ECG Interpretation Part 1: Understanding Mean Electrical Axis

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The ability to determine electrical axis is important to detect subtle early warning signs of a change in the patient's cardiovascular condition. Abnormal or altered conduction patterns may occur as a result of changed physical conditions (e.g., increased ascites), conduction disturbances (e.g., bundle branch or fascicular blocks), or biochemical imbalances (e.g., hyperkalemia). Furthermore, determination of the electrical axis may assist in the differentiation of aberrant paroxysmal supraventricular tachycardia from ventricular tachycardia.

The purpose of this article is to provide a concise overview of the electrophysiologic concepts of axis determination including vectors and the hexaxial reference system and the common causes of axis deviation.

Electrical Conduction

The electrical impulse usually originates in the sinoatrial node, high in the right atrium, traveling through the atria to the atrioventricular node and then down the bundle of His, bundle branches, and fascicular pathways to the ventricles. Purkinje fibers then conduct the electrical impulse from the inner surface (endocardium) to the outer surface of the heart (epicardium).[1] Therefore the impulse travels from the sinoatrial node (from 11 o'clock, by use of the clock-face analogy) to the left ventricular apex (5 o'clock).[2]

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The overall direction of depolarization in the healthy heart is down and to the left.[3]

Each myocardial cell must be depolarized in turn to enable effective mechanical contraction. To reach all cells, the electrical activity travels in almost infinite directions instantaneously. It is the average, or mean, of these combined depolarizations (and repolarizations) that we measure to determine the mean electrical axis of the heart.[1,4] The mean axis of the P or T wave, T-P, or ST segment can be determined; however, it is most common to measure the QRS axis because it depicts ventricular depolarization.[5] The QRS complex is also relatively large in comparison to other complexes, so it is easily measured.

Vectors and Deflections

A *vector* is a force that has magnitude, direction,[1] and polarity.[5] It is depicted by an arrow that signifies the strength and direction of the relevant force or energy. Every depolarized myocardial fiber produces its own small vector. If many cells are depolarized in the same direction at the same time, a larger vector is created.[5] Thus the mean cardiac axis represents the net direction and magnitude of electrical force.[6] Each component of the ECG represents the dominant vector for that point in time when viewed from any of the 12 leads. For instance, the left-to-right movement of the electrical vector across the interventricular septum produces the small q wave seen in lead I as the vector moves away from the positive pole.[1]

Vectors of equal size that travel in exactly opposite directions negate or cancel out the other. An electrical axis that is parallel to a given lead produces the maximum positive deflection of the ECG complex; an axis oblique to a given lead has a smaller biphasic deflection. If the axis is perpendicular, then the net deflection will be 0 and an equiphasic deflection produced.[6,7] Hence, in a normal heart, where the net electrical impulse travels from approximately 11 o'clock to 5 o'clock, the lead pointing to 5 o'clock will exhibit the greatest positive deflection (lead II) and the lead pointing to 11 o'clock will have the greatest negative deflection (aVR).[2]
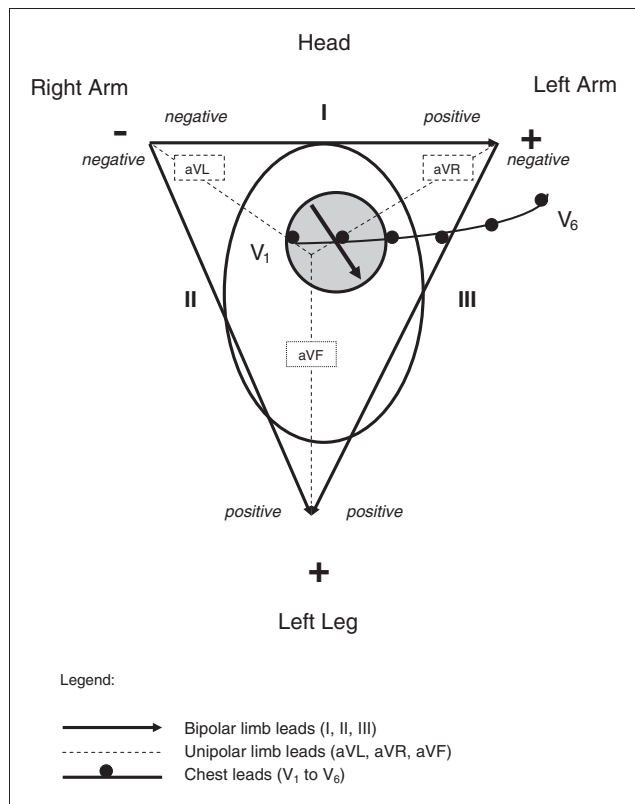
FIGURE 1

Einthoven's triangle with frontal plane and chest leads illustrated in relation to heart (gray circle) and torso (oval).

