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Examination of the Cardiovascular system (CVS)

Examination of CVS should follow the following sequence:

I. Arterial pulses.
II. Blood pressure.
III. Venous pulses.
IV. Precordium.

I. Arterial pulses

Presence of main arterial pulses (radial, brachial, carotid, femoral, popliteal, posterior tibial, dorsalis pedis**)** should be noted & both sides compared. The observation made are regarding:

1. Rate 2. Rhythm 3. Volume & Character 4. Radio-femoral delay

In newborn & infants, it may not be possible to appreciate radial pulse. In such case, the brachial, femoral or carotid pulse should be palpated.

1. Pulse Rate

Count the pulse rate in about 1 minute. In newborn & infants, it is rapid & rate fluctuates widely. As the child grows older, pulse rate becomes slower.

Throughout childhood, pulse rate is labile & increase rapidly in response to muscular activity & emotional stimuli. Persistent tachycardia (over 200 in neonates, 150 in infancy & 120 in older children) may be due to pathologic conditions like fever, dehydration, anemia, heart failure, or cardiac arrhythmia or hypoxia.

To determine the cardiac rate uninfluenced by external stimuli, pulse should be recorded several times throughout the day & night, preferably when child is quite or asleep.

Slow pulse is rare in children until adolescence, when rate as low as 40 bpm may be seen in athletic boy. In case of atrial fibrillation (AF), heart rate may be more than pulse rate; this difference is called "pulse deficit".

***Average & upper limit Heart Rate at rest in pediatrics age groups (bpm)**

Age	Average	Upper limit
0-6 months	140	160
6-12 months	130	150
1-2 years	110	130
2-6 years	100	120
6-10 years	95	110
10-14 years	85	100

2. Pulse Rhythm

The rhythm of heart beat in newborn & infant is often irregular & closely related to respiration. When the infant is asleep, there may be periods of apnea & slow cardiac rate, which speed up when respiration is resumed. This arrhythmia is even more evident in prematures & in cases of shock or intracranial hemorrhage.

Normally in children, heart rate speed up with inspiration & slow down with expiration (sinus arrhythmia) which has no pathological significance. After excluding these factors, decide whether rhythm is regular or irregular & if irregular, whether regularly irregular (heart block) or irregularly irregular (extra systole or fibrillation). Extra systole are occasional irregularities which disappear on exercise. It may be due to digitalis toxicity, rheumatic carditis & infectious fever (as influenza & diphtheria) but has no prognostic significance. Pathological irregularities of rhythm are quite uncommon in children.

3. Pulse Volume & Character

It is usually difficult to determine in younger children.

- **Large volume & rapid collapse (water-hammer or collapsing pulse):** seen in PDA (common), AR (rare) & generalized vasodilation (as in fever & severe anemia), thyrotoxicosis & arteriovenous communication of big size.
- **Small volume:** seen in HF, shock & outflow obstruction (AS, PS, pericardial effusion).
- **Small volume & slow-rising & sustained (plateau pulse):** seen in AS.
- **Varying volume:** seen in extrasystole, AF & incomplete heart block.
- **Normal volume & rapidly rising & ill sustained (jerky pulse):** seen in hypertrophic obstructive cardiomyopathy (HOCM).
- **Pulsus paradoxus:** not a paradox at all but an exaggeration of a normal phenomenon (fall in BP with inspiration, if > 15 mmHg, it is abnormal & possible causes include pericardial effusion, constrictive pericarditis & severe airway obstruction (asthma)

Rarely, volume may be very low in pulses of upper extremities & higher volume & blood pressure (BP) in lower extremities. It is seen in Tkayasu disease (pulsless disease).

4. Radio-femoral Delay

Routine examination of all children should include palpation of femoral pulses. Characteristically femoral pulsation is diminished & delayed in nearly all cases of coartication of aorta (COA), while normally it occurs a little earlier than radial.

II. Blood Pressure (BP)

Blood pressure varies with age of the child with variable method for its measurement.

III. Venous Pulse

Inspection of cervical veins may yield considerable diagnostic information. The child should lie in bed or in the lap of mother at angle of 45 degree. Neck muscle should be relaxed.

In many children, normally, the distention of external jugular veins may be seen due to constriction of vein while passing through deep cervical fascia. Venous pulsation may be seen without visible distention.

For measuring venous pressure, mean height of the venous column is measured by observing vertical height to which the distended & pulsating portion of vein rises above the sternal angle.

Since great veins are in direct communication with right atrium, changes of pressure & volume of the chamber are transmitted to the vein directly.

Raised venous pressure (apparent as engorged veins) is indicative of right heart failure. When neck veins are not engorged although some signs & symptoms are suggestive of congestive cardiac failure (CCF), do the "hepato-jegular reflux" which is positive in case of prominence of jugular veins due to pressing over the liver.

Normal height of venous pulse is less than 4 cm & it is increased in right side heart failure, fluid overload, constrictive pericarditis, tricuspid stenosis (TS), superior vena cava obstruction & valsalva maneuver.

IV. The Precordium

1. Inspection & Palpation

Note any deformity in the chest wall & bulging or depression in bony cage, which may be due to cardiomegaly, mediastinal displacement, or nutritional & vitamin deficiency.

