ELECTROCARDIOGRAM INTERPRETATION DOI: https://doi.org/10.18502/fem.v6i3.9406

The Hexaxial Reference Grid: The emergency ECG interpreter's most important tool

Jerry W. Jones* **MD FACEP FAAEM**

Chief Instructor, Medicus of Houston, Texas, USA.

***Corresponding Author:** Jerry W. Jones; **Email:** jwjmd@medicusofhouston.com

Published online: 2022-04-22

Cite this article as: Jones JW. The Hexaxial Reference Grid: The emergency ECG interpreter's most important tool. Front Emerg Med. 2022;6(3):e44.

This is the third installment in the electrocardiogram (ECG) interpretation series by Jerry W. Jones MD FACEP FAAEM for this journal. In the first installments, he discussed simple atrioventricular (AV) dissociation versus AV dissociation caused by third degree AV block (1); and in the second one, he shares some very important pearls regarding ECG interpretation (2).

Introduction

As emergency physicians, we must all interpret electrocardiograms (ECGs) form time to time. The 12-lead ECG is one of the most frequently ordered tests in the emergency department, often read by physicians with the least formal training in ECG interpretation. Emergency physicians do not have the luxury of waiting one to two days for an official cardiologist's interpretation; we must know the results immediately. Here is where the process breaks down. I am going to introduce you to the tool that electrocardiographers use that greatly assists with interpretation.

The Hexaxial Reference Grid (HRG)

The HRG is a compilation of all six frontal plane leads (I, II, III, aVR, aVL, aVF) into a single circular (360°) pattern (the drawing of the heart is for teaching purposes). In this diagram of the HRG (Figure 1), I have labelled each of the six limb leads at its positive pole. Each line is an axis.

This HRG represents the vectors that occur during depolarization of the left ventricle and is measured in degrees (total 360°). Many years ago, all 360° were utilized in the description, so you would have to know exactly where 140° or 231° were located – not an easy task! It was then decided to make things easier by dividing the HRG into two sections: an upper section and a lower section, using the Lead I axis as the dividing line. Thus, we now only have to deal with up to 180°, which is more manageable. But a new problem arose in that now there were two 30°, two 45°, two 60° and so on. How could we designate a vector pointing 30° above the Lead I axis as opposed to the 30° below the Lead I axis? We could say 30A and 30B, or 30α and 30β… but no, it was decided that all degrees below the Lead I axis would be designated as "+" and all those above the Lead I axis as "–".

It was only intended that the symbols "+" and "–" would be used to as a tool to indicate which 30° was intended. It was never the intent to ascribe an arithmetic or algebraic significance to those symbols. Algebraic addition of -30° and +30° would equal 0°, when in actuality the correct answer would be 60°! So the "+" and "–" symbols only refer to the position of the lead or vector above or below the dividing line, which is the horizontal Lead I axis. They have no arithmetic or algebraic meaning.

The axes on the hexaxial reference grid are all equally separated by 30°. The positive pole of Lead I is at 0° and its opposite (negative) pole is designated as ± 180°. It is designated as "+" or "–" depending on whether you are approaching it from below the Lead I axis ("plus" territory) or from above the Lead I axis ("minus" territory). The positive poles for Leads aVL and aVR are both located above the Lead I axis, in "–" territory. Remember: the "–" only serves to locate the lead above the Lead I axis. They also have their "–" poles in "+" territory. Again, whether a pole is positive or negative has nothing to do with its location above or below Lead I. An easy way to remember these leads and poles is this:

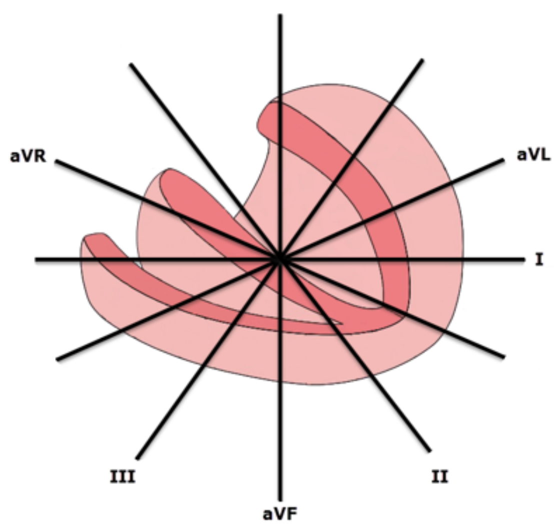

Figure 1 The Hexaxial Reference Grid

1. The positive pole of Lead I is always at 0° and is the horizontal axis.
2. The positive pole of Lead aVF is always at +90° and is always the vertical axis.
3. The positive poles of Leads aVL and aVR are both located just 30° above Lead I, aVL on the left (the "L" indicates left) and aVR on the right (the "R" indicates right).
4. Just as Leads aVR and aVL are 30° away from the Lead I horizontal axis, Leads II and III are just 30° away from the Lead aVF vertical axis. Lead II is always to the left of aVF and Lead III to the right.

