

CARDIOVASCULAR SYSTEM: CARDIAC CYCLE

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CARDIAC CYCLE

- ✘ SEQUENTIAL CHANGES (MECHANICAL & ELECTRICAL) TAKING PLACE IN THE HEART FROM BEGINNING OF ONE HEART BEAT TO ANOTHER.
- ✘ SYSTOLE: CONTRACTION OF HEART
- ✘ DIASTOLE: DIASTOLE OF HEART

- ✘ ATRIAL SYSTOLE AND DIASTOLE
- ✘ VENTRICULAR SYSTOLE AND DIASTOLE



CARDIODYNAMICS

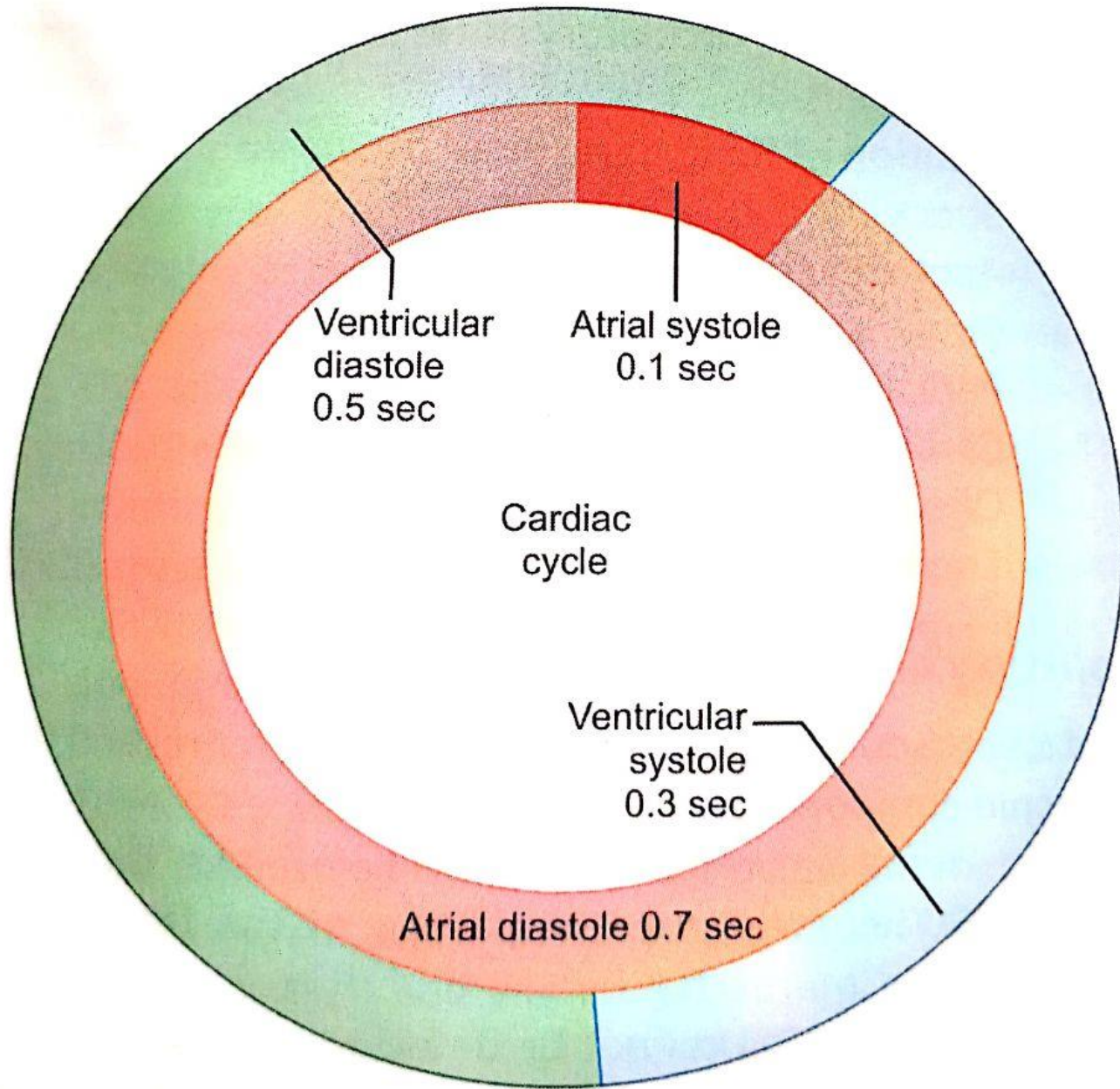
- PRESSURE CHANGES IN VENTRICLES
- PRESSURE CHANGES IN ARIA
- PRESSURE CHANGES IN AORTA
- VOLUME CHANGES IN VENTRICLES
- VALVULAR EVENTS: HEART SOUNDS

DIVISIONS OF CARDIAC CYCLE

- HEART RATE: 75/MINUTE
- TOTAL DURATION OF CARDIAC CYCLE: 0.8 SEC
- ATRIAL SYSTOLE :0.1 SECOND
- ATRIAL DIASTOLE : 0.7 SECOND.
- VENTRICULAR SYSTOLE :0.3 SECOND
- VENTRICULAR DIASTOLE :0.5 SECOND.

EVENTS

- VENTRICULAR VOLUME
- VENTRICULAR PRESSURE
- ATRIAL PRESSURE
- AORTIC PRESSURE
- ELECTROCARDIOGRAM
- PHONOCARDIOGRAM



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Fig. 89.6: Duration of ventricular systole and diastole, atrial systole and diastole.

