Stroke volume

Is the volume of blood pumped by each ventricle per beat.

Normally it is about 70 ml/beat.

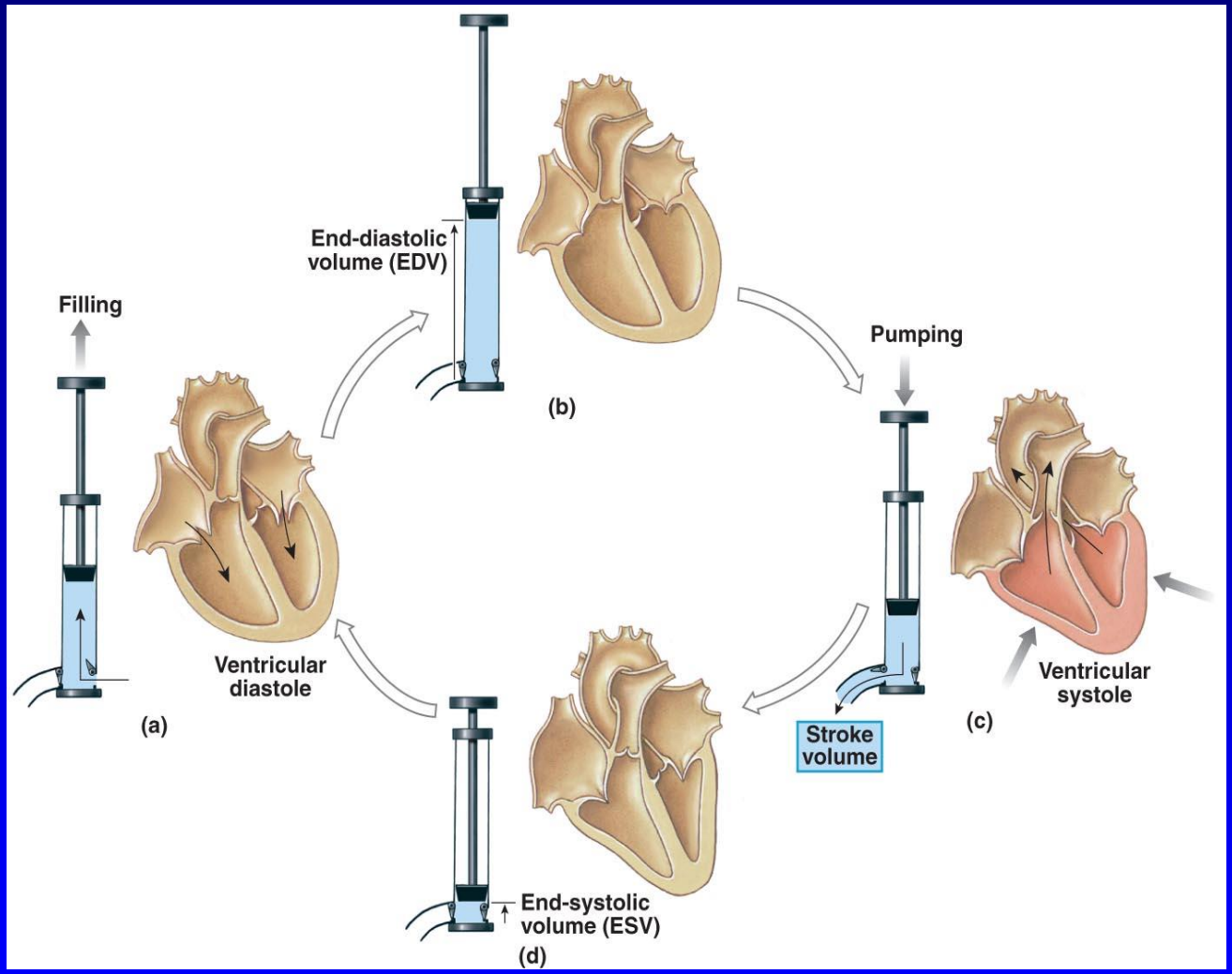
END-SYSTOLIC VOLUME (ESV) & END-DIASTOLIC VOLUME (EDV):

During ventricular diastole, filling of the ventricles with blood normally increases the volume of each ventricle to about 120-130 ml.

The volume of blood present in each ventricle at the end of ventricular diastole is called end-diastolic volume (EDV) or preload, which is about 120-130 ml.

The volume of blood ejected by each ventricle during each ventricular systole is called stroke volume (=70-80 ml).