Now you can determine the location of each positive pole very easily. Take Lead II, for instance. It is located just 30° to the left of Lead aVF, and we know that the positive pole of aVF is at +90°. So, since the leads are separated by 30°, the positive pole of Lead II is located at +60°. The positive pole of Lead III is just 30° to the right of Lead aVF's positive pole, so it must be located at +120°. The positive pole of Lead aVR is located just 30° above Lead I's negative pole (-180°), so it is located at -150° while the positive pole of Lead aVL is located at -30°.

Using the Hexaxial Reference Grid

Let's now visualize the heart diagram that I placed beneath the hexaxial reference grid. As I said, this is for reference purposes only and is not part of the HRG. However, you can see that the lead axes and their positive poles do correlate at least somewhat with locations on or within the heart.

First, since all normal ventricular depolarizations begin on the left side of the interventricular septum a bit more than halfway between the base and the apex, that is where the leads intersect. Although we usually use the HRG in reference to events in the left ventricle, it also is applicable to the right ventricle. Lead aVL overlies the upper lateral wall of the left ventricle (formerly "high lateral" but now "basolateral"). Lead II has a good look at the left side of the inferior wall, Lead aVF is directly under the inferior wall of the left ventricle and Lead III is looking at the inferior wall of the right ventricle and the rightmost portion of the inferior wall of the left ventricle. Thus, even though they are both inferior leads, Lead II is also a left-sided lead and Lead III is also a right-sided lead. We consider Lead II to reflect events in the left-sided circulation (LAD, LCx) and Lead III to reflect events in the right-sided circulation (RCA).

The HRG is an excellent adjunct to understanding reciprocal changes taking place on the twelve lead ECG. First, notice that no lead is 180° away from another lead. One hundred eighty degrees from the positive pole of Lead I is… Lead I. The most opposite any two leads can be in the frontal plane is 150° apart. So which leads are 150° apart?

Lead III and Lead aVL (most important reciprocal pair)
Lead I and Lead aVR (rarely used)
Lead II and Lead aVR (rarely used)

Another fact that the HRG makes very apparent is that – in spite of their location next to each other on the ECG tracing – Leads II and III are not really adjacent to each other.

Have you ever noticed that sometimes Leads III and aVF seem to be doing something different than Lead II? For instance, an inferior STEMI with STE only in Leads III and aVF? Or STE in Leads I and aVL with reciprocal ST depression in Leads III and aVF only? As you can see from the HRG, there is a very clear explanation why that is happening.

Sometimes there is a Q wave in Lead III, but is it pathological? Even if it is 40 msec in width it may still have no significance. Why? Infarctions do not cause a Q wave in just one lead. To confirm, the HRG suggests that you should look in Lead aVF – not in Lead II. If no Q in Lead aVF – no infarction is present.

Let's assume a profound left axis deviation with the mean QRS axis (ÂQRS) pointing toward -60° (Figure 2, blue arrow). Since the positive pole of Lead aVL is located at -30° (30° above the Lead I axis) and is the closest positive pole to the ÂQRS, it is easy to understand why Lead aVL would produce a tall R wave during left axis deviation. But look back at the HRG once more. Is there any other lead that would – under these circumstances – produce a deflection of even greater amplitude? Absolutely! Minus sixty degrees is actually the negative pole of Lead III. Since the positive pole of Lead III, located at +120°, sees the ÂQRS traveling directly away from it, it will inscribe an S wave that has even greater amplitude than the R wave in Lead aVL (i.e., it will be deeper than the R wave in Lead aVL is tall).

An occlusion of the LAD or the LCx may result in acute epicardial ischemia (STEMI) in the basolateral wall of the left ventricle (green oval). Using the HRG, it is easy to see why there are reciprocal changes in Leads III and aVF but perhaps not in Lead II. Did you know that 75 to 80% of us have type 3 ("wrap-around") left anterior descending arteries (anterior interventricular arteries)? These are LADs that extend be-

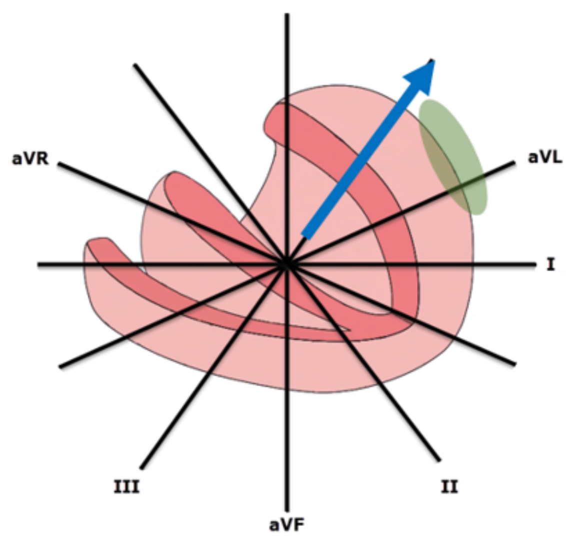

Figure 2 The Hexaxial Reference Grid shows a profound left axis deviation with the mean QRS axis (ÂQRS) pointing toward -60°

yond the apex and provide circulation to about 25% of the inferior wall of the left ventricle (sometimes more, sometimes less). A proximal occlusion of a type 3 ("wrap-around") LAD will cause basolateral, anterior and inferior STEMIs – simultaneously!

