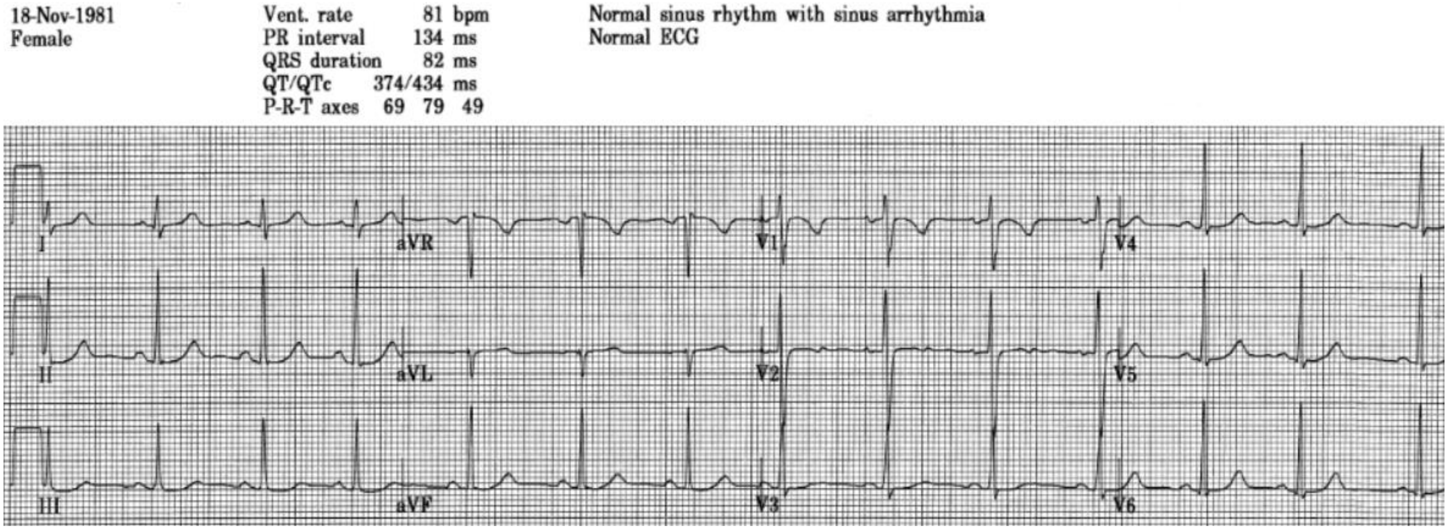
What Is the Mean QRS Axis and Why Is It so Important?

Jerry W. Jones, MD FACEP FAAEM



```
18-Nov-1981      Vent. rate        81 bpm      Normal sinus rhythm with sinus arrhythmia
Female           PR interval      134 ms       Normal ECG
                 QRS duration      82 ms
                 QT/QTc       374/434 ms
                 P-R-T axes    69  79  49
```

Figure 1

One of the first things beginning ECG students are taught to do is determine the mean QRS axis in the frontal plane. It's almost like a right of passage – "you can't go any further without doing this!" Personally, I cannot think of a greater waste of a beginning student 's time than learning how to calculate the mean QRS axis in the frontal plane.

First, the person teaching it likely doesn't understand it or they wouldn't be teaching it so soon. I often hear these reasons:

a) "It's an indication that everything is basically OK with the heart."

> *No, it isn't*. While it is true that most people with healthy hearts will have a normal mean QRS axis, there is no reason that people with very diseased hearts can't have a normal mean QRS axis, also. It is not a reliable indicator of the health of the heart.

b) "This is something that you just have to know!"

> Although I basically agree, my question is "but why now when the student has no idea what to do with the information once it is determined?"

Second, it is information that is used by more advanced students of electrocardiography. And, it is usually used in a *comparative* sense, i.e., noting whether the axis has changed and – if so – by how much.

Third, it raises questions that the instructor who insists on teaching it so early usually cannot answer. For instance, one usually begins by finding the most isoelectric or the most equiphasic QRS of all the frontal plane leads (I, II, III, aVR, aVL, aVF). And then – if found – one has to look at the lead perpendicular to the lead in which the isoelectric or equiphasic QRS was located.

