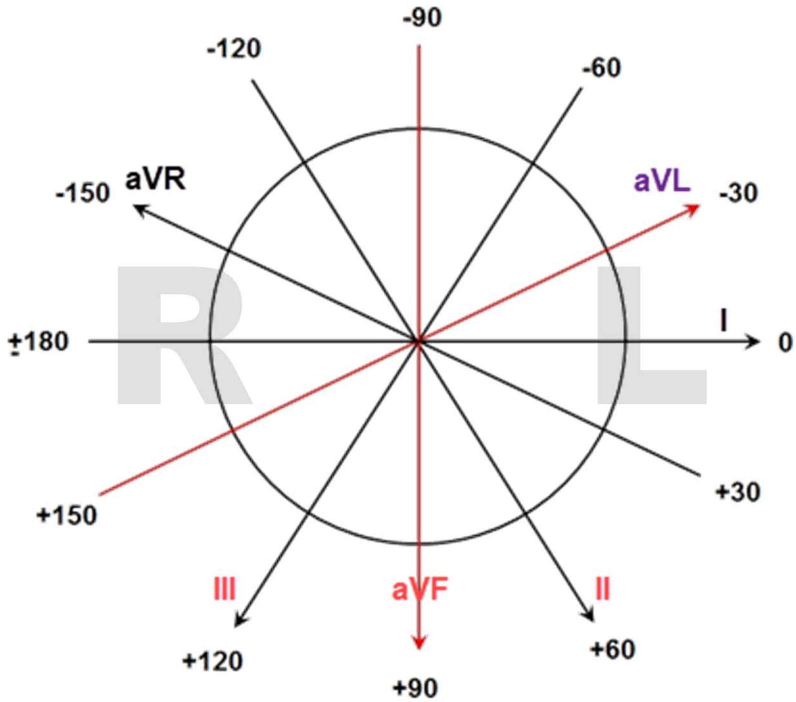
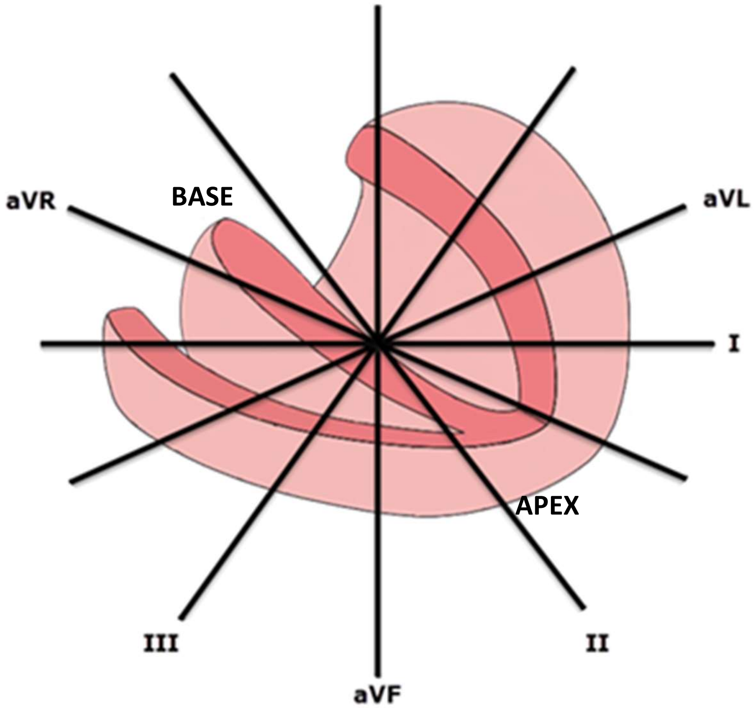
The Hexaxial Reference Grid (HRG): Part 3



In this third and last (for now!) installment of my discussion of the Hexaxial Reference Grid (HRG), I'm going to show you how we actually use the mean QRS vector (ÂQRS) in the frontal plane to check on what is happening on the ECG tracing. We can use it to…

1. determine if a QRS *complex* (or, QRS *interval*… the *real* term is *QRS interval*) is appropriate given the (ÂQRS) in the frontal plane;
2. check if someone's interpretation is appropriate (you'll see an example of this later);
3. determine not only where an impulse is going but also where it originated;
4. learn how to view (and understand) an "indeterminate" axis, and
5. how to view impulses that did not begin at the point that normal impulses begin in the ventricles (mid-left septum).