The volume of blood present in each ventricle at the end of ventricular systole is called end-systolic volume (ESV) and it is about 50-60 ml.


End-diastolic volume (EDV)
Filling
Pumping
(b)
Ventricular diastole
(a)
Ventricular systole
(c)
Stroke volume
End-systolic volume (ESV)
(d)

Factors Affecting the Stroke Volume

1- The end diastolic volume (EDV) or preload

Is the amount of blood a ventricle contains at the end of diastole, depends on:

1- Filling time:

Which is the duration of ventricular diastole

2- Venous return:

The rate of blood flow during ventricular diastole

The Frank–Starling Principle
(Starling's law of the heart)

As end diastolic volume (EDV) increases, stroke volume increases.

The more that the cardiac muscle is stretched, the stronger the contraction.

Changing heart rate is the most common way to change cardiac output.

Factors Affecting the Stroke Volume

2- End-Systolic Volume (ESV)

- **The amount of blood that remains in the ventricle at the end of ventricular systole is the ESV.**

↑ End-Systolic Volume (ESV) → ↓ stroke volume

↓ End-Systolic Volume (ESV) → ↑ stroke volume

Afterload

It is expressed as tension which must be developed in the wall of ventricles during systole to open the semilunar valves and eject blood to aorta /pulmunary artery.

Is increased by any factor that restricts arterial blood flow like:

1- Increased arterial blood pressure.

2- Vasoconstriction.

As afterload increases, stroke volume decreases.

