Narrative review article

Fast method to determine the cardiac axis with D1 and D3

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Método rápido para determinar el eje cardíaco con D1 y D3

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Abstract
The cardiac axis represents the average of the direction of the electrical activation process of the cardiac cells. It is one of the parameters determined in the correct reading and interpretation of the electrocardiogram. Also, not only is it useful as a diagnostic criterion for heart disease but also as a marker of prognosis and mortality in other diseases. Over the years, new formulas have emerged that allow its value to be calculated more accurately. The method using D1 and aVF is one of the most popular. However, it has two unmeasurable points. The first is between 0 and -30 degrees, and the second is between the values of 90 and 110 degrees. Although there are proposals with algorithms that use other leads, an alternative method was explored with D1 and D3 based on the algebraic formula of the inverse tangent and mathematical method for the exact calculation of the cardiac axis. A quick method is proposed that maintains the reliability of the algebraic formula to determine if the cardiac axis is within the normal ranges (-30 to 110 degrees).

Keywords
Electrocardiography, Heart, Heart Conduction System.

Resumen
El eje cardíaco representa el promedio de la dirección del proceso de activación eléctrica de las células cardíacas, es uno de los parámetros que debe determinarse en la correcta lectura e interpretación del electrocardiograma y es útil no solo como criterio diagnóstico de cardiopatías, sino también como marcador de pronóstico y mortalidad de otras enfermedades. Con el paso de los años han surgido nuevas fórmulas que permiten calcular con mayor exactitud su valor. El método que utiliza D1 y aVF es uno de los más populares, sin embargo, presenta dos puntos no medibles. El primero es entre 0 y -30 grados, y el segundo entre los valores de 90 y 110 grados. Aunque existen propuestas con algoritmos que utilizan otras derivaciones, se exploró un método alternativo con D1 y D3 basados en la fórmula algebraica de la tangente inversa y método matemático para el cálculo exacto del eje cardíaco. Se destaca este como una propuesta de método rápido que mantiene la confiabilidad de la fórmula algebraica para determinar si el eje cardíaco se encuentra dentro de los rangos normales (-30 a 110 grados).

Palabras clave
Electrocardiografía, corazón, sistema de conducción cardíaco.

Introduction

The cardiac electrical axis represents the average direction of the electrical activation process, depolarization or repolarization, of the cardiac cells[1], represented in the electrocardiogram; it symbolizes the cardiac ventricular depolarization vector[2].

The identification of the cardiac axis is useful not only as a diagnostic criterion for some diseases, including ischemic heart disease, hypertensive heart disease, and blockages, among others,[3] but also as a prognostic and mortality marker for several diseases[1].

Multiple methods have been described to determine the cardiac axis. One of the most accepted due to its practical way of measuring it, mainly in emergency areas, is that which consists of expressing the voltage of leads D1 and aVF in the Cartesian plane. However, the aforementioned one presents two non-measurable points; the first one is between 0 and -30 degrees, and the second one is between the values of 90 and 110 degrees[3].

Another of the most prominent methods is the three-lead method, so called because it includes leads 1, 2, and aVF, although some authors believe that the aVF lead is not necessary in some cases. The third simple way of assessing the ventricular axis consists of the location of the most isoelectric limb lead[1].

Most authors agree on using mathematical formulas to determine the most accurate way to calculate the cardiac axis[1]. Therefore, this article presents an alternative method with electrocardiogram leads D1 and D3 based on the algebraic formula of the inverse tangent and mathematical method for the exact calculation of the cardiac axis.

Discussion

There are multiple methods and formulas to determine whether the cardiac axis is within normal ranges or presents deviation to the right or left. The most commonly used method makes use of D1 (which represents the angle between 0 degrees and 180 degrees) or X axis and aVF (which represents the angle between -90 and 90 degrees)[4] or Y axis, also known as Two thumbs-up signel[5], this is useful in most scenarios[6]; however, some factors can alter it, among them deep inspiration[7] and some inconveniences identified from the very definition of a normal cardiac axis, since the value considered normal in adults is between -30 to 90 degrees[8-10]. However, several authors consider that the normal value is actually up to 100[11], 105[6,12,13] or 110 degrees[2,14,15] (Figure 1).