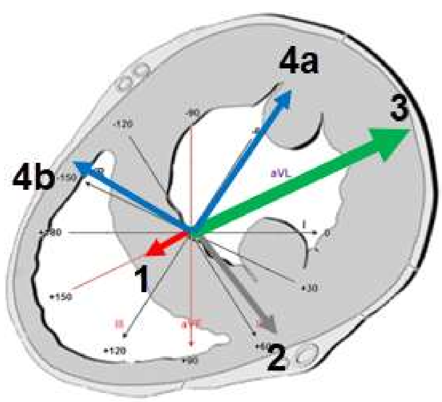
First, a reminder about how to draw a vector on the HRG (copy and save the last page of this post which has five grids that you can print and use to practice or work with): we use the center of the grid as the point at which all impulses begin (under *normal* circumstances) in the ventricles (remember: the HRG displays *ventricular* conduction only).That point is on the surface of the left side of the interventricular septum about mid-way between the base and apex. I've seen this described in several references as "the middle of the middle third of the septum" (think about it – it's a rather long way of saying "the middle!"). It is *not* located over the AV node. The AV node is *in the right atrium*. Each vector is a straight line or arrow. An impulse may be able to curve or change directions but a vector – which represents just one infinitesimal moment in time – does not. A *vector* is always straight. So how do we indicate an impulse that is changing directions on the HRG?



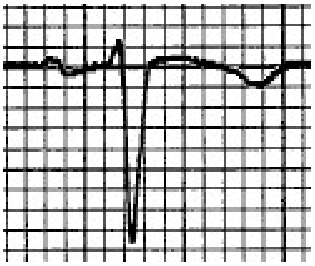
We use more than one vector! This is a representation of the origin of the normal ventricular impulse that has entered the ventricles through the His bundle and left and right bundle branches. Note that it is on the left surface of the septum about mid-way between the ***base*** and ***apex***. *All vectors will begin at this point*.

There are generally considered to be three (3) or four (4) vectors for each depolarization, though there can be two forms of the last vector (either #3 or #4, whichever you are considering).

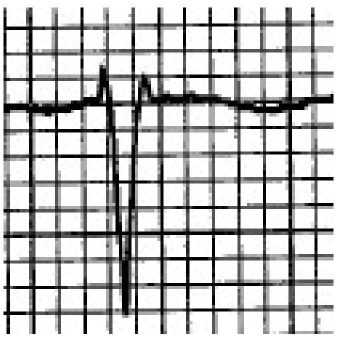
Vector #1 (illustration below) is the initial depolarization of the septum beginning on the left side. This is a very short vector because it is immediately offset by the depolarization beginning on the right side of the septum (the septum is actually depolarized from BOTH sides) and the near-simultaneous depolarization of the left lateral ventricular wall – both of which are traveling in a direction opposite to **vector #1**. Here is a more realistic cross-section of the heart demonstrating these vectors:



Some people omit **vector #2** as an apical vector and so the next vector is the left lateral wall vector (**vector #3**, on our diagram here). **Vector #3** is depicted as being wider since it is the predominant vector, depolarizing the full thickness of the very thick, lateral wall of the left ventricle. In older people (or overweight people of any age), the final vector is often **vector #4a** indicating that the ventricular depolarization impulse ends in *basolateral area of the left ventricle*. In younger (or thinner people of any age), the final vector is often **vector #4b** indicating that the ventricular depolarization impulse ends in the *right ventricular outflow tract area*. The right ventricular outflow tract (RVOT) is the area of the right ventricle just below (and occasionally just above) the pulmonic valve. It includes parts of the septum, the anterior, inferior/posterior, and lateral walls of the right ventricle. What does this look like on the ECG? We can see these vectors well in Lead V1:



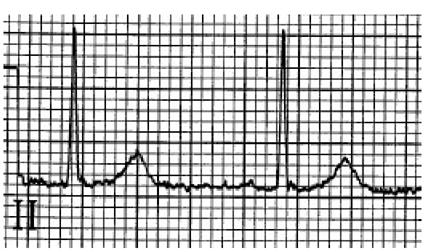
This is a snippet from Lead V1 on a normal ECG. The r wave (lower case "r" because it is small) represents **vector #1**. Note that it has a very small amplitude and a very short duration. That is because it is immediately opposed by an impulse coming from the right side of the septum (the septum is *normally* depolarized from BOTH sides) and **vector #3**. **Vector #2** has less impact because it is traveling more perpendicular to Lead V1. The terminal deflection is the S wave due mostly to **vector #3** and **vector #4a**, which tells us that the ventricular impulses for this patient terminate in the basolateral area of the left ventricle. **Vector #4a** is viewed by Lead V1 as traveling *away from* it and thus is inscribed as a *negative* deflection. Since **vector #3** is also negative (as viewed by Lead V1), **vector #4a** just blends in with it; it does *not* create a second negative deflection. I don't know the patient's weight, but he was 39 years old at the time this ECG was recorded).



