Pathophysiology of Heart Failure

Blood Pathway through the Heart

1. Deoxygenated blood enters the right-side of the heart through the inferior and superior vena cavas:
    a. Right Atrium
    b. Tricuspid Valve
    c. Right Ventricle
    d. Pulmonary Valve
    e. Blood exits through the Pulmonary Arteries
        i. In the lungs, de-oxygenated blood receives fresh oxygen
2. Oxygenated blood then enters the left-side of the heart through the pulmonary veins
    a. Left Atrium
    b. Mitral Valve
    c. Left Ventricle
    d. Aortic Valve
    e. Blood exits through the Aorta
        i. The left ventricle ejects blood out into the aorta with enough force to propel blood to all organs
        ii. When blood reaches organs, oxygen and nutrients are delivered
        iii. De-oxygenated blood then returns to the right-side of the heart through the superior and inferior vena cavas to continue to process all over again
            1. Venous return from the head passes through the jugular veins and returns to the heart through the superior vena cava
            2. Venous return from the lower extremities passes through the iliac veins and returns to the heart through the inferior vena cava

Terms to Know

1. **Preload**: the **volume** (amount) of blood entering the heart
    a. Right-side of heart preload comes from the vena cavas
    b. Left side of heart preload comes from pulmonary veins
2. **Afterload**: the amount of **resistance** it takes to eject blood out of the pump
    a. How hard the heart must squeeze to eject blood

   b. Right-side of heart afterload comes from the pulmonary arteries
   c. Left side of heart afterload comes from aorta
3. **Contractility:** how **strong** the heart contracts
   a. Contractility depends on:
      i. Cardiac Action potential (electrolyte movement in myocardial and nodal cells)
      ii. Muscle strength
4. End-diastolic volume (ESV): volume of blood in ventricle after diastole
   a. Diastole occurs when the heart is fully relaxed
   b. Diastole is when the ventricle is full of blood
   c. So, end-diastolic volume is when the ventricle is full of blood
5. End-systolic volume (EDV): volume of blood in ventricle after systole
   a. Systole occurs when heart is contracting (squeezing)
   b. Systole is when ventricle has squeezed blood out
   c. So, end-systolic volume is when the ventricle has the least amount of blood in it (after squeezing)
6. Stroke volume: the amount of blood ejected into the aorta in one contraction
7. Ejection Fraction (EF): the percentage of EDV ejected into the aorta
   a. **How to calculate EF:**
      i. **$\frac{\text{SV}}{\text{EDV}}$ x 100 = Ejection Fraction**
   b. 60% or more is normal
8. Cardiac Output (CO)
   a. How to calculate CO
   b. **SV x HR = Cardiac Output**

What is BNP?

1. Brain Natriuretic Peptides
2. Purpose:
   a. Little messengers stored in the ventricles
   b. BNP monitors the stretch of the ventricles
3. How the work:
   a. If the ventricle is overstretched (aka from too much blood volume), the BNP messengers are released into the bloodstream
   b. The BNP messengers tell the brain that the heart is overloaded
   c. Then the brain tells the kidneys to release fluid and sodium out of the body
   d. This effect reduces blood volume, so the heart isn't overstretched anymore

What is Heart Failure?

1. Heart Failure is pump failure (two possible locations):
    a. Right-side failure
    b. Left-side failure (often the first side to fail)
2. How the pump fails (two ways):
    a. Heart failure with a *reduced* ejection fraction (low EF)
    b. Heart failure with a *preserved* ejection fraction (normal EF)

Heart Failure with a REDUCED Ejection Fraction (HFrEF)

