Stroke volume

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Stroke volume

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

Normally it is about 70 ml/beat.

END-SYSTOLIC VOLUME (ESV) and 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.

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)

- The Frank Starling principle is based on the length-tension relationship within the ventricle.
- If ventricular end diastolic volume (preload) is increased, it follows that the ventricular fiber length is also increased, resulting in an increased 'tension' of the muscle.
- Cardiac output is directly related to venous return, the most important determining factor is preload.
- The contraction and therefore stroke volume in response to changes in venous return is called the Frank-Starling mechanism (or Starling's Law of the heart).

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

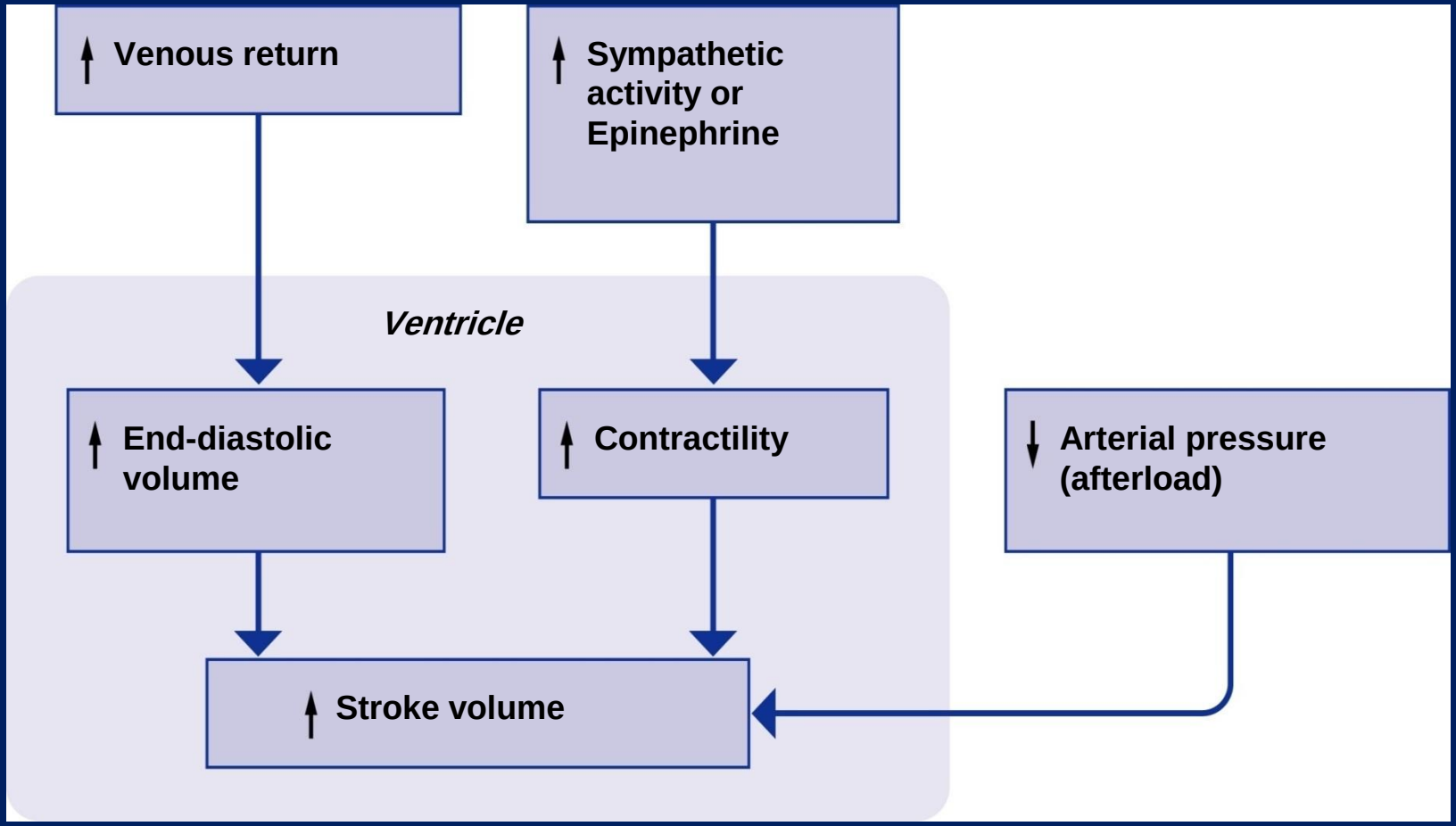
1- End-Diastolic Volume (EDV) or Preload