This Lead V1 snippet is from a female who was 54 years old when this ECG was recorded. As you may have begun to surmise, age is *not* the best predictor of how the ventricular impulse terminates. Now, some of you may ask "But isn't that an incomplete RBBB (iRBBB)?" For this to be iRBBB, the duration of the QRS interval would have to be ≥100 msec (0.10 seconds) and < 120 msec (0.12 seconds). As you can clearly see, it is *not*! This is what Lead V1 looks like when the terminal vector for the ventricular impulse is **vector #4b**. When it ends in the RVOT, it ends near a structure – a ridge – call the *crista terminalis*. In the older literature, you can find references to this rSr' morphology as the *cristal* pattern. It's referring to the same thing – a QRS morphology in Lead V1 that demonstrates termination of the ventricular depolarization impulse by **vector #4b**. A V1 electrode that is placed too high on the chest wall can result in the same QRS – *be careful!*

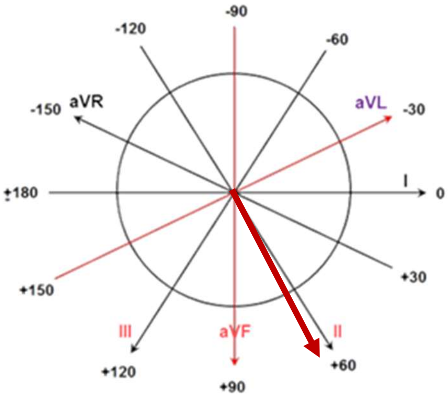
Is the QRS APPROPRIATE for This Lead?

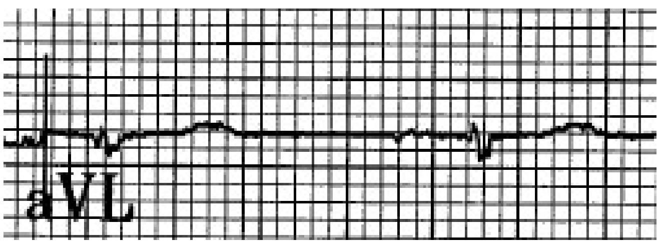
Let's take a look at a specific lead an see if the QRS is what we would expect for the ÂQRS…



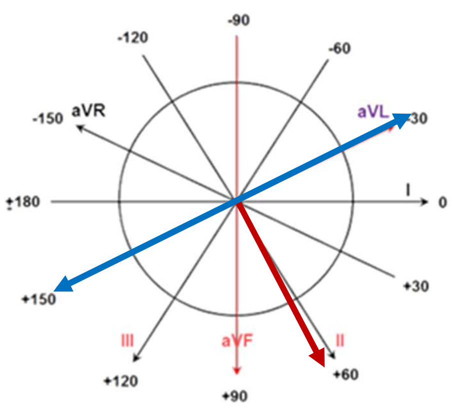
The ÂQRS for this ECG is +65°. Is that appropriate for this **Lead II**? Let's check the HRG…

In the HRG shown below, we can see that the positive pole for the Lead II axis is located at +60°. An ÂQRS located at +65° would result in a large-amplitude QRS since it is nearly parallel to the Lead II axis – and that is certainly the case here. Therefore, I would say that the QRS in Lead II matches how I would expect it to appear based on the ÂQRS and my knowledge of the Hexaxial reference grid. I didn't have to look at the HRG to see where the positive pole of Lead II was located *and neither should you!* Let's take a look at another lead from the same 12-lead ECG…

