The Nature of Disease
Pathology for the Health Professions
Thomas H. McConnell

Chapter 9
Disorders of the Heart
Lecture 9

Overview of Cardiac Lectures

– Review of Cardiac Physiology
– Heart Failure
– Coronary Artery Disease & Myocardial Infarction
– Valvular Heart Disease
– Diseases of the Myocardium (Heart Wall)
– Pericardial Disease
– Arrhythmias

Blood Flow Through the Heart

[Diagram of blood flow through the heart with labels]
Coronary Blood Flow

Cardiac Conduction System & EKG

Factors Affecting Cardiac Output

Also recall:
- Electrical signals normally follow the same pathway with every beat
- Atria and ventricles are electrically insulated from one another
- Every part of the CCS is capable of self-stimulation

Factors Affecting Cardiac Output

CO – Cardiac Output (~5L/min). Dependent upon Stroke Volume (SV; ~70 ml) and Heart Rate (HR)

CVP – Central Venous Pressure; Pressure in vena cava near the right atrium (affects preload; Starling mechanism)

Contractility – Increases in force of muscle contraction without change in resting length of sarcomeres

Afterload – Local against which the heart must pump, i.e., pressure in pulmonary artery or aorta

SV – Stroke Volume; Volume of blood left in heart after it has ejected blood (~50 ml)

EDV – End Diastolic Volume; Volume of blood in the ventricle before the heart contracts (~120–140 ml)

EDV – End Diastolic Volume; Volume of blood left in heart after it has ejected blood (~50 ml)

Figure adapted from: Aaronson & Ward, The Cardiovascular System at a Glance, Blackwell Publishing, 2007
Relationship of CO to Blood Pressure (MAP)

MAP (BP) → TPR

MAP = Mean Arterial Pressure
Average effective pressure driving blood flow through the systemic organs

**The MAP is dependent upon CO and TPR, i.e., MAP = CO x TPR**

TPR = Total Peripheral Resistance, depends upon Blood vessel radius, vessel length, blood viscosity, and turbulence.

MAP (BP) → TPR

MAP (BP) → HR

MAP (BP) → SV

MAP (BP) → EDV

MAP (BP) → ESV

MAP (BP) → CVP

MAP (BP) → ANS

MAP (BP) → Parasympathetic

MAP (BP) → Sympathetic

MAP (BP) → Contractility

MAP (BP) → Afterload

MAP (BP) → CVP

Frank-Starling Law

- Amount of blood pumped by the heart each minute (CO) is almost entirely determined by the venous return
- Frank-Starling mechanism
  - Intrinsic ability of the heart to adapt to increasing volumes of inflowing blood
  - Cardiac muscle reacts to increased stretching (venous filling) by contracting more forcefully
  - Increased stretch of cardiac muscle causes optimum overlap of cardiac muscle (length-tension relationship)

What does the term “Ejection Fraction” mean?

General Mechanisms Leading to Heart Disease

1. Pump failure
   - Weak contraction
   - Reduced CO
2. Obstructed flow
   - Atherosclerosis
   - Valvular defects
3. Abnormal Conduction
   - Poorly timed, premature/late, or mechanically inefficient beats
   - Result is reduced CO
4. Regurgitant flow (regurgitation)
   - Valvular defects
   - Heart must re-pump blood
5. Shunted flow
   - Diversion by congenital defects, e.g., patent foramen ovale
   - Heart must work harder and re-pump blood
Heart Failure (HF)

• Definition: A syndrome of ventricular dysfunction in which
  – CO cannot meet metabolic demands, or
  – Ventricle must be dilated to meet metabolic demands (recall Frank-Starling Law and point of 'decompensation')
  – The endpoint for most serious heart diseases

• Causes of HF fall into two major groups
  1. Increased workload on the heart
  2. Muscle failure

Left/Right Sided Heart Failure

• Left heart failure (Congestive heart failure; more common)
  – Causes of increased workload on left ventricle
    • Hypertension
    • Mitral or aortic valve regurgitation
    • Aortic valve stenosis
    • Congenital disease
  – Reduced CO activates RAA System; ↑ fluid, BP

• Right heart failure
  – Causes of increased workload on right ventricle
    • *Most common cause: increased workload due to left ventricular failure
    • Increase in left ventricular filling pressure that is reflected back into the pulmonary circulation

• General causes of left & right ventricular muscle failure
  • Ventricular infarction (most common cause of left-sided failure)
  • Cardiomyopathy

Heart Failure (HF)

• Before failing, heart tries to compensate
  – SNS and adrenal NE release
  – Cardiac Muscle Hypertrophy