Why *perpendicular*? And how can I tell which leads are perpendicular on an ECG?

Why *isoelectric* **or** *equiphasic*? One is essentially a *flat line* and the other can have *very large R and S waves*! Why can't I just look for the lead with the tallest R wave?

And, when I finally determine the mean QRS axis in the frontal plane, what use do I have for it if it can't assure me that the heart is healthy?

And how about the precordial leads? Isn't there a mean QRS axis in the horizontal plane?

OK… pour yourself a cup of tea or coffee, sit down in a comfortable chair and prepare to learn something!

1. Why look for *isoelectric* or *equiphasic* QRS complexes?

The *flatness* or the *equality of two oppositely-directed deflections* is not the issue here. The issue is ***voltage!*** The more an electrical inpulse traveling through the myocardium is directed toward the positive pole of a lead, the more voltage it will manifest on the printed ECG and the larger its deflection will be *in that lead*. Let's look at an illustration I use in my Masterclass:

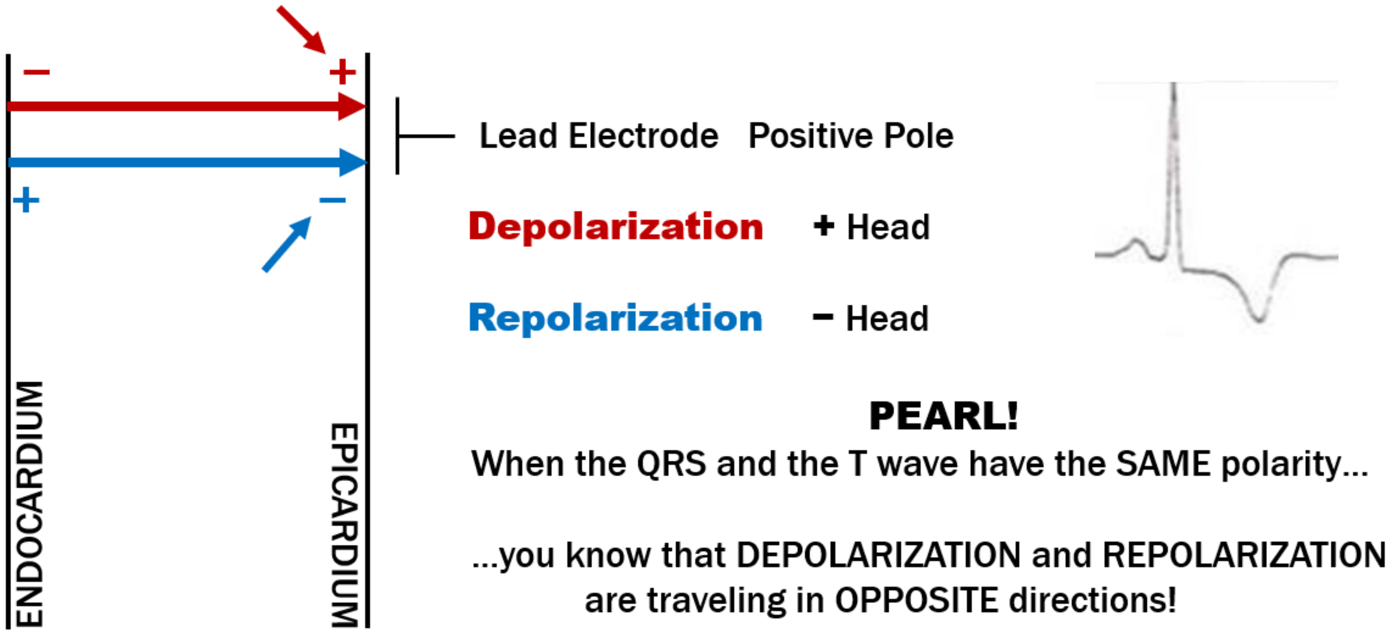
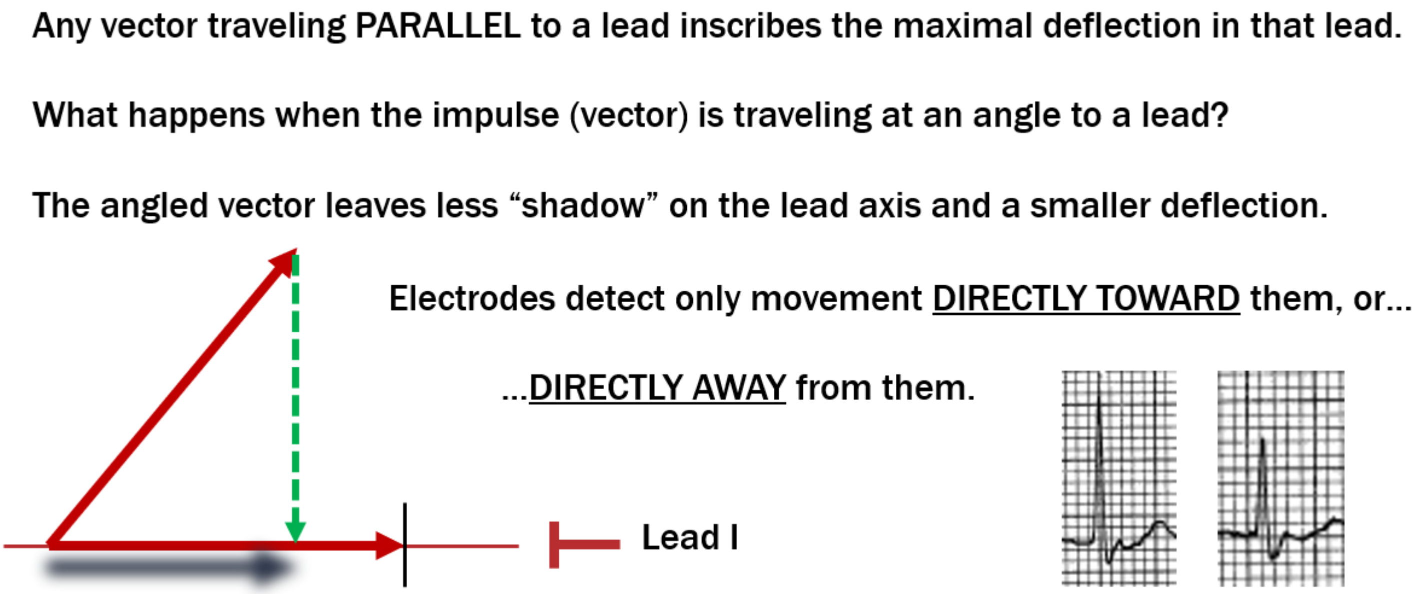


