5 Lead Electrode Placement

- **RA**
  Right infraclavicular fossa medial to the border of the deltoid muscle and 2 cm below the lower border of the clavicle

- **LA**
  Left infraclavicular fossa medial to the border of the deltoid muscle and 2 cm below the lower border of the clavicle

- **C**
  Right 4\textsuperscript{th} intercostal space at the sternal border

- **RL**
  Right anterior axillary line, halfway between the costal margin and the crest of the ilium.

- **LL**
  Left anterior axillary line, halfway between the costal margin and the crest of the ilium.
**Chest Lead Placement**

\[
\begin{align*}
V_1 & \quad 4^{\text{th}} \text{ Intercostal Space, Right Sternal Border} \\
& \quad (\text{abbreviated } 4^{\text{th}} \text{ ICS at RSB}) \\
V_2 & \quad 4^{\text{th}} \text{ Intercostal Space, Left Sternal Border} \\
& \quad (\text{abbreviated } 4^{\text{th}} \text{ ICS at LSB}) \\
V_3 & \quad \frac{1}{2} \text{ of the distance between } V_2 \text{ and } V_4 \\
V_4 & \quad 5^{\text{th}} \text{ Intercostal space, Midclavicular Line} \\
V_5 & \quad \text{Same horizontal plane as } V_4, \text{ in the anterior} \\
& \quad \text{axillary line} \\
V_6 & \quad \text{Same horizontal plane as } V_4, \text{ in the} \\
& \quad \text{midaxillary line}
\end{align*}
\]
36. Obtaining the 18-Lead ECG

Using a standard 12-lead ECG machine, record a 12-lead ECG, then re-arrange the precordial leads as seen in the diagrams below: A) to record the right ventricular (RV) surface, and B) to record the posterior surface. Run the 12-lead again with the leads in these positions and remember to re-label leads V1-V3 as V4R, V5R, and V6R. Also be sure to re-label V4-V6 as V7, V8, and V9.

A) Right Ventricular Leads

B) Posterior Leads
Contiguous Leads

- Lateral wall (I, aVL, & V₅ & ₆)
- Septum (V₁ & ₂)
- Inferior wall (II, III & aVF)
- Anterior wall (V₃ & ₄)

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Correct Lead Placement

\[ V_1 \quad V_2 \quad V_3 \quad V_4 \quad V_5 \quad V_6 \]
Incorrect Lead Placement
Onset of wide QRS complex tachycardia shows a taller right peak pattern in lead V1, unhelpful in distinguishing between ventricular tachycardia and supraventricular tachycardia with aberrant conduction.

Examination of the patient revealed V1 electrode misplaced to 5th rather than the 4th intercostal space.

After lead placement corrected, another episode of wide QRS complex tachycardia showed a taller left peak pattern in lead V1, strongly suggestive of ventricular tachycardia.

Subsequently, invasive cardiac electrophysiological study confirmed patient had ventricular tachycardia.
Normal shape of V₁
1st gold standard lead for identifying wide QRS patterns

• P waves: inverted, upright or biphasic
• QRS complex: inverted rS
• T waves: gently inverted
Normal shape of $V_6$
$2^{nd}$ gold standard lead for identifying wide QRS patterns

- P waves: upright
- QRS complex: upright qRs
- T waves: upright

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Bundle Branch Block may be Complete or Incomplete:

- Complete right bundle branch block measures slightly less than complete left bundle branch block and begins when the QRS measures 0.11 sec. or greater, whereas complete left bundle branch block begins when the QRS measures 0.12 sec. or greater.

- Incomplete bundle branch block begins when the QRS measures 0.10-0.11 sec. (the normal QRS width is between 0.05-0.09 sec).
Summary of the 3 Causes of Positive Wide-QRS in V1
(Remember to employ V6 for help)

- Right Bundle Branch Block
- Lt. Ventricular Ectopy
- Wolff-Parkinson-White

Rs
“Short P-R, Slur of Initial part of R wave”

qRs

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Right Bundle Branch Block Morphology in V6 and Lead I

V6 or her near equivalent MCL6, and lead I

A. Positive wide-qRs of 0.011 sec. or greater, creating a triphasic pattern with the telltale wide s wave (normal s waves are very narrow and shallow).

B. Standard lead I will look similar to V6 because the positive electrode for both leads is on the left side of the body creating a qRs complex, with a widened “s” wave like we see in V6.