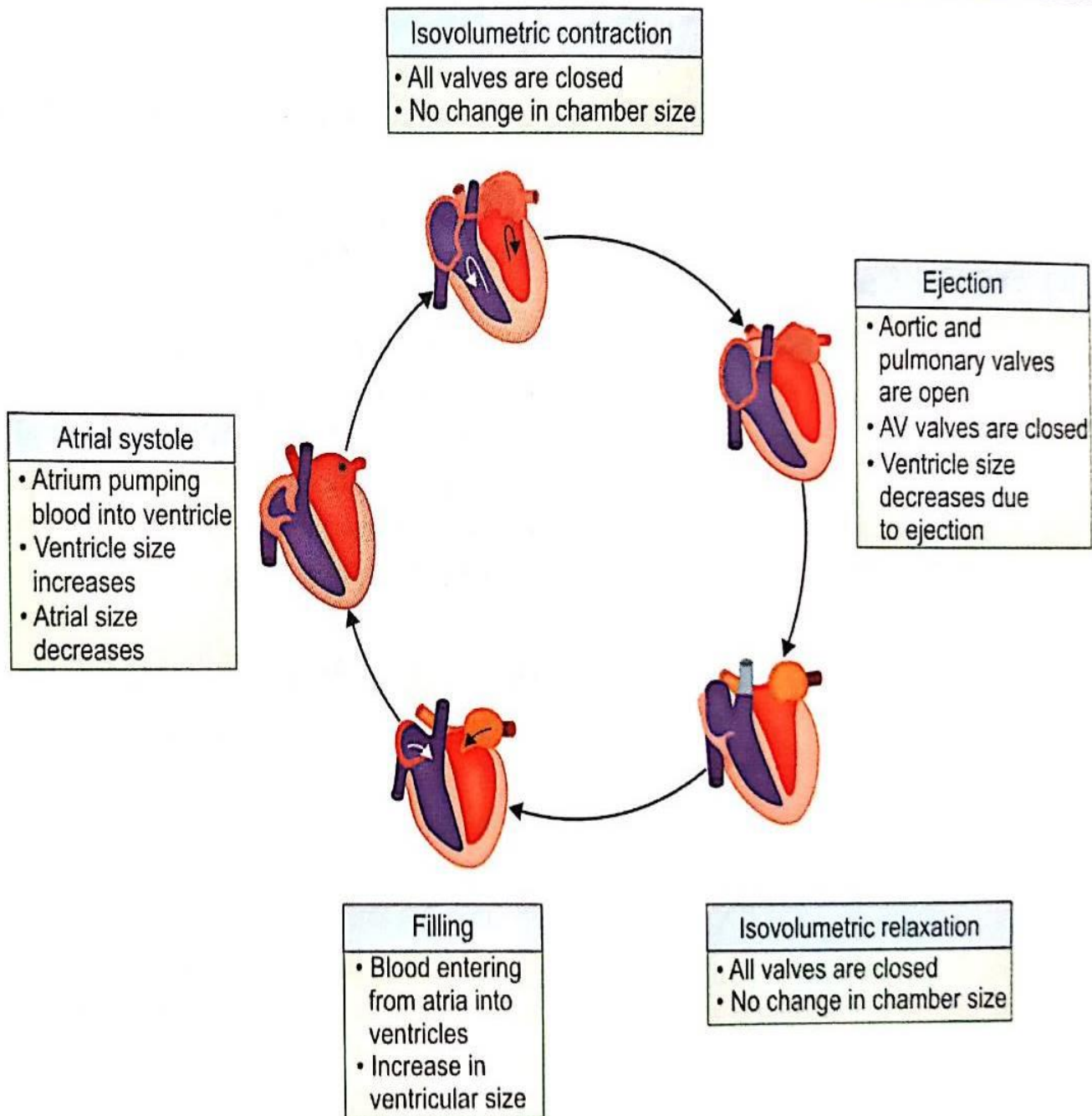


Fig. 89.2: Major changes in the cardiac chambers in five principal steps of cardiac cycle.

ATRIAL SYSTOLE (0.8 SEC.)

- BEFORE ATRIAL SYSTOLE, **JOINT DIASTOLIC PHASE** : ATRIA AND VENTRICLES FORM A CONTINUOUS CAVITY. ABOUT 75% OF THE BLOOD FLOWS TO VENTRICLES.
- THEREAFTER BOTH ATRIA CONTRACT ALMOST SIMULTANEOUSLY AND PUMP THE REMAINING 25% OF BLOOD INTO THE RESPECTIVE VENTRICLES .
- PRESSURE IN RT. ATRIUM; 4-6 MM HG, LEFT ATRIUM; 7-8 MM HG.
- MITRAL VALVE CLOSSES AT THE END OF ATRIAL SYSTOLE : VENTRICULAR PRESSURE BECOMES MORE THAN ATRIAL PRESSURE.

ATRIAL DIASTOLE (0.7 SEC).

- ATRIAL DIASTOLE OCCURS DURING VENTRICULAR SYSTOLE AND MOST OF VENTRICULAR DIASTOLE.
- ATRIAL FILLING OCCURS FROM SUPERIOR AND INFERIOR VENA CAVA ON RIGHT SIDE AND PULMONARY TRUNK ON LEFT SIDE.

VENTRICULAR SYSTOLE : (0.3 SEC.)

- ✘ (I) ISOVOLUMIC (ISOMETRIC) CONTRACTION :(0.05 SEC).
- ✘ (II) RAPID EJECTION (0.11 SECOND),
- ✘ (III) REDUCED EJECTION (0.14 SECOND).

VENTRICULAR DIASTOLE : (0.5 SEC.)

- ✘ (I) PROTODIASTOLE (0.04 SECOND).
- ✘ (II) ISOVOLUMIC (ISOMETRIC) RELAXATION (0.06 SEC).
- ✘ (III) RAPID PASSIVE FILLING (0.11 SECOND).
- ✘ (IV) REDUCED FILLING (DIASTASIS) (0.19 SECOND).
- ✘ (V) SECOND RAPID FILLING (CORRESPONDING TO ATRIAL SYSTOLE) (0.01 SECOND)

VENTRICULAR SYSTOLE :

(0.3 SEC.)

✘(I) ISOVOLUMIC (ISOMETRIC) CONTRACTION
:(0.05 SEC).

✘(II) RAPID EJECTION (0.11 SECOND),

✘(III) REDUCED EJECTION (0.14 SECOND).