1. Pathophysiology:
    a. **Muscle wall is thin and dilated**
        i. **Ventricular contractions become weak**
            1. Ventricle is too stretched out
            2. Ventricle can't "squeeze" strong enough
            3. **This is systolic failure**
    b. **HFrEF leads to congestive heart failure**
        i. Ventricle can't eject blood
        ii. Blood continues to *try* to enter the ventricle from atria
        iii. The ventricle continues to stretch to accommodate incoming blood and the blood that won't eject
        iv. Heart become congested when blood can't advance any longer
            1. **<u>Left-sided systolic failure:</u>** congestion causes blood to **back up into the lungs**
            2. **<u>Right-sided systolic failure:</u>** congestion causes blood to **back up into the vena cavas**
2. **Systolic failure means that the ejection fraction declines**
    a. **HFrEF is systolic failure**
    b. **Ejection fraction is 40% or LESS**
3. Systolic failure causes:
    a. A decline in cardiac output
    b. Low cardiac output leads to organ failure from not receiving enough oxygenated blood
    c. Volume overload in the heart
4. **S3 Heart Sound**
    a. Systolic failure can produce a third heart sound called an S3 sound
        i. The sound comes from the chordae tendineae (mitral valve)
        ii. The chordae tendineae is pulled tight when the large volume of blood rapidly fills the ventricle
        iii. The tension "plucks" those strings and creates that S3 sound
    b. **This S3 sound is heard right after the S2 sound, during <u>early diastole</u>**

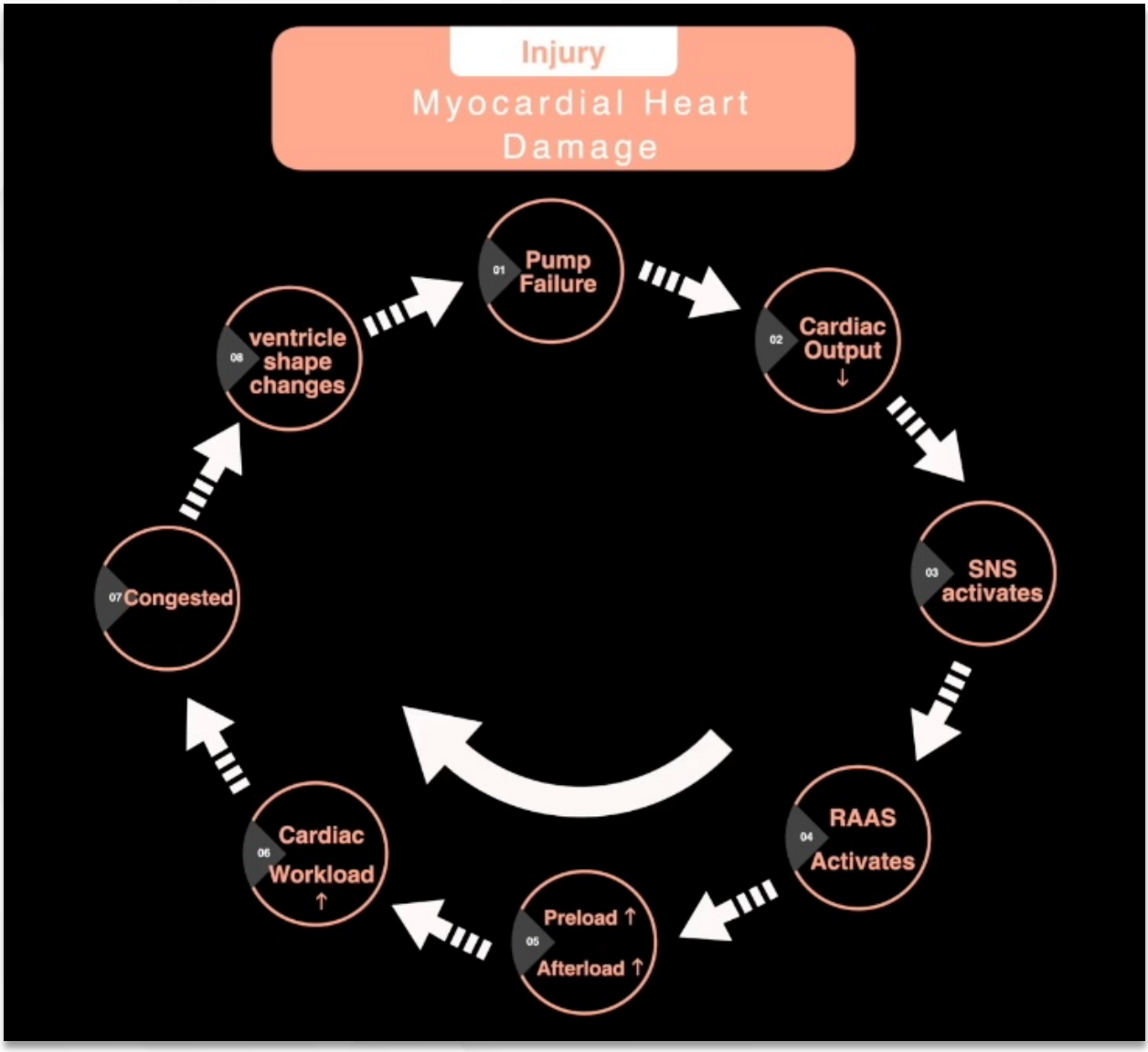
c. **Nick-named a "Ventricular gallop"** because the extra sound is coming from inside the ventricle
d. **Cadence sounds similar to the word "Ken-Tuck-Y"**
e. Best heard with a stethoscope:
    i. Listen at the mitral valve "spot"
        1. **The 5th intercostal space at the left midclavicular line**
    ii. **Heard BEST when the patient is in the <u>left lateral recumbent</u> position**
        1. When the patient lays on their left side, the heart shifts and becomes closer to the rib cage, which is closer to the stethoscope.
f. **S3 sound is a sign of VOLUME overload in a DILATED ventricle**
g. **S3 is sometimes normal in:**
    i. **Children**
    ii. **Pregnant women**
    iii. **Athletes**
h. **Most common cause of S3 sound is systolic heart failure**