Figure 2

We are interested in the *depolarization vector* here (red arrow). We see it traveling directly toward the positive pole of a lead thus inscribing the tall R wave seen in the QRS on the right. Because the *repolarization* vector is oppositely-charged (with a negatively charged head), the positive pole of the lead sees a negative charge traveling toward it and inscribes a negative deflection – a T wave. The presence of an upright R wave (of course, *all* R waves are upright by definition) and an inverted T waves tells you that both forces are traveling in the same direction – toward the lead's positive pole. If the QRS and the T wave have opposite polarities, then the repolarization vector is traveling in a direction opposite the depolarization vector (as mentioned in the illustration). Let's look at another illustration from the Masterclass:



Any vector traveling PARALLEL to a lead inscribes the maximal deflection in that lead.

What happens when the impulse (vector) is traveling at an angle to a lead?

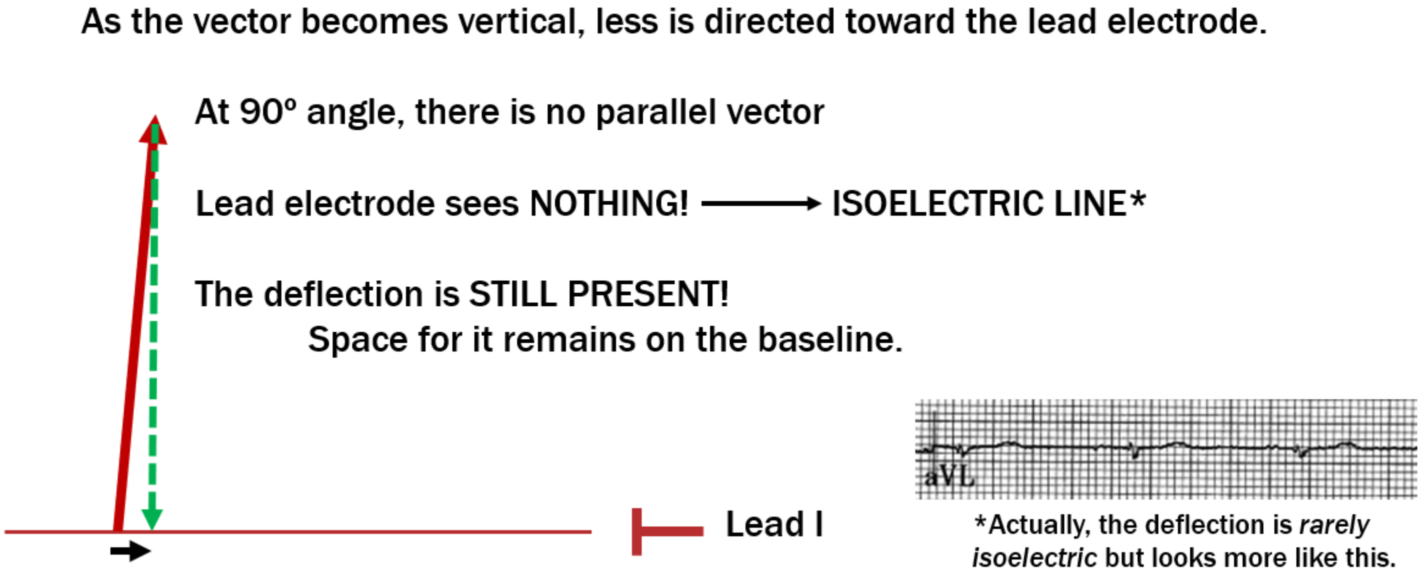
The angled vector leaves less "shadow" on the lead axis and a smaller deflection.

Electrodes detect only movement <u>DIRECTLY TOWARD</u> them, or…

…<u>DIRECTLY AWAY</u> from them.

Figure 3

As the depolarization vector travels less directly towards a lead's positive pole, it directs less voltage toward it. This results in a smaller R wave. Now, one more illustration:



As the vector becomes vertical, less is directed toward the lead electrode.

At 90° angle, there is no parallel vector

Lead electrode sees NOTHING! ⟶ ISOELECTRIC LINE*

The deflection is STILL PRESENT!
Space for it remains on the baseline.

***Actually, the deflection is *rarely isoelectric* but looks more like this.**

Figure 4

As the impulse travels more and more perpendicular to a lead's axis (towards the positive pole of that lead), it leaves less and less of a mark on that lead, i.e., the deflection becomes smaller and smaller until it is isoelectric. Basically, ZERO voltage is recorded in that lead. That is why the lead that is perpendicular to the lead with the largest QRS is either isoelectric or close to it.

But zero NET voltage of the QRS can manifest in another way. I say NET voltage because zero voltage in a deflection can also be caused by equal parts positive and negative voltage. If the R wave and the S wave are of equal magnitude, the NET voltage will also be zero. So a lead that records a vector traveling directly toward it immediately followed by a vector (usually on the opposite side of the heart) traveling directly away from it, will record a net zero voltage *for the QRS in that lead*. This has the same meaning as an isoelectric deflection.

In both cases, the lead perpendicular to the lead with the least voltage will be the lead with the maximum voltage representing the mean QRS axis.

“But, wait!” you exclaim. “The term *mean* implies *average* and there have been no calculations of an average!”

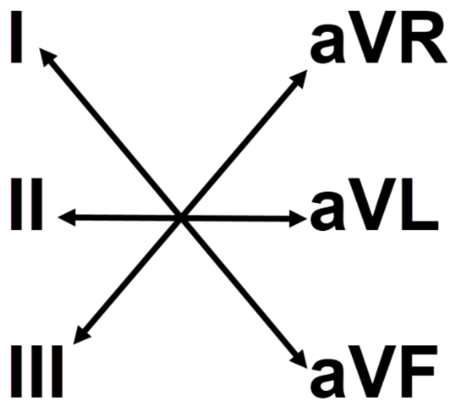
“That’s right!” I reply. “And that’s because *every lead recorded* is an *average*!”