• After failing
  – Systolic failure
    – Ventricle contracts poorly
    – Incomplete emptying of ventricle (↓ ejection fraction, CO)
  – Diastolic failure
    – Impaired ventricular relaxation
    – Impaired ventricular filling
  – Uncompensated failure (falling CO)
    – Forward failure (Low CO)
    – Backward failure (upstream venous congestion)

  - Cor Pulmonale – Right HF due to pulmonary hypertension
Heart Failure (cont’d)

- Manifestations of left heart failure:
  - Associated with both forward and backward failure
  - Result of pulmonary vascular congestion and inadequate perfusion of the systemic circulation
  - Include dyspnea, orthopnea, cough of frothy sputum, fatigue, decreased urine output, and edema
- Manifestations of right heart failure:
  - Result of backward failure
  - Engorgement of system venous system
    - Hepatomegaly, splenomegaly
    - Edema of feet/legs (peripheral edema)
    - Ascites
    - Pleural effusion
Heart Failure - Modes

Heart Failure – Compensated/Uncompensated

Signs and Symptoms of Heart Failure
General Mechanisms Leading to Heart Disease - Review

1. **Pump failure**
   - Weak contraction
   - Reduced CO

2. **Obstructed flow**
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3. **Abnormal Conduction**
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CAD, Myocardial Ischemia, and Myocardial Infarction

- **Continuum of diseases that narrows or occludes the coronary arteries leading to myocardial ischemia**
- **Coronary Artery Disease (CAD)**
  - Usually occurs first, followed by MI or other heart damage
  - Typically caused by atherosclerosis
  - May lead to myocardial ischemia and infarction (MI) or irreversible heart damage (acute coronary syndromes)

### Typical Risk factors for CAD and atherosclerosis

- **Major:**
  - Increased age
  - Family history
  - Male gender or female gender post menopause

- **Modifiable:**
  - Dyslipidemia
  - Hypertension
  - Cigarette smoking
  - Diabetes mellitus
  - Obesity/sedentary lifestyle
  - Atherogenic diet

**Myocardial Ischemia**

- **Local, temporary deprivation of the coronary blood supply**
- **Some clinical manifestations**
  - **Stable angina** - chest pain with gradual onset with exertion; relieved by rest
  - **Unstable angina**
    - Aggregation of platelets on an atherosclerotic plaque
    - Intensification of existing angina, new angina, nocturnal angina, prolonged angina
    - **Very serious:** May indicate a MI is imminent
    - Not usually relieved by rest or medicine
  - **Unremitting angina**
    - **Caused by myocardial infarction**
    - Doesn’t fluctuate and can’t be relieved by rest or medication
  - **Prinzmetal angina** (Transient, unpredictable, occurs at rest; vasospasm)
    - Silent/mental-stress ischemia (silent; more common in women)
Acute Coronary Syndromes

- Result of sudden coronary obstruction by thrombus or ruptured atherosclerotic plaque
- Unstable angina
  - Reversible
  - Indicator of impending infarction
  - Caused by platelet aggregation
- Myocardial infarction
  - Prolonged ischemia
  - Irreversible damage
  - STEMI or non-STEMI
  - Unremitting angina
- Sudden death can result from either

Myocardial Infarction

- Myocardial infarction
  - Sudden and extended obstruction of the myocardial blood supply
    - Subendocardial infarction
      - Only myocardium immediately beneath endocardium
      - Usually ST depression and T-inversion = non-STEMI
    - Transmural infarction
      - Endocardium through the epicardium
      - ST segment elevation = STEMI
      - Highest risk for complications
- Pathophysiology
  - Cellular injury
  - Cellular death
  - Structural and functional changes:
    - Myocardial stunning
    - Hibernating myocardium
    - Myocardial remodeling
  - Repair

ECG Changes and Myocardial Ischemia

- Normal ECG deflections
- ST segment depression
- T wave inversion
- ST segment elevation
- Subendocardial
- Transmural
Myocardial Infarction (cont’d)

- **Clinical Manifestations:**
  - Sudden severe chest pain (angina); may radiate
  - Upset stomach
  - Light headed
  - Shortness of breath (Dyspnea)
  - Excessive Sweating (Diaphoresis)

- **Complications:**
  - Sudden cardiac arrest due to ischemia, left ventricular dysfunction, and electrical instability
  - The above three are most closely correlated with sudden death from MI.

