascending aorta and myocardial fibrosis. CMR is the reference method for the evaluation of RV volumes and function and is useful to evaluate the consequences of TR.CMR has the highest accuracy of all imaging modalities for LV volumes,mass, and functional assessment. CMR LV end-diastolic volume has shown an ability to predict the need for surgery in aortic and mitral regurgitation.It is also possible that myocardial fibrosis detected by CMR will predict events in AS and aortic regurgitation, but further data is required before clear recommendations are made.

COMPUTED TOMOGRAPHY

Multislice computed tomography (MSCT) may contribute to evaluation of the severity of valve disease, particularly in AS and of the thoracic aorta. MSCT plays an important role in the workup of patients with VHD considered for transcatheter intervention, in particular TAVI, and for pre-procedural planning. MSCT may be useful to rule out CAD) in patients who are at low risk of CAD. In addition, CT quantification of valve calcification can help identify a higher likelihood of future progression in certain subsets of patients.

BIOMARKERS

BNP serum levels are related to NYHA functional class and prognosis,particularly in aortic stenosis and mitral regurgitation. Natriuretic peptides may be of value for risk stratification and timing of intervention, particularly in asymptomatic patients.

Table 2: Cardiac imaging for valve disease

1. DETECTION

Echocardiography indicated:

- Likely pathological murmur (not short soft ejection murmur with well-heard second sound)
- Atrial fibrillation
- Breathlessness or chest pain of potentially cardiac origin
- Aortic valve calcification as an incidental finding on chest CT
- First-degree relative with bicuspid aortic valve
- Women presenting to obstetric clinics who originate in countries with a high incidence of rheumatic disease
- High radiation exposure (Hodgkin or left breast cancer)
- High-dose drugs known to cause valve disease (cabergoline, pergolide, phentolamine, fenfluramine, benfluorex)
- Pre-CABG to detect clinically silent MR which may require additional repair
- Conditions known to be associated with valve disease (e.g. Turner's and Marfan syndromes, SLE)

Echocardiography not indicated

- General population screening
- Screening based on age alone
- Low-dose dopamine agonists used for treating microprolactinoma
- Ejection systolic murmur clearly identified as a flow murmur

CT and CMR

- These are not indicated for routine detection but incidental aortic valve calcification on CT chest is an under-recognized indication for echocardiography

2. ASSESSMENT OF VALVE DISEASE

2.1 Valve Assessment

Echocardiography indicated

- For assessing valve morphology and haemodynamic performance
- Dobutamine stress echocardiography for low gradient, severe AS with reduced LV EF
- Low-flow low-gradient aortic stenosis if LV cavity size normal
- Stress echocardiography usually with exercise for patients with symptoms despite moderate aortic stenosis

CT indicated

- For assessing valve morphology and opening if echo suboptimal and CMR not possible (pacemaker is severe claustrophobia)
- Valve calcification if results discrepant on echocardiography especially low-flow normal LV EF

CMR indicated

- For valve morphology if echo suboptimal
- Better than echocardiography for the pulmonary valve and subpulmonary and branch pulmonary artery stenoses.
- For transvalvar forward flow if echo recordings poor
- For grading mitral or aortic regurgitation if uncertain on echocardiography or additional quantification required
- Better than echocardiography for grading pulmonary regurgitation

Echocardiography not indicated

- Dobutamine stress for low-flow normal LV EF aortic stenosis if LV cavity size small

CT/CMR not indicated

- If echocardiographic data are consistent with the clinical formulation

2.2 LV and RV response

Echocardiography indicated

- For assessing anatomy and function of both LV and RV

CMR indicated

- If accurate RV volumes required

2.3 Aorta

Echocardiography indicated

- For assessing the aortic root and the proximal ascending aorta if feasible
- For detecting coarctation

- For serial assessment of a dilated aorta

CT or CMR indicated

- At baseline unless echocardiographic images certain
- If echocardiographic image quality good repeat as threshold for surgery approaches (CT better as this allows coronary anatomy and an assessment of aortic calcification)
- If echocardiographic imaging suboptimal CMR

3. RISK ASSESSMENT

Echocardiography indicated

- Assesses risk of events in aortic stenosis based on peak transaortic velocity and change in velocity with time (if the decision for surgery is uncertain based on resting measures or before non-cardiac surgery or planned pregnancy).

CMR indicated

- No clear clinical role currently but this is likely to develop based on regurgitant volume (in aortic and mitral regurgitation), LV volumes, evidence of fibrsis

4. SURVEILLANCE

Echocardiography indicated

- Moderate or severe native valve disease
- Dilated aorta or high risk of dilatation (e.g. Turner's syndrome, Marfan)
- Normally functioning bicuspid aortic valve

Echocardiography not indicated

- Aortic valve thickening without stenosis
- Tricuspid aortic valve and no more than mild aortic regurgitation
- Mild mitral regurgitation with normal valve appearance or mild prolapse and no risk factors (atrial fibrillation, dilated left atrium, age >50)

CT/CMR indicated

- Aortic dilatation if echocardiographic imaging suboptimal or region of dilatation beyond echo window

5. CARDIAC SURGERY FOR VALVE DISEASE

Pre-operative

Echocardiography indicated

- For confirming valve disease and LV and RV response

CT indicated

- For coronary angiography, assessment of aortic size and calcification and for mitral annulus calcification before transcatheter mitral valve procedures

CMR indicated

- For aorta if CT not needed for angiography, or for viability if myocardial infarction possible/present

Perioperative and on intensive care units

- TEE usually indicated, but TTE can sometimes provide useful post-operative information

Post-operative

- Echo for post-operative assessment then routine surveillance indicated (Table 3)
- Symptoms or signs consistent with dysfunction or infective endocarditis
- Before and during pregnancy or before major non-cardiac surgery

CT and CMR not indicated

CMR, cardiac magnetic resonance; CT, computed tomography; LV, left ventricle; RV, right ventricle; TEE, transoesophageal echocardiography; TTE, transthoracic echocardiography. CABJ, coronary artery bypass grafting; MR, mitral regurgitation; SLE, systemic lupus erythematosus.

Table 3: Guide to frequency of routine serial echocardiography for valve disease

Aortic valve disease	
Aortic valve thickening with no stenosis and trace or mild AR	No follow-up usually needed
Bicuspid with no AS and no more than mild AR	3–5 years
Bicuspid with valve thickening and mild AS	2 years
Tricuspid AV with mild AS with little calcification	3–5 years
Moderate AS	1–2 years
AS with Vmax>3.5 m/s and with heavy calcification or severe AS	6–12 months
Mild to moderate AR	3–5 years
Moderate AR	1–2 years
Severe AR	6–12 months
Mitral valve disease	
Normal MV appearance and trace to mild MR	No follow-up usually needed
Mild prolapse and mild MR	5 years
Moderate MR	2 years
Severe MR close to cutpoints for surgery or no previous study	6 months or less
Severe MR and normal LV	6–12 months
Right-sided Valves	
PS mild (Vmax < 3 m/s)	5 years
Moderate	2 years
Severe PS	1 year
Mild or moderate TR and normal valve and RV	No follow-up usually needed
Severe TR	1 year
Aorta (echo, CT, or CMR)	
Non-dilated with Turner's syndrome	5 years
Dilatation unless high risk or close to cutpoints for surgery	1 year

CORONARY ANGIOGRAPHY

It is indicated for the assessment of CAD when surgery or an intervention is planned, to determine if concomitant coronary revascularization is indicated. Indications are

1. Evaluation of moderate to severe secondary MR
2. CAG is recommended before valve surgery in patients with severe VHD and any of the following
   A. History of cardiovascular disease
   B. Suspected myocardial ischaemia
   C. LV systolic dysfunction
   D. In men >40 years of age and postmenopausal women
   E. One or more cardiovascular risk factors.

MULTI MODALITY INVESTIGATIONS

This may be required in selected cases and examples are given below.

i) Bicuspid AV disease assessed by echocardiography and the aorta by CMR or CT
ii) Possible low-flow, low-gradient severe AS identified on echocardiography complemented by aortic valve calcium scoring using CT
iii) Pulmonary regurgitation identified on echocardiography and RV volumes assessed by CMR
iv) Assessment before transcatheter aortic or mitral valve procedures using echo and CT.

AORTIC REGURGITATION

1. AR can be caused by primary disease of the aortic valve cusps and/or abnormalities of the aortic root and ascending aorta.
2. Degenerative diseases,Bicuspid valve and RHD are the common causes
3. Acute severe AR is mostly caused by infective endocarditis

Indication for Surgery in Chronic Severe AR

1. Symptomatic severe AR
2. Patients for CABG/ or undergoing surgery of ascending aorta or any other valve
3. Asymptomatic severe AR with LVEF≤50%.
4. Asymptomatic severe AR with LVEF≥50% with severe LV Dilatation
   a. LVEDD >70mm or
   b. LVESD >50mm or
   c. LVESD>25mm/m2 BSA in patients with small body size
5. Irrespective of the severity of aortic regurgitation
   a. Marfan syndrome who have aortic root disease with aorticdiameter≥50mm
   b. In the presence of Aortic root disease with maximal AA diameter
      (i) ≥ 45mm in Marfan syndrome and additional risk factors
      (ii) ≥ 50mm in Bicuspid valve with additional risk factors or coarctation.
      (iii) ≥ 55mm for all other patients.