Stroke Volume Control Factors

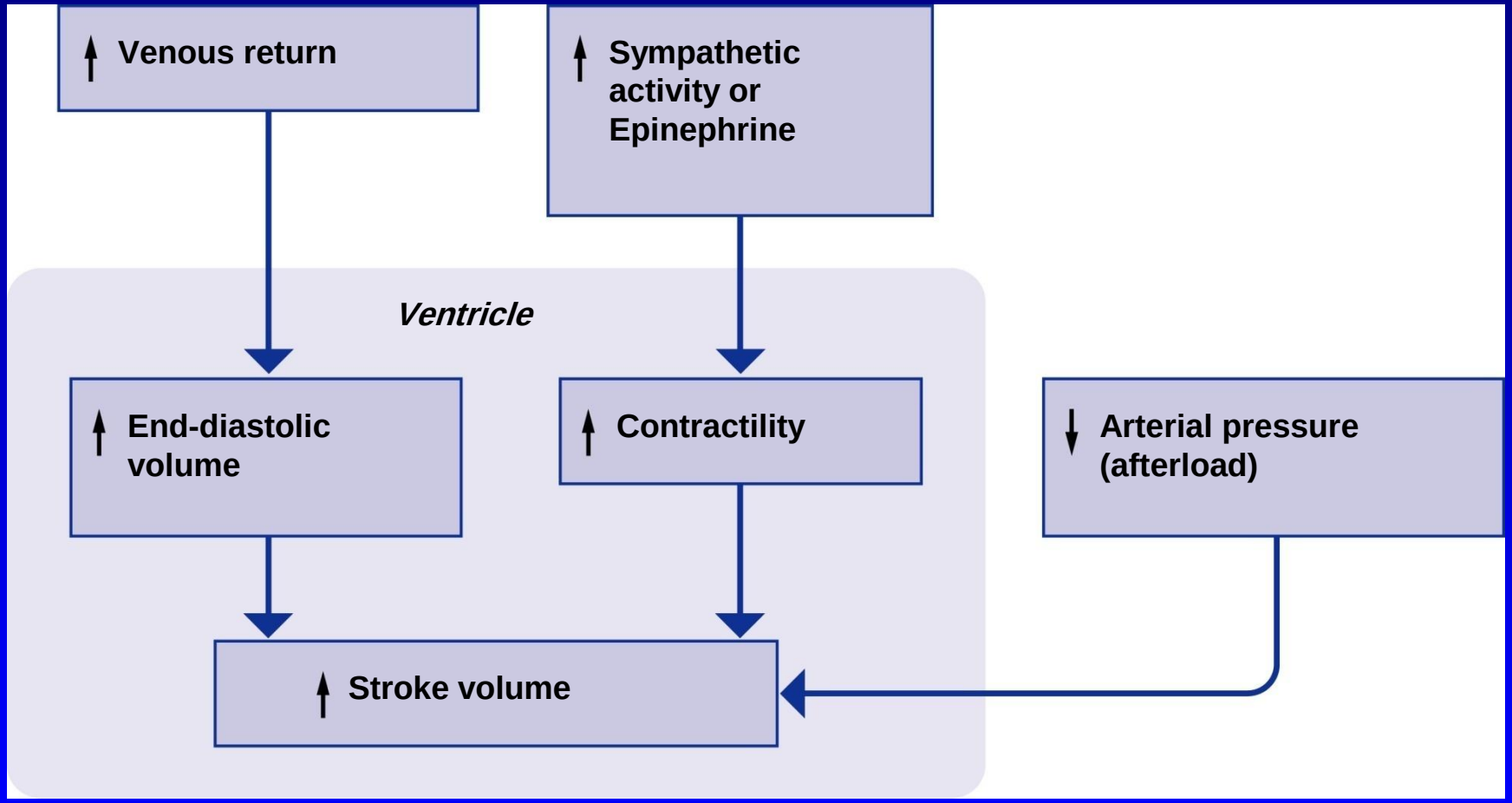
End-Diastolic Volume (EDV) or Preload