- **Blood markers of MI**
  - Creatine Kinase (CK-MB); for 2-3 days
  - cTnI and cTnT; for 7-10 days
  - LDH1 (less useful; elevated late)

Valvular Disease (Endocardium)

- **Valvular dysfunctions:**
  1. Valvular stenosis
     - Narrowing of valve opening
     - Aortic stenosis (most common valvular abnormality)
     - Mitral stenosis
  2. Valvular insufficiency (regurgitation)
     - Retrograde flow of blood through a valve
     - Aortic regurgitation
     - Mitral regurgitation
     - Tricuspid regurgitation
     - Mitral valve prolapse syndrome (MVPS)
        - Accumulation of myxoid material
        - Most common valve disease in U.S.
        - Most patients are asymptomatic

Acute Rheumatic Fever and Rheumatic Heart Disease

- **Rheumatic fever**
  - Systemic, inflammatory disease
  - caused by a delayed immune response to pharyngeal infection by the group A beta-hemolytic streptococci
  - Febrile illness
    - Inflammation of the joints, skin, nervous system, and heart
  - If left untreated, rheumatic fever causes rheumatic heart disease
    - Endocardium and valves may be involved
    - Mitral and aortic valves most often

Figure from: McConnell, The Nature of Disease, 2nd ed., LWW, 2014
Infective Endocarditis (cont’d)

Endocarditis – growth of vegetations on cardiac valves (occasionally other endocardial sites)

Strepto- and enterococci infection most commonly.

Disorders of the Myocardium: Cardiomyopathy

- Inflammatory = myocarditis
- Intrinsic muscle disease = cardiomyopathy

Types of Cardiomyopathy:
- Measurable dysfunction of the myocardium
- Dilated cardiomyopathy (congestive cardiomyopathy)
- Hypertrophic cardiomyopathy
  - Thickening of myocardium
  - Asymmetrical septal hypertrophy
  - Hypertensive (valvular hypertrophic) cardiomyopathy
- Restrictive cardiomyopathy

Disorders of the Pericardium

- Most common disorders of the pericardium
- Localized manifestation of another disorder:
  - Acute pericarditis (< 2 wks)
    - Acute inflammation of pericardium
    - Usual cause is viral infection or MI
  - Pericardial effusion
    - Tamponade (when effusion is rapid); heart cannot fill
    - Hemopericardium (undiluted blood)
  - Constrictive (restrictive) pericarditis
    - Chronic scarring and obliteration of pericardial sac
    - Impaired diastolic filling
Arrhythmias (Dysrhythmias)

- Abnormalities of the heart rhythm
- Range from occasional “missed” or rapid beats to severe disturbances that affect the pumping ability of the heart
- Some definitions to know:
  - Escape rhythm – rhythms not initiated by the SA node
  - Ectopic beat – Originating at a site other than the SA node
  - Cardiac arrest – Sudden cardiovascular collapse and unconsciousness
  - Electroconversion – defibrillation
  - Sinus arrest – lack of any electrical discharge from the SA node
  - Premature atrial contractions (PACs) – ectopic, originate in atria
  - Premature ventricular contractions (PVCs) – ectopic, originate in ventricles (do not pass backwards to SA node)
  - Flutter – rapid, but regular and evenly spaced beats
  - Fibrillation – rapid, irregular and unevenly spaced (little/no CO)
  - Reentry loop – originates in CCS, but loops back into it again
  - Junctional arrhythmia – ectopic beat with origin near AV node

General Classification of Arrhythmias

Cardiac Arrhythmias (Dysrhythmias)

- Arrhythmias classified into three broad categories
  1. Those associated with impulses arising from SA node
     - Sinus brady- and tachycardia, sinus arrhythmia, sinus arrest
  2. Those associated with impulses arising from OTHER than the SA node; Ectopic signals
     - In atria: Premature, Flutter (rapid, regular), Fibrillation (irregular)
     - In ventricles: Premature, Flutter (tachycardia), Fibrillation
       - Ventricular tachycardia (≥ 3 consecutive ectopic beats; rate >120 bpm)
       - Ventricular fibrillation (CO is effectively zero)
     - At AV node junction (junctional arrhythmia)
       - Originate near the AV node
       - Sometimes called Supraventricular Tachycardia
       - Causes tachycardia
Cardiac Arrhythmias (Dysrhythmias)

- Arrhythmias classified into three broad categories (cont'd)
  3. Those associated with impulses arising from OTHER than the SA node; Ectopic signals
    - In atria
      - Premature atrial beats (usually not pathologic)
      - Atrial flutter (rapid, but regular)
      - Atrial fibrillation (rapid and irregular)
    - In ventricles
      - Premature Ventricular Contractions (PVC)
        - Early ventricular beat
        - Interferes with next impulse from SA node
      - Ventricular tachycardia (≥ 3 consecutive ectopic beats; rate >120 bpm)
      - Ventricular fibrillation (CO is effectively zero)
    - At AV node junction (junctional arrhythmia)
      - Originate near the AV node
      - Sometimes called Supraventricular Tachycardia
      - Causes tachycardia

EKGs

- Normal Sinus Rhythm
- Sinus Tachycardia
- Sinus Arrest

EKGs

- Normal Sinus Rhythm
- Atrial Flutter
- Atrial Fibrillation