- Filling time
- Rate of venous return

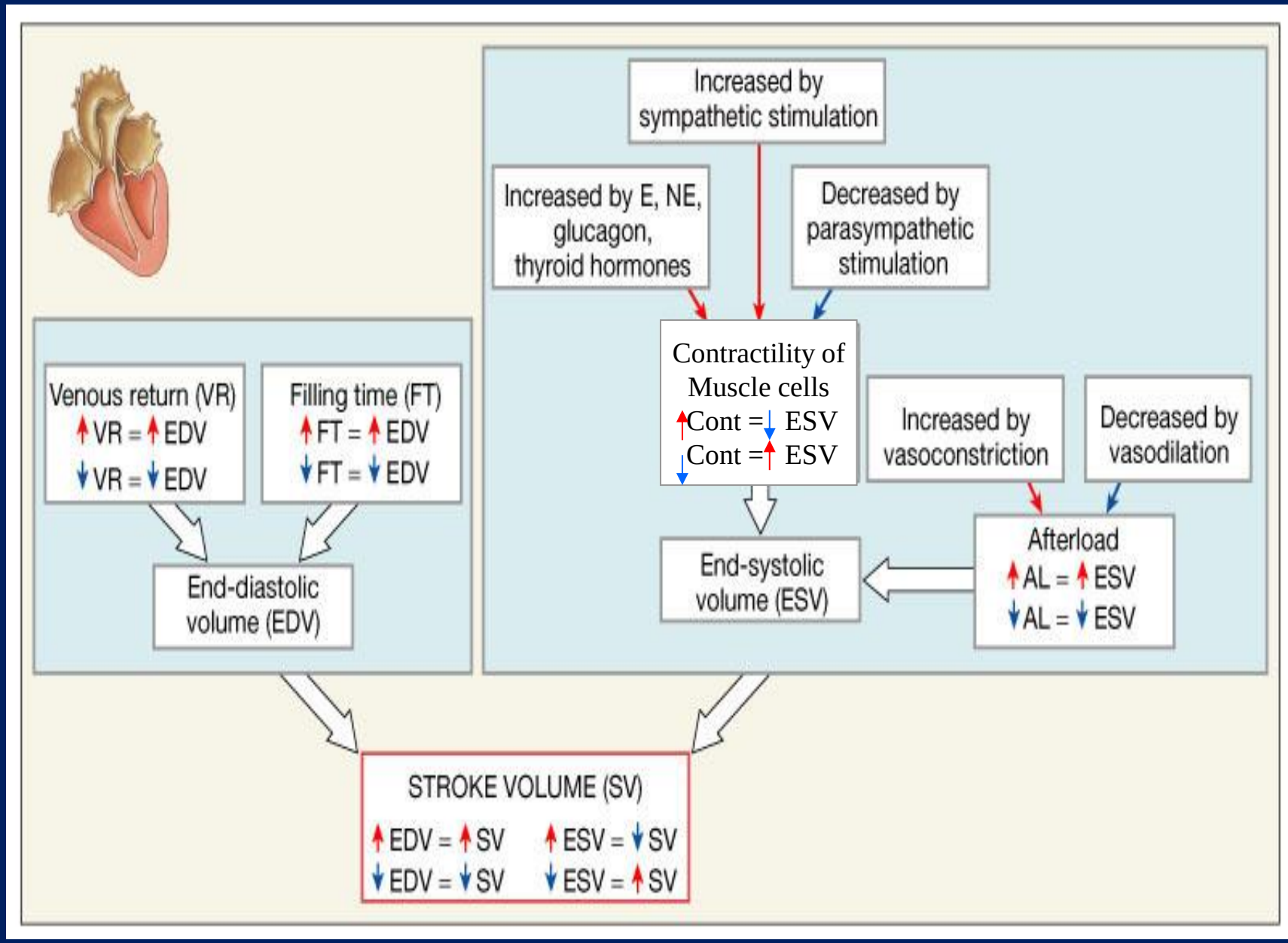
2- End-Systolic Volume (ESV)