- Filling time
- Rate of venous return

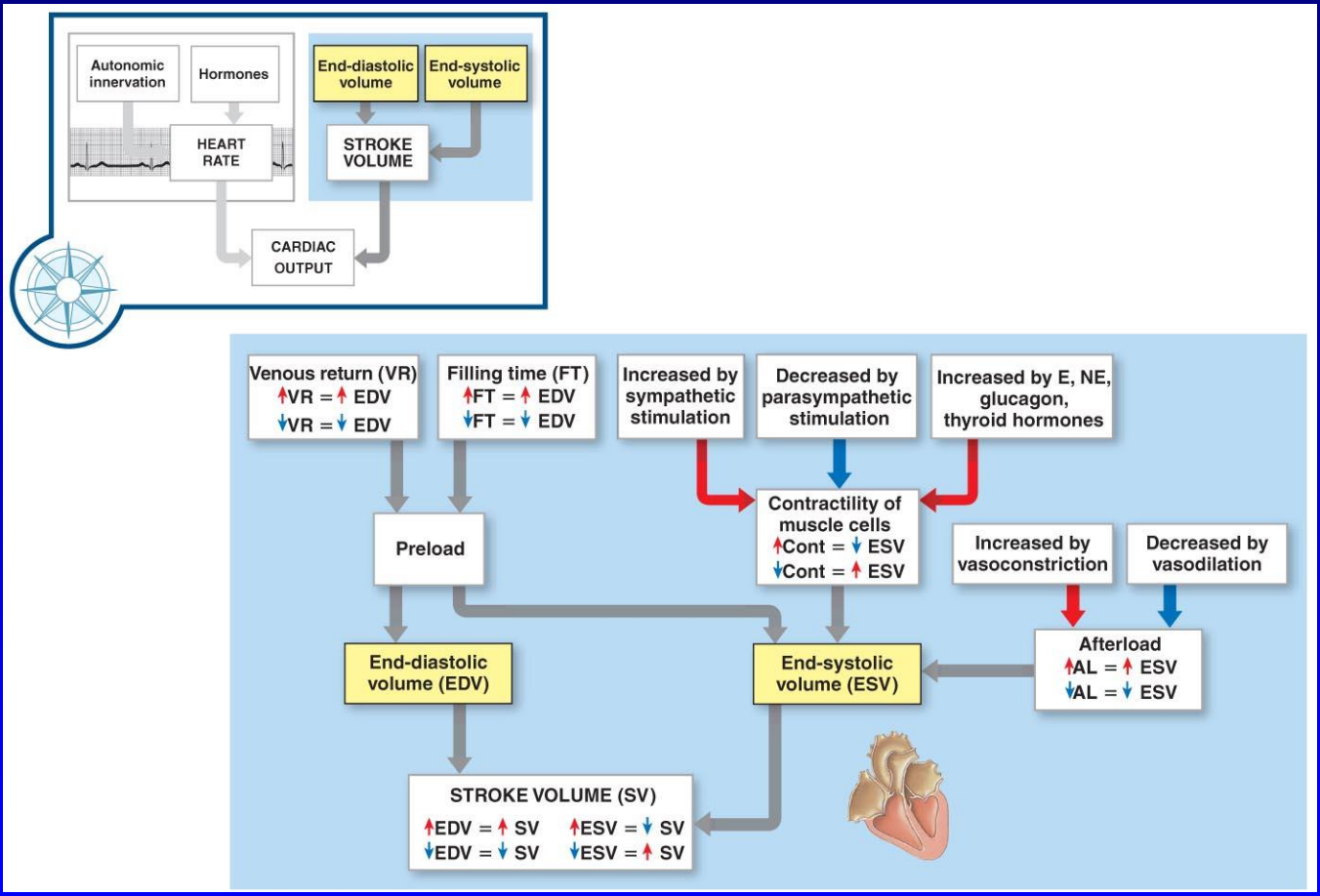
End-Systolic Volume (ESV)