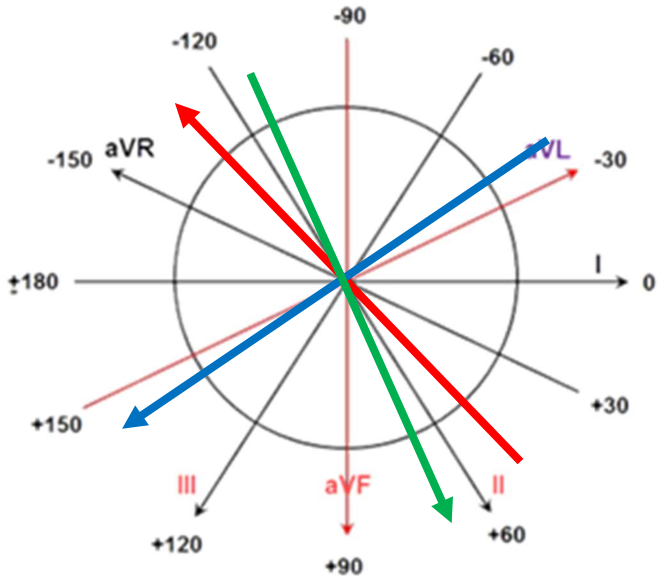




This is **Lead aVL** from the same ECG. I have had to enlarge it considerably because the QRS in this lead is almost isoelectric! As you can see from the HRG (below), Lead aVL is exactly *perpendicular* to Lead II. Remember that an impulse that is traveling *perpendicularly* to a lead will appear *isoelectric* or occasionally *equiphasic* in that lead. Well, the impulse is not *exactly* perpendicular to Lead aVL (for that matter, it wasn't *exactly* parallel to Lead II, either), but it is very close. Although the QRS complex here is very small, it confirms that the ÂQRS is traveling ***almost parallel to Lead II*** which makes it ***almost isoelectric in Lead aVL***. Now consider this: what if the ÂQRS is almost parallel to Lead II but there is an acute STEMI in the basolateral (high lateral) area of the heart? That would result in STE in Leads I and aVL. How adept would you be in discerning STE in Lead aVL if the QRS were no larger than this one? This is a case where you might have to depend more on reciprocal changes in Leads II, III and aVF to detect the acute STEMI!



Where Did This Impulse Originate?



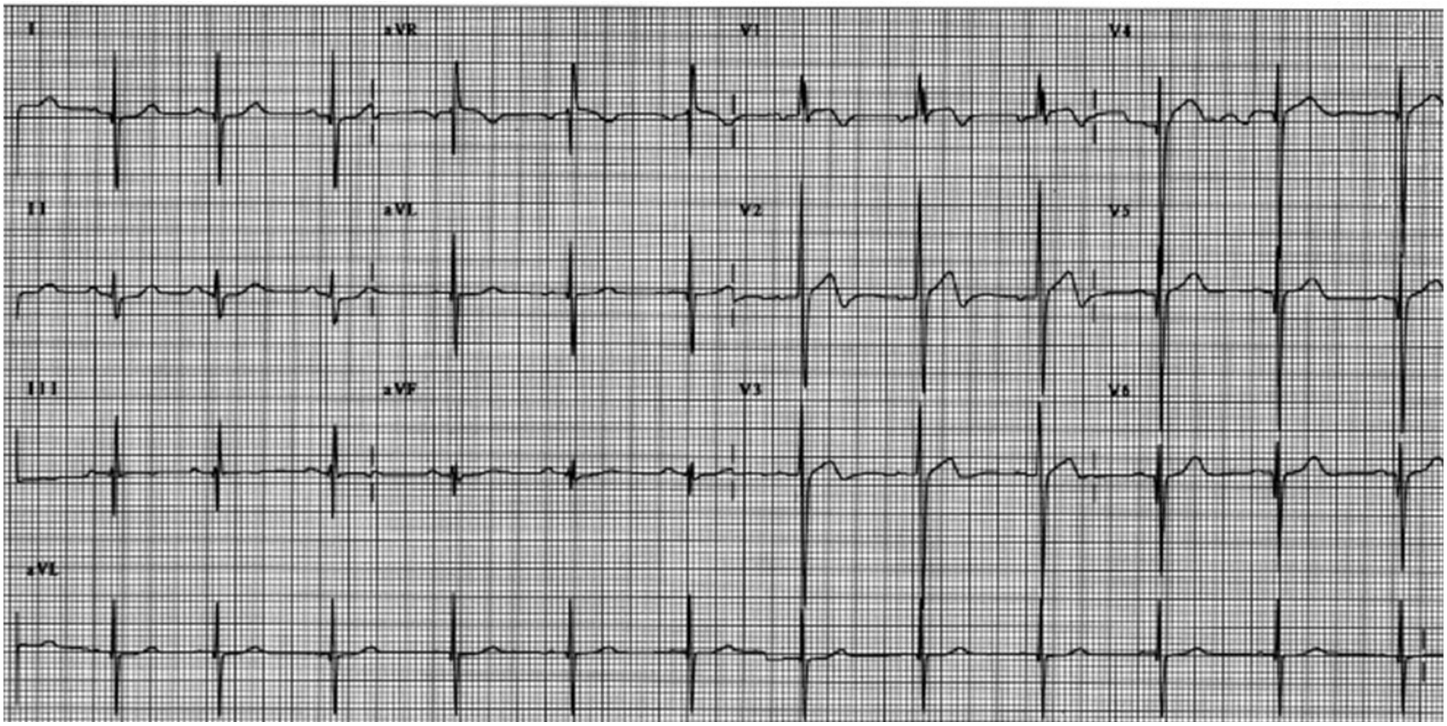
As you can see, the vector represented by the **GREEN** arrow is the most physiologic (normal) on this grid. Mean QRS vectors in the frontal plane represented by the **RED** and **BLUE** arrows require more explanation.