VENTRICULAR SYSTOLE 0.3 SEC

✘ *ISOVOLUMIC OR ISOMETRIC CONTRACTION (0.05 SEC)*

✘ STARTS WITH CLOSURE OF MITRAL VALVE AND ENDS WITH OPENING OF AORTIC VALVE.

✘ SHARP RISE IN VENTRICULAR PRESSURE ; RT. VENTRICLES: 8 MMHG, LT. VENTRICLE: 80 MMHG.

✘ VENTRICULAR VOLUME REMAINS THE SAME : HENCE ISOVOLUMIC.

✘ AORTIC BLOOD FLOW IS NIL.

✘ THIS PHASE ENDS WITH OPENING OF SEMILUNAR VALVES WHEN VENTRICULAR PRESSURE BECOMES MORE THAN AORTIC PRESSURE.



- ***RAPID EJECTION PHASE (0.11 SECOND):***

- ✘ STARTS WITH OPENING OF AORTIC VALVE.

- ✘ 2/3 RD OF BLOOD IS EJECTED IN THIS PHASE.

- ✘ LT. VENTRICULAR PRESSURE: 120 MMHG,

 - RT. VENT. PR.: 25 MMHG.

- ✘ AORTIC BLOOD FLOW INCREASES.

- ✘ AORTIC PRESSURE RISES :BUT REMAINS BELOW THE VENTRICULAR PRESSURE.

- ✘ VENTRICULAR VOLUME FALLS STEEPLY.

- ✘ ATRIAL PRESSURE RISES SLOWLY AFTER INITIAL FALL DUE TO VENOUS RETURN.



REDUCED EJECTION PHASE (0.14 SECOND):

- ✘ VENTRICULAR AND AORTIC PRESSURE DECREASE**
- ✘ AORTIC BLOOD FLOW DECREASES GREATLY.**
- ✘ VENTRICULAR VOLUME IS DECREASED FURTHER.**
- ✘ ATRIAL PRESSURE CONTINUES TO INCREASE SLOWLY DUE TO BLOOD RETURNING TO ATRIA (ATRIA RELAX THROUGHOUT THE VENTRICULAR SYSTOLE).**

VENTRICULAR DIASTOLE :

(0.5 SEC.)

- ✘ (I) PROTODIASTOLE (0.04 SECOND).
- ✘ (II) ISOVOLUMIC (ISOMETRIC) RELAXATION (0.06 SEC).
- ✘ (III) RAPID PASSIVE FILLING (0.11 SECOND).
- ✘ (IV) REDUCED FILLING (DIASTASIS) (0.19 SECOND).
- ✘ (V) SECOND RAPID FILLING (CORRESPONDING TO ATRIAL SYSTOLE) (0.01 SECOND)

VENTRICULAR DIASTOLE OR RELAXATION (0.5 SEC):

PROTODIASTOLE (0.04 SEC)-


- AORTIC AND PULMONARY SEMILUNAR VALVES CLOSED: SECOND HEART SOUND (CLOSURE OF SEMILUNAR VALVES).

ISOVOLUMIC OR ISOMETRIC RELAXATION (0.06 SEC)-

- RAPID FALL OF PRESSURE INSIDE THE VENTRICLES (FROM 80 MM HG TO ABOUT 2 TO 3 MM HG IN THE LEFT VENTRICLE).
- NO CHANGE IN VENTRICULAR VOLUME.
- AORTIC BLOOD FLOW IS NIL.
- ENDS WITH OPENING OF ATRIOVENTRICULAR VALVES.



- ***RAPID FILLING PHASE: 0.1 1***

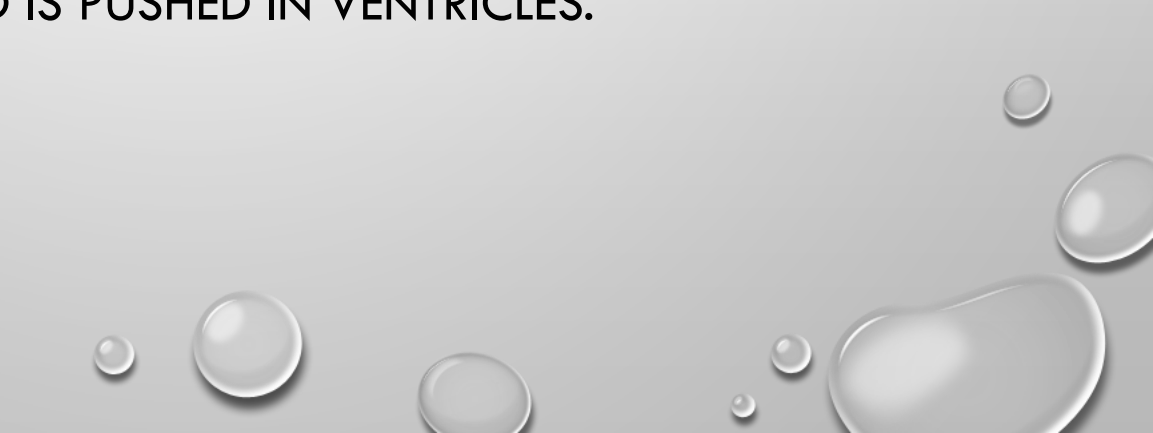
- MITRAL VALVE OPENS.
 - HIGH ATRIAL PRESSURE CAUSES THE BLOOD TO FLOW RAPIDLY INTO THE VENTRICLES. INSPITE OF RAPID FILLING, VENTRICULAR PRESSURE CONTINUES TO FALL DUE TO VENTRICULAR RELAXATION. THE RAPID FLOW OF BLOOD FROM LEFT ATRIUM TO LEFT VENTRICLE DECREASES THE LEFT ATRIAL PRESSURE.
 - THIRD HEART SOUND.
 - LARGE INCREASE IN VENTRICULAR VOLUME.
- 

REDUCED FILLING PHASE OR DIASTASIS: 0.19 SEC

- VENTRICULAR VOLUME RISES SLOWLY.
- VENTRICULAR AND ATRIAL PRESSURE REMAINS UNCHANGED.
- DURING RAPID FILLING AND DIASTASIS PHASE ABOUT 75% OF BLOOD PASSES FROM ATRIA TO VENTRICLES. THEN THE NEXT CYCLE BEGINS WITH ATRIAL CONTRACTION.