Because the electrodes used in recording the limb leads have been placed (theoretically, at least) at least 18 inches from the origin of the electrical activity (i.e., the heart), they are viewing the electrical activity at essentially (and theoretically) an infinite distance. The ECG machine is viewing the “forest” and not each individual “tree.” Therefore, the machine has already averaged everything for you.

So, that is why we look for the lead with an isoelectric or equiphasic QRS complex and also why we look in the lead that is *perpendicular* to that lead for the mean QRS axis.

2. How do I know which leads are perpendicular to each other? Is there an easy way to determine this?

You can easily determine which leads are perpendicular to each other by using the Hexaxial Reference Grid. This is a diagram that anyone hoping to read and interpret ECGs must know very thoroughly. I can say with confidence and conviction that if you do not know the Hexaxial Reference Grid completely, you will get nowhere in electrocardiography. I cannot even remember the last time I picked up an ECG without visualizing that figure in my mind at least once – if not several times! But there *is* an easy way to determine which leads are perpendicular to each other without using the Hexaxial Reference Grid. You just have to remember the pattern used in printing the limb leads on an ECG (next page):



As you can see:

I and **aVF** are perpendicular

II and **aVL** are perpendicular, and

III and **aVR** are perpendicular.

Figure 5

It's almost like playing a game of "Tic-Tac-Toe."

3. Why can't I just look for the lead with the *tallest* R wave?

The idea of reading and interpreting a 12-lead ECG is that you can quickly gain a lot of important information about the patient. It was never meant to be analyzed for hours at a time; therefore, we occasionally take useful "shortcuts" to speed up the process. One such shortcut is assuming that the *height of an R wave* or the *depth of an S wave* determines their magnitude. That is not entirely true – remember: *that is only an estimate!* But interpretation is faster when we do so.

The true magnitude rests in the "area under the curve," i.e., the area within the deflection using the baseline as the third side. (Note: I am *not* referring to the statistical tool – the AUC.) Each true deflection has an area within it enclosed by an *ascending limb*, a *descending limb* and the *baseline*. Many of the earlier textbooks on electrocardiography insisted that one should count every small square within a deflection – including those squares with only a fraction of their area within the deflection to determine the magnitude and, therefore, which deflection was really the largest. Apparently *those* doctors had a lot of time on their hands! Needless to say, we don't do that anymore.

My point is this: a QRS may have a very tall but narrow R wave and an S wave that isn't very deep, but is very wide, resulting in *a net negative QRS complex*. So you see, it really isn't just the height of the R wave or the depth of the S wave that determines the magnitude of the deflection (and therefore the magnitude of the vector the deflection represents). By finding the lead with the QRS manifesting the *least voltage*, we avoid this situation; you may find occasionally that the lead that represents the mean QRS axis does *not* have the tallest R wave.

Here's a **PEARL** for you: ***the QRS with the greatest amplitude may be negative – a Qr or a QS wave!*** When determining the mean QRS axis in the frontal plane always think of the magnitude of a vector (deflection) as an *absolute value* – without positive or negative signs! Lead aVR with a deep QS wave could actually represent the mean QRS axis. Lead III often has very deep S or QS waves when there is left axis deviation.

4. Having determined the mean QRS vector in the frontal plane, how do I use that information?

If the mean QRS vector in the frontal plane is more leftward than -45°, then we should suspect an anterior fascicular delay or block (most likely explanation) or an old inferior myocardial infarction with very large and deep Q waves (certainly possible, but less likely).

If the mean QRS axis is more to the right – approaching or even beyond +90°, in adults we should suspect a strain on the right heart caused by an acute pulmonary embolus or pulmonary emphysema with depression of the diaphragm. Infants and very young children can also have right axis deviation normally, though many do not.