- 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

Congestive Heart Failure

Symptoms:

- **Shortness of breath**
- **Leg swelling (edema)**
- **Breathing worsens with lying flat (orthopnea)**
- **Fatigue**

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

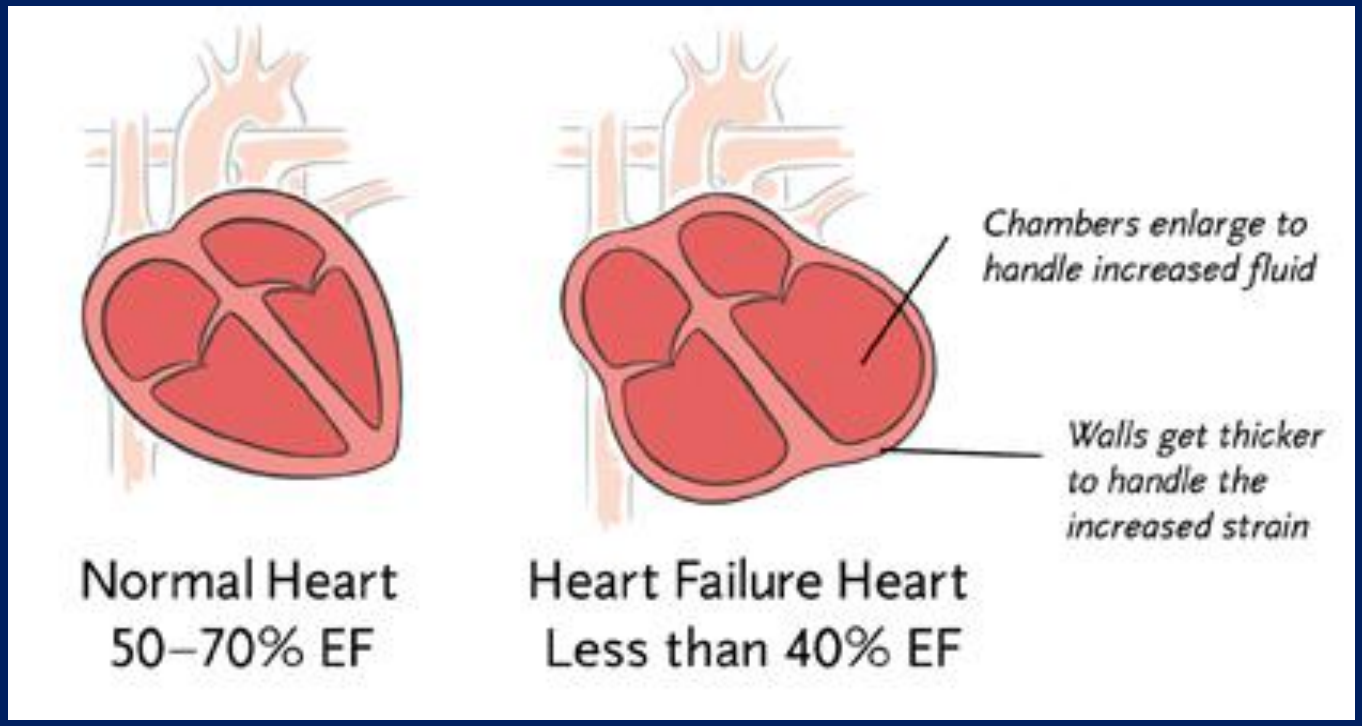
3- Acute non-cardiac conditions

- Volume overload
- Hyperthyroidism, Fever, Infection

Indicator for Diagnosing Heart Failure

Ejection Fraction (EF)