SECOND RAPID FILLING (CORRESPONDING TO ATRIAL SYSTOLE) (0.01 SECOND)

- COINCIDES WITH ATRIAL SYSTOLE
 - ADDITIONAL 25% OF BLOOD IS PUSHED IN VENTRICLES.
- 

✘ VENTRICULAR END DIASTOLIC VOLUME:

THE VOLUME OF BLOOD IN THE VENTRICLE JUST PRIOR TO THE ONSET OF VENTRICULAR CONTRACTION: 110-120 ML

✘ VENTRICULAR END SYSTOLIC VOLUME: VOLUME OF BLOOD REMAINING IN THE VENTRICLE AT THE END OF EJECTION IS CALLED END SYSTOLIC VOLUME. :40 TO 50 ML.

✘ EJECTION FRACTION: THE FRACTION OF END-DIASTOLIC VOLUME THAT IS EJECTED IS CALLED THE EJECTION FRACTION. NORMALLY IT IS ABOUT 60%.

REDUCED FILLING PHASE OR DIASTASIS: 0.19 SEC

- ✘ VENTRICULAR VOLUME CURVE RISES SLOWLY.
- ✘ VENTRICULAR AND ATRIAL PRESSURE REMAINS UNCHANGED.
- ✘ IN ECG, 'P' WAVE BEGINS TO APPEAR TOWARDS END OF THIS PHASE.
- ✘ DURING RAPID FILLING AND DIASTASIS PHASE ABOUT 75% OF BLOOD PASSES FROM ATRIA TO VENTRICLES. THEN THE NEXT CYCLE BEGINS WITH ATRIAL CONTRACTION.

EVENTS

- VENTRICULAR VOLUME
- VENTRICULAR PRESSURE
- ATRIAL PRESSURE
- AORTIC PRESSURE
- ELECTROCARDIOGRAM
- PHONOCARDIOGRAM

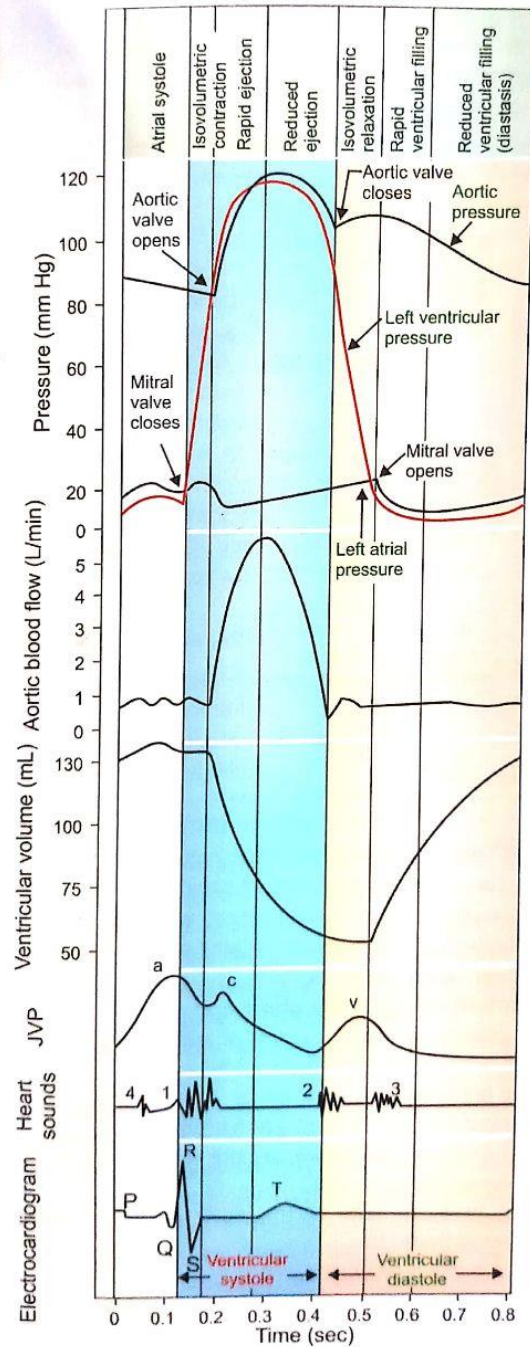


Fig. 89.1: Timing of various electromechanical events in different phases of cardiac cycle at a heart rate of 75 beats per min. JVP: Jugular venous pressure depicting a, c, and v waves.

