Bradycardia and Heart Block

At this point you have learned to recognize the ECG pattern associated with normal impulse formation (in the SA node) and conduction (via the AV node, His-Purkinje system and ventricular myocardium). Normal impulse formation and conduction results in an upright P wave in lead II, a P wave before every QRS complex, a QRS complex for every P wave, a normal PR interval (0.12-2.0 sec) and a normal QRS duration (< 0.10 sec). A normal heart rate is 60-100 beats per minute. When impulse formation and conduction are normal, but the heart rate is either less than 60 beats per minute, or greater than 100, the rhythms are called Sinus Bradycardia or Sinus Tachycardia, respectively. In this section of the handbook, you will learn about the various disorders of impulse formation and conduction that can cause bradycardia, heart block or both. Before discussing the individual bradycardias and heart blocks, we need to introduce one new concept.

Concept: Escape

Normal cardiac impulses originate in the cells of the SA node due to the characteristic feature of the action potential (spontaneous phase 4 depolarization) that allows those cells to depolarize themselves in a rhythmic fashion. This feature is referred to as automaticity. However, some cells that make up the other parts of the specialized conduction system (e.g. AV Node) also possess automaticity. The SA node cells and not these other cells are the dominant pacemaker in the normal heart because phase 4 depolarization is fastest in the SA node. However, if the SA node fails to form an impulse, or if the impulse fails to be propagated distally, these other cells may serve a backup or secondary pacemaker function. For simplicity, we refer to these secondary pacemaker sites as junctional, when the impulse originates from the AV node or ventricular, when the impulse originates from further down in the conduction system (e.g. His-Purkinje). Secondary pacemakers are generally slower than the SA node, and the further down the conduction system, the slower they are. When normal impulse conduction or propagation is absent, and when the heart rate is driven by a secondary pacemaker in the AV node or His-Purkinje system, we refer to this as an escape rhythm. Junctional (AV Node) escape rhythms are generally 40-60 beats/minute while Ventricular (His-Purkinje) escape rhythms are generally 30-40 beats/minute. Some examples of escape will be shown as we discuss the various bradycardias and heart blocks.
Sinus Bradycardia

Sinus Bradycardia describes slowing of impulse formation (due to slower phase 4 depolarization) in the SA node leading to a heart rate less than 60 beats per minute. Since impulse conduction is in the normal direction, the P wave appears normal (upright in lead II). Sinus Bradycardia can be a normal physiological finding due to enhanced vagal tone (e.g. in well-conditioned subjects), be the result of medications that suppress SA node activity (e.g. beta blockers) or reflect intrinsic disease of the SA node. The rhythm is typically regular (equal spacing between P waves) but slight phasic variation (less than 10%) due to breathing is also common. The term Sinus Arrhythmia refers to this slight phasic variation in heart rate often seen in Normal Sinus Rhythm and Sinus Bradycardia. Sinus Bradycardia is considered a benign arrhythmia in the absence of symptoms, but is treated with a pacemaker when extreme slowing leads to symptoms of reduced cardiac output.

![Sinus Bradycardia Diagram]

### Key Features
- Heart Rate < 60 bpm
- Upright P wave in Lead II
- P before each QRS
- QRS for every P wave
- Enhanced vagal tone or
- Medications or
- Disease involving SA node

**Figure 2.** Sinus Bradycardia
Sinus Pause, Sinus Arrest

Sinus Pause is a result of transient failure of impulse formation in the SA node. When the pause is very extreme, it is called Sinus Arrest. There is no precise definition that distinguishes Sinus Pause from Sinus Arrest. In practice, it is best to use the term Sinus Pause along with the length of the pause. For example, in the first example below one would say there is a “2.2-second Sinus Pause”. Note that when Sinus Pause occurs, the next beat may be a normal sinus beat (first figure below), a junctional escape beat (second figure below) or a ventricular escape beat (third figure below). Note that junctional escape QRS complexes look the same as sinus QRS complexes since conduction of the impulse follows the normal His-Purkinje System. Conversely, ventricular escape beats are wide since ventricular activation does not occur via the specialized conduction pathway.

Figure 3. Sinus Pause and escape

There are two other terms you may hear in association with Sinus Node dysfunction. You are not expected to know these terms for HuBio 540 but they are mentioned here since they are frequently used in clinical medicine. Sick Sinus Syndrome is a common but poorly defined term that refers to patients with unexplained sinus bradycardia or frequent sinus pauses. Tachy-Brady Syndrome is another loosely defined term that refers to patients who alternately exhibit both bradycardia (either from Sinus Node problems or conduction problems) and tachycardia. Such patients are often difficult to treat because medications used to treat the tachycardia may worsen the bradycardia.
Heart Block

The specialized cardiac conduction system consists of the AV Node, Bundle of His and Right and Left Bundle Branches. When conduction is impaired in these structures, the ECG will show at least one of the following: (a) a long PR interval, (b) a failure of some or all P waves to be followed by a QRS complex or (c) a wide QRS complex. The next section discusses the various ECG patterns resulting from abnormal impulse conduction.