The value defined as normal can reach up to 120 degrees in patients between eight and 16 years of age[16,17] or borderline (findings between normal and abnormal values) in young high-performance athlete patients (caused by physical activity)[18]. The cardiac axis value could vary due to factors such as deep inspirationa[7].

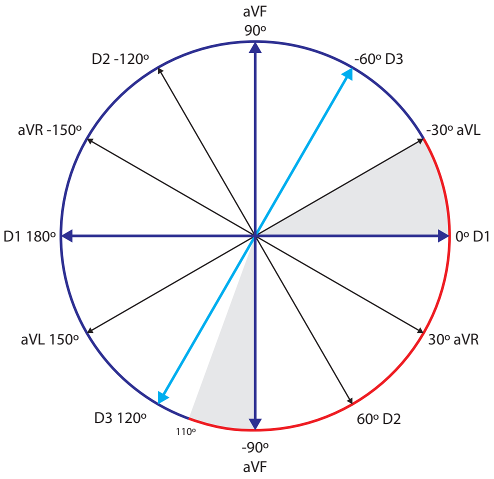

Figure 1. The hexaxial system shows the relationship between the different leads and their axes. The typical range of the cardiac axis is in red (30 to 110 degrees); in blue, lead D1 and aVF; and in light blue, lead D3[3].

These limits are even more relevant when considering that the diagnosis of pathologies associated with left axis deviation, such as left ventricular hypertrophy, is made based on an angle greater than -30 or even -45 for left bundle branch block[19]. In other disorders, such as the posterior fascicular block, the right deviated axis can be considered from +90 to +180 degrees. However, the axis markedly deviated to the right from +120 degrees[16].

On the other hand, some pulmonary affectations such as pneumothorax, specifically left pneumothorax,[20] COVID-19[21], and pulmonary thromboembolism can also deviate the axis to the right. In the latter case, the axis usually has values from +110 to +140 degrees[22]. Likewise, the axis is representative at +110 and +120 degrees allowing diagnoses such as right bundle branch block accompanied by fascicular block or right ventricular hypertrophy[2,23-25].

Therefore, some authors state that, in practice, the normal value of the cardiac axis is between the range of -30 to +110 degrees[2,14,26] (Figure 1). Then, It is as an axis deviated to the left, presented with a value less than -30 degrees[27] and the axis to the right with a value greater than +110 degrees[14,26].

The disadvantage of the traditional D1 and aVF method is that the range of the cardiac axis is between 0 and +90 degrees[6,28], when both values are positive[6]. It represents at least one blind or unmeasurable point between -30° and 0° within the parameter considered normal (-30 to -90 degrees)[27,29] or two blind points in the extended parameter (-30 to 110 degrees)[1] and includes patients who may be normal within the left or right shift category. The first blind spot of this method lies between -30 and zero degrees which is considered by most authors as normal range[26,27]. The second blind spot is between +90 and +105 degrees[6,26] or even up to +110 degrees[2], a range that can still be considered normal or non-pathological by some authors.

Algebraic formulas for calculating the exact cardiac axis based on a bipolar and a unipolar lead (D1 and aVF) are not exempt from this problem[30].

The fast method using D1 and aVF is popular due to its ease of application and understanding. Other methods as the "six-tap method"[31] or the mathematical or algebraic model for the calculation are not practical, and their application requires more time[3].

However, using the method and the algebraic formula for the calculation of the exact cardiac axis using leads D1 and D3, several scenarios can be extracted that allow a proposal to determine the cardiac axis quickly and reliably without having the spaces or blind spots described above. Therefore, the method using electrocardiogram leads D1 and D3 was explored, based on the algebraic formula of the inverse tangent and mathematical method for calculating the cardiac axis in which two bipolar leads (D1 and D3)[3] are used.

The formula for calculating the cardiac axis proposed by Tarricone[1] using D1 and D3 is: $tan\text{-}1\ [(D1 + 2D3)/\sqrt{3} \times D1]$[1,19] Where (*tan-1*) is the inverse tangent or arctangent of the result of the algebraic operation of adding the net value of the QRS complex in D1 with the result of multiplying two by the net value of the QRS complex in D3, previously divided by the result of the square root of the product of three by the net value of the QRS in D1[19]. The formula is based on the principle of the Cartesian plane which essentially represents the hexaxial system when calculating the cardiac axis. Like other proposed formulas, this formula adapts the direction of the resulting axes to the Cartesian plane, generating a value in degrees that correlates with the resulting vector, which is what we know as the electrical axis or cardiac axis[1]. The use of the D1 and D3 leads instead of D1 and aVF overcomes the blind spots described above because aVF limits the projection between -90 and +90 degrees, while D3 extends it between -60 and +120 degrees.