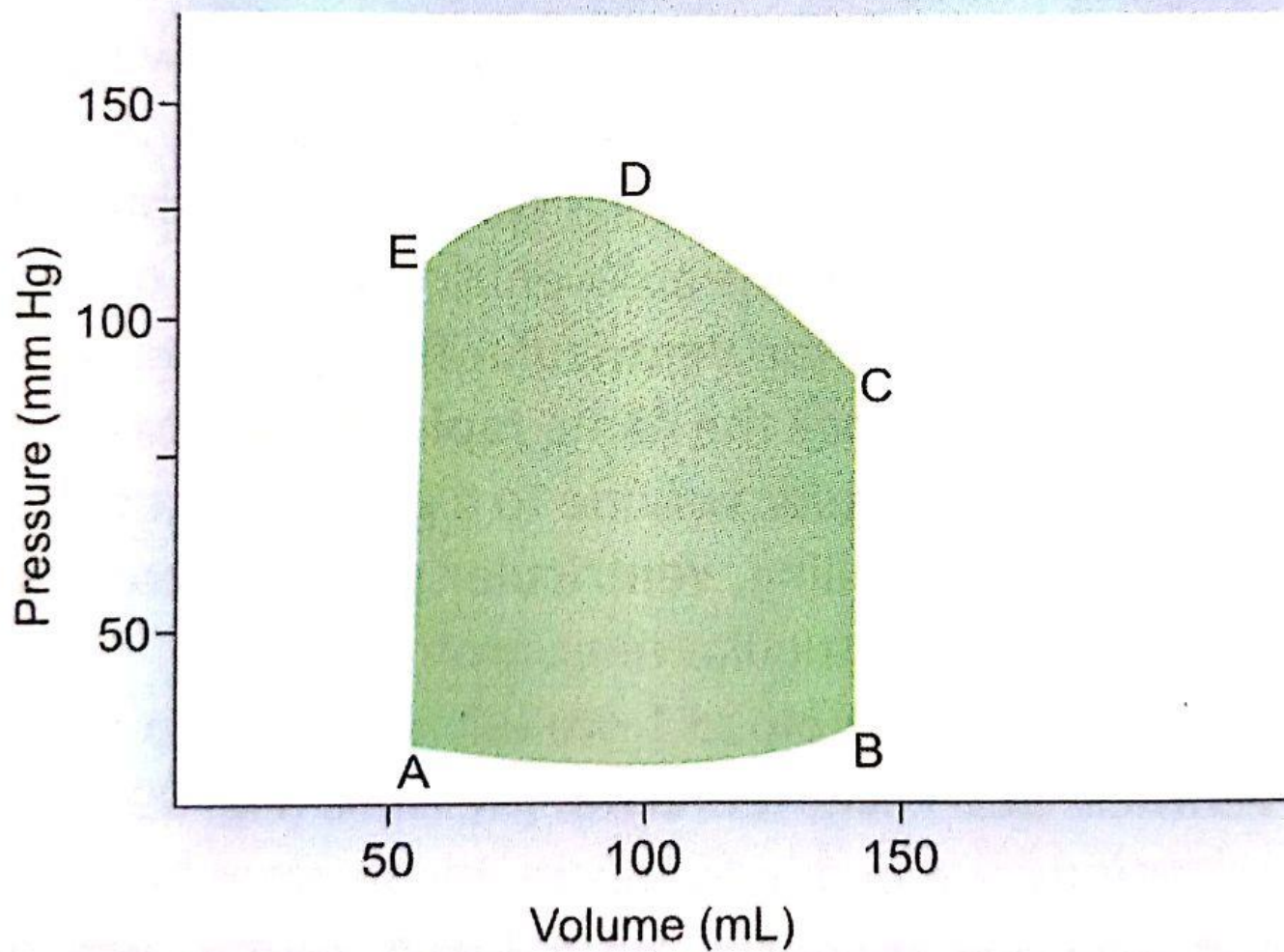
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PRESSURE CHANGES IN THE LEFT VENTRICLE

- **ATRIAL SYSTOLE:** PRESSURE RISES TO ABOUT 7 MM HG.
- **ISOMETRIC CONTRACTION:** PRESSURE INSIDE THE VENTRICLE RAPIDLY RISES FROM 7 MM HG TO 80 MM HG.
- **RAPID EJECTION PHASE:** PRESSURE TO RISE TO A PEAK LEVEL OF 120 MM HG
- **REDUCED EJECTION PHASE:** PRESSURE DECREASES TO 100 MM HG
- **ISOVOLUMIC RELAXATION PHASE:** GREAT PRESSURE FALL IN THE LEFT VENTRICLE FROM 100 MM HG TO ABOUT 2 TO 3 MM HG
- **RAPID FILLING AND DIASTASIS:** PRESSURE IN THE VENTRICLE DROPS TO ALMOST ZERO