- Preload ↑ preload → ↓ ESV
- Contractility ↑ Contractility → ↓ ESV
- Afterload ↑ Afterload → ↑ ESV

Factors Influencing Stroke Volume



Factors Affecting Stroke Volume



Ejection Fraction

Fraction of end-diastolic volume ejected during a heart beat.

Ejection fraction =
stroke volume / end diastolic volume
= 70 mL / 130 mL = 0.54

Factors affecting myocardial contractility: (Inotropic effectors)

1. End-Diastolic Volume (Starling's law of the heart).
2. Cardiac innervation.
3. Oxygen supply.
4. Calcium & potassium ions concentration in ECF.
5. Physical factors.
6. Hormonal & chemical factors (drugs).
7. Mechanical factors.

1- Starling's law of the heart:

"Length-tension relationship"

Within limits, the power of contraction is directly proportional to the initial length of the muscle fiber.

Overstretching the fiber as in heart failure its power of contractility decreases.

2- Cardiac Innervation

Sympathetic NS → ↑ force of contraction.

Parasympathetic NS (vagus) → ↓ atrial force of contraction with no significant effect on ventricular contraction.

3- Oxygen supply:

Hypoxia → ↓ contractility.

4- Calcium & potassium ions concentration in ECF:

↑ Ca^{2+} → ↑ contractility.

↑ K^{+} → ↓ contractility.

5- Physical factors:

Warming → ↑ contractility.

Cooling → ↓ contractility.

6- Hormonal & chemical factors (drugs):

Positive inotropics:

(Adrenaline, noradrenaline, alkalosis, digitalis, Ca^{2+} and caffien)

Negative inotropics:

(Acetylcholine, acidosis, ether, chloroform, some bacterial toxins (e.g. diphtheria toxins), K^{+}, …)

7- Mechanical factors:

a. Cardiac muscle obeys ‘all or none law:
Minimal or threshold stimuli lead to maximal cardiac contraction, because cardiac muscle behaves as a syncytium.

b. Cardiac muscle can’t be stimulated while it is contracted, because its excitability during contraction is zero due to long absolute refractory period, so it can’t be tetanized.

c. Cardiac muscle can perform both isometric & isotonic types of contractions.

Heart failure

Definition

It is the pathophysiological process in which the heart as a pump is unable to meet the metabolic requirements of the tissue for oxygen and substrates despite the venous return to heart is either normal or increased.

Heart Failure

Heart failure can involve the left or right side of the heart or both.

Usually the left side is affected first.

Heart failure occurs when either side of the heart cannot keep up with the flow of blood.