Follow Ups

1. All asymptomatic patients with severe AR and normal LVF should be followed-up at least every year.
2. In patients with a first diagnosis/LV diameter and/or EF show significant changes or come close to thresholds for surgery, follow-up should be continued at 3–6-month intervals
3. In inconclusive cases BNP may be used to assess deterioration of LV function
4. Patients with mild to moderate AR can be reviewed on a yearly basis and echocardiography performed every 2 years.
5. If the ascending aorta is dilated >40 mmCT or CMR is recommended
6. Any increase >3mm should be validated by CT angiography/CMR

AORTIC STENOSIS

Doppler echocardiography is the preferred technique for assessing the severity of aortic stenosis. Hypertensive patients should be reassessed when normotensive.

Categories of AS

1. High-gradient AS(valve area <1 cm2, MG >40 mmHg)
2. Low-flow, low-gradient AS with reduced EF [valve area <1 cm2 MG<40 mmHg, EF<50%, stroke volume index (SVi) ≤35mL/m2]
3. Low-flow, low-gradient AS with preserved EF (valve area <1 cm2, mean gradient <40 mmHg, EF ≥ 50%, SVi ≤35mL/m2).
4. Normal-flow, low-gradient AS(valve area <1 cm2, mean gradient <40mmHg, EF≥50%, SVi >35mL/m2. These patients will in general have only moderate aortic stenosis.

Special Evaluation

1. Low-dose dobutamine echo is recommended in Category 2 to identify pseudo severe AS which is defined by an increase in AVA of > 1.0 cm2 with flow normalization.Contractile reserve/ Flow reserve can be also assessed - 'increase of stroke volume >20%'
2. Category 3 is more challenging and more integrated methods are used to assess severity (MSCT,3D ECHO,CMR,Invasive data etc)
3. Exercise testing - unmasking symptoms and for risk stratification of asymptomatic patients with severe AS
4. Exercise stress ECHO - increase in mean pressure gradient and change in LV function (prognostic information in asymptomatics)
5. CMR-detection and quantification of myocardial fibrosis, additional prognostic information regardless of CAD
6. BNP-predict symptom-free survival and outcome in normal and low-flow AS, useful in asymptomatic patients to determine optimal timing of intervention
7. MSCT is the preferred imaging tool before transcatheter aortic valve implantation. CT is also used to assess extent of calcification of aortic valve to confirm severity

Indications for Intervention

Symptomatic AS

1. Severe high gradient AS
2. Symptomatic severe low-flow, low-gradient AS with reduced EF and preserved contractile reserve
3. Symptomatic low-flow, low-gradient AS with normal EF after careful confirmation of Severity
4. Symptomatic low-flow, low-gradient AS with reduced EF and no contractile reserve when CT calcium scoring confirms severe aortic stenosis.

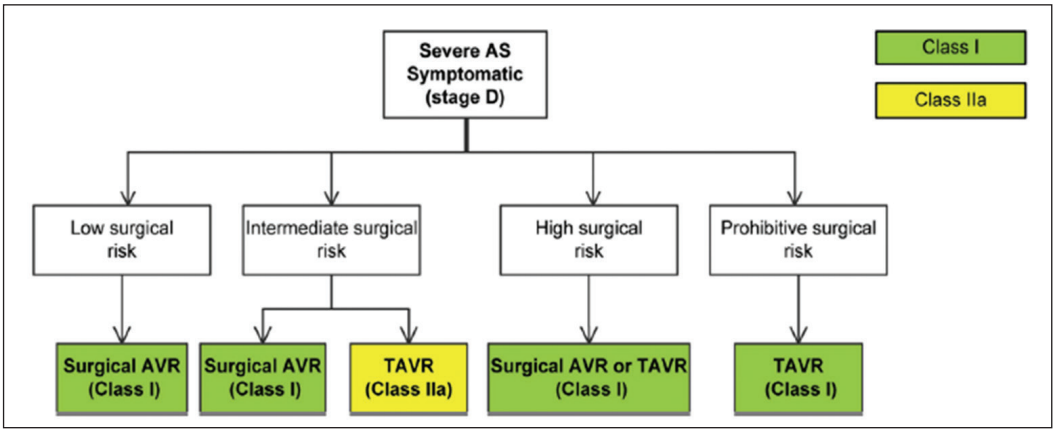


Figure 4: Choice of Transcatheter Aortic Valve Replacement (TAVR) vs. Surgical AVR in a patient with severe symptomatic AS

Asymptomatic Severe AS(Surgical AVR)

1. LV Dysfunction(LVEF< 50%) not due to another cause
2. Symptoms on exercise test clearly related to AS
3. Abnormal exercise test showing a decrease in BP below baseline
4. Low surgical risk and any of the following
   A. Very severe AS :Vmax >5.5 m/s
   B. Severe valve calcification+rate of Vmax progression ≥ 0.3 m/s/year
   C. Markedly elevated BNP levels (>3fold)by repeated measurements without other explanations
   D. Severe PAH (systolic PAPat rest >60 mmHg by invasive measurement) without other explanation

Follow up

1. Asymptomatic severe AS should be re-evaluated at least every 6 months.BNP measurement may be considered..
2. Mild and moderate aortic stenosis should be re-evaluated yearly in presence of severe calcium
3. 2 to 3 year interval in young patients with non calcified mild AS

MITRAL REGURGITATION

It is important to distinguish between primary and secondary MR. In chronic primary MR, the pathology of ≥1 of the components of the valve causes valve incompetence with systolic regurgitation. RHD and Degenerative diseases are the major causes of primary MR. Correction of the MR is curative in primary. Thus, MR is "the disease."

Normal valve components with a change in LV geometry results in secondary MR. Because MR is only 1 component of the disease restoration of mitral valve competence is not by itself curative; thus, the best therapy for chronic secondary MR is much less clear.

The rationale behind early repair in asymptomatic severe MR before pathological changes have occurred is to preserve patients in a state of normal ventricular and atrial chambers, normal rhythm and good long-term valve function, the aim being to ultimately ensure a survival rate and quality of life identical to the matched population.

Early markers of initial MR decompensation

1. Dilatation of the left atrium (volume index ≥ 60 ml/m^2)
2. Elevated BNP levels
3. Reduced functional capacity
4. Exercise induced pulmonary hypertension (≥60 mm Hg)

Superiority of mitral valve repair

The MV plays a fundamental role in the structural and functional integrity of the LV. The anterior MV leaflet is believed to act like a rudder during systole, supporting blood flow through the LV outflow tract. The chordae tendineae prevent ventricular dilatation, and discontinuation of this geometry results in progressive LV stress.LV function improves after MV repair, despite a higher degree of residual MR. Although LV function post MVR need not deteriorate (which may be a result of preservation of the subvalvular apparatus), LV function may not improve, despite optimal function of the replaced valves. Possibly, future strategies to implant a MV interventionally may overcome this problem as the entire subvalvular apparatus will be preserved with less lateral chordal displacement.

Indications for intervention in Severe primary MR

1. Mitral valve repair(MVr)should be the Preferred technique when the results are expected to be durable
2. Surgery is indicated in Symptomatic patients with LVEF >30%.
3. Surgery is indicated in Asymptomatic patients with LV dysfunction (LVESD≥45mm/LVEF≤60%).
4. Surgery should be considered in Asymptomatic patients with preserved LV function (LVESD <45mm and LVEF >60%) and AF secondary to MR or PAH (systolic pulmonary pressure at rest >50 mmHg).
5. MVR in Asymptomatic patients with preserved LVEF (>60%) and LVESD 40–44mm when a durable repair is likely, surgical risk is low and at least one of the following findings is present:
   - Flail leaflet or
   - Significant LA dilatation (volume index >_60 mL/m2 BSA) in sinus rhythm.
6. In Symptomatic patients with severe LV dysfunction (LVEF <30% and/or LVESD >55 refractory to medical therapy as follows
   i) MVR when the likelihood of successful repair is high and comorbidity low.
   ii) MVR when the likelihood of successful repair is low and comorbidity low.
7. Percutaneous edge-to-edge procedure in inoperable/ high surgical risk cases

Indications for mitral valve intervention in chronic Secondary MR

1. Severe secondary MR undergoing CABG and LVEF >30%.
2. In Symptomatic patients with severe secondary MR, LVEF <30% but with an option for revascularization and evidence of myocardial viability.
3. When revascularization is not indicated in patients with severe secondary MR and LVEF >30% who remain symptomatic despite optimal medical management (including CRT if indicated)
   i) MVR may be considered if low surgical risk
   ii) Percutaneous edge-to-edge procedure may be considered if surgical risk is not low and valve morphology is suitable
   iii) Who have no option for revascularization, the Heart Team may consider a percutaneous edge-to-edge procedure or valve surgery after careful evaluation for a ventricular assist device or heart transplantation according to individual patient characteristics

MITRAL STENOSIS

Indications for Percutaneous Mitral Commissurotomy (PMC) and mitral valve surgery in clinically significant (moderate or severe) MS (valve area ≤1.5cm2)

1. PMC is indicated in **Symptomatic** patients without unfavourable characteristics
2. PMC is indicated in **Symptomatic** patients with a contraindication or a high risk for surgery
3. MV surgery is indicated in **Symptomatic** patients who are not suitable for PMC.
4. PMC as **initial treatment** in **Symptomatic** patients with suboptimal anatomy but no unfavourable clinical characteristics for PMC
5. PMC should be considered in **Asymptomatic** patients without unfavourable clinical and anatomical characteristics for PMC and:
   i) High thromboembolic risk (history of systemic embolism, dense spontaneous contrast in the LA, new-onset or paroxysmal atrial fibrillation), and/or
   ii) High risk of haemodynamic decompensation (systolic PAP>50 mmHg at rest, need for major noncardiac surgery, desire for pregnancy).