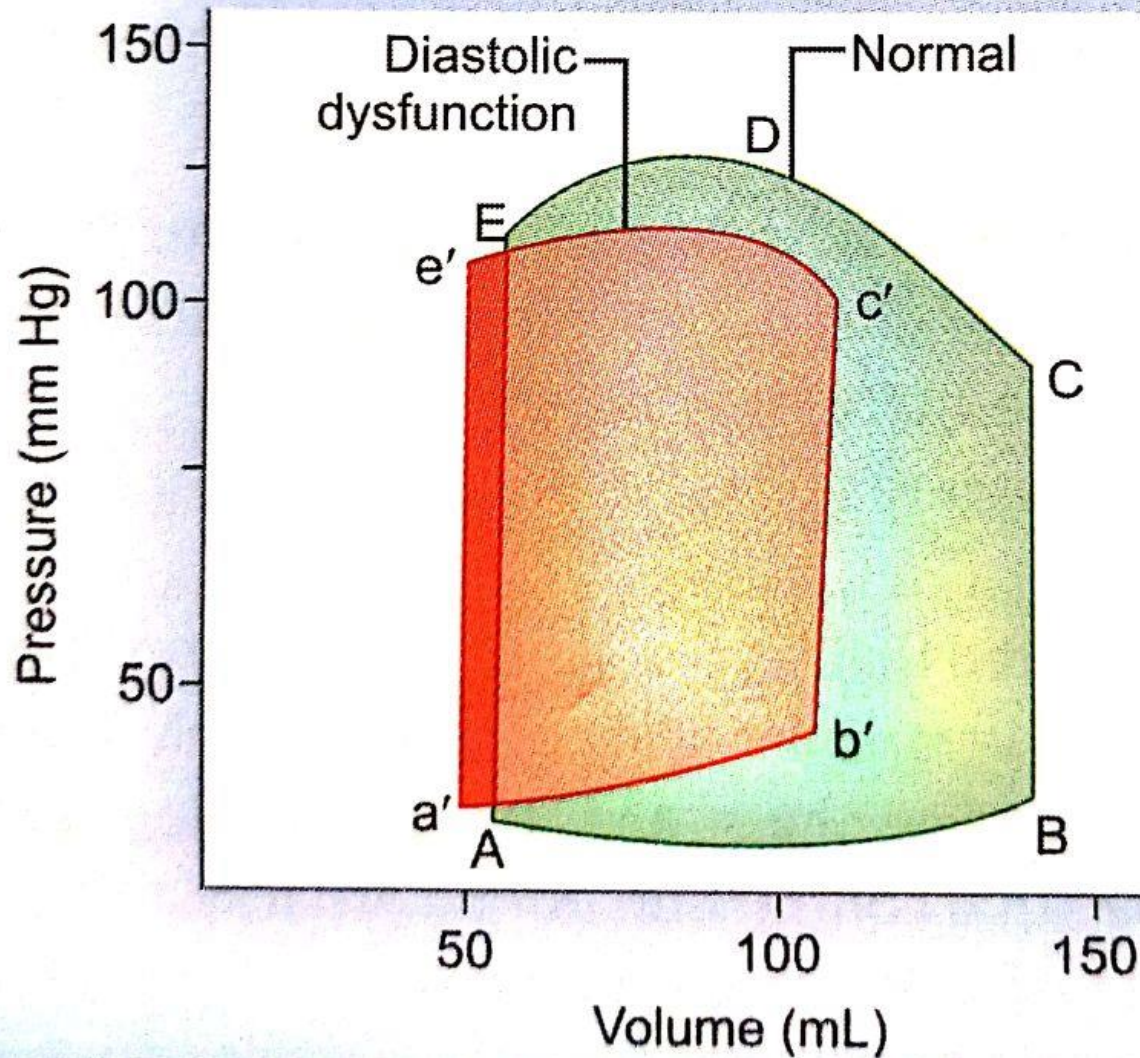
VOLUME CHANGES IN THE LEFT VENTRICLE

- **ATRIAL SYSTOLE:** VOLUME INCREASES SLIGHTLY
- **ISOMETRIC CONTRACTION:** NO CHANGE IN VOLUME
- **RAPID / REDUCED EJECTION PHASE:** FALL IN VOLUME TO 40 TO 50 ML (70 ML BLOOD IS PUMPED OUT): END SYSTOLIC BLOOD VOLUME IS 40 TO 50 ML.
- **ISOVOLUMIC RELAXATION PHASE:** NO CHANGE IN VOLUME.
- **RAPID FILLING AND DIASTASIS:** FILLING OF VENTRICLES :110 TO 120 ML ,END DIASTOLIC VOLUME.



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Fig. 89.3: Normal pressure-volume loop of the left ventricle (ABCDE). At point A, mitral valve opens; AB: phase of ventricular filling; at point B, mitral valve closes; BC: phase of isovolumetric contraction; at point C, aortic valve opens; CD: phase of rapid ejection; DE: phase of slow ejection; at point E, aortic valve closes.



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Fig. 89.5: Normal pressure-volume loop of the left ventricle (ABCDE). Note, pressure-volume loop shifts to the left (a' b' c' e') in diastolic dysfunction.