The **RED** arrow represents an ectopic beat arising in the left ventricle. Without any scar or fibrosis impeding it, if it has arisen in the lower left lateral ventricle, it will spread (generally) up and to the right and, likely, anteriorly if we consider this three dimensional. A vector pointing to the right upper quadrant of the HRG (also known as "no man's land" or "northwest quadrant") is a very good sign of ectopic impulse formation. It can occur with supraventricular impulses coming down through the AV node and bundle of His, however. That is *very, very rare* and involves the presence of several concurrent abnormalities. It can also happen during ***hyperkalemia*** and ***Na^+ channel blocker toxicity*** (especially ***flecainide***)!

The **BLUE** arrow represents right axis deviation and requires certain abnormalities to be present, though not necessarily at the same time (RVH, LPFB, RBBB and situs inversus being the most common). (**Pearl:** while most clinicians recognize the term *situs inversus*, many are not familiar with *situs solitus*. *Situs solitus* means "normal placement," i.e. ***normal!***).

We don't extend the tail of the arrows as we did here unless we are indicating ventricular ectopy. Otherwise, all the other beats begin at the left septal border as indicated on the HRG.

What Is an Indeterminate Axis?



Indeterminate axis is somewhat of a misnomer. Granted… it represents a mean QRS axis on the frontal plane that cannot be designated by a *single* vector. By definition, an *indeterminate axis* represents an axis that results in equiphasic QRS complexes in *all frontal plane leads*. I suppose – in theory, at least – it could also present as *isoelectric baselines* in place of the QRS intervals in all the limb leads, but I have never seen that, nor have I ever seen it reported in any literature. Do NOT confuse this with an ***extreme axis*** which is often used to designate a mean QRS vector in the right upper quadrant ("no man's land" or northwest quadrant). I recently read an article in which the author pointed out that the ÂQRS in the frontal plane had an "indeterminate axis" *located in the right upper quadrant!* Isn't that a bit like saying, "I've never been married; now let me introduce my wife"?

A mean QRS axis located in the right upper quadrant of the HRG is called an **EXTREME** axis! It is ***NOT*** an **INDETERMINATE** axis. Can you tell me where the axis is located for the ECG posted above? No, I'm sure you can't… ***because THAT is what an INDETERMINATE axis looks like!***

What is the solution? Theoretically, you designate an *axis for the first major deflection* and a second *axis for the second major deflection* (which are – *not surprisingly* – usually about 180° apart). Here's what I do: I just ***note that an indeterminate axis is present*** and then ***consider some conditions that may result in such an axis (Warning: this is NOT a complete list)***…