Table 4: Unfavourable characteristics for PMC

Clinical characteristics	Anatomical characteristics
Old age	Echocardiographic score8<
History of commissurotomy	Cormier score 3 (calcification of mitral valve as assessed by fluoroscopy)
New York Heart Association class IV	Very small mitral valve area
Permanent atrial fibrillation	Severe tricuspid regurgitation
Severe PAH	

TRICUSPID STENOSIS/TRICUSPID REGURGITATION

TS is a rare condition, whereas TR is more common, especially in its secondary form.Secondary TR has to be clearly distinguished from primary TR for optimal management. Primary TR requires intervention sufficiently early to avoid secondary damage of the RV, which is associated with poor outcome.Secondary TR should be liberally treated at the time of left-sided valve surgery.

Surgery for tricuspid stenosis

1. Surgery is indicated in symptomatic patients with severe TS
2. Surgery is indicated in patients with severe TS undergoing left-sided valve intervention(Percutaneous balloon valvuloplasty can be attempted if PMC can be performed on the mitral valve)

Surgery for primary tricuspid regurgitation

A. Surgery is indicated in patients with severe primary TR undergoing left-sided valve surgery
B. In symptomatic patients with severe isolated primary TR without severe RV dysfunction.
C. In patients with moderate primary TR undergoing left-sided valve surgery
D. Surgery should be considered in asymptomatic or mildly symptomatic patients with severe isolated primary TR and progressive RV dilatation or deterioration of RV function.

Surgery for secondary tricuspid regurgitation

1. Severe secondary TR undergoing left-sided valve surgery.
2. Mild or moderate secondary TR with a dilated annulus (≥40mm or > 21 mm/m2 by 2D echocardiography) undergoing left-sided valve surgery.
3. In patients undergoing left-sided valve surgery with mild or moderate secondary TR even in the absence of annular dilatation when previous RVF has been documented.
4. After previous left-sided surgery and in absence of recurrent left-sided valve dysfunction, surgery should be considered in patients with severe TR who are symptomatic or have progressive RV dilatation/ dysfunction, in the absence of severe RV or LV dysfunction and severe pulmonary vascular disease/hypertension.

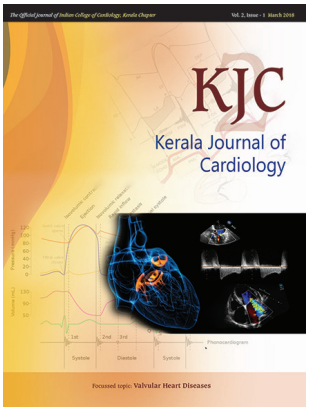
COMBINED AND MULTIPLE VALVE DISEASES

Significant stenosis and regurgitation can be found on the same valve.There is a lack of data on combined or multiple-valve diseases. This does not allow for evidence-based recommendations. When either stenosis or regurgitation is predominant, management follows the recommendations concerning the predominant VHD. When the severity of both stenosis and regurgitation is balanced, indications for interventions should be based on symptoms and objective consequences rather than on the indices of severity of stenosis or regurgitation. In this setting, consideration of the pressure gradient that reflects the haemodynamic burden of the valve lesion becomes more important. Besides the separate assessment of each valve lesion, it is necessary to take into account the interaction between the different valve lesions. Indications for intervention are based on global assessment of the consequences of the different valve lesions. The decision to intervene on multiple valves should take into account the extra surgical risk of combined procedures.

CONCLUSION

Transthoracic echocardiography remains the mainstay for imaging native and replacement valvular heart diseases. Multimodality techniques are used according to their strengths to piece together different aspects of clinical assessment which would not have been possible with single investigation alone.

KJC Pearls



Rheumatic Heart Disease in Kerala: Recent Data

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Kerala is at the threshold of achieving another milestone in healthcare sector in India. Can we achieve the goal of eliminating Rheumatic fever and rheumatic heart disease (RHD) in Kerala? This question is getting some clarity from some recent studies and reports from Kerala.

India contributes to nearly 25% to 50% of the global burden of RHD.[1,2,3,4] It is currently estimated that at least 15.6 million people all over the world have clinically recogonized RHD with annual mortality rate between 3 and 12.5%.[1,2,3,4] Recent epidemiological studies from India based on clinical criteria suggests prevalence of rheumatic heart disease in India as between 0.5 - 0.6 per 1000 children. (Table 1)

Several population-based surveys of the school children identified high volume of clinically unrecognized cases detected by echocardiographic screening.[5,6,7,8,9,10] The low sensitivity of cardiac auscultation for the detection of RHD and thereby underestimation of the disease burden has been recognized in these epidemiological studies.

Table 1: Recent epidemiological studies of rheumatic heart disease in school-children from India. (Based on clinical criteria)

Study	Publication year	Region	Age	Sample size	Prevalence of RHD (per 1000 children)
Jose et al.	2003	Vellore	6-18 years	229829	0.68
Periwal et al.	2006	Bikaner	5-14 years	3292	0.67
Misra et al.	2007	Gorakhpur	4-18 years	118212	0.5
Negi et al.	2013	Shimla (rural and urban)	5-15 years	15145	0.59

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Echocardiographic screening of Rheumatic Heart Disease in school children, suggested more than 20 times higher prevalence, of clinically 'silent' Rheumatic Heart Disease.[11,12,13,14] The reliability and acceptability of prevalence data based on Echocardiography was much higher than clinical screening.

In India, there are a few studies carried out which estimated echocardiographic prevalence of RHD in children. Bhaya et al. screened 1059 school children

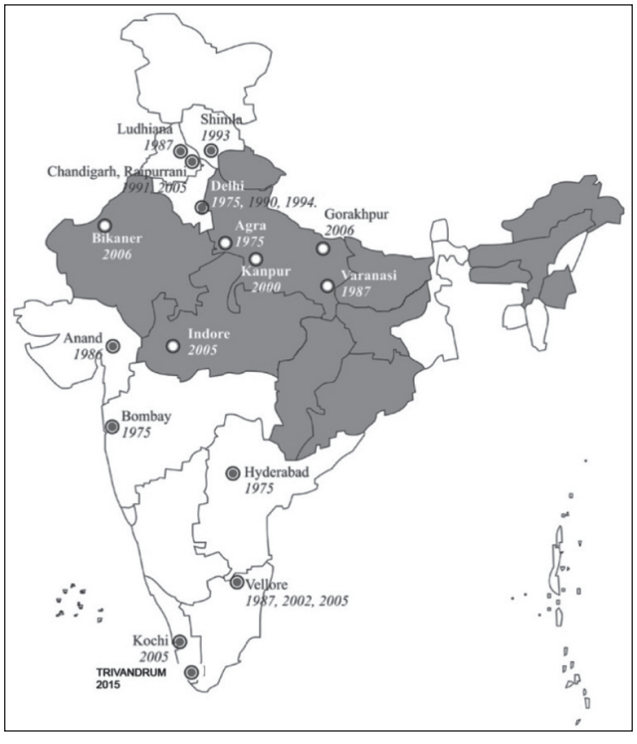

Figure 2: Rheumatic Heart Disease prevalence studies conducted in India over last 40 years (dark colour represents high prevalence rates)

aged 6–15 years from coeducational schools of Bikaner city. The prevalence of RHD was found to be 51 per 1,000 school children (95% CI: 38 to 64 per 1,000 school children) by using WHO echocardiac criteria. Similarly, a cross-sectional survey carried out by Saxena et al. among 6270 randomly selected school children (aged 5-15 years) using WHO echocardiac criteria demonstrated prevalence of 20.4 per 1000 school children (95% CI: 16.9 to 23.9 per 1000 school children).[15]

Compared to rest of India, the state of Kerala has lesser incidence of rhuematic fever and rhuematic heart diseses. Early studies conducted at Alappuzha in Kerala in 1975 showed a clinical prevalence of 2.2/1000 school children.[16] In 2002-2005, an ICMR study found clinical prevalence of rheumatic heart disease to be 0.12/1000 among school children of Kochi.[17] Suspected children were screened with WHO echocardiac criteria in this study. It has also been noted that the number of new cases of rheumatic fever reported in Kerala are coming down in recent years. (Figure 1)

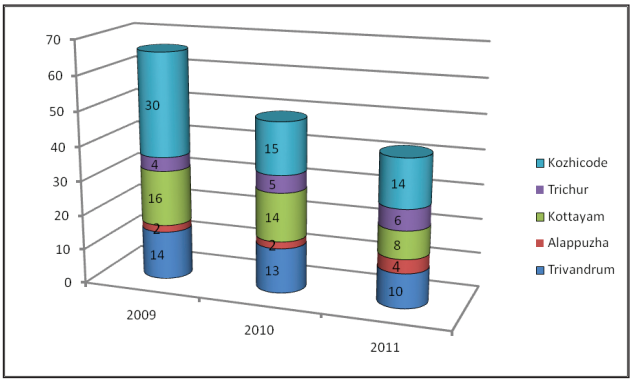

Figure 1: Rheumatic fever new cases identified in OPD from Medical colleges in Kerala during 2009-2011

In 2013-14, Medical College, Thiruvananthapuram conducted a population based cross sectional screening study, in which all the schools in rural and urban Thiruvananthapuram were included. 2060 school children between 5 - 15 years were screened, clinical examination done; followed by echocardiographic examination. The latest World Heart Federation (WHF) criteria (Table 2) were used to diagnose RHD in this study.