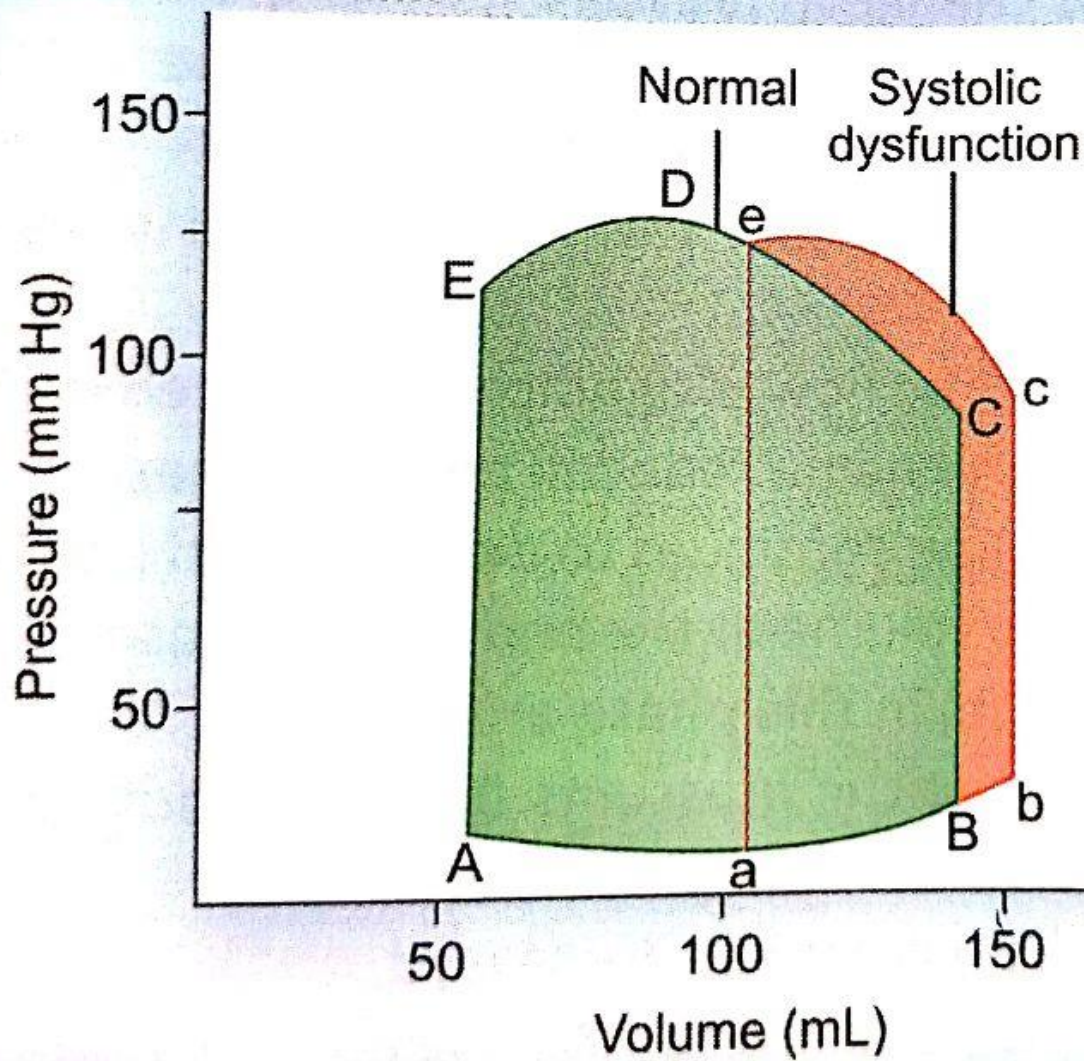


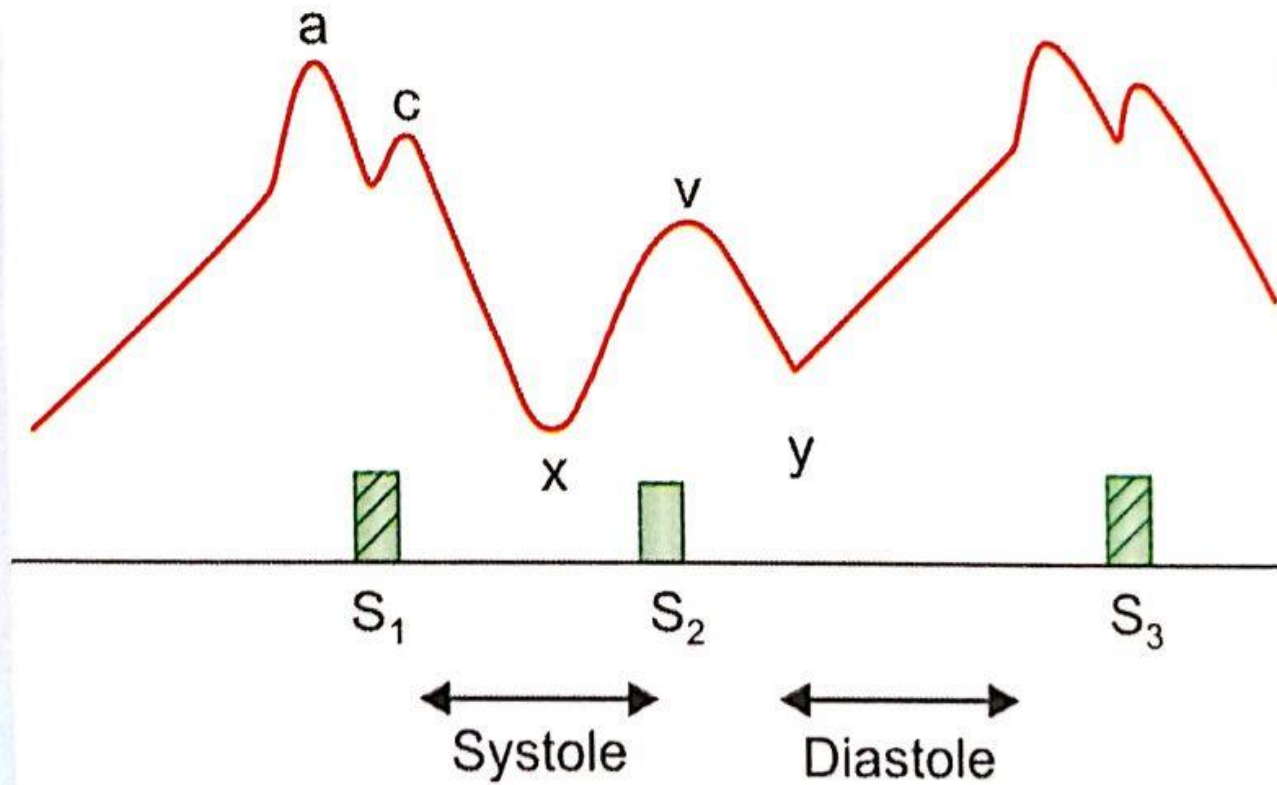
Fig. 89.4: Normal Pressure volume loop of the left ventricle (ABCDE). Note, pressure volume loop shifts to right (abce) in systolic dysfunction.

PRESSURE CHANGES IN THE AORTA

- * PRESSURE VARIES BETWEEN 80-120 MMHG.
- **RAPID EJECTION PHASE:** PRESSURE TO RISE TO A PEAK LEVEL OF 120 MM HG
- **REDUCED EJECTION PHASE:** PRESSURE DECREASES
- **DIASTOLE:** :PRESSURE IN THE AORTA FALLS SLOWLY THROUGHOUT BECAUSE BLOOD STORED IN DISTENDED ELASTIC ARTERIES CONTINUES TO FLOW TO THE PERIPHERY
AORTIC PRESSURE FALLS TO 80 MM HG (DIASTOLIC PRESSURE)
- PRESSURE CURVE IN THE **PULMONARY ARTERY** IS SIMILAR TO THAT OF AORTA BUT PRESSURES ARE LOW.

PRESSURE CHANGES IN THE ATRIA

- * 'A', 'C', 'V', 'X', 'Y'. WAVES
- **ATRIAL SYSTOLE:** 'A' WAVE. RIGHT ATRIAL PRESSURE RISES ABOUT 4 TO 6 MM HG AND LEFT ATRIAL PRESSURE RISES ABOUT 7 TO 8 MM HG.
- **ISOMETRIC CONTRACTION:** 'C' WAVE: INCREASED PRESSURE, DUE TO BULGING OF AV VALVES TOWARDS THE ATRIA BECAUSE OF INCREASING PRESSURE IN THE VENTRICLES
- **ISOVOLUMIC RELAXATION PHASE:** 'V' WAVE: SLOW BUILD UP OF PRESSURE IN ATRIA DUE TO COLLECTION OF BLOOD FROM VEINS WHILE AV VALVES ARE CLOSED DURING VENTRICULAR CONTRACTION
- **RAPID FILLING AND DIASTASIS:** DECREASE PRESSURE: RAPID FLOW OF BLOOD INTO THE VENTRICLES CAUSING 'V' WAVE TO DISAPPEAR



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Fig. 89.7: Jugular venous pulse. Note the a, b, and c waves, and x and y descents, and their relation to the cardiac cycle.