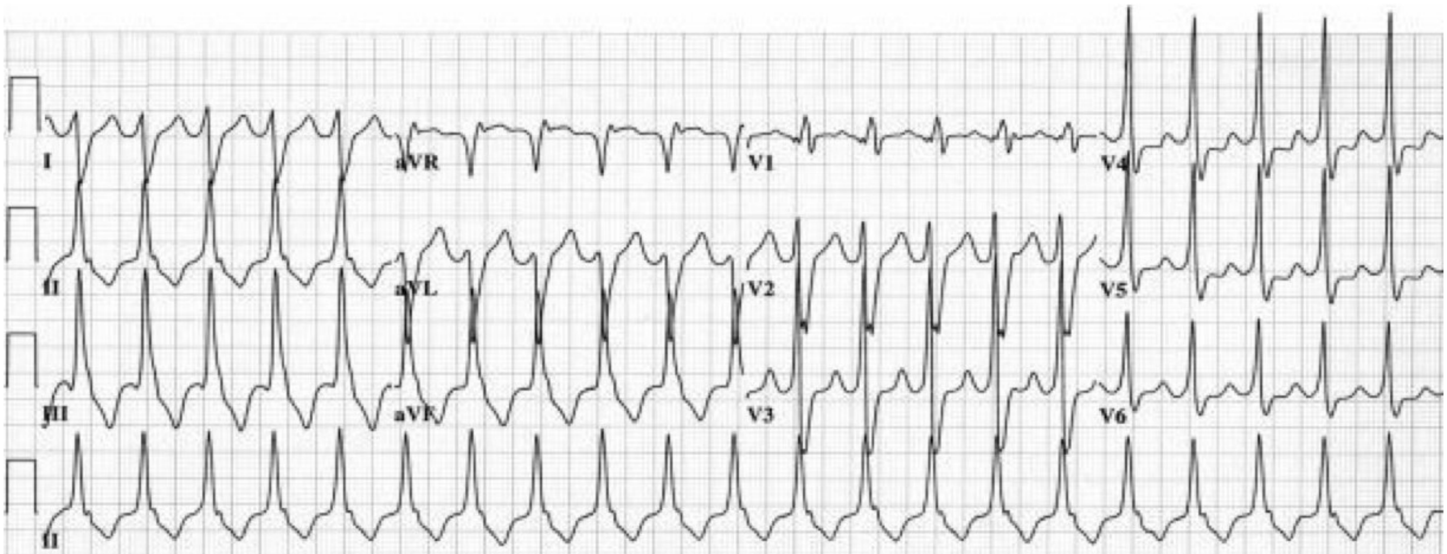
1. congenital cardiac defects associated with right ventricular hypertrophy;
2. conditions causing chronically increased right ventricular pressure;
3. advanced emphysema;

4. hypertrophic cardiomyopathy; and
5. normal variant (a diagnosis of exclusion).

The presence of equiphasic QRS intervals in all of the frontal plane leads suggests that the main QRS vector is actually oriented almost exclusively in the horizontal plane. Remember: the ÂQRS is really three-dimensional and we just consider two of those dimensions!

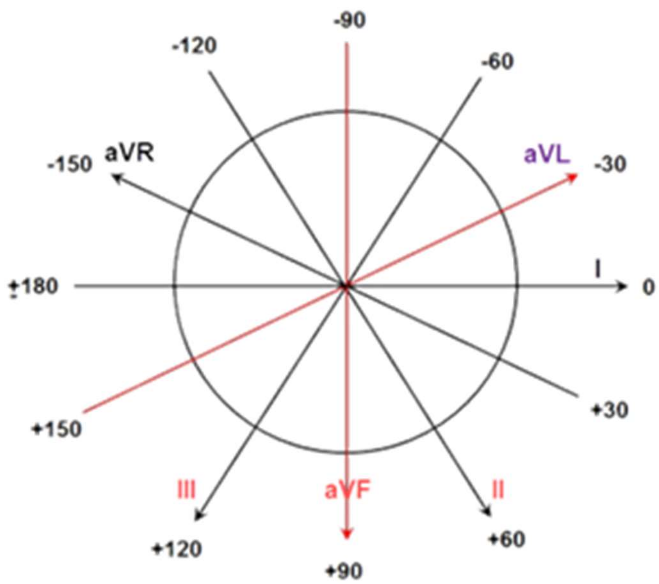
How Can I Check on the Validity of an Axis Determined by Someone Else?

You check by simply comparing *their* axis to *your* axis based on the HRG. Recently I was reading a fairly well-known emergency medicine blog and it showed this 12-lead ECG:



The problem I had with the blog is that the person discussing this ECG stated that it had to be ventricular tachycardia *because there was an extreme axis*. I wasn't taking issue with the diagnosis (it was *indeed* ventricular tachycardia!), but my issue rather was with his pronouncement of an *extreme axis* (axis in right upper quadrant). There was, indeed, a right axis deviation, but an extreme axis would have required Lead aVF to be negative also – which it *wasn't!* To the less informed, that might seem intuitive because Lead aVF is "located right there at the end of the inferior leads." But nothing could be further from the truth and I recognized this immediately based on my knowledge of the HRG (and also on the fact that *I know that an extreme axis requires a negative QRS in Lead aVF!*).