- **Ejection Fraction (EF) is the percentage of blood that is pumped out of your heart during each beat**



How Heart Failure Is Diagnosed

- Medical history is taken to reveal symptoms
- Physical exam is done
- Tests
  - Chest X-ray
  - Blood tests
  - Electrical tracing of heart (Electrocardiogram or “ECG”)
  - Ultrasound of heart (Echocardiogram or “Echo”)
  - X-ray of the inside of blood vessels (Angiogram)

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

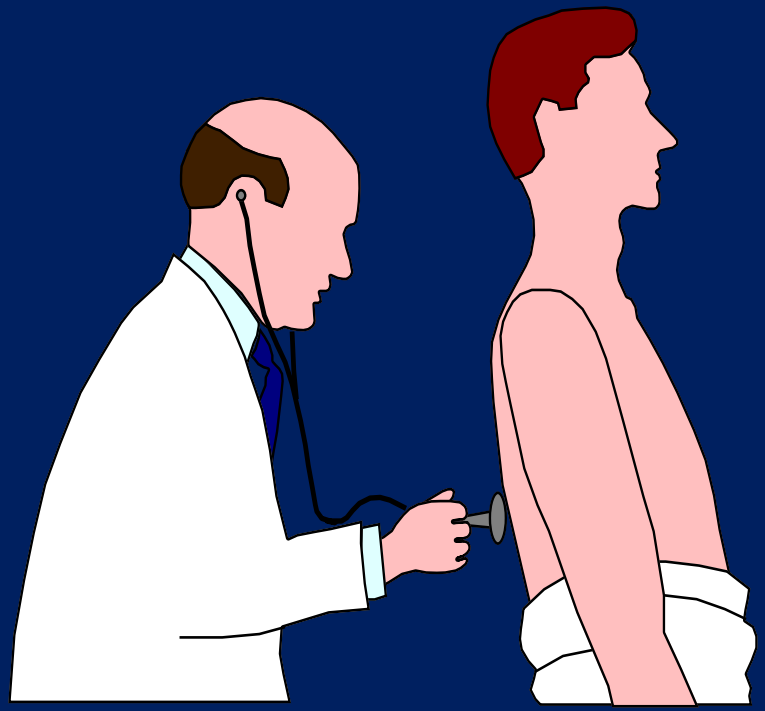
SYMPTOMS

Feeling of being full or sick to your stomach

Left Ventricular Failure

Signs and symptoms

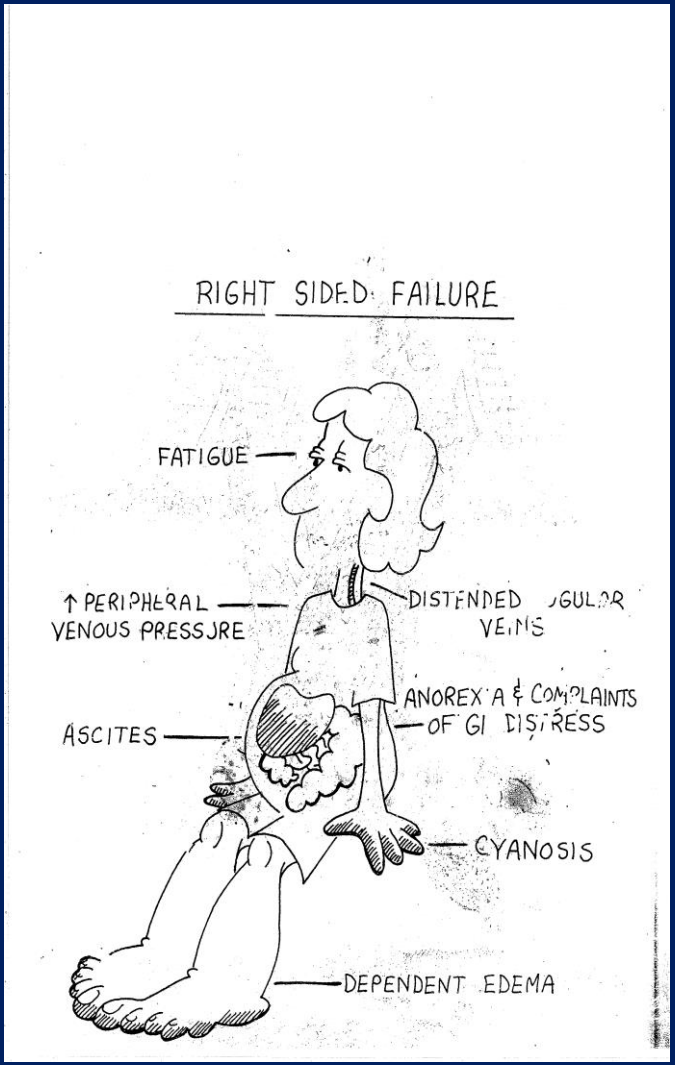
- Dyspnea
- Orthopnea and paroxysmal nocturnal dyspnoea
- Cheyne Stokes breathing
- fatigue
- Anxiety
- Rales
- pallor, cyanosis
- Increased HR and BP