Heart Failure

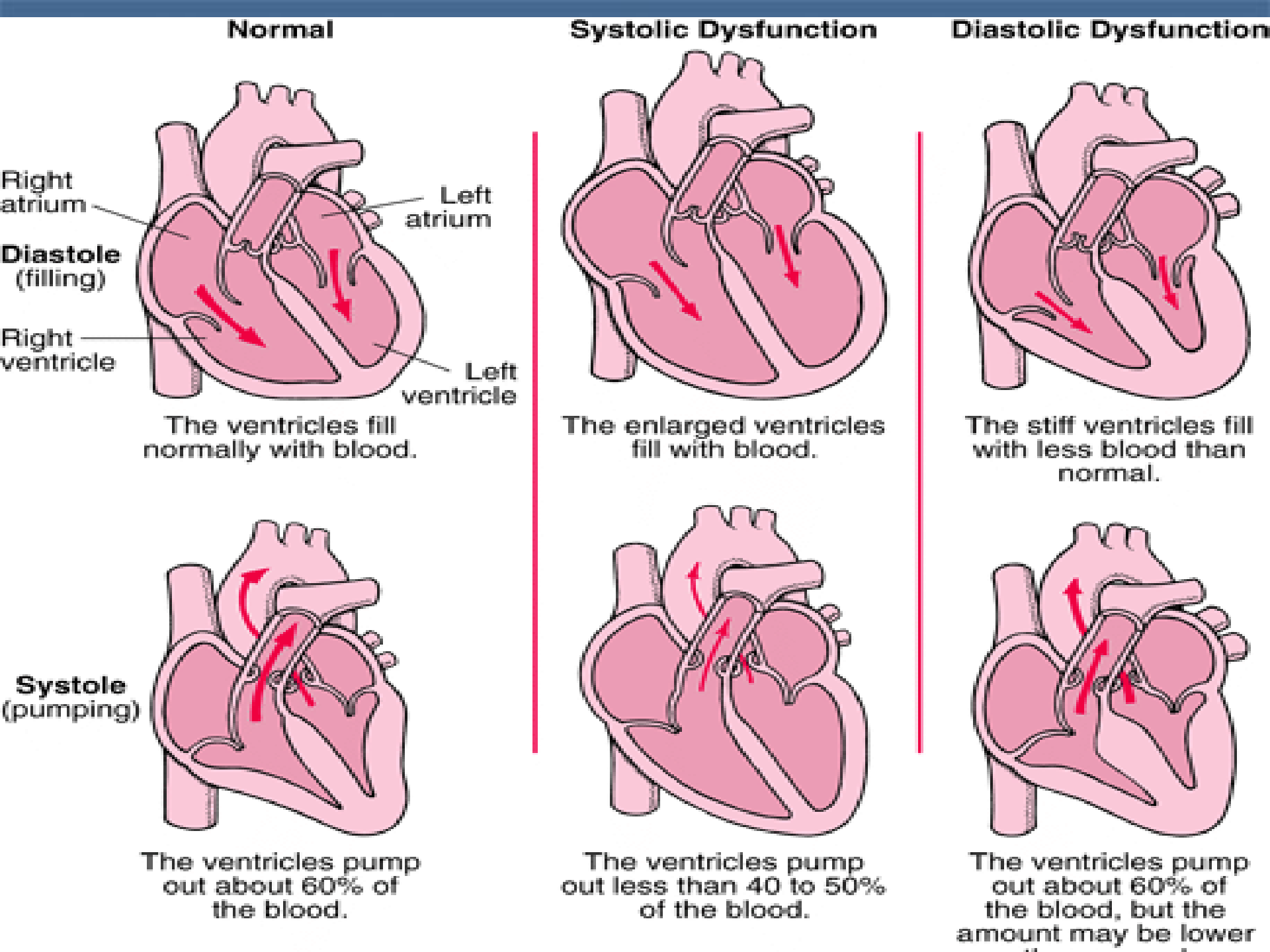
Systolic failure

- The heart looses it's ability to contract or pump blood into the circulation

Diastolic failure

- The heart looses it's ability to relax because it becomes stiff

- Heart cannot fill properly between each beat


Normal
Systolic Dysfunction
Diastolic Dysfunction
Right atrium
Left atrium
Diastole (filling)
Right ventricle
Left ventricle
The ventricles fill normally with blood.
The enlarged ventricles fill with blood.
The stiff ventricles fill with less blood than normal.
Systole (pumping)
The ventricles pump out about 60% of the blood.
The ventricles pump out less than 40 to 50% of the blood.
The ventricles pump out about 60% of the blood, but the amount may be lower

Heart Failure

What is Left Heart Failure?

Systolic and diastolic heart failure are treated with different types of medications

In both types, blood may “back up” in the lungs causing fluid to leak into the lungs

(pulmonary edema)

Fluid may also build up in tissues throughout the body (edema)

Heart Failure

What is Right Heart Failure?

Usually occurs as a result of left heart failure.

Occasionally isolated right heart failure can occur due to lung disease or blood clots to the lung (pulmonary embolism).

Heart Failure

How fast does heart failure develop?

Usually a chronic disease

The heart tries to compensate for the loss in pumping function by:

- Developing more muscle mass
- Enlarging
- Pumping faster

Causes of Heart Failure

1- Impaired cardiac function

- Coronary heart disease
- Cardiomyopathies (muscle disease)
- Rheumatic fever
- Endocarditis

2- Increased cardiac workload

- Hypertension
- Valvular disorders
- Anemias
- Congenital heart defects

3- Acute non-cardiac conditions

- Volume overload
- Hyperthyroid, Fever, Infection

Heart Failure

Signs and Symptoms of Heart Failure

Persistent Cough or Wheezing

WHY?