C. The mimic of right bundle branch block is left ventricular rhythms. **Note:** it is easy to tell the difference in the positive triphasic pattern created by RBBB in the first 2 beats of V1, and the monophasic R with its left peak taller in V1 (a common pattern seen in many left ventricular rhythms); and furthermore it is very easy to differentiate the positive triphasic qRs pattern of RBBB in the first 2 beats of V6, and the negative wide-rS pattern of a left ventricular rhythm in V6. **Note:** In the ventricular rhythm there is opposite polarity of the QRS from the normal shapes in V1 and V6: V1 should be down and V6 should be up.
Right Bundle Branch Block Morphology

Seen in V1; there are three common patterns, though slight variations in shape may occur:

A. **Positive wide-rsR'** with late right peak, measures from 0.11 sec. and greater (most common pattern)

B. **Positive monophasic R'** *without* the classic rsR' pattern (keep in mind if there is a P wave in front of this positive wide-QRS it must be right bundle branch block. **Note:** you have your P and it is positive and wide).

C. **Positive wide-qR pattern** (initial “r” missing due to old anteroseptal injury wiping it out from death of the septal tissue, leaving the patient of a “q” wave from necrosis of tissue, followed by an R’ wave with a delayed right peak.

FYI: What all three patterns have in common is that they are all positive and wide and can therefore mimic left ventricular rhythms (V6 and lead I are now needed to differentiate between supra Ventricular rhythms with right bundle branch block and left ventricular rhythms before drug therapy can be considered (if a differential diagnosis cannot be made, it is always safer to cardiovert a patient if the rhythm with this pattern is going fast enough to drop the blood pressure).
6 - Right Bundle Branch Block

Evidence:
1. Wide QRS
2. rsR’ in V1
3. qRs in V6 and lead I
6 - Supraventricular Tachycardia (SVT) with Right Bundle Branch Block Aberration

**Evidence:**
1. QRS wide
2. rsR' in V1
3. Rs (deep wide “s” wave) in V6 (often has qRs)
4. rS in lead 1 (note the deep wide S wave)

**Management:** If unstable, administer adenosine

rSR' in V1 and Rs in V6 & I
Try your hand at identifying the next few rhythms, you should be able to easily identify each one.
**Left Bundle Branch Block Morphology**

**V1 or MCL 1**

**A.** QS pattern with slick down-stroke reaching an early nadir (deepest point of the QRS) within 0.06 sec. (to measure the nadir, begin at the beginning of QRS where it falls off the baseline, and go straight down to its deepest point and count the number of tiny boxes to this point). One and a half tiny boxes = 0.06 sec. This is an example of a premature atrial beat producing a LBBB pattern which is often mistaken for a ventricular rhythm; the ST elevation is probably secondary to the deep QRS complex. The QS pattern occurs in about 70-75% of LBBBs.

**B.** Negative wide rS pattern with slick down-stroke reaching an early nadir within 0.06 sec. The rS pattern occurs in about 25-30% of LBBBs.

**FYI:** A minority of LBBB patterns will show a slurring and or notching on the way down to the deepest point and therefore which may be confused with her mimic, right ventricular rhythms, however this only happens in about 2-5% of LBBB patterns.
Evidence:
1. Wide QRS
2. QS in V1 with slick down-stroke to an early nadir within 0.06 sec.
3. R in V6 with a quick up-stroke to an early apex within 0.07 sec. (seen in 75% of LBBB)
4. Has r in V1 indicating the RV was depolarized slightly before the septum
5. Q in lead 1 and aVL indicating an old lateral wall MI
6. Deep QRS in V1-V3 with LBBB can produce a lift off the baseline in the opposite direction mimicking an injury pattern.
7. Normal upward concavity of ST, with elevation in V1-V3 classic of LBBB with deep QRS in V1-V3
RVE typically produces a negative wide QRS in V1 with a delayed downstroke (often slurred and notched) to a delayed nadir (bottom peak) in V1 greater than 0.06 sec. If there is an initial R wave be sure include it in your measurement.

RVE: most of the time it produces a positive complex in V6 as seen in example A above, and when it does, it will have a delay up to the apex of greater than 0.07 seconds. Occasionally, RVE will have a negative wide QRS in V6 like you see in example B above, and when it does, don’t try to differentiate anything, just assume it is ventricular.
9 - Identify the origin of this wide-QRS Tachycardia?

Evidence:
1. Wide QRS
2. Positive wide QRS in V1 with left peak taller
3. Negative wide QRS in V6 with an rS pattern
4. Not possible to distinguish the cause of the negative wide QRS in lead 2 since the four common causes of a wide-QRS can all look the same in lead 2
Left Ventricular Beats or Rhythm is one of Three Causes of a Positive Wide-QRS Complex in V1

Remember the basic principles of electricity: as current travels toward a positive electrode, a positive waveform is inscribed on the graph paper, and likewise, when current travels away from a positive electrode, a negative waveform is inscribed on the graph paper. A complete reversal of polarity in V1 and V6 have occurred. Management: Administer Amiodarone or cardiovert.
Atrial Tachycardia

1. Three atrial premature beats (APBs or PACs) occur in a row, two with fairly normal conduction, while the third one is not conducted.