Veins on the chest wall, if prominent, must be noted & direction of flow is seen. In superior mediastinal tumor or growth, the blood flow in collaterals from above downwards, while in inferior vena cava obstruction, the blood flows from below upwards. If child is asked to stand leaning forwards, arterial collaterals may be visible on his shoulder & back in case of COA.

Localize the "apex beat" which is the furthest lateral & inferior position at which the finger is lifted by the cardiac impulse. Up to 2 years of life, it may be in the 4^{th} intercostals space, in or just lateral to mid-clavicular line, while later on it is in the 5^{th} space at or just medial to that line. Flexibility of mediastinum permits the heart to shift towards the side on the child lies. The real shift of heart can be due to pulmonary, cardiac or skeletal causes. In left ventricular hypertrophy (LVH), the beat quality is "forceful" & it may extend down & outwards. In right ventricular hypertrophy (RVH), the beat quality is "tapping" & it may be shifted outside in the same intercostals space.

RVH is usually associated with clockwise rotation of the heart, so that right ventricle accounts for nearly all the anterior surface of heart which can be palpated by the ulnar border of palm & felt as "parasternal lift" or "heave". Epigastric pulsations are also seen & felt in RVH.

Biventricular hypertrophy can be suspected by a combination of these signs (parasternal lift associated with heaving down & outwardly shifted apex).

Pulmonary artery can be palpated (when it is enlarged in pulmonary hypertension) in 2^{nd} intercostal space, on expiration.

Failure to detect apex beat in the usual position is commonly due to the fact it is hidden underneath a rib or due to dextrocardia where it is felt on the right side.

Other pulsations may be seen & felt: in Suprasternal notch (COA, AS), Carotid pulsations (AR, PDA, thyrotoxicosis), in Epigastrium (nervousness & excitement in older children, RVH, thyrotoxicosis, TR: rare & may be associated with expansile liver. Pulsations produced by aneurysm or collateral vessels may also be detected.

When the cardiac disease develops in early life, enlargement of either ventricle, especially the right, tends to push the left side of the chest wall forward (precordial bulge) due to softness of the ribs. It is usually not seen in acquired heart diseases because of more rigid ribs in later life.

Thrills may be felt. The character, timing & variation with respiration must be noted. It resembles the corresponding murmur. If the child is cooperative, thrills should be felt when he holds breath on expiration. Apical thrills are better felt when the patient is in the left lateral position while basal thrills in sitting & leaning forward position.

2. Percussion

Cardiac borders in infants are difficult to percuss owing to the thick layer of subcutaneous fat on the chest wall & the barrel shape of the chest. Percussion can give information of gross changes only (in pericardial effusion: the area of dullness is increased, in dextrocardia: the dullness on right side, & in case of shifting of mediastinum secondary to pulmonary or pleural diseases.

Accurate assessment of cardiac size, shape & position can usually be made by radiography & echocardiography.

3. Auscultation

Auscultation of heart is considered the most difficult portion of the examination of CVS. It is because of more rapid heart rate & thus of more quickly passing of events is cardiac cycle. Non-cooperative child may create problems. As with other skills, it requires a great deal of practice & repetition. Child found asleep is the best opportunity to auscultate.

Identifying first heart sound (S1) & second heart sound (S2) by timing of S1 with carotid is important.

It is customary to auscultate the 4 areas on precordium (Mitral, Tricuspid, Pulmonary & Aortic area), but it does not mean that auscultation must be confined to these areas only.

Cardiac cycle

S1 is produced by almost simultaneous closure of mitral & tricuspid valve at the onset of ventricular systole. The aortic & pulmonary valves then open inaudibly. When systole is complete & diastole just started, aortic & pulmonary valves close & produce 2 component of S2 (Aortic: A2 & Pulmonary: P2). Because of the lower pressure in right ventricle compared with left, pulmonary valve closes later than aortic valve. After a brief period, mitral & tricuspid valve open inaudibly. The cardiac cycle takes about 0.6 second to complete when heart rate is 100 bpm.

The abnormalities expected on auscultation can be divided into 4:

1. Sounds may have a change in intensity, either absolute or relative to each other.
2. Sounds may be abnormally split.
3. Triple rhythm may be present.
4. Adventitious sounds may be present.

1. Alteration in Intensity

It is significant only when considered in relation to all other features of the case. In pericardial effusion, heart sounds are distinct or inaudible & in myocarditis, both sounds are muffled. Loud S1 is found in ASD & mechanical prorthetic valve. In MS & tachycardia due to any reason, S1 is accentuated. Loud S2 is found in increased pulmonary flow (like in PDA, ASD, large VSD) & in pulmonary hypertension. Single S2 is seen in TOF & PS (inaudible pulmonary component).

2. Splitting

Time taken by a valve to close depends upon the pressure on the valve for closing. Valve under more pressure closes earlier. Mitral valve closes a little earlier than tricuspid valve, however, splitting of S1 is not evident because both components are very low pitched & merge into each other. Similarly, aortic valve closes little before pulmonary valve. This splitting is audible because both component of S2 (A2 & P2) are high pitched (best detected by using diaphragm of stethoscope). P2 is heard in close to pulmonary area while A2 is heard in all areas.