Hexaxial Reference System

Although a clock face provides a useful analogy, it is necessary to understand the hexaxial reference system to interpret an ECG. The 12-lead ECG is the combination of the 6 chest leads, which represent the myocardium's horizontal plane from the right sternum to the left midaxillary line, the standard bipolar limb leads (I, II, and III), and the augmented unipolar limb leads (aVR, aVL, and aVF) (Figure 1). The bipolar and augmented unipolar leads represent the frontal plane and are collectively known as the *hexaxial reference system*. If a vector moves toward any of the 6 frontal leads, then the associated deflection seen on that lead of the ECG will be positive. If the vector moves in the opposite direction from a lead, the deflection will be negative.[7]

The hexaxial reference system is divided into 4 quadrants to define normal axis and axis deviation. The degree at which each quadrant is arbitrarily differentiated from the next differs between texts. Some authors divide the circle into 4 equal quadrants[3,8]; however, because of the normal variation that can occur because of age and body habitus
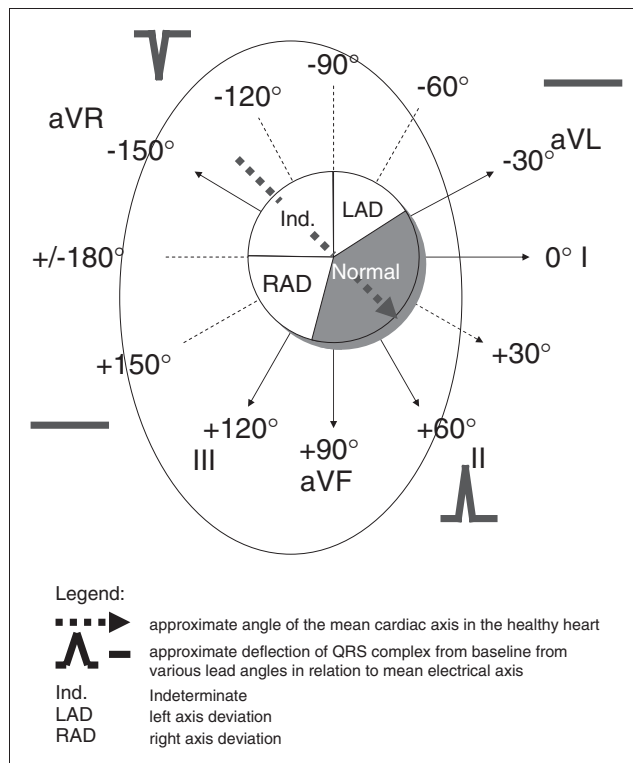

FIGURE 2

Hexaxial reference system with 4 axes and degrees by segment.

(e.g., obesity), the broader limit for normal axis as defined by Conover[1] is used in this article. Conover defines normal axis as –30° to +105°, right axis from +105° to ±180°, left axis from –30° to –90°, and movement toward what is known as an *indeterminate axis*, or *no man's land*, as –90° to ±180° (Figure 2). By use of either a protractor or division of the circle into the 30° segments, vectors can be assigned a degree and defined as slightly, markedly, or extremely deviated.[4] Detection of an alteration in the mean electrical axis may indicate a change in the patient's circulatory or conduction state, or both.

Causes of Altered Vectors

In a healthy adult heart the larger muscle mass of the left ventricle cancels out detection of the right ventricle's electrical activity in what can be described as a "tug of war," leaving approximately 20% of the left ventricle's electrical activity for the ECG to sense.[3] This is why the normal QRS axis is directed downward and toward the left. When depolarization does not occur via an intact conduction system or healthy myocardial cells, the QRS axis may be altered. In the presence of a damaged or necrosed section of myocardium or conduction pathway, the electrical activity

is not depolarized normally through the area of damage.[9] This alters the mean QRS axis and the direction from which the myocardial cells are eventually depolarized.

Normal Variants

Right axis deviation may be a normal variant in the young and thin population.[3,9] In addition, it is normal for the newborn to infant (aged 0-6 months) to have a right axis deviation.[1,7,10] This is because the fetus's right ventricle is anatomically larger than the left due to differences associated with fetal circulation.[10]

Normal leftward shifts have been noted in the elderly and obese population.[1] This is also a normal variant on expiration and during pregnancy for some patients.[9] Women aged in their forties tend to have less of a normal leftward shift than men.[1] All left axis deviations greater than –30° are abnormal.[5]

Abnormal Variants

There are a number of factors that explain abnormal axes (Table).