Heart Failure with a PRESERVED Ejection Fraction (HFpEF)

1. Pathophysiology
    a. **Ventricular muscle wall is thick**
        i. The thick wall impedes into the ventricle, making the ventricle cavity too little to fill with enough blood
            1. Not enough end-diastolic volume
            2. Ineffective ventricular filling
            3. Not enough blood to eject
        ii. This is diastolic failure
            1. **Ventricle can't "relax" fully between contractions**
2. **HFpEF also leads to congestive heart failure**
    a. Ventricle doesn't contain enough blood to eject
    b. Blood in the atria can't empty fully into the ventricle
    c. Atria becomes congested with the blood it can't propel forward
        i. **<u>Left-sided diastolic failure:</u>** congestion causes blood to **back up into the lungs**
        ii. **<u>Right-sided diastolic failure:</u>** congestion causes blood to **back up into the vena cavas**
3. **Diastolic failure means ventricle can't relax**
    a. **HFpEF is diastolic failure**
    b. **Ejection fraction is NORMAL**
4. Diastolic failure causes:
    a. Decline in cardiac output

        i. Low cardiac output leads to organ failure from not receiving enough oxygenated blood
    b. Volume overload in the heart
    c. **Symptom: dyspnea on exertion**
        i. When heart rate increase = diastolic time decreases
            1. Tachycardia reduces diastole time and ventricular filling time, which reduces cardiac output even further
        ii. So patients are very symptomatic with exertion
5. **The most common cause of diastolic failure is hypertension**
6. **S4 sound:**
    a. Diastolic failure can produce a third heart sound called an S4 sound
        i. The sound comes from the force of blood hitting the ventricle wall and making the **stiff wall vibrate**
    b. **This S4 sound is heard right before the S1 sound, during <u>late diastole</u>**
    c. **Nick-named "Atrial" gallop"** because the extra sound is from the atria squeezing so hard
    d. **Cadence sounds similar to the word "Ten-ne-see"**
    e. Best heard with a stethoscope:
        i. Listen at the mitral valve "spot"
            1. **The 5th intercostal space and the left midclavicular line**
        ii. **Heard BEST when the patient is in the left lateral recumbent position**
            1. When the patient lays on their left side, the heart shifts and becomes closer to the rib cage, which is closer to your stethoscope.
    f. **S4 sound is NEVER EVER normal; it is always abnormal**

The Heart Failure Cycle



1. Heart Failure is a vicious cycle because the body tries to compensate, but makes things worse, making pump failure worse
    a. 50% of heart failure patients die in 5 years without medical interventions
2. **Heart failure patients are high risk for readmissions/rehospitalizations**
    a. Patients go to the hospital when they are in the CONGESTED part of the cycle
    b. Every episode of congestion can cause the ventricle to remodel
    c. Every episode of congestion reduces patient's life expectancy
    d. **Reducing hospitalizations means slowing down this cycle and extending patient's life expectancy**