Splitting of S2 is seen in normal children (A2 followed by P2) & it widens during inspiration & narrows in expiration. Fixed splitting (no change with respiration) is seen in ASD. Wide splitting is seen in ASD, PS & right bundle branch block (RBBB). Reverse splitting (widens on expiration) is seen in left bundl branch block (LBBB) & severe AS.

3. Triple Rhythm

Normally, the 3rd & 4th heart sound (S3 & S4) are not prominent. Prominence of any of these sounds gives rise to "triple rhythm".

S3: after S2 (early diastole), low pitched, heard best with bell over the apex (mitral area), may be confused with split S2 or opening snap, seen in:

- Some normal children.
- HF of either ventricle.
- When mitral diastolic flow is increased like in ASD & MR.

S4: before S1 (late diastole), low pitched, easily confused with ejection click, never a normal finding, seen in:

- HF of either ventricle
- Pulmonary hypertension.

When heart rate is more than 100 bpm & because of short diastole, S3 may overlie S4 given rise to "summation gallop"

4. Additional sounds

Ejection click: after S1, high pitched, occurs in AS & PS (early systole) & floppy mitral valve (mid-systole).

Opening snap: after S2 (early diastole), high pitched, occurs in MS & TS (very rare).

Murmurs: have a musical or blowing quality, produced due to turbulence in blood flow, at or near a valve or abnormal communication within the heart. It can be due to:
- Normal valve but abnormally increased flow through it (flow murmur, functional or innocent murmur).
- Narrowed valve while blood flow through it is normal (pathological murmur).

It is often difficult in children to decide whether a systolic murmur signifies heart disease because innocent murmur are very common.

Innocent murmur is characterized by (10 S) criteria: Symptom free, Sign free (like thrill), Systolic, Soft, Short, heard over Small area, normal S1 & S2, changes or disappears with Sitting/Standing position, may be found with Sternal depression (pectus excavatum), & normal Special tests (EEG, CXR, echocardiography). The innocent murmurs include:

- **Peripheral pulmonary stenosis:** newborn, pulmonary area.
- **Vibratory Stills murmur:** 3-8 yr, lower left sternal border or apex, decreases with standing.
- **Carotid bruit:** 3-8 yr, supraclavicular to carotid area.
- **Venous humm:** 3-8 yr, infraclavicular area to jugular vein, continous.
- **Pulmonary flow murmur:** 6-18 yr, pulmonary area.

Murmurs are studied with following parameters:
1.Timing 2.Change with respiration 3.Maximal intensity & propagation 4.Character 5. Intensity

1. Time of occurrence:
- **Systolic:** Pansystolic (VSD, MR, TR)
  Ejection systolic (ASD, AS, PS)

- **Diastolic:** Immediate diastolic (AR, PR)
  Delayed diastolic: mid or late (MS, TS)
- **Continuous:** PDA

2. Changes with respiration: as the stroke output of right ventricle increases with inspiration, murmurs originating on the right side become louder. Similarly, murmurs originating on the left side become louder in expiration. In severe cardiac lesion, however, this phenomenon is not seen.

3. Point of maximal intensity & direction of selective propagation: normally, the murmur produced at a valve has a maximal intensity overlying that area with few exceptions:
- Pansystolic murmur of MR is equal in intensity from mitral area to the axillary area or may be even increase toward axilla.
- Ejection systolic murmur of AS may be best heard in mitral area & over carotids, although it is produced in aortic area.
- Murmur of PDA may be best heard at the back.

4. Character of murmur: murmurs produced due to obstruction to the onward flow through a narrowed valve are usually rough & low pitched like rumbling murmur of MS. Regurgitant murmurs are softer, blowing & high pitch like murmur of AR.

Low pitched murmur are best heard by the bell of stethoscope when applied very lightly to the skin while high pitched murmur are best heard with diaphragm applied firmly to the skin.

5. Intensity of murmur: loudness of murmur has no relation to its importance. Murmurs are classified on the basis of intensity into 6 grades:

- **Grade 1:** very soft, heard by experienced examiner only in some particular position.
- **Grade 2:** soft, weakest murmur heard in all positions.
- **Grade 3:** loud, not accompanied by thrill.
- **Grade 4:** loud, with thrill.
- **Grade 5:** loud, easily heard with stethoscope.
- **Grade 6:** loud, can be heard without stethoscope.

Area	Murmur
Upper right sternal border	**AS** (harsh), **venous humm**
Upper left sternal border	**PS** (harsh), **pulmonary flow murmur**, **ASD, PDA**
Lower left sternal border	**Vibratory Stills murmur**, **VSD** (harsh), **TR, HOCM**
Apex	**MR** (blowing or whooping)

In old & cooperative child, heart sounds & murmurs can be heard more clearly by changing the child's position, listening in various phases of respiration & noting the relation to exercise. Diastolic murmurs are best heard in lying in left-lateral position after exercise, while basal murmurs may more obvious in sitting & leaning forward during full expiratory apnea.