- **'X' WAVE:** CAUSED BY FALL OF RIGHT ATRIAL PRESSURE DUE TO RELAXATION OF RIGHT ATRIUM.
- **'Y' WAVE:** DUE TO FALL IN RIGHT ATRIAL PRESSURE WHEN BLOOD ENTERS INTO THE RIGHT VENTRICLE AS TRICUSPID VALVE OPENS.

● JUGULAR VENOUS PULSE TRACING: JVP

- PRESSURE CHANGES IN THE ATRIUM ARE DIRECTLY REFLECTED IN INTERNAL JUGULAR VEIN.
- THEREFORE, JVP IN RIGHT SIDE OF NECK IS EXAMINED CLINICALLY TO ACCESS ATRIAL PRESSURE CHANGES.
- JUGULAR PRESSURE TRACING IS SAME AS THAT AS ATRIAL PRESSURE CURVE: A,C,V WAVES.

CONDITIONS THAT ALTER JVP

- **RAISED JVP:** IT IS ONE OF THE EARLIEST AND MOST RELIABLE SIGN OF CARDIAC FAILURE.
- RIGHT SIDED HEART FAILURE
- OBSTRUCTION OF SUPERIOR VENA CAVA
- INCREASE IN CIRCULATING BLOOD VOLUME.
- CONGESTIVE CARDIAC FAILURE
- CONSTRICTIVE PERICARDITIS.

- **PROMINENT 'A' WAVE:** DUE TO INCREASED FORCE OF RIGHT ATRIAL CONTRACTION, WHEN RIGHT ATRIA CONTRACTS AGAINST INCREASED RESISTANCE. E.G. TRICUSPID STENOSIS, PULMONARY STENOSIS.
- **CANNON WAVE:** WHEN THE AMPLITUDE OF 'A' WAVE IS ABNORMALLY BIG, IT IS CALLED GIANT WAVE OR CANNON WAVE. IT OCCURS WHEN RIGHT ATRIUM CONTRACTS AGAINST CLOSED TRICUSPID VALVE. E.G. COMPLETE HEART BLOCK.
- **PROMINENT 'V' WAVE:** OCCURS IN TRICUSPID REGURGITATION BECAUSE WHEN VENTRICLE CONTRACTS DURING SYSTOLE, BLOOD ENTERS INTO RIGHT ATRIUM THROUGH INCOMPETENT TRICUSPID VALVE.

HEART SOUNDS

FIRST HEART SOUND:

- DUE TO CLOSURE OF AV VALVES
- SOFT, LOW PITCHED, LONG
- 0.15SEC, 25-45 HZ.
- LUBB

✘ SIGNIFICANCE:

- ✘ INDICATES THE ONSET OF CLINICAL SYSTOLE OF THE VENTRICLES.
- ✘ DURATION AND INTENSITY OF THE FIRST SOUND INDICATES THE CONDITION OF MYOCARDIUM.
- ✘ NORMAL FIRST SOUND ALSO INDICATES THAT A-V VALVES ARE PROPERLY CLOSING (THERE IS NO INCOMPETENCE).

- ✘ - LOUD 1ST HEART SOUND IS HEARD DURING EXERCISE, ANEMIA.
- ✘ - VERY SOFT 1ST HEART SOUND IS HEARD IN SHOCK, PERICARDIAL EFFUSION.

SECOND HEART SOUND

- CLOSURE OF SEMILUNAR VALVES
- SHARP, HIGH PITCHED, SHORT
- 0.12 SEC, 50 HZ
- DUB
- REDUPLICATION / SPLITTING OF 2ND SOUND

SIGNIFICANCE:

- ✘ INDICATES END OF SYSTOLE AND BEGINNING OF DIASTOLE OF THE VENTRICLES.
- ✘ CLEAR SECOND SOUND INDICATES THAT THE SEMILUNAR VALVES ARE CLOSING PROPERLY, I.E. THERE IS NO INCOMPETENCE.
- ✘ SPLITTING OF SECOND HEART SOUND:
- ✘ SOMETIMES TWO VALVES AORTIC AND PULMONARY DO NOT CLOSE SIMULTANEOUSLY DURING INSPIRATION (AORTIC VALVE CLOSSES BEFORE PULMONARY VALVE). THIS CAUSES SPLITTING OF SECOND SOUND DURING INSPIRATION. NORMALLY, IT IS CLEARLY HEARD IN CHILDREN.

THIRD HEART SOUND

- RAPID FILLING PHASE DUE TO RUSHING OF BLOOD FROM ATRIA AND VENTRICLES

FOURTH HEART SOUND

- DUE TO ATRIAL SYSTOLE

- PHONOCARDIOGRAM

CARDIAC MURMURS

DUE TO TURBULENCE OF BLOOD

- VALVULAR STENOSIS
- VALVUAR REGURGITATION
- VENTRICULAR SEPTAL DEFECT
- ASD
- COARCTATION OF AORTA

MURMURS

- TIMING: SYSTOLIC OR DIASTOLIC
- INTENSITY: 1-6
- LOCATION
- RADIATION

SYSTOLIC MURMURS

- EJECTION SYSTOLIC: AORTIC & PULMONARY STENOSIS
- PANSYSTOLIC: MITRAL & TRICUSPID REGURGITATION, VSD
- LATE SYSTOLIC: MITRAL VALVE PROLAPSE

DIASTOLIC MURMURS

- EARLY DIASTOLIC: AORTIC & PULMONARY REGURGITATION
- MID DIASTOLIC: MITRAL & TRICUSPID STENOSIS

CONTINUOUS MURMUR: PATENT DUCTUS ARTERIOSUS

The background features a light gray gradient with several realistic water droplets of various sizes scattered in the corners. The droplets have highlights and shadows, giving them a three-dimensional appearance.

**THANK
YOU**