CONGENITAL

People born with atrial and ventricular septal defects are likely to exhibit a right axis deviation, as are those with dextrocardia[1] because of the heart's location in the right hemithorax.

HEART POSITION IN CHEST

Any physical condition that causes the heart to be tilted upward and to the left, such as obesity or pregnancy, will cause the axis to shift leftward. In contrast, conditions that cause the heart to be elongated downward, such as thin body shape, lung hyperinflation due to severe airways disease, and left-sided pneumothoraces will cause the axis to deviate toward the right.[4]

VENTRICULAR HYPERTROPHY

Hypertrophy of the left ventricle often occurs after myocardial infarction (MI) of this ventricle as a result of the remodeling process or lesions of the mitral or aortic valves. It can also occur due to MI in the right ventricle; however, this is less common. Right-sided ventricular hypertrophy often occurs with the remodeling and stretching that occur with chronically increased right-sided heart pressures such as those caused by pulmonary hypertension and mitral valve stenosis. Although these conditions tend to cause a more chronic right axis deviation, a massive pulmonary embolus may lead to sudden dilatation of the right ventricle resulting in a sudden right axis deviation.[8] In hypertrophy, the electrical axis shifts toward the affected ventricle,

which may be left or right.[4] In the case of generalized disease of the heart such as in cardiomyopathy, where there is diffuse alteration in electrical vectors, an indeterminate axis is the most likely result.

ALTERED CONDUCTION PATHWAYS

Wolff-Parkinson-White syndrome causes altered axes. A left-sided accessory pathway will cause a right axis deviation, and the opposite is the case for right-sided accessory pathways. Alterations in electrical conduction along the bundle branch and fascicular pathways also cause axis deviations. Diagnosis of such disturbances is an important reason for understanding cardiac axis determination and will be examined in more detail in the second part of this ECG series. Dysrhythmias may also be differentiated via cardiac axis determination.[5] For instance, in the setting of a wide-complex tachycardia of unknown origin, an abnormal axis supports the diagnosis of ventricular tachycardia over aberrant paroxysmal supraventricular tachycardia.[8] In the diseased heart the direction of depolarization may be altered as damaged areas will be depolarized last and necrosed areas are no longer capable of depolarization. Thus MI and necrosis also alter the path of the vector as the axis deviates away from the scarred regions.[4]

ELECTROLYTE DISTURBANCES

Electrolytes that impact upon depolarization will affect the mean electrical cardiac axis.[1] Life-threatening hyperkalemia may result in left axis deviation. However, there will be other important clues on the ECG likely to herald this lethal imbalance before the alterations are noted in the cardiac axis.

How to Calculate Mean Electrical Axis

There are numerous methods for calculating mean electrical cardiac axis; however, only 2 will be discussed here. The first method—the "at-a-glance" method,[1] or "two-lead method"[3]—is simplistic but useful for rapid determination of the QRS axes' general direction, required in acute MI or differentiation of broad-complex tachycardias. The second method, known as "quadrant and degree,"[4,11] is more accurate.

By use of the at-a-glance, or two-lead, method, the QRS complexes in leads I and aVF are examined to determine whether each is predominantly positive (upright) or negative (downward). If the axis is normal, both lead I and lead aVF will have positive QRS complexes. The mnemonic LAD (left axis deviation [ladies adore diamonds]) is used to illustrate the diamond pattern depicted by joining the upward deflection of lead I and the downward deflection of lead aVF. Therefore RAD (right axis deviation) will

TABLE
Causes of axis deviation

Axis variants	Right axis deviation	Left axis deviation	Indeterminate axis
Normal	(Less than +105°)	(Less than −30°)	None
	Children	Expiration	
	Thin adults	Pregnancy	
	Inspiration	Obesity	
Congenital	Atrial septal defect	Ventricular septal defect	None
	Ventricular septal defect	Coarctation of aorta	
Position	Dextrocardia	Subdiaphragmatic tumor	
Hypertrophy	RV enlargement due to the following:	LV enlargement due to the following:	Cardiomyopathy
	COPD	Systemic hypertension	Severe chronic lung disease
	Pulmonary embolus	IHD	Congenital heart disease
	Pulmonary stenosis	Aortic stenosis	
	Mitral or tricuspid valvular lesions		
Altered conduction	Wolff-Parkinson-White (left-sided accessory pathway)	Wolff-Parkinson-White (right-sided accessory pathway)	Lead transposition
	RBBB	LBBB	Ventricular tachycardia
	LPFB	LAFB	Ventricular pacing
	Anterolateral MI	PVCs	Third-degree AVB with ventricular escape rhythm
	Lateral MI (late)	VT (right origin)	
		Inferior MI (Q waves)	
		Pacing RV or LV apex	
		Emphysema (unknown mechanism)	
Electrical imbalances		Hyperkalemia (severe)	Hyperkalemia

RV, right ventricle; *LV*, left ventricle; *COPD*, chronic obstructive pulmonary disease; *IHD*, ischemic heart disease; *RBBB*, right bundle branch block; *LBBB*, left bundle branch block; *LPFB*, left posterior fascicular block; *LAFB*, left anterior fascicular block; *PVC*, premature ventricular contraction; *AVB*, atrioventricular block; *VT*, ventricular tachycardia.

be the opposite; lead I will be negative and point downward, and aVF will have a positive deflection. When the axis is indeterminate, both lead I and lead aVF will have negative deflections.