The Echocardiographic prevalence of rheumatic heart disease was found to be 5.83/1000 school children, of which definitive rheumatic heart disease prevalence was 2.91/1000 school children. This is very low when compared to study conducted by Saxena.et al,[15] in which 6270 school children were screened by echo using WHO criteria and the prevalence of rheumatic heart disease was 20.4/1000 school children.

Clinical prevalence of rheumatic heart disease in ICMR collaborated study in Kerala over last 40 years, was 5.3/1000 in 1972-75 and 2.5/1000 in 1984-87. Study done in 2000-2010 showed a prevalence of 0.9/1000 in Jai Vignan Mission, which also used clinical criteria. The latest echocardiographic prevalence study from Kerala is showing further decline in prevalence compared to the national study conducted by Dr. Saxena in Delhi and is consistent with the declining trends shown in the ICMR studies in Kerala.

The whole credit for this declining RHD in Kerala goes to the primary health care system, school health program initiatives, higher literacy rates among females,

Table 2: WHF criteria for echocardiographic diagnosis of RHD (2012)

➢ Echocardiographic criteria for individuals aged ≤20 years

- Definite RHD (either A, B, C, or D):
  - A) Pathological MR and at least two morphological features of RHD of the MV
  - B) MS mean gradient ≥4 mmHg*
  - C) Pathological AR and at least two morphological features of RHD of the AV†
  - D) Borderline disease of both the AV and MV§
- Borderline RHD (either A, B, or C):
  - A) At least two morphological features of RHD of the MV without pathological MR or MS
  - B) Pathological MR
  - C) Pathological AR
- Normal echocardiographic findings (all of A, B, C, and D):
  - A) MR that does not meet all four Doppler echocardiographic criteria (physiological MR)
  - B) AR that does not meet all four Doppler echocardiographic criteria (physiological AR)
  - C) An isolated morphological feature of RHD of the MV (for example, valvular thickening) without any associated pathological stenosis or regurgitation
  - D) Morphological feature of RHD of the AV (for example, valvular thickening) without any associated pathological stenosis or regurgitation

Criteria for pathological regurgitation

Pathological mitral regurgitation
(All four Doppler echocardiographic criteria must be met)
- Seen in two views
- In at least one view, jet length ≥2 cm*
- Velocity ≥3 m/s for one complete envelope
- Pan-systolic jet in at least one envelope
- Pathological aortic regurgitation
- (All four Doppler echocardiographic criteria must be met)
- Seen in two views
- In at least one view, jet length ≥1 cm*
- Velocity ≥3 m/s in early diastole
- Pan-diastolic jet in at least one envelope

**A regurgitant jet length should be measured from the vena contracta to the last pixel of regurgitant color (blue or red).*

Morphological features of RHD

Features in the MV
- AMVL thickening* >3 mm (age-specific)†
- Chordal thickening
- Restricted leaflet motion§
- Excessive leaflet tip motion during systole||
- Features in the AV
- Irregular or focal thickening¶
- Coaptation defect
- Restricted leaflet motion
- Prolapse

availability of prompt medical care, lesser over crowding and better socio economic status compared to any other State in India. Government of Kerala should start an initiative for mass screening with focused echocardiac study in unidentified areas (eg. tribal areas) for early detection of subclinical rheumatic heart disease and emphasis should be given to timely implementation of secondary prevention methods. This may lead to a possible eradication of this devastating illness from Kerala similar to some of the Western countries.

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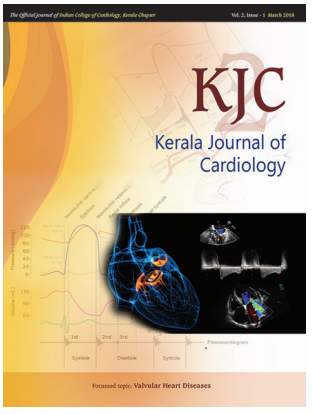

Orbital Atherectomy

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Introduction

Severe coronary artery calcification predisposes to worse outcomes in terms of stent underexpansion, increased restenosis and stent thrombosis. Rotablation facilitates better delivery of stent by ablation of calcified plaques. However, recent innovation of orbital atherectomy has been found to have more advantages than rotablation in facilitating revascularisation. Severely calcific coronaries are difficult lesions to complete revascularisation. Both rotational and orbital atherectomy enables adequate decalcification and ensures complete revascularisation.

Orbital atherectomy

Diamond 360® Coronary Orbital atherectomy[1] device facilitates stent delivery in patients with denovo severely calcified coronary artery lesions. It is an atherectomy device utilizing an orbiting eccentric diamond-coated crown on the end of a drive shaft powered by a pneumatic drive console (Figure 1). The shaft and crown are advanced over a pre-placed 0.014" proprietary guidewire, the Viper Wire™. The orbital motion of the crown removes plaque from within a diseased arterial segment; as the crown orbits, the debulking area increases, and with increments in speed, the area increases further. Only one size 1.25 mm is required for the coronary orbital atherectomy. Unlike Rotational atherectomy, it does not need another device to increase lumen area.

Principles

Works by mechanism of differential sanding technique. Facilitate stent delivery in patients who are acceptable candidates for PCI due to de novo, severely calcified coronary artery lesions. In October 2013, Cardiovascular Systems Inc. received FDA approval for the use of the Diamondback coronary orbital atherectomy in the US, whereas it is yet to receive CE Mark in Europe.

Device can be guided over 0.014" Viper guidewire Advance R coronary guide wire (335 cm), which provide more support than rotawire. It can be advanced over

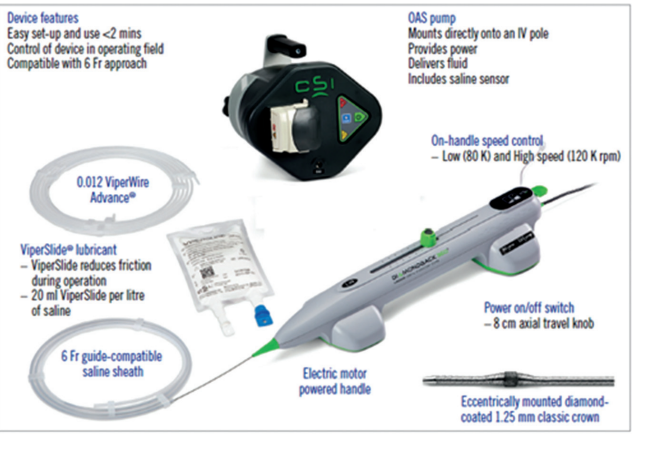

Figure 1: Diamondback 360® Coronary Orbital Atherectomy system

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a very tight stenosis due to better support. Orbital atherectomy device has unique properties of expanding orbital motion and hence increased debulking sanding surface. It can achieve increased luminal area with same size device by increasing speed of motion.

In addition, device doesn't interfere with blood perfusion, allowing its microparticles of approximately 2 micrometers to flush downstream (Figure 2). These microparticles are of smaller size compared to RBC size; hence risk of slow flow/no-reflow is minimum, compared to rotablation. In view of diamond microchips on forward and backward surface, it causes sanding of luminal obstruction in both forward and backward motion, without risk of burr entrapment (Figure 3). Diamond chips at tip increase penetration power.

It differentially ablates luminal obstruction, which is inelastic and leaves normal media which deflects away from the device, once it comes into contact with the device. The crown's orbital diameter expands radially via centrifugal force according to the following formula:

$$F = mv^2/R$$

(F = centrifugal force; m = mass of the crown; v = velocity [device rotational speed]; R = radius of rotation).

Operators can control the speed of rotation with the knowledge that a higher speed will create a larger sanding diameter by increasing lateral pressure. Based on carbon block testing, the average particle size created by Orbital atherectomy is 2.04 μm; 98.3 % of particles are smaller than red blood cell diameter; and 99.2 % of particles are smaller than capillary diameter.

Indications

Device is suited for complex calcified and fibrotic lesions, which can be prepared better with atherectomy device prior to stent delivery. Luminal area can be achieved with single size device of 1.25 mm which can achieve luminal area of 4.5 mm. In most cases, the simple passage of a single burr is sufficient to smoothen the vessel lumen, or to disrupt the continuity of intravascular calcium rings, to enable subsequent balloon dilatation and stent implantation.