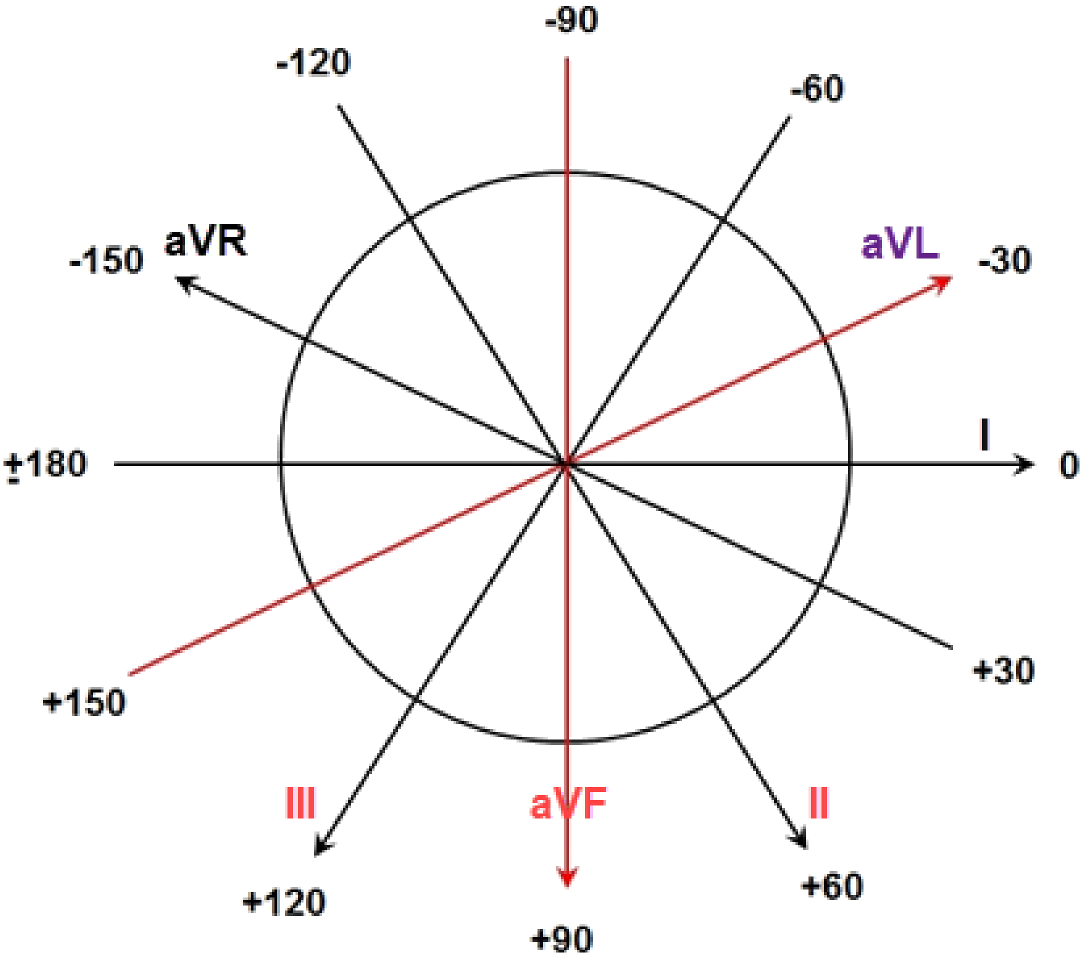
If the patient is experiencing a wide complex tachycardia and the mean QRS axis is between -90° and ±180°, then the most likely diagnosis is ventricular tachycardia, though hyperkalemia and sodium channel blocker toxicity (usually flecanide) can cause the same axis deviation.

Again, all these determinations using degrees (°) are based on the **Hexaxial Reference Grid**. I have included a copy of this grid on the next page. You should learn it thoroughly.

I will save its discussion for another time.

5. Why am I not determining the mean QRS axis for the horizontal plane, using the precordial leads?

You *will* learn how to do this, but hopefully a bit later after you've learned more about ECGs. One issue is that when we use the precordial leads, we don't call it a "mean QRS axis" – we call it ***rotation***. To determine the rotation, we look for the *transition point* or *transition lead*. You may have already heard about the transition lead, but I will wager that you really have no idea what it actually represents nor what it indicates. I will cover this in another post.



Hexaxial Reference Grid