The second and preferred method is the quadrant-and-degree method. This method can easily be calculated on a small section of the ECG paper. Again, it is convenient to use lead I, which indicates whether a vector is moving toward or away from the positive pole along the horizontal line, and aVF, which indicates whether a vector is moving down (to the positive pole) or upward (away from the positive pole for that lead).

STEP 1

Draw a cross on a section of the ECG paper that will not interfere with subsequent interpretation of the ECG in the north-to-south and east-to-west configuration. Label the 4 ends with "I" or "aVF," and mark whether each is at the positive or negative pole for that lead (Figure 3).

STEP 2

Identify a QRS complex that is clear and not the product of aberrant conduction (e.g., ventricular ectopic beat) in leads I and aVF. Examine the QRS complex in each lead for deflection above (positive) and below (negative) the isoelectric line. Calculate the total, or net, deflection in millimeters, subtracting the negative from the positive measurements when necessary (Figure 3). This is usually a straightforward calculation; however, in the setting of a right bundle branch block, use only the first 0.04 seconds (1 small square on the ECG paper) along the QRS deflection to calculate the net measurement.
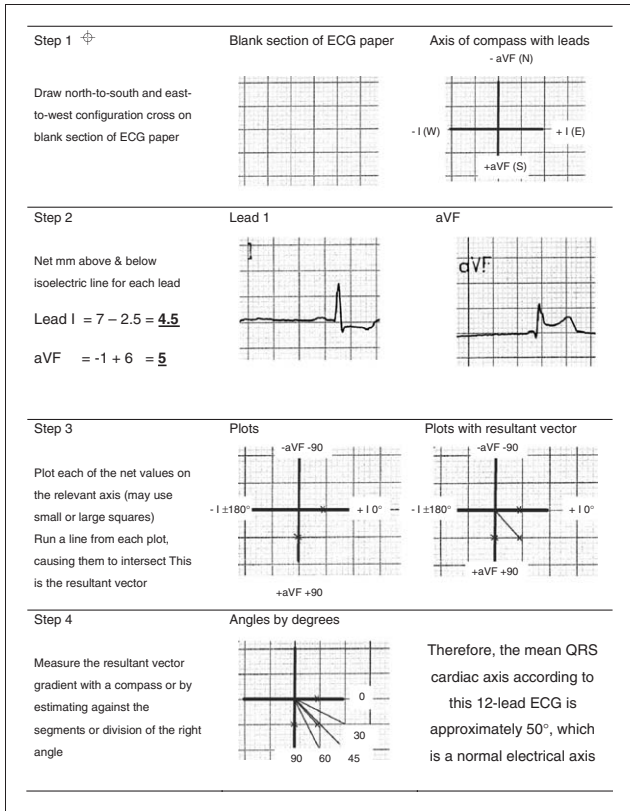
FIGURE 3

Steps for calculation of mean cardiac axis by quadrant or degree method.

STEP 3

Plot the net deflection for both lead I and lead aVF along each lead. If the sum of the deflection is negative, plot toward the negative pole of the relevant lead; if positive, plot toward the positive pole. Then, run a line from each of the plotted points for lead I and lead aVF to cause them to intersect. This gradient is the resultant vector.

STEP 4

The resultant vector will be traveling through the quadrant, reflecting whether it represents a normal, left, right, or indeterminate mean electrical axis. This gradient may be measured with a protractor for accuracy or may be estimated to within 10° to 15° accuracy by marking each quadrant with the degrees assigned to each segment (Figure 3).

Summary

We have provided a concise overview of the knowledge required to interpret the mean electrical axis on the 12-lead ECG. In essence, the QRS electrical axis is useful because it helps determine the position of the heart in the chest, patency of electrical pathways, and integrity of muscle mass. By itself, it is not diagnostic, but it does lend support to the observant clinician's suspicions for each of these anomalies. The ability to determine the mean electrical axis provides the emergency nurse with an additional readily available clinical tool to assist in the early and rapid detection of potentially life-threatening changes in the patient's cardiovascular status.

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