Table 1 Differences between Rotational atherectomy and orbital atherectomy[2]

	Rotational atherectomy	Orbital atherectomy
Motion	Concentric motion	Orbital motion
Mechanism	Differential Cutting	Differential sanding
Guidewire	Rotawire	Viper guide wire
Device	Rotaglide	Viperglide
Support wire	Guided over 0.009" wire	Over 0.014" wire
Speed and luminal area	Increase in speed does not increase luminal gain, need to change burr size.	Increase in speed increase the orbital circumference motion and increase debulking area and increase luminal area
Microparticle size	5-10 micrometres	2 micrometres
Distal perfusion	Does not allow blood and debris to pass across burr	Allow blood flow across stenosis – hence flushing particulates downstream and reduces generated heat
Speed	Works in speed of 1,30,000-1,60,000 rpm	Works at low speed 80000 and high speed 1,20,000
TPI	TPI usually required	TPI may be required but activation needed in only 0.9%
Perforation	0.4-2.5%	1.8%
Slow flow/No-reflow		0.9%
Plane of motion	Only forward cutting with diamond microchips	Both forward and backward sanding with diamond microchips – less entrapment of burr.
Complexity	Time-consuming	Time-saving

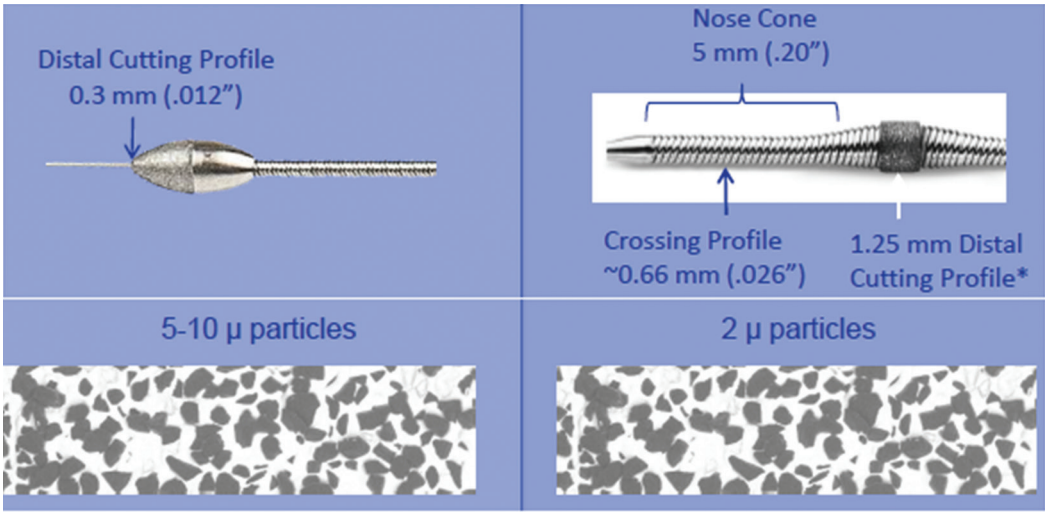

Figure 2: Rotablator vs. Orbital Atherectomy device profile and micro particles produced

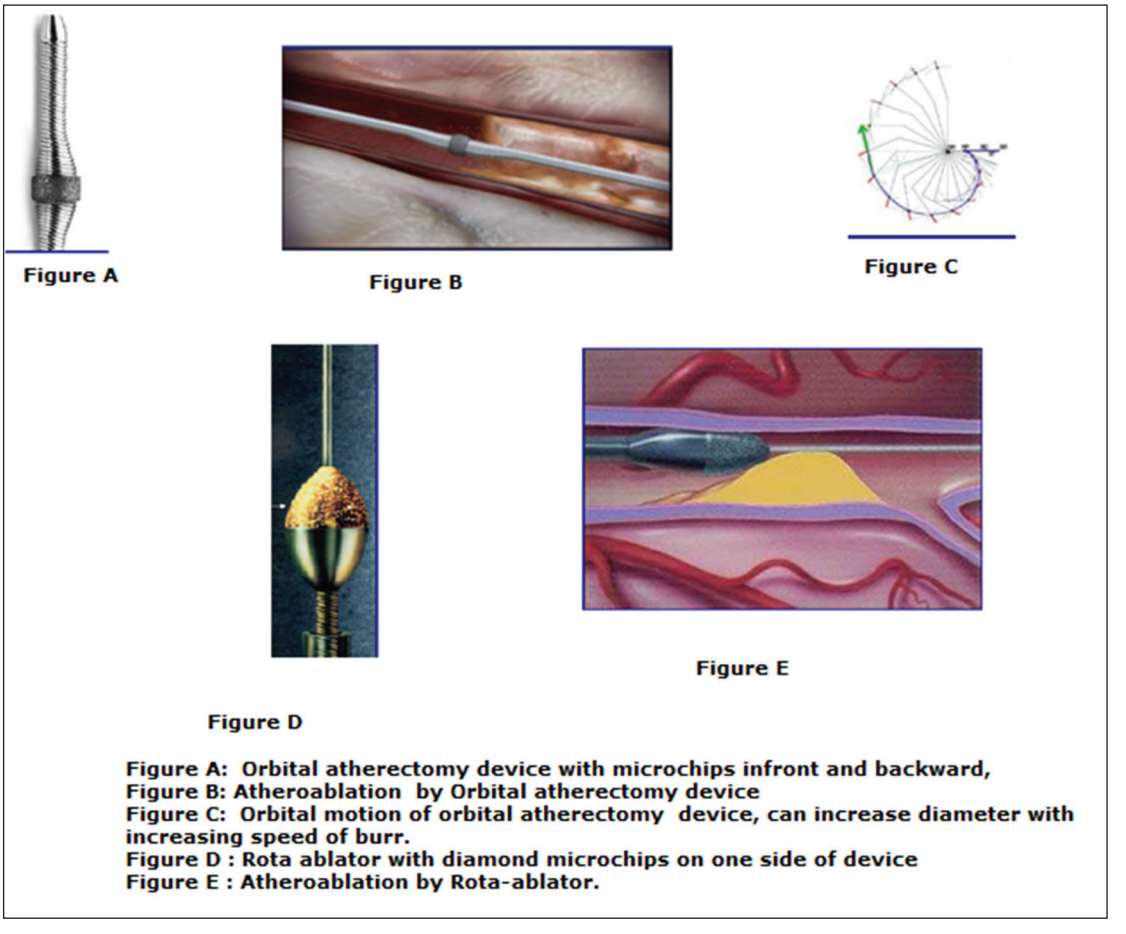

Figure 3: A - E

Data

Two landmark trials (ORBIT I and ORBIT II) from India and the US have demonstrated the clinical safety and efficacy of the orbital atherectomy, resulting in the approval by FDA in 2013.

ORBIT I

The first-in-man assessment of the coronary orbital atherectomy[3] to treat denovo calcified coronary lesions was performed in the ORBIT I clinical trial. Fifty patients with de novo calcified coronary lesions were enrolled in this non-randomised, multi-centre trial in India (CIMS, Ahmedabad).

Procedural success, defined as ≤20 % residual stenosis after stent placement, was achieved in 94 % of patients. There was no incidence of slow flow or distal embolisation. In contrast to previous PCI trials with rotational atherectomy, ORBIT I reported low rates of major adverse cardiac events (MACE) (6 % at 30 days and 8 % at 6 months). Long-term follow-up was collected on a single-centre subset of ORBIT I subjects enrolled at CIMS Hospital, India (n=33). Of the 33 subjects, the observed MACE rate at 2 years was 15 % (5/33), 3 years was 18 % (6/33) and 5 years 21 % (7/33).

ORBIT II

The ORBIT II trial[4] was a prospective, single-arm multicentre, non-blinded clinical trial that enrolled 443 consecutive patients with severely calcified coronary lesions at 49 US sites from 25 May 2010 to 26 November 2012. The Diamondback 360® Coronary orbital atherectomy was used to prepare severely calcified lesions for stent placement. The primary safety endpoint was 89.6 % freedom from 30-day MACE compared with

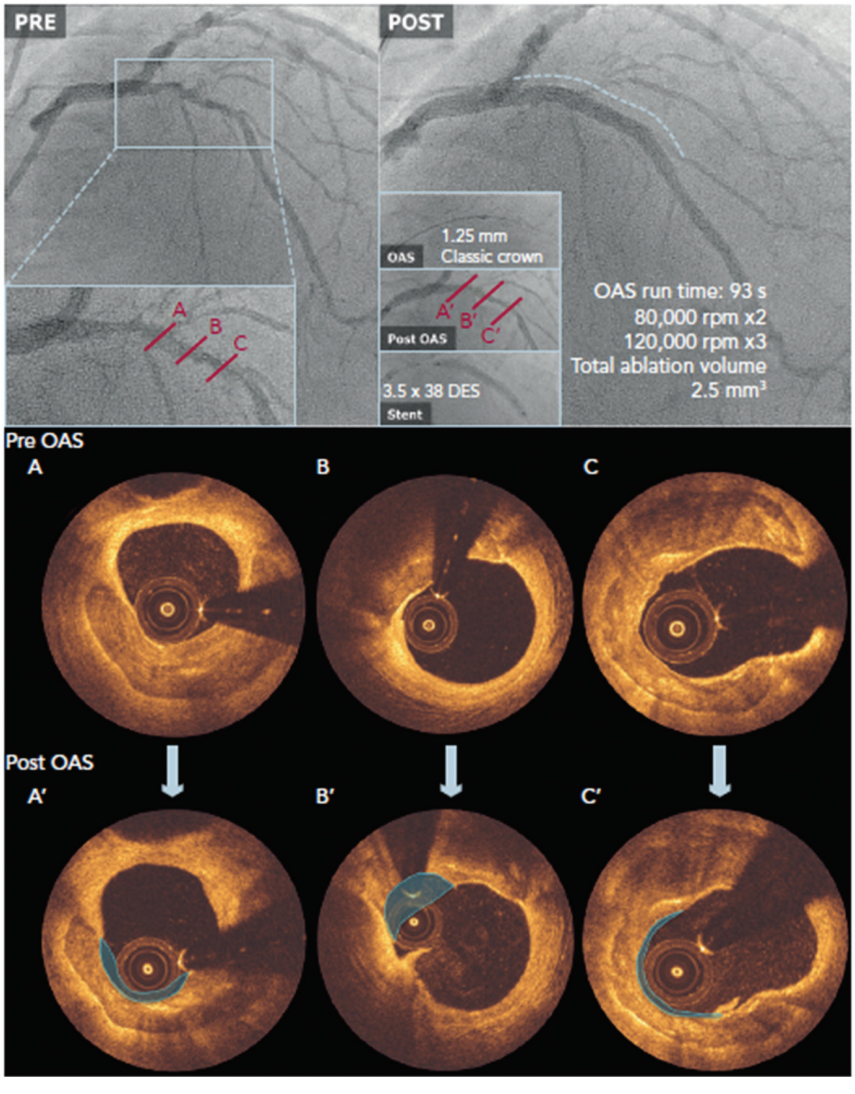

Figure 4: Example of atheroablation by orbital atherectomy device in calcific coronary lesions