From the formula based on D1 and D3, it can be observed that whenever both QRS values on D1 and D3 are positive, and the difference between them is one, the cardiac axis is within normal ranges, specifically between values of +71 and +60 degrees (Table 1), which is also within the mid-range of the cardiac axis (+30 to +75 degrees)[1].

A projection was made showing that when both leads (D1 and D3) are positive, the cardiac axis is between 60 and 71 degrees. A projection was made showing that when both leads (D1 and D3) are positive, the cardiac axis is between 60 and 71 degrees. However, it was identified that to reach values of 60 degrees, the values of D1 and D3 must be 33 and 34 mm respectively. In addition, it can be observed that the closer the values are to 100, the closer the axis will be at +60 degrees (Table 1).

On the other hand, it was identified that the greater the difference between both values, in favor of D3, the result is negative and the angle is closer to 90 degrees, i.e. aVF; whereas, the greater the difference in favor of D1, it is positive and the angle is closer to 30 degrees, i.e. aVR. Even when the difference between both QRS is notable (x10 or more) and both net values are positive, the axis will be in normal ranges (Table 2). Similarly, if the values are reversed, where D1 is greater than D3, and both parameters are always positive, the axis will remain in normal values.

Alternative methods using the D1, D2, and D3 leads to determine the cardiac axis give values between zero and +90 degrees when all three leads are positive32, which is consistent with the findings of the method using the D1 and D3 values[33].

Therefore, from these data, five important aspects can be derived to simplify the formula:

1. As long as the net QRS values on D1 and D3 are positive, the axis will be in normal ranges.

Table 1. Variation in degrees of the cardiac axis with the algebraic formula D1 and D3 when the difference is 1

Value of D1	Value of D3	Angle in degrees
1	2	71
2	3	67
3	4	65
5	6	63
7	8	62
9	10	62
11	12	61
33	34	60
100	101	60

Table 2. Variation in degrees of the cardiac axis with positive D1 and D3

Value of D1	Value of D3	Difference	Angle in degrees
1	3	-2	76
1	4	-3	79
2	7	-5	78
2	9	-7	80
3	12	-9	79
1	36	-35	89
1	101	-100	90
2	1	1	49
4	3	1	55
6	5	1	57
6	6	0	60
10	1	9	35
20	1	19	32
101	1	100	30

2. The higher both values are and the closer their difference is to one, the closer the cardiac axis value will be to +60 degrees.
3. If the values of D1 and D3 are equal, the cardiac axis will be +60 degrees.
4. The greater the difference between D3 and D1 (with D3 greater than D1) the closer the value will be to +90 degrees.
5. The greater the difference between D1 and D3 (with D1 greater than D3) the closer the value is to +30 degrees.

The formula also allows to determine the scenarios when D1 or D3 are negative. In the case of D1, the distribution behaves as follows. Table 3 shows that when the D1 value is negative, the cardiac axis is almost completely verticalized or deviated to the right. It can be seen that when the difference between the two is negative, the axis is extremely deviated (-169 or +169 degrees), which is observed, for example, in ventricular arrhythmias[34].

When the value of D3 is twice that of D1, the value of net D3 is obtained, represented by +120 degrees in the Hexaxial system, and coincides with that described in the axis findings when D3 is the derivative of greater amplitude[35].

The formula's condition distributes the pattern and generates the need for a value in D3 at least three times greater than the negative net value of D1 for the axis to be over the upper limit (when considering the axis normal to +110 degrees) or a value four times greater to consider the value of +104 (with +105 the maximum value in degrees). However, a value 100 times greater than D1 in D3 is required for the axis to be over +90 degrees.

Likewise, the calculation was performed with negative values of D1 and positive values of D3, and it was verified that the result of the angle remains between 169 and 90 degrees except when the difference between D1 and D3 is less than or equal to -2 (Table 3). Thus, it is possible to establish that when D1 is negative, and D3 does not have a value at least three times greater in absolute values, the axis will have deviated to the right.