2. After another sinus conducted beat there is another run of three APBs or PACs (atrial tachycardia since there are three conducted in a row faster than 100 bpm)—although atrial tachycardia is generally much faster up to 240 bpm.

3. Note that these APBs or PACs are conducted with left bundle branch block aberration, and finally, one lone APB or PAC occurs at the end of the strip.

Don’t mistake the negative wide-QRSs as right ventricular tachycardia just because they are wide; look at the early P’ wave that started the run, and the early nadir of the wide QRS measuring within 0.06 sec in a V1 lead.
I. First degree AV block

A. All impulses are conducted

B. PR interval is prolonged to more than 0.20 second

C. Constant PR

PR interval 0.32 second
Second Degree

– Type I (Mobitz type I or Wenckebach)

• Each Impulse generated from the SA node has a more difficult time passing through the AV junction.

• Finally the stimulus is not conducted at all.

• The blocked beat is followed by relative recovery of the AV junction.

• The PR interval after the non-conducted P is shorter than the PR interval of the beat before the non-conducted P wave.

• The whole cycle starts again
The PR interval lengthens progressively with successive beats until one sinus P wave is not conducted at all.

Then the cycle repeats itself.

Notice that the PR interval after the non-conducted P wave is shorter than the PR interval of the beat just before it.
“Footprints” of Wenckebach.

1. Small groups of beats, especially pairs, trios, etc.

2. As the PR interval lengthens, the R-R interval shortens in succeeding cycles.

3. The longest cycle (of the dropped beat) is less than twice the shortest cycle.
### Type I vs. Type II

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Mobitz Type I</th>
<th>Mobitz Type II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pattern of block</td>
<td>Cycles of gradually increasing PR intervals followed by nonconducted P waves</td>
<td>Abrupt nonconducted P waves without preceding changes in the PR intervals</td>
</tr>
<tr>
<td>Usual location of block</td>
<td>AV node</td>
<td>His bundle or bundle branches (infranodal)</td>
</tr>
<tr>
<td>Occurrence with acute myocardial infarction</td>
<td>Inferior</td>
<td>Anterior</td>
</tr>
<tr>
<td>Risk of progression to complete heart block</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Indication for permanent pacemaker</td>
<td>Not usually</td>
<td>Usually</td>
</tr>
</tbody>
</table>

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• 2:1 second degree AV block (consistent).

• Unable to tell if the mechanism is from Mobitz I or II.
  • Constant 2:1 ratio

Second Degree Type II Advanced

- Refers to the specific ECG findings when you have CONSTANTLY more than 2:1 P waves for each QRS complex.

- Lethal Rhythm and Permanent Pacing is the only thing that this patient will get (Temporary Pacing at minimum).
Complete heart block with underlying sinus rhythm is characterized by independent atrial (P) and ventricular (QRS complex) activity. The atrial rate is almost always faster than the ventricular rate. The PR intervals are completely variable. Some sinus P waves fall on the T wave, distorting its shape. Others may fall in the QRS complex and be “lost.” Notice that the QRS complexes are of normal width, indicating that the ventricles are being paced from the atroventricular junction.

This example of complete heart block shows a very slow idioventricular rhythm and a faster independent atrial (sinus) rhythm.
Electrolyte Practice

Try your hand at identifying the next few electrolyte patterns, you should be able to easily identify each one.

1

a. Hyperkalemia  
b. Hypokalemia  
c. Hypercalcemia  
d. Hypocalcemia
a. Hyperkalemia
b. Hypokalemia
c. Hypercalcemia
d. Hypocalcemia
a. Hyperkalemia
b. Hypokalemia
c. Hypercalcemia
d. Hypocalcemia
a. Hyperkalemia  
b. Hypokalemia  
c. Hypercalcemia  
d. Hypocalcemia
Patterns Suggestive of Myocardial Ischemia

1. Horizontal ST-T depression
2. Down sloping ST-T
3. Symmetrical T wave inversion
4. ST-T angles upward and elevates
5. Long ST segment greater than 0.12
6. Sharp ST-T angle producing symmetrical T
7. Inverted U wave
8. Low voltage T wave with normal sized QRS
9. Swinging T waves in V1-V3 (up-down T waves)
10. TV1 taller TV6

Patients may have more than one of these patterns at the same time.