First Degree AV Block

First degree AV Block is caused by slowed conduction somewhere (most commonly, the AV Node) between the SA Node and ventricles. The ECG shows a long PR interval (> 0.20 sec). First degree AV block rarely requires specific treatment, as all Sinus Node impulses are conducted 1:1 to the ventricles. First Degree AV Block can be due to increased vagal tone or medications which slow AV Node conduction. In the figure below the PR interval is approximately 7 small boxes (0.28 sec) and is best seen in Lead II where the P wave is more distinct than in Lead AVL.

**Key Features**
- Long PR interval (> 0.2 sec)
- QRS follows each P wave
- AV Node is usual site of impaired conduction
- Clinically benign

Figure 4. First Degree AV Block
Second Degree AV Block

Second degree AV Block is present when there is intermittent failure of the sinus impulse to conduct to the ventricles. Therefore, QRS complexes do not follow some P waves. There are 2 subtypes of Second degree AV block. Mobitz I (also called Wenckebach) is caused by intermittent block in the AV node. The ECG shows progressive lengthening of the PR interval in the beats preceding the “dropped” beat (P wave not followed by QRS). Mobitz I is generally benign and can be seen in normal individuals with heightened vagal tone or can be due to medications active at the AV Node. Mobitz II is much less common and is usually caused by intermittent block at or below the His Bundle. The QRS is usually wide and there is no progressive PR prolongation leading up to the block. Mobitz II is considered a more serious finding and often leads to pacemaker implantation.

Key Features

- No QRS for some P waves
- Mobitz I (Wenckebach)
  * Common
  * Block at AV Node
  * Progressive PR lengthening
  * Less serious
- Mobitz II
  * Less common
  * Block at His or below
  * No PR lengthening before drop
  * More serious → pacemaker

Figure 5: Second degree AV Block. Examples of Type I second degree heart block (Wenckebach, top) and Type II second degree heart block (bottom) are shown.
Third Degree AV Block (Complete Heart Block)

Third degree AV Block is present when there is complete failure of the sinus impulses to conduct to the ventricles. Ventricular activation depends on Escape. As a result, there is no fixed relationship between P waves and QRS complexes (A-V dissociation). The 3 criteria for the diagnosis of Complete Heart Block are (1) A-V dissociation, (2) atrial rate faster than ventricular rate and (3) a regular “escape” rhythm. Third Degree AV Block is most commonly due to myocardial infarction or degenerative disease of the conduction system, but may also be congenital. Pacemaker implantation is usually required.

Figure 6: Third degree AV Block. Shown is an example of third degree (complete) AV block with a junctional escape rhythm. Note that some of the P waves are “hidden” within either the QRS or T waves.

Terminology in Second and Third Degree Heart Block

When second or third degree AV block is present, it is common to preface the diagnosis with a separate description of the atrial rhythm. For example, in Figure 6, one would describe the rhythm as “sinus rhythm with third degree A-V block” to indicate that the atrial activity appears to be driven by the SA Node. However, it would be incorrect to call this “Normal” Sinus Rhythm with third degree AV block as the term Normal Sinus Rhythm implies one to one conduction from the atria to the ventricles.

Bundle Branch Block

Abnormal conduction confined to either the left or right branch of the His-Bundle is relatively common. In isolation, isolated Left Bundle Branch Block (LBBB) or Right Bundle Branch Block (RBBB) do not inhibit conduction of sinus impulses to the ventricles and thus do not cause bradycardia or require specific treatment. Since the “blocked” ventricle is not activated via the specialized conduction system but rather by slower muscle-muscle conduction, the QRS is prolonged (>0.12 sec) in both LBBB and RBBB.
Left Bundle Branch Block (LBBB)

With LBBB, the right ventricle is depolarized first and normally via the right bundle while the left ventricle is activated only by slow muscle-muscle conduction. The ventricular septum is therefore depolarized from right to left (normal is left to right) and thus the small “septal” Q waves that are normally seen in the left-sided leads (I, V5, V6) are absent. The lateral leads typically show a broad and notched or slurred R wave. In LBBB, repolarization is also abnormal and ST segments and T waves are usually directed in the opposite direction to the QRS. The QRS axis often is normal but may be deviated either to the left or (less commonly) to the right.

**Key Features**
- Slow LV activation
- Wide QRS (> 0.12 sec)
- Loss of septal Q (I, V5, V6)
- Broad slurred lateral R waves
- ST & T waves opposite QRS

**Figure 7. LBBB**: Note the wide (>0.12 sec QRS) and wide R waves in Leads I, V5 and V6. In these lateral leads, the latter portion of the QRS is above the baseline, indicating that the wave of depolarization is moving toward the patient’s left since activation of the left ventricle is delayed. Conversely, the latter portion of the QRS is below the baseline in lead V1, indicating that the wave of depolarization is moving away from the patient’s right.
Right Bundle Branch Block (RBBB)

With RBBB, the left ventricle is depolarized first and normally via the left bundle while the right ventricle is activated only by slow muscle-muscle conduction. The ventricular septum is activated normally (left to right). Late activation of the RV is recognized by a secondary R wave (R’) in Lead V1 and a broad S wave in the lateral leads (I, V5, V6). Since activation of the dominant left ventricle is unaffected, the QRS axis is normal in isolated RBBB.