The distribution with D3 as the negative value is reflected with a value in degrees as a negative maximum at +71 degrees and as a positive maximum at +30 degrees.

n summary, the interpretation of the cardiac axis according to the projected findings is shown as a quick method to determine the cardiac axis using D1 and D3 by the inverse tangent formula (Table 4).

Therefore, it can be established that whenever the value obtained from the division of D1 by D3 is equal to or less than one, the value of the angle of the cardiac axis will be deviated to the left. However, whenever the product of this division is greater than one, the angle will be above -30 degrees and below or equal to +30 degrees.

From these data four other key aspects can be determined:

1. If D1 is negative and D3 is not three times greater than D1, the axis is deviated to the right (considering the normal axis up to +110 degrees)..
2. If D3 is negative, but the net QRS value on D1 is greater than at least 0.01 at D3, the axis is in normal ranges.
3. If D1 is twice the absolute value of D3, the axis will be at zero degrees.

Table 3. Cardiac axis variation with negative D1 and positive D3

Value of D1	Value of D3	Difference (D3/D1)	Angle in degrees
-3	1	-2	-169
-3	2	-1	169
-3	3	1	150
-3	6	2	120
-3	9	3	109
-3	12	4	104
-3	15	5	101
-3	27	9	96
-3	30	10	95
-3	300	100	90

Table 4. MRapid method to determine the cardiac axis with D1 and D3

D1	D3	axis interpretation
Positive	Positive	Normal
Negative	Positive and 3 times greater than D1	Normal
-	Positive, but not 3 times higher than D1	Desviado a la derecha
Positive and greater than the absolute value of D3	Negative	Normal
Positive, but equal to or less than the absolute value of D3		Deviated to the left
Negative	Negative	Extremely deviated

4. If D3 is negative and the absolute value of D3 is greater than D1, the axis is deviated to the left.

If both D1 and D3 have a negative absolute value, the cardiac axis will be between -60 and -150 degrees, i.e., extremely deviated. This method changes the value of D3 when it is present with D1 with a negative value. In this case, D3 would have to be four times the absolute value of D1 to be within the normal range (+105 degrees).

From the key aspects that have been extracted from the formula, it is highlighted that the results of the cardiac axis retain the reliability of the algebraic formula to determine if the cardiac axis, given that it is within the normal ranges using D1 and D3, which poses a fast and reliable method to determine the cardiac axis (-30 to +110 degrees); when it is clear that the cardiac axis is within the ranges of -30 to +105 degrees.

When assuming a cardiac axis with the classic values between -30 and +90 degrees, it is possible to establish whether the axis is in normal ranges just by observing the positivity or negativity in D1 and D3. If both values are positive, the axis is in the normal range.

If the derivative of D1 were negative, but the derivative D3 remained positive, and its absolute value is at least three times the value of D1, then the axis will always remain in normal ranges, although borderline (around 109 degrees). If the value of D3 is four times the value of D1, then the axis will be around 104 degrees; otherwise, the axis will be deviated to the right (greater than 105 degrees).

If it is derivative D3 that has a negative value, but D1 is positive, then the axis will be within the normal range as long as D1 is greater than D3 in absolute values. If the value is equal to or less than D3, the axis will be deviated to the left (less than -30 degrees).

It is worth mentioning that since the pathologies that present the axis deviated to the left are representative of axes lower than -30 degrees, most authors consider this as the limit of the left cardiac axis[3,10,11,16].

A similar situation occurs with entities that deviate the axis to the right; the representative value in most scenarios and even in patients with a structurally healthy heart is the limit of +110 degrees,[13,17] which is why several authors consider the normal range of the cardiac axis to be between -30 and +110 degrees. Although there are algebraic formulas that use D1 and aVF to calculate the cardiac axis[3,30] and more advanced methods based on algorithms and the use of one or more leads to determine the cardiac axis,[13] they are not easy to apply or remember in clinical practice.

The inverse tangent formula using D1 and D3 has demonstrated to be a reliable formula for calculating the cardiac axis.[3,30] As a consequence, when this formula is projected, a fast method can be obtained that maintains the same reliability for determining the cardiac axis without the non-measurable points of the traditional method of D1 and aVF.

Conclusions

The fast method highlighted for the calculation of the cardiac axis using D1 and D3 allows obtaining a value extracted from a range that maintains the reliability of the inverse tangent formula without the defects or blind spots presented by the other methods.

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