What can we understand about such a huge area at risk from the HRG?

Here (Figure 3) we have a representation of the acute ischemia of the basolateral and inferior walls of the left ventricle. Each area would be expected to result in ST elevation – STE in Leads I and aVL and simultaneous STE in Leads II, III and aVF. This results in injury vectors that are pointing in opposite directions.

When simultaneous vectors of essentially equal magnitude have opposite directions, what happens? They cancel each other! There may be no STE in either of the two areas. Thus, it is quite possible that there is a massive STEMI with a huge area at risk and the ECG may look rather benign! At least, even if it does manifest ischemic changes (V4-6), ischemia limited to that area is often viewed as relatively minor! What are the chances of this happening? Remember what I just told you: 75 – 80% of us have type 3 LADs.

What if there is an occlusion of the RCA which results in STE in Leads II, III and aVF? The ischemic injury vector (Figure 4, blue arrow) will point toward the inferior wall leads. So, there is STE in Leads II, III and aVF. But, let's say that this is very early in the course of the occlusion and the STE is minimal and somewhat questionable in your mind. Where else can you look for validation of your impression of acute inferior wall ischemia? You would look in Leads I and aVL – but especially in Lead aVL. The Lead III electrode (left foot) sees the injury current traveling directly toward it, producing ST elevation. But, at the same time, the Lead aVL electrode (left shoulder) sees the injury current traveling away from it, producing ST depression - and validates the presence of the injury current with a reciprocal change!

The **HRG** is to the ECG interpreter what the alphabet is to an author or the multiplication tables to a mathematician. Each represents the most basic knowledge required by the respective disciplines. You cannot expect to advance your knowledge of ECG interpretation without a mastery of this tool. Many different problems requiring different management principles can occur in electrocardiography – and they may all look the same. Using the knowledge provided by the HRG will keep you from being trapped by, or at least limited to, pattern recognition.

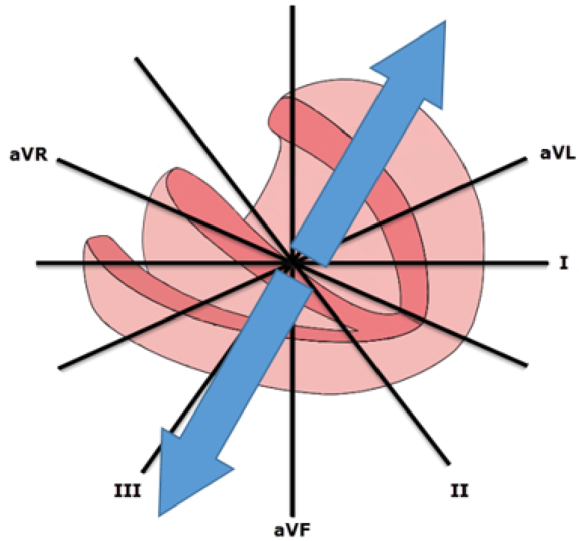

Figure 3 The Hexaxial Reference Grid illustrates the opposite directions of the injury vectors of the ischemic basolateral and inferior walls of the left ventricle

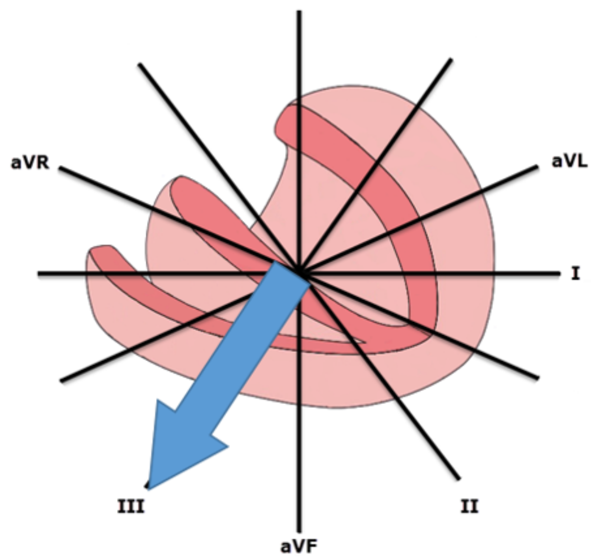

Figure 4 The Hexaxial Reference Grid in which The ischemic injury vector points toward the inferior wall leads

References

1. Jones JW. Simple atrioventricular (AV) dissociation or AV dissociation caused by third degree AV block? Front EmergMed. 2022;6(1):e13.
2. Jones JW. Five tips to help keep you from making a big mistake! Front Emerg Med. 2022;6(2):e29.