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Myocardial Ischemia Practice

Try your hand at identifying the next few ischemic patterns, you should be able to easily identify each one.
18. Patterns Suggestive of Acute Myocardial Infarction

1. ST-T, and J-point elevation
2. Severe up-sloping of ST-T with broad based T wave
3. Up-sloping of ST segment in any group of leads
4. Severe up-sloping of ST-T without perceptible J-point, resulting in broad based T wave
5. Symmetrical T wave inversion may indicate a transmural infarction
Various Criteria to Diagnose LBBB with Acute Antero-septal MI

Marriott’s Criteria – The only infarction the is difficult in the Face of LBBB is Anterior
1) ST elevation with upward concavity to the ST segment in V1-V4 – Anteroseptal MI

Sgarbossa’s Criteria - Three criteria are included:
1) ST elevation ≥1 mm in a lead with a positive QRS complex (ie: concordance) = 5 points
2) ST depression ≥1 mm in lead V1, V2, or V3 = 3 points
3) ST elevation ≥5 mm in a lead with a negative (discordant) QRS complex = 2 points

≥3 points = 90% specificity of STEMI (sensitivity of 36%)

Cabrera’s Sign
1) Notching at 40 milliseconds in the upslope of the S wave in lead V3 and V4.

This has a poor sensitivity of 27% for myocardial infarction.

Chapman’s Sign
1) The presence of a notch in the ascending limb of the leads I, aVL or V6.

Smith’s Sign – Modified the Third Criteria from Sgarbossa’s Criteria
≥ 1 lead with ≥1 mm of concordant ST elevation
≥ 1 lead of V1-V3 with ≥ 1 mm of concordant ST depression
≥ 1 lead anywhere with ≥ 1 mm STE and proportionally excessive discordant STE, as defined by ≥ 25% of the depth of the preceding S-wave.
1. Wide QRS
2. QS in V1 with slick down-stroke to an early nadir within 0.06 sec.
3. R in V6 with a quick up-stroke to an early apex within 0.07 sec. (seen in 75% of LBBB)
4. Has r in V1 indicating the RV was depolarized slightly before the septum
5. Q in lead 1 and aVL indicating an old lateral wall MI
6. Deep QRS in V1-V3 with LBBB can produce a lift off the baseline in the opposite direction mimicking an injury pattern.
7. Normal upward concavity of ST, with elevation in V1-V3 classic of LBBB with deep QRS in V1-V3
Evidence:
1. Wide QRS
2. rS in V1 with slick down-stroke to an early nadir within 0.06 sec.
3. R in V6 with a delayed up-stroke to a delayed apex greater than 0.07 sec. (seen in approximately 25% of LBBB)
4. Loss of septal q in lead I and V6
5. Dome shape ST elevation in V2-V5 due to myocardial infarction – loss of normal upward concavity seen in LBBB.
23. Anteroseptal Infarction: V1-V4

V1-V4 show ST-T elevation with no real perceptible J-point (red arrows). There are reciprocal depressions seen in leads I, II, aVL, and V5-V6 (black arrows). This anterior infarction is complicated by a left bundle branch block (note the wide QRS complex with the slick down-stroke in V1 and early upstroke in V6 with loss of septal Q waves in V5-V6 and lead 1 and aVL. Anticipate arrhythmias and further serious conduction disturbances to appear.
24. Anterolateral Infarction: V1-V6

V1-V6, leads I and aVL show ST-T elevation. This is an extensive anterolateral infarction complicated by a right bundle branch block (note the wide rsR’ pattern in V1, and the qRs pattern in leads I and V6 (with wide “s” wave). Anticipate arrhythmias and further serious conduction disturbances.
24. Anterolateral Infarction: V1-V6, I & aVL

V1-V6 and leads I and aVL show ST-T elevation while leads II, III, and aVF show reciprocal depressions. This is an extensive anterolateral infarction. Anticipate arrhythmias and serious conduction disturbances.
Case Study: In 1997 a 63 year old woman was concerned enough about herself to drive to an emergency department for help. Upon admission her complaints were GI upset after meals, general exhaustion lately, and shortness of breath with minimal exertion.

Pattern 8: Low Voltage T Wave With Normal Sized QRS

Note the low voltage in the inferior and lateral leads indicating a RCA lesion and possibly a circumflex vessel.

TV1 is flat; should be gently inverted and is on the way up.
Same patient as in the previous image 24 hours later while complaining of scapular pain. The patient coded and died right after this ECG. Her autopsy revealed acute myocardial injury and a left ventricular rupture. This patient lost her life due to our ignorance of the “subtle” or “less obvious patterns suggestive of ischemia.

Pattern 8: Low Voltage T Wave With Normal Sized QRS

Remember the T wave that was flat. It is now upright as anticipated.