the performance goal of 83 %. The primary efficacy endpoint (residual stenosis <50 % post-stent without in-hospital MACE) was 88.9 % compared with the performance goal of 82 %. Stent delivery was performed successfully in 97.7 % of cases with <50 % residual stenosis in 98.6 % of subjects.

Low rates of in-hospital Q-wave MI (0.7 %), cardiac death (0.2 %) and target vessel revascularisation (0.7 %) were reported. The incidence of slow flow or no reflow in the rotational atherectomy had been reported to be 6 % - 15 %, whereas in the ORBIT II trial the rate of persistent slow flow/no reflow for orbital atherectomy were notably very low, occurring in 0.9 % of patients. Perforations occurred in 1.8 % of patients compared with 0.4 % to 2.5 % in the several rotational atherectomy studies reporting on this complication.

Another study by Kini et al[5] assessed the mechanistic difference of impact by rotational atherectomy and orbital atherectomy with OCT. Precise imaging analyses revealed that tissue modification with deep dissections in around a third of lesions after rotational atherectomy and orbital atherectomy; however, post-orbital atherectomy dissections were significantly deeper than post-rotational atherectomy (1.14 versus 0.82 mm; P=0.048). Stents after orbital atherectomy were associated with a significantly lower per cent of stent strut malapposition than those after rotational atherectomy (4.36 versus 8.02 %; P=0.038).

COAST trial

'COAST trial' investigated primary safety and efficacy endpoints of MACE at 30 days and stent delivery success and inhospital MACE. MACE was 14% with more non Q MI, and delivery success was 85%. 99% achieved stent delivery with residual stenosis <99%.

'COAP- PCI study 2017

'COAP- PCI study 2017' examined the safety and efficacy of patients with calcified coronary artery disease who underwent atherectomy prior to PCI. 292 patients were in the orbital atherectomy arm and 416 patients were included in the rotational atherectomy group. No deaths in orbital atherectomy groups vs 6 in rota group (0% vs. 1.4%, p= 0.018). There was no significant differences in procedural safety endpoints including dissection, perforation, tamponade, need for new dialysis or major bleeding complications. Orbital atherectomy was associated with significantly decreased in-hospital mortality, and procedural radiation time compared with rotational atherectomy in this study.

Ostial lesions, unprotected left main disease and chronic total occlusions have not been studied in a clinical trial with orbital atherectomy, but crossable lesions might be safely treated with a small crown size and adjustable ablation diameter with the rotational speed control. Stent ablation is contraindicated for orbital atherectomy.

Conclusion

Severely calcified coronary lesions may necessitate atheroablation to aid PCI. Atherectomy generates microparticles which may compromise hemodynamics and induce arrhythmia. Anecdotal reports and smaller studies suggest that orbital atherectomy may induce less hemodynamic compromise and arrhythmia than rotablation. In addition, orbital atherectomy has the potential to simplify a very complex angioplasty procedure compared to rotablation in this subset of patients.

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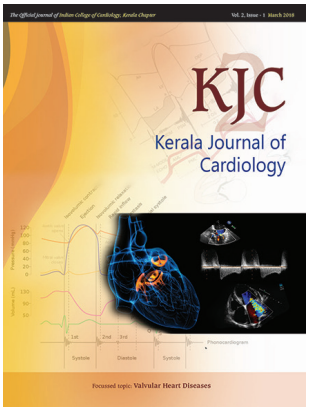

Leadless Pacemakers

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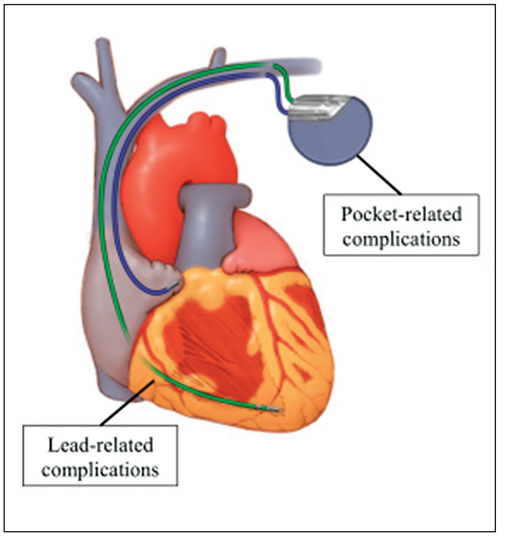
There is constant advancement in the technology and the devices used for cardiac rhythm management evolve over time. Recent advances in pacemaker devices, cardiac resynchronization therapy (CRT) devices, implantable cardioverter defibrillators (ICD) are perfect examples in this regard.

Basically all these devices have two components, a pulse generator and a lead system. The latest technological achievements in the field of pacing lead to better battery longevity, miniaturization of devices, optimal lead performance, remote monitoring systems and easier implantation techniques. Despite the progress, pacemaker therapy is still associated with significant peri- and/or post-procedural complications with transvenous lead systems. Device implantation related complications may be related to either pulse generator pocket or lead (see figure 1)

Occasionally, implantation process may result in acute or early post-procedural complications such as pneumothorax, lead dislodgment, cardiac perforation, and tamponade.[1,2,3] Moreover, chronic lead problems, such as venous thrombosis and obstruction of superior



Complications	Rate (%)
Immediate complications	
Pneumothorax	0.6-0.9
Cardiac perforation	0.1-0.3
Hematoma	0.2-0.7
Intermediate complications	
Lead dislodgement	0.4-1.7
Pocket revision because of pain	0.4
Late complications	
Lead Fracture / Insulation break	1.7-2.4
Pacemaker infections	1.8-1.9/1000 pacemaker years

Figure 1: Tranvenous Pacemaker - complications

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caval system branches, significant regurgitation of the tricuspid valve, and, most importantly, infections, occur at an incidence of 1-2% and often require a technically demanding lead extraction procedure. Overall, the rate of peri-procedural and early post-procedural complications in cardiac pacing therapy is estimated, approximately, to be 5-10%.[1] In addition, chronic lead failure due to insulation problems, lead fractures etc. were reported to be as high as 15% especially with respect to ICD leads.[4] These issues have triggered an attempt to eliminate the pacemaker lead by developing a leadless system, as early as 40 years ago.[5,6]

Leadless Pacemaker Systems

Currently, two types of leadless pacing systems are available: the Nanostim Leadless Pacemaker System (LCP) (St. Jude Medical, St Paul, MN, USA), introduced in 2012, and the Micra Transcatheter Pacing System (TPS) (Medtronic, Minneapolis, MN, USA), introduced in 2013.[7,8,9] Both systems have received a CE mark (i.e., Nanostim-LCP in 2013 and Micra-TPS in 2015) whereas, currently, only Micra-TPS is approved for use in the United States by the Food and Drug Administration (FDA). Both systems are completely intra-cardiac, and in both cases, the generator and the pacing and sensing electrodes are incorporated in a single capsule-shaped compartment implanted directly in the right ventricular wall. (Figure 2)

The cathode, in both systems, is located on the distal end of the pacemaker and is steroid eluting to reduce inflammation. For the Micra-TPS, the anode consists of a titanium ring in the proximal part of the pacemaker case, whereas for the Nanostim-LCP, most of the surface of the device serves as the anode. The Micra-TPS and Nanostim-LCP are smaller than conventional transvenous pacemakers, and the Micra-TPS is shorter and wider than the Nanostim-LCP. Therefore, a larger introducer sheath, of 24-French, is required for the Micra-TPS, compared to an introducer sheath of 18-French used for the Nanostim-LCP, to guide the device to the right ventricle. Implantation is performed in the catheterization laboratory, under fluoroscopy, through the femoral vein approach under local anaesthesia. A dedicated deflectable delivery catheter with the pacemaker adjusted on its distal part is advanced, through the inferior vena cava and the right atrium, to the right ventricle (RV).