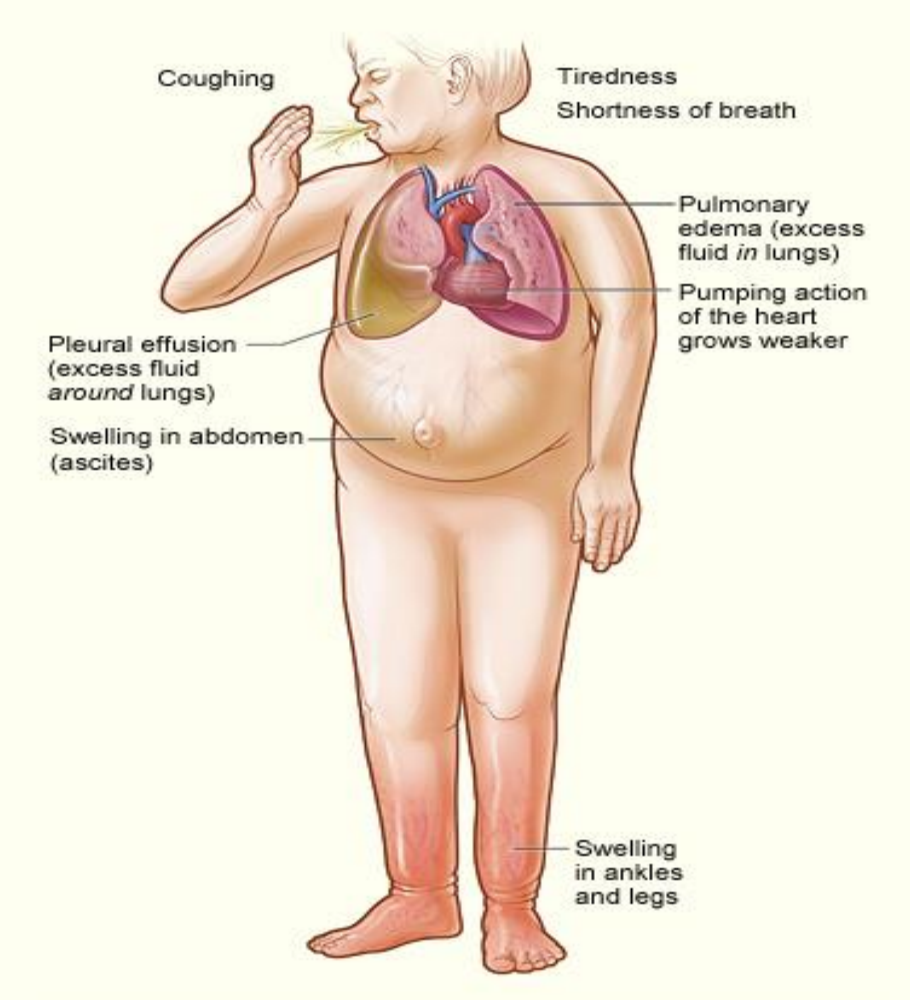
Right Heart Failure

Signs and Symptoms

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



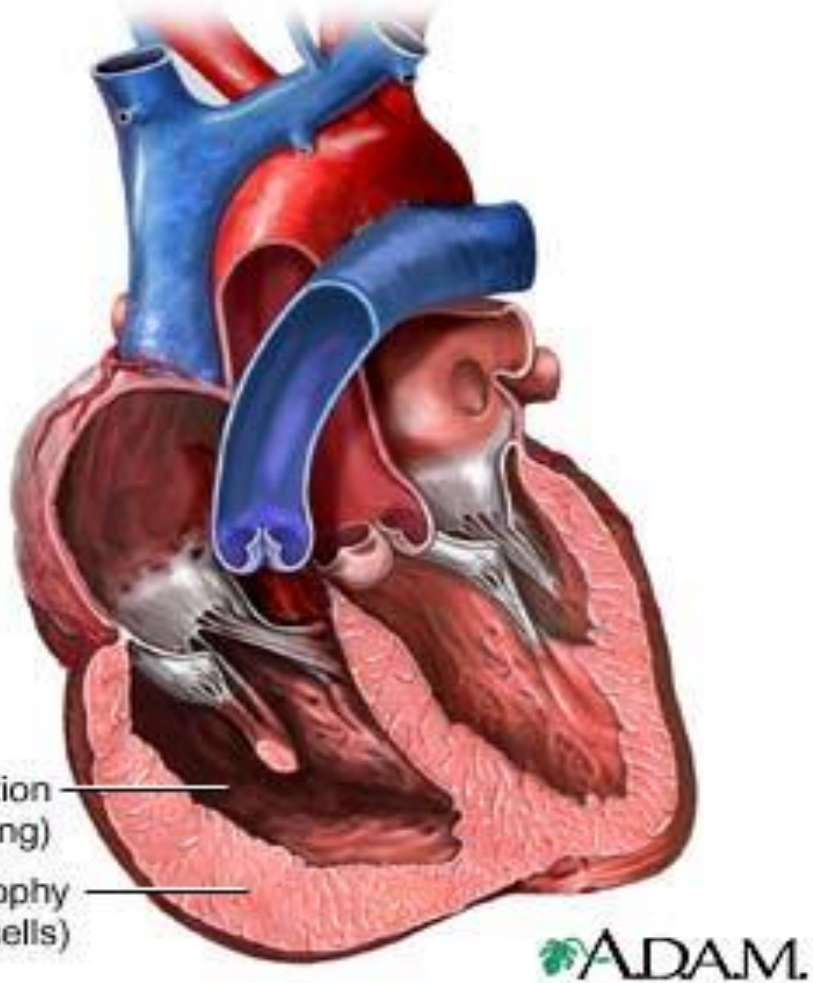
What is present in this extremity, common to right sided HF?



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



For further readings and diagrams:

Textbook of Medical Physiology by Guyton & Hall

Chapter 19 (Cardiac Failure)