Let's see how the HRG debunks this assertion of his:



While we often refer to the inferior leads as "Leads **II**, **III** and **aVF**" – that is NOT the order in which the leads are actually located! As you can clearly see, Lead aVF lies *between* Leads II and III. Show me a vector that will appear *positive* in Leads II and III but *negative* in Lead aVF. I'll check back with you in a couple of months, but (Spoiler Alert!) I already know what your answer will be!

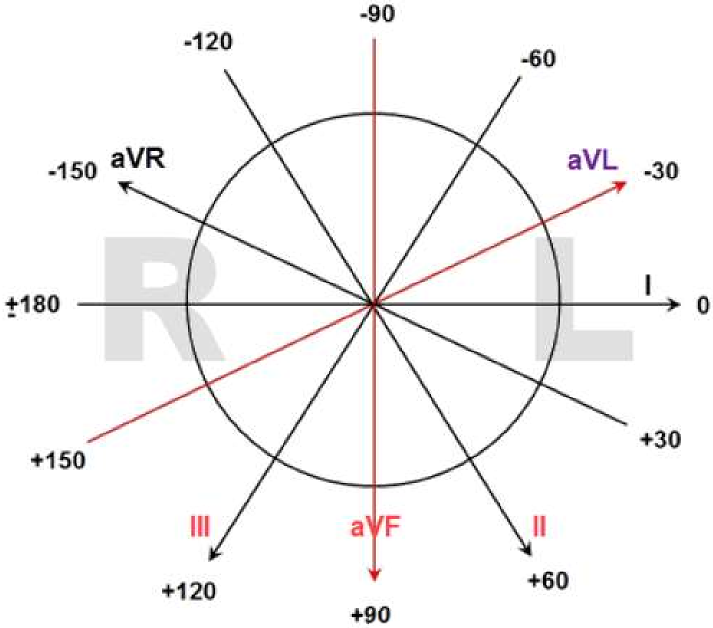
It just can't happen! Whether the QRS in Lead aVF is *positive* or *negative*, either Lead II or Lead III (if not both) *will have the same polarity*. Lead aVF cannot be different than the other two leads.

I hope you have benefitted from my discussion of the **Hexaxial Reference Grid (HRG)**. The easiest way to start feeling comfortable with it is to draw the mean QRS vector (ÂQRS). Then look at each frontal plane lead and see if the ÂQRS can explain the *morphology*, *amplitude* and *polarity* of the QRS interval in that lead.

You will soon note, for instance, that when the ÂQRS is MORE positive than +60° or MORE negative than -120°, the QRS in Lead aVL will be *negative*. And when the ÂQRS is LESS positive than +30° or LESS negative than -150°, the QRS in Lead III will be *negative*.

Your first step should be memorizing where the POSITIVE POLES for the six limb leads are located.