The fixation of the Micra-TPS on the ventricular wall is achieved by four self-expanding nitinol tines, which are located at the distal end of the device, that hook on the myocardium, whereas the fixation mechanism of the Nanostim-LCP consists of a primary active screw-in helix and a secondary mechanism of three-angled nitinol tines perpendicular to the helix. After selecting the target region, the Nanostim-LCP is screwed by rotation, whereas for the Micra-TPS, the protective outer sheath is retracted allowing the tines to be deployed, engaging the myocardium and thus fixing the pacemaker in place. Following fixation, the pacemaker is liberated from the delivery catheter, although it still maintains a connection to it by a tethering mechanism. In this way, both pacemaker parameters (threshold testing, sensing and impendence) and stability (e.g., via the "tug-test"

	Nanostim™ (LCP)	Micra™ (TPS)
Dimensions (mm)	42 × 5.99	25.9 × 6.7
Volume (cm^3)	1.0	0.8
Weight (g)	2	2
Sheath size (French)	18	23
Fixation mechanism	Primary: Screw-in helix Secondary: Nylon tines	Nitinol-tines
Polarity	Bipolar	Bipolar
Pacing mode	VVI- VVIR	VVI- VVIR
Rate-responsive sensor	Blood temperature	Accelerometer
Battery	Lithium carbon monofluoride	Lithium silver vanadium oxide/carbon monofluoride
Estimated battery longevity		
• Standard settings (y)	9.8	4.7
• Alternative settings (y)	14.7	9.6
Telemetry	SJM, Model 3650	Medtronic, Model 2090
Option for retrieval	Yes	Yes

LCP: Leadless Pacemaker System, TPS: Transcatheter Pacing System, SJM: St. Jude Medical.

Figure 2: Characteristics of leadless pacing systems

under fluoroscopy) can be tested. In the case that the pacemaker performance is adequate, the system is finally released. If sensing and pacing parameters are not satisfactory, the pacemaker may be repositioned to an alternative position before final release from the delivery catheter.

Pacing mode for both the systems is similar to that for conventional VVI(R) pacemakers.[9] For the Micra-TPS, pacing thresholds are measured automatically daily, whereas rate response is provided by an accelerometer. Programming is performed using the Medtronic Model 2090 Programmer, similar to that for conventional pacemakers. The rate-responsive modality is also available for the Nanostim-LCP through measuring blood temperature. Programming is performed using the St Jude Medical Merlin Model 3650.

Battery longevity of both systems is considered comparable to that of conventional pacemakers. The battery life of the Nanostim-LCP programmed at the standard settings (e.g., 2.5 V @ 0.4 ms, 60 bpm and 100% pacing) is reported to be 9.8 years. However, the projected battery life at the alternative settings of 1.5 V @ 0.24 ms and 100% pacing increases to 14.7 years. The battery life for the Micra-TPS is reported to be 4.7 and 9.6 years at the standard and alternative settings, respectively.

Both systems are theoretically retrievable, and they contain a recapturing mechanism at their proximal end, if repositioning is required during implantation after device deployment, or, possibly, if a chronically implanted device needs to be retrieved. However, at present, experience on device retrieval is limited. Most

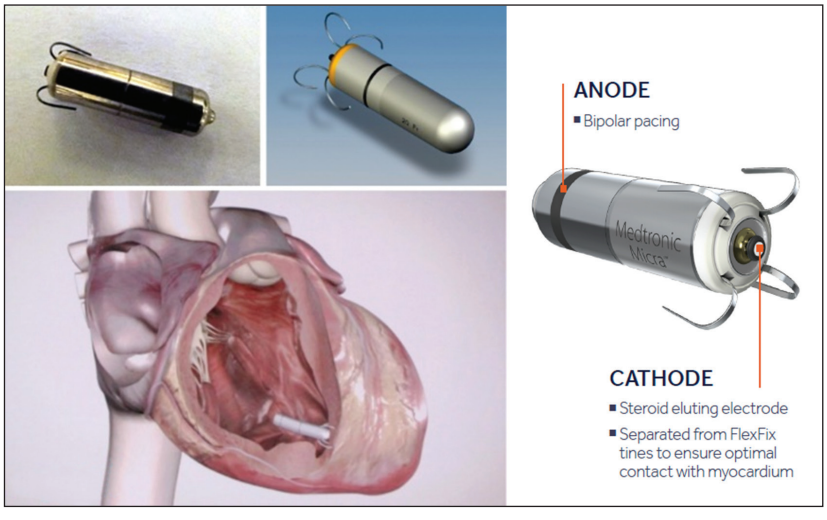

Figure 3: Micra TPS

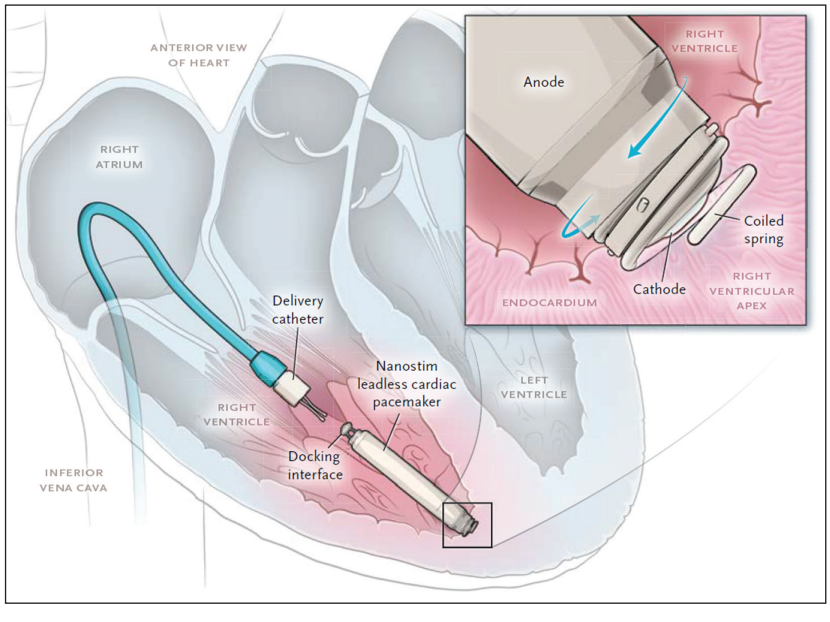

Figure 4: Nanostim LCP

data, originating from animal studies, demonstrate the feasibility of chronic extraction.[10,11] Data on humans are scarce and mostly originate from the LEADLESS II trial.[12] In this study, dislodgement of the device was reported in six patients (four to the pulmonary artery and two to the right femoral artery), and in all cases, devices were retrieved percutaneously. Furthermore, in seven patients, the leadless cardiac pacemakers were successfully retrieved at 160-180 days without complications.

Special retrieval catheters are available for the Nanostim-LCP, thus allowing the operator to snare the proximal part of the device, connect it to the retrieval catheter, and unscrew it from the ventricular wall. In the Micra Transcatheter Pacing Study, however, the device was retrieved, using a percutaneous snare, in one patient, 17 days post implantation, when intermittent loss of capture was noted without evidence of dislodgement.[13] No dislodgements were reported in this study. Retrievals of Micra devices were performed using a special Cook Retrieval Catheter equipped with a snare that captures the pacemaker's distal portion, thus enabling the delivery sheath to slide over the nitinol tines to disengage them. In most of the cases, the devices were retrieved within the first year post implantation; therefore, long-term data are still required to verify the feasibility of the removal of leadless pacemakers beyond this point, as this may be critical in the case of system infection. In addition, in the case of battery depletion, it remains questionable whether the preferred strategy is to remove the pacemaker or to proceed to an implantation of a new device at a different. Although no long-term data from studies in human exist, an animal study demonstrated that multiple Nanostim-LCPs may be successfully implanted in the RV without complications.[14]

The safety and efficacy of the Nanostim-LCP were initially studied in the LEADLESS trial, which was the first study with results in humans.[15] LEADLESS is a prospective, non-randomized, multicentre trial that was conducted in three European centres from December 2012 to April 2013. Patients having an indication for VVI(R) cardiac pacing, such as permanent atrial fibrillation with atrioventricular block, normal sinus rhythm with second- or third-degree atrioventricular block with a low level of physical activity, or short expected life span or sinus bradycardia with infrequent pauses or unexplained syncope, were recruited for the study. Thirty-three patients (mean age 77 +/- 8 years, 67% male) were enrolled in this study and received the Nanostim-LCP system. The patients were followed up pre-discharge and at 2, 6, and 12 weeks postimplantation. The implantation success rate was 97% (32 of 33 patients), and the mean procedure duration was 28 +/- 17 min. Repositioning of the system was required in 10 patients (30%). The overall complication-free rate was 94% (31 of 33 patients), and two serious adverse device events were reported (RV perforation and cardiac tamponade) during implantation. After the 12-month follow-up, the mean R-wave amplitude was 10.3 mV, the mean pacing threshold (at a 0.4-ms pulse width) was 0.43 V, and the impedance was 627 Ohms.[16] However, longer follow

Table 1: Potential advantages and disadvantages of the leadless pacemaker system

Advantages	Disadvantages
• Elimination of potential complications of conventional pacemakers related to » Venous access, vascular manipulation of the lead, and implantation of the lead at the RV (e.g., pneumo-thorax, lead dislodgment, cardiac perforation/tamponade) » Chronic lead-related complications (e.g., venous thrombosis and obstruction, tricuspid valve incompetence, infections) » Pocket-related complications (e.g., hematomas, skin erosion, pocket infections) • Cosmetic advantage • Battery longevity comparable or longer than that of conventional single-chamber transvenous pacemakers • Probably safe for use with magnetic resonance imaging • Probably causes less radiation exposure for the implanting operator	• Data demonstrating safety and efficacy of the system originating only from three nonrandomized clinical trials (LEADLESS, LEADLESS II, and Micra Transcatheter Pacing Studies) • No data regarding long-term prognosis (safety and effectiveness) • Available only for single-chamber ventricular pacing, and thus, it is reserved for patients with an indication for a VVI(R) only • Potential vascular complications related to femoral access site, due to the large-sized venous introducer sheaths (24 French for the Micra-TPS and 18 French for the Nanostim-LCP). Potential myocardial injury due to the manipulation of large catheters in the right ventricle • Potential risk of system dislodgment and device embolization, myocardial injury and pericardial effusion/ tamponade (probably carries the same risk as in conventional pacemaker implantations) • Long-term data for extraction of chronically implanted devices (e.g., in the case of infection) are missing • The best strategy for device management after battery depletion is unknown • Additional training is required for implanting operators

up data showed loss of telemetry and pacing function secondary to battery issues in some of these patients and nanostim LCP had to be recalled from market.