Fluid “backs up” in the lungs

SYMPTOMS

Coughing that produces white or pink blood-tinged sputum

Heart Failure

Signs and Symptoms of Heart Failure

Edema

WHY?

- Decreased blood flow out of the weak heart
- Blood returning to the heart from the veins “backs up” causing fluid to build up in tissues

SYMPTOMS

- Swelling in feet, ankles, legs or abdomen
- Weight gain

Heart Failure

Signs and Symptoms of Heart Failure

Tiredness, fatigue

WHY?

- Heart can't pump enough blood to meet needs of bodies tissues
- Body diverts blood away from less vital organs (muscles in limbs) and sends it to the heart and brain

SYMPTOMS

- Constant tired feeling
- Difficulty with everyday activities

Heart Failure

Signs and Symptoms of Heart Failure

Lack of appetite/ Nausea

WHY?

The digestive system receives less blood causing problems with digestion

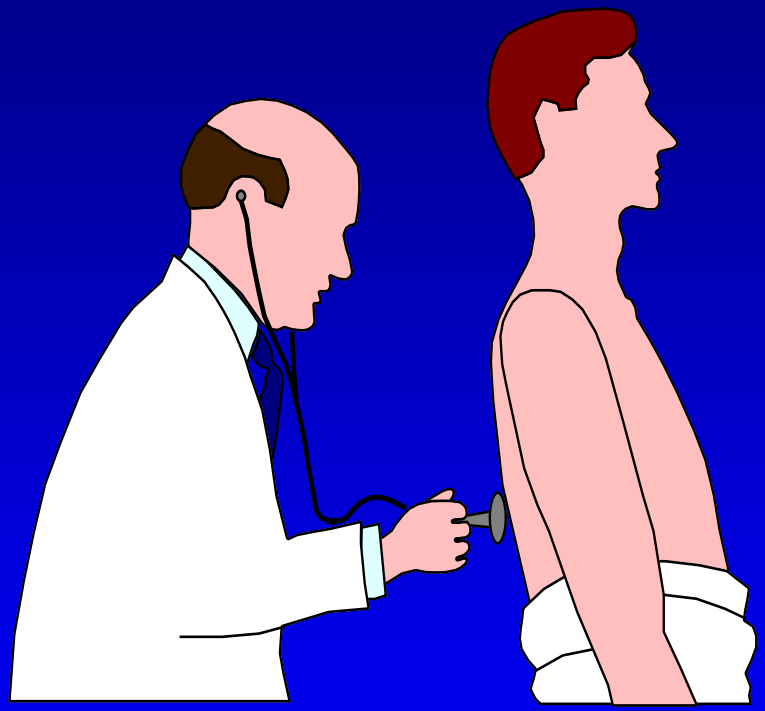
SYMPTOMS

Feeling of being full or sick to your stomach

Left Ventricular Failure

Signs and symptoms

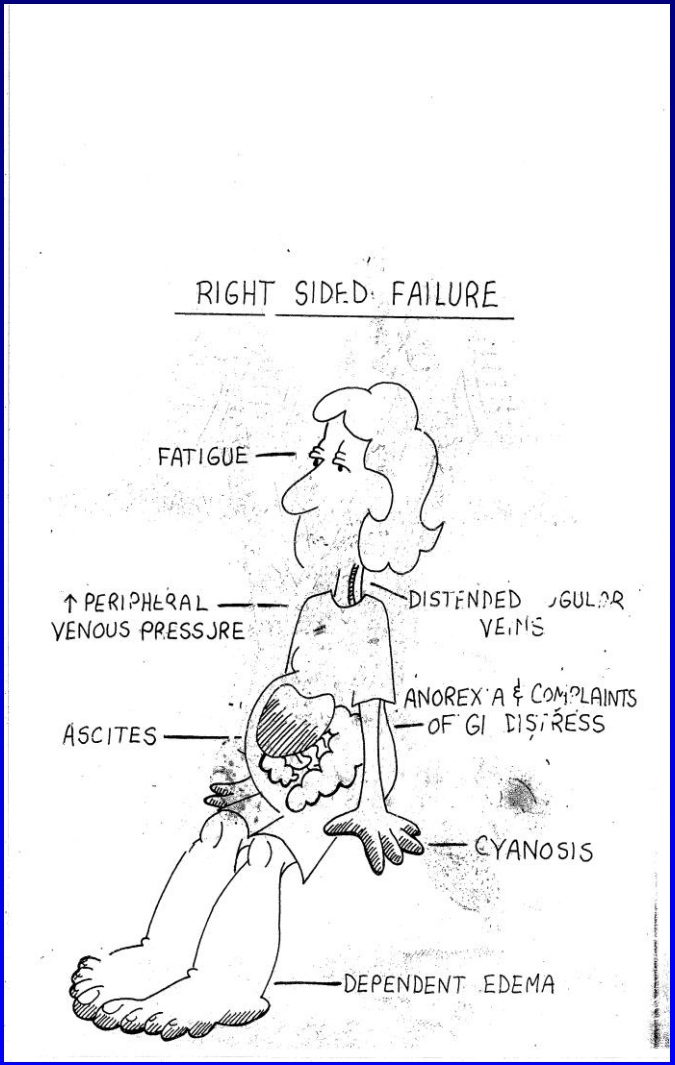
- Dyspnea
- Orthopnea and paroxysmal nocturnal dyspnoea
- Cheyne Stokes breathing
- fatigue
- Anxiety
- Rales
- pallor, cyanosis
- Increased HR and BP