Best of luck to you!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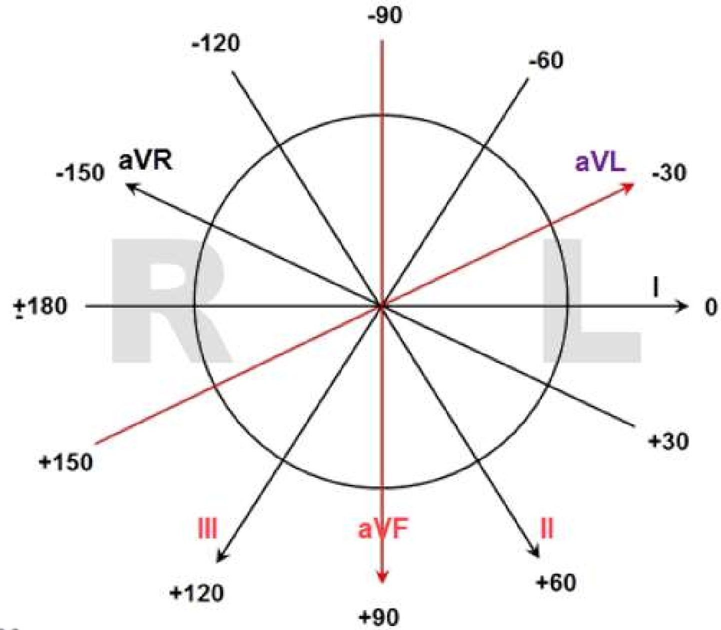
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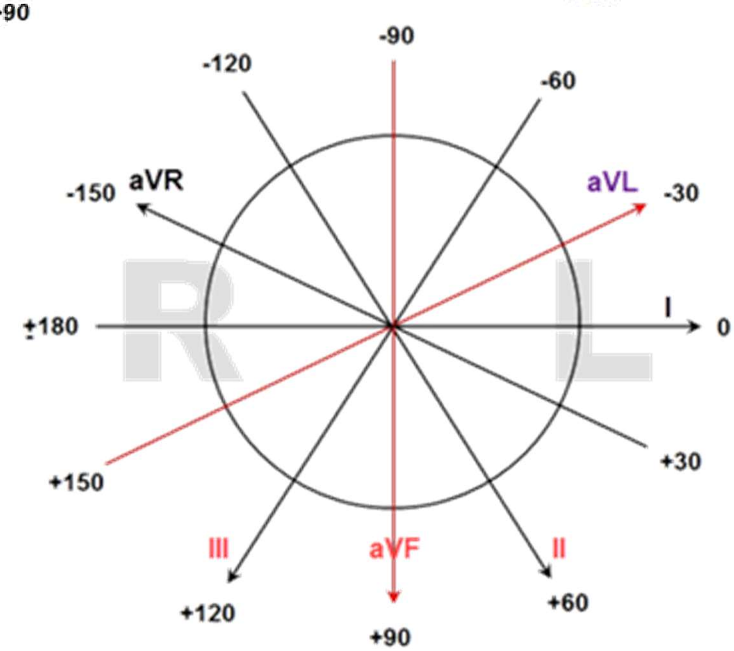
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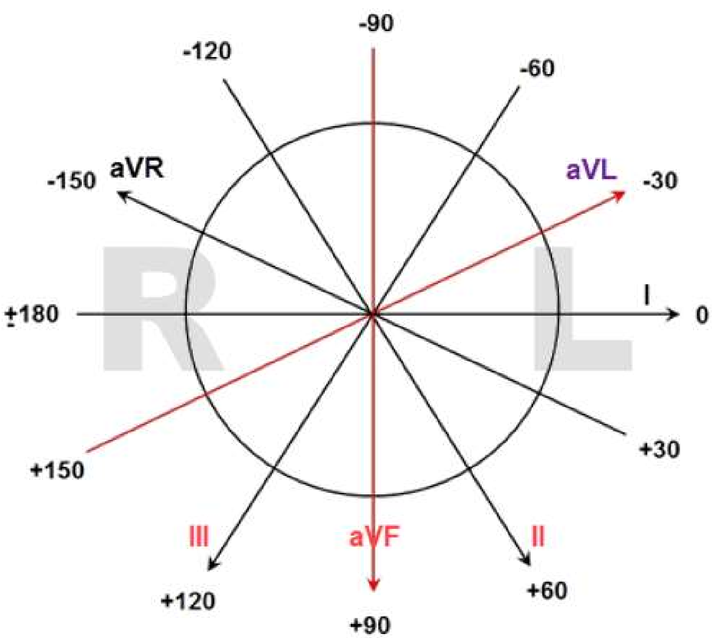
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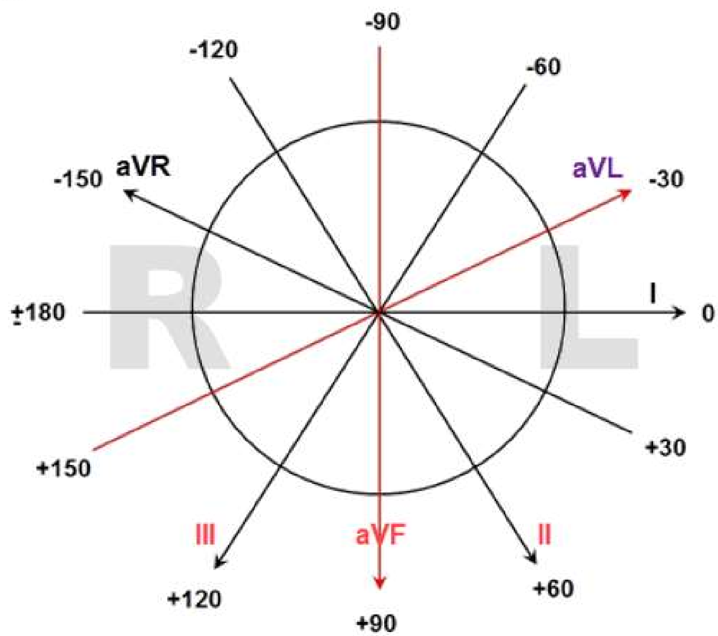
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