Micra Transcatheter Pacing Study is a prospective, nonrandomized, single study group, multisite, international clinical study that evaluated the safety and efficacy of the Micra-TPS.[13] The study included 725 patients who underwent an implantation attempt at 56 sites in 19 countries, and the analysis of the primary end points included 297 patients who reached a 6-month follow-up. The primary safety end point was that the patients should be free of system-related or procedure-related major complications. The primary efficacy end point was the percentage of patients with low and stable pacing capture thresholds at 6 months (2.0 V at a pulse width of 0.24 ms and an increase of 1.5 V from the time of implantation). The rates of major complications were also compared with those in a control cohort of 2,667 patients with transvenous pacemakers from six previously published studies. The device was successfully implanted in 719 of the 725 patients (99.2%). The primary safety end point was met in 96.0% of the cases. The major complications included 11 cardiac injuries, 5 complications at the groin puncture site, 2 cases of thromboembolism, 2 pacing issues, and 8 other complications. The rate of the primary efficacy end point was 98.3% among 292 of the 297 patients followed up for 6 months. At the 6th month, the average battery life was 12.5 years. Therefore, despite the lack of long-term data, results from these studies reveal that leadless pacing therapy is an efficacious and safe alternative to conventional pacemakers.

The introduction of leadless cardiac devices in clinical practice, undoubtedly, represents the dawn of a new era in pacing. However, further technological advances, such as development of dual-chamber leadless pacing, are necessary for their wide spread usage. Additional randomized clinical studies are required to further establish long-term efficacy and safety to determine whether leadless pacing systems can replace conventional transvenous and epicardial pacemakers. However, first encouraging data have already made leadless pacing an additional weapon in our armamentarium for the treatment of patients in whom an indication for a single-chamber pacemaker is established. This is all the more important for those patients with difficult venous anatomies and complex structural heart diseases which make conventional transvenous pacing systems technically impossible.

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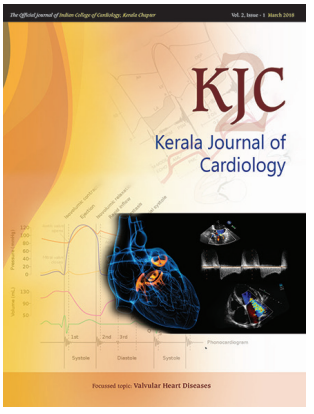

Infective Endocarditis – the 'Peripheral' Signs

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Infective endocarditis (IE), in its various avatars, continues to vex the clinician. The adjunctive manifestations, often termed the 'peripheral signs or stigmata' add an element of reassurance when making a diagnosis of this important condition. In general, these may reflect either embolization from a vegetation or the effect of circulating immune complexes and systemic immunopathologic factors. A careful physical examination (beyond the heart) is a must in any case of unexplained fever, and especially so in a patient with heart disease. Even if the transthoracic echocardiogram appears normal, the presence of a typical peripheral sign should heighten clinical suspicion and prompt an early consideration of transesophageal echocardiography and blood investigations including blood culture.

1. How common are the peripheral signs of infective endocarditis (IE) ?

In the pre-antibiotic era, these signs were very common. However, in the current era of antibiotic therapy, the incidence has come down significantly. In the ICE-PCS (International Collaboration on Endocarditis – Prospective Cohort) study, peripheral stigmata other than petechiae and conjunctival haemorrhage were seen in less than 10% of patients with documented IE.[1]

2. Which is the most common among these ?

Petechiae are the most common lesions, reported in 10-40% of cases.[2] They may be conjunctival, mucosal (oral) or cutaneous (on extremities). Purpura and ecchymosis may occur in fulminant, acute IE.[3]

3. What are splinter hemorrhages ?

They are small (2-3 mm long) linear subungual hemorrhages usually seen in the proximal nailbed.[2]They are seen in 5-15% of patients. They change in colour with time over one or two days, from reddish-brown to brownish-black, and may coalesce. Those seen in the distal one-third of the finger nails may be related to trauma and are less likely to be related to IE. Other causes of splinter hemorrhages are : rheumatoid arthritis, trauma, vasculitis, meningococcemia, trichinosis and atrial myxoma.[4]

4. What are Roth's spots ?

Roth spots are round, oval or flame shaped retinal hemorrhages with a white centre, seen on fundus examination. It was initially described in 1872 by Moritz Roth, a Swiss pathologist as 'retinitis septica'.[5] The white centre is believed to be due to embolic occlusion from the vegetation and anoxia. Another postulate is

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the formation of a platelet-fibrin thrombus secondary to rupture of an inner retinal capillary.[6] It is seen in 2-10 % of patients with IE. However, it is a non-specific sign of IE as it is also seen in conditions like leukemia, severe anemia, anoxia, CO poisoning, vasculitis, HIV, hypertensive and diabetic retinopathy, neonatal birth trauma and battered baby syndrome.[7]

5. Osler's nodes – What do they look like ?

Classically, these are painful , pea-sized nodules seen on the pulp or tips of fingers or toes. It is named after the great Physician Sir William Osler, who described it in 1893 as an important feature of endocarditis. Seen in 5-10% of patients with IE, these are immunologically mediated and pathologically demonstrate a leucocytoclastic vasculitis and perivasculitis without microabscess formation or visible organisms.[8] Rarely, organisms have been cultured from Osler's nodes, probably indicating that the organism could have triggered the immunologic reaction.[9] They can occur suddenly, may have premonitory parasthesias and usually resolve in a few days after appropriate antibiotic therapy , without leaving any sequelae. Other conditions in which these lesions are described are : bacteremia, typhoid fever, gonococcemia and SLE (Systemic Lupus Erythematosus).[10]

6. What are Janeway lesions ?

These are painless erythematous or hemorrhagic , macular lesions, often with an irregular outline seen on palms and soles, thought to be caused by septic microemboli. It is named after the American Physician Edward G Janeway, who described it in 1899 as a feature of 'malignant endocarditis'. They are believed to be due to septic microemboli to the skin, producing an inflammatory infiltrate in the dermis, but not the epidermis.[4,11] Janeway lesions are seen in 5-10% of patients, may occur in crops and are most often associated with Staphylococcal IE.[2] Biopsy reveals microabscesses without arteritis, and organisms may even be cultured from them.[12]

7. What are the 2 major clinical differences between Osler's nodes and Janeway lesions ?

Osler's nodes are painful, while Janeway lesions are not. Osler's nodes usually occur on the pulp of fingers, while Janeway lesions occur on the palms and soles, and not on the pads of fingers.

8. How often do embolic events occur ?

Vigilance for symptoms and signs of embolic events is essential, along with daily examination of peripheral pulses in all patients with endocarditis. Cerebral embolism is the most common (10-20%) and stroke is a particularly devastating complication, with adverse prognosis. The second most common location for septic embolization is the spleen.[13] Renal involvement in IE can be due to renal infarcts, but may also be related to immunologically mediated glomerulonephritis or antibiotic toxicity. Peripheral arterial, mesenteric and coronary embolisms may also occur. Many of these embolisms may be clinically silent and will be detected by investigative modalities like ultrasound or CT imaging. Larger vegetations (>10 mm), hypermobile ones and those on the anterior mitral leaflet are more prone for embolism.[14]

9. Does significant splenomegaly occur in IE ?

Splenomegaly is a feature of subacute IE rather than acute IE and occurs in around 10% of patients.[15] Most patients are asymptomatic. However, some patients may complain of vague left upper quadrant abdominal fullness or pain, especially if there are septic splenic infarcts from a left sided endocarditis, or if splenic abscesses (<5%) develop.[14] Massive splenomegaly is very unusual in IE, and an alternative diagnosis must be considered.

10. What about clubbing in IE ?

Ofcourse, clubbing (seen in 10-15%) should not be forgotten amidst the fascination for named signs.[12,16] Clubbing in IE is usually mild and advanced stages of clubbing (like the 'drumstick' appearance) are uncommon in the current era.

11. What is the status of the peripheral signs according to the IE diagnostic criteria ?

Vascular phenomena and immunologic phenomena are two among the five minor criteria as per the Modified Duke criteria.[2] The vascular phenomena included are: major arterial emboli, septic pulmonary infarcts (in right sided IE), mycotic aneurysm, intracranial haemorrhage, conjunctival hemorrhages and Janeway lesions. The immunologic phenomena included are: glomerulonephritis, Osler nodes, Roth spots and rheumatoid factor.

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