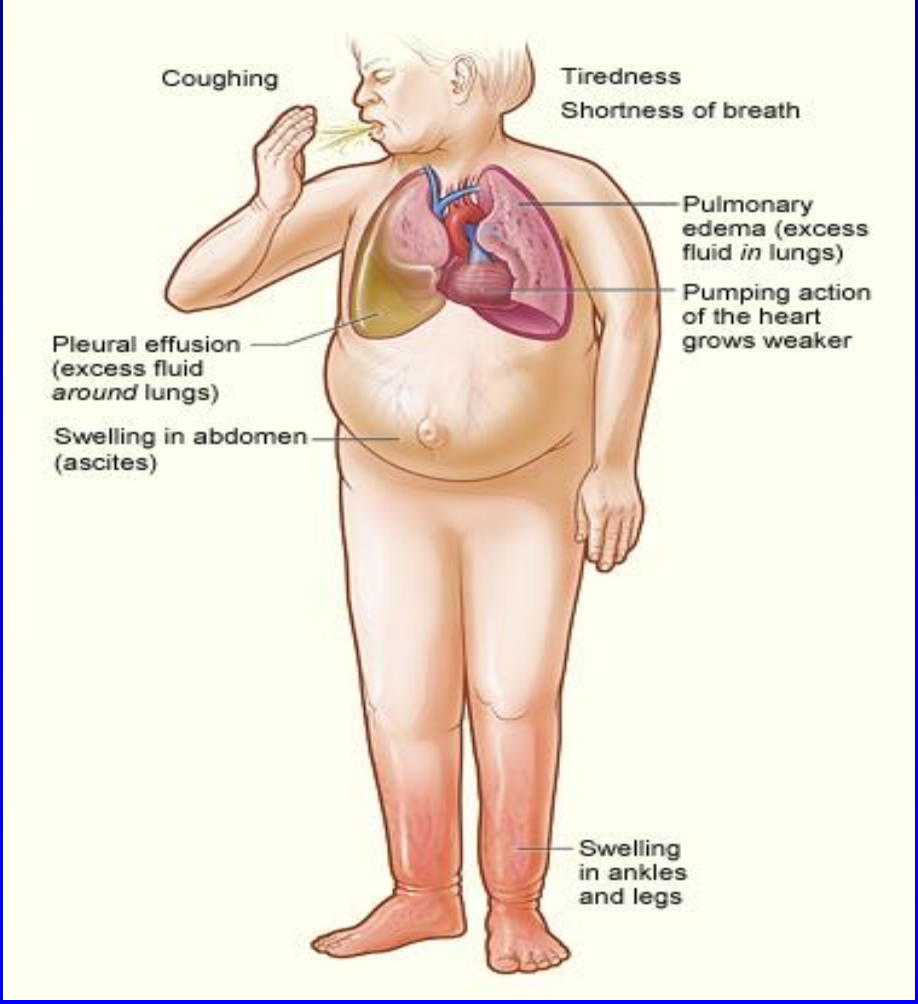
Right Heart Failure

Signs and Symptoms

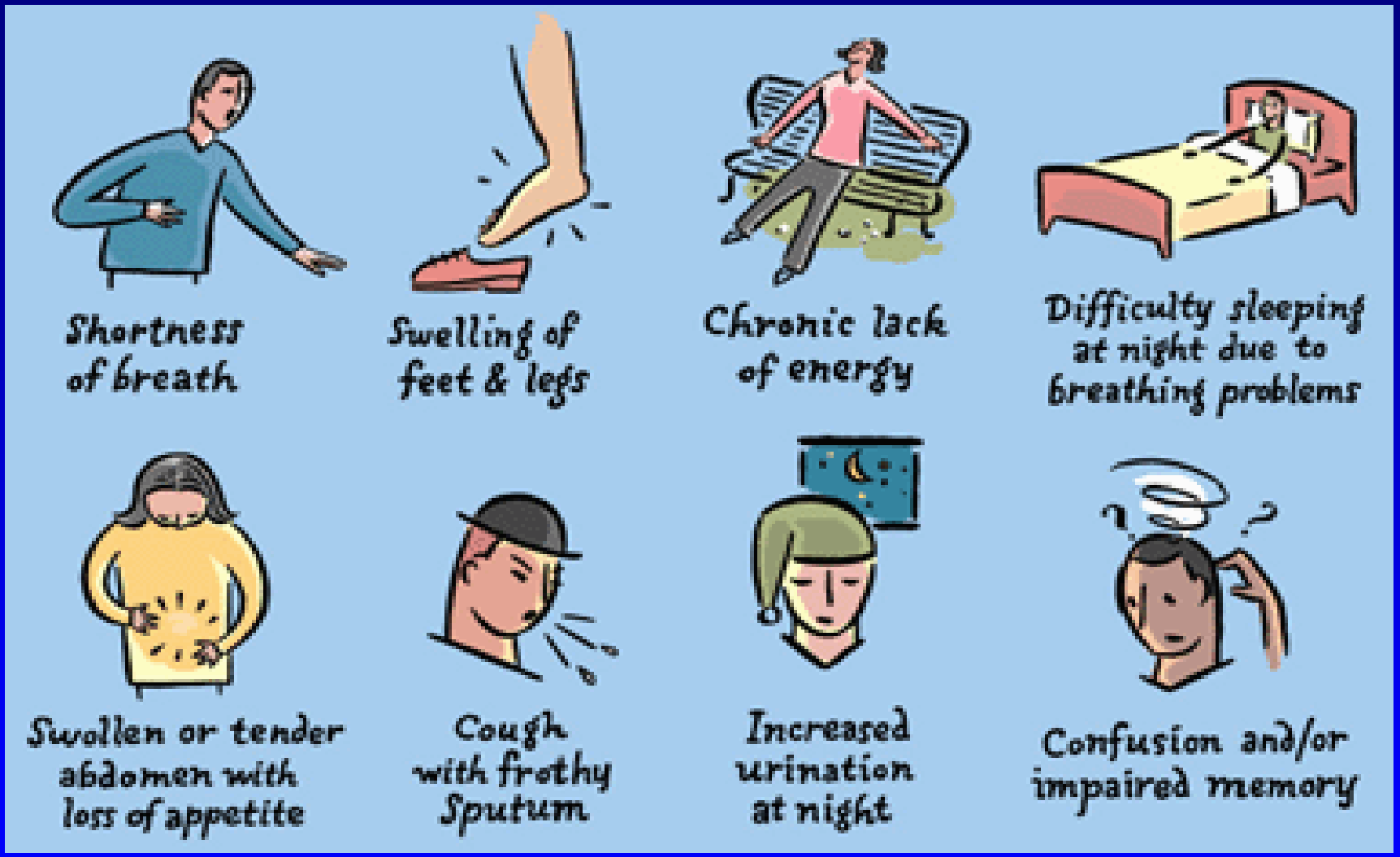
- Fatigue
- Weakness
- Lethargy
- Weight gain, including abdominal girth
- Anorexia
- Elevated neck veins
- Hepatomegaly



What is present in this extremity, common to right sided HF?



Symptoms


Shortness of breath
Swelling of feet & legs
Chronic lack of energy
Difficulty sleeping at night due to breathing problems
Swollen or tender abdomen with loss of appetite
Cough with frothy Sputum
Increased urination at night
Confusion and/or impaired memory

Can You Have RVF without LVF?

This is called COR PULMONALE

Cor pulmonale, or right-sided heart failure, is an enlargement of the right ventricle due to high blood pressure in the lungs usually caused by chronic lung disease