**Key Features**
- Slow RV activation
- Wide QRS (> 0.12 sec)
- Secondary R wave (R’) in V1
- Broad lateral S waves (I, V5, V6)
- Normal QRS axis

**Figure 8. RBBB:** Note the wide (>0.12 sec QRS), the secondary R wave (R’) in Lead V1 and the broad S wave in the lateral leads. In the latter portion of the QRS, the wave of depolarization is moving toward the patient's right indicating delayed activation of the right ventricle. The wide S wave in the lateral leads (I, V5 and V6) shows that in the latter portion of the QRS the wave of depolarization is moving away from the patient’s left.
Fascicular Block (Hemiblock)

The left bundle branch divides into two fascicles. The anterior fascicle is located anterior and superior and the posterior fascicle is located posterior and inferior. Conduction may be blocked in either fascicle alone, or in combination with RBBB. (When both fascicles are blocked, the ECG shows LBBB). When there is conduction block in one of the fascicles, it is called fascicular block (you may also hear the older term “hemiblock”). Isolated fascicular blocks may slightly prolong the QRS (0.10 - 0.12 sec). Fascicular blocks alone do not require specific treatment, but may indicate underlying structural heart disease. Left anterior fascicular block (LAFB) results in relatively late activation of the left and superior portion of the LV. The late spread of relatively unopposed forces leftward and superiorly results in left axis deviation (QRS up in I and down in II). Conversely, left posterior fascicular block (LPFB) results in relatively late activation of the right and inferior portion of the LV. The late spread of relatively unopposed forces rightward and inferiorly results in right axis deviation (QRS down in I and up in II). LAFB is much more common than LPFB and is frequently seen together with RBBB. Remember that isolated RBBB does not cause a shift in the QRS axis, so if you see a RBBB with an abnormal axis, consider that there may also be a block in one of the fascicles of the left bundle.

Pacemakers

When abnormalities of impulse formation and/or conduction lead to symptoms or a significant potential for symptoms, pacemaker implantation may be required. In an emergency situation or when the problem is thought to be temporary, a temporary transvenous pacemaker is placed. The pacing wire is introduced into a major vein (most commonly the jugular, subclavian or femoral) and the distal tip is advanced to the apex of the right ventricle. The proximal end of the catheter is then connected to a pacing box which is kept at the bedside and which can deliver a pacemaker impulse at a programmable rate. Permanent pacemakers are implanted subcutaneously (most often just below the left clavicle) and connected to pacing leads that are advanced to the right atrium and/or right ventricle. When the problem is impulse conduction from atrium to ventricle (e.g. third degree heart block), at a minimum a lead must be placed in the right ventricle. When the problem is impulse formation in the Sinus Node, but conduction to the ventricles is normal, a single lead in the right atrium may suffice. Permanent pacemakers with leads placed in both the right atrium and right ventricle are called Dual-Chamber Pacemakers. Electronic pacemaker activity on the ECG is recognized as narrow spikes immediately preceding the P wave and/or QRS complex. When the right ventricle is “paced”, ventricular activation does not occur via the specialized conduction tissues and is therefore slower, and the QRS will be wide (> 0.12 sec).

Figure 9. Pacemaker spikes and wide QRS
Bullet Point Review

Problems with **Impulse Formation**

- **Sinus Bradycardia**
  - Sinus P wave (upright P in lead II)
  - HR < 60 bpm
- **Sinus Pause, Sinus Arrest**
  - Transient failure of impulse formation in the SA node
  - Describe by saying “an X second sinus pause”
- **Concept of “Escape”**
  - Junctional ~ 40-60 bpm
  - Ventricular ~ 30-40 bpm

Problems with **Impulse Conduction**

- **First Degree AV Block**
  - PR interval > 0.2 seconds
  - All P waves conduct (QRS follows all P waves)
- **Second Degree AV Block**
  - Some P waves do not conduct
  - Mobitz I (Wenckebach)
    - Progressively longer PR in beats preceding the “dropped” beat
    - More common; less serious; block usually at AV Node
  - Mobitz II
    - Constant PR in beats preceding the “dropped” beat
    - Less common; more serious; block usually distal to AV Node
- **Third Degree AV Block**
  - No P wave conducts to ventricles (need to have escape rhythm)
  - AV dissociation; atrial rate faster than ventricular rate; regular escape rhythm

- **Bundle Branch Block**
  - QRS > 0.12 second
  - Left Bundle Branch Block (LBBB)
    - Slow activation of LV
    - Loss of “septal” Qs and broad R waves in lateral leads (I, V5, V6)
  - Right Bundle Branch Block (RBBB)
    - Slow activation of RV
    - R’ in lead V1; broad S wave in lateral leads; normal QRS axis
  - Fascicular Block
    - LAFB – common – causes left axis deviation
    - LPFB – less common – causes right axis deviation

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