EDITORIAL

Recommendation for Revision of the Standard Presentation of the Frontal Plane ECG Leads Including Reversal of Lead aVR (to $-aVR$): It Is Time for a Change

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The 12-lead, standardized presentation of the ECG, as determined by the American Heart Association more than 70 years ago, was an important contribution to clinical cardiology and has also become accepted worldwide.

Two major improvements can be made to the frontal plane ECG, both of which can be set up simply and quickly. Two inadequacies are present, both of which are entirely the result of the presentation format in which the standard ECG was designed, and these have remained the same to this day. The two possible improvements are: (1) a precise, 180 degree alteration in the configuration of Lead aVR (to $-aVR$); and (2) a transfer of the entire six-lead frontal plane to an orderly, sequential angular position for each lead. We believe it is time to revise the standard frontal plane ECG presentation with these improvements.

It is well known that aVR has long been neglected in basic ECG interpretation.¹ This neglect has undoubtedly resulted from the unusual appearance and anatomical position of aVR, resulting in the lack of a clear and easy relationship with other more diagnostic frontal plane leads. Thus, the use and importance of aVR as part of the clinical report has been of little value until more recently, when it became evident that aVR changes can actually be of considerable importance and may be among the most valuable of all ECG changes in some cardiac illnesses. Moreover, there currently appears to be little general understanding of the actually well-defined and fixed relationship of aVR to all other

frontal plane leads, such that even now aVR is often regarded as having unusual, undefined, and unique properties not possessed by other leads.

All of these problems can be solved easily by the use of an electrically inverted lead aVR to $-aVR$ (Fig. 1). This $-aVR$ lead, with its angular presentation of $+30$ degrees, now fits nicely into a commonly used ECG area, falling half way between traditional lead I at 0 degrees, and lead II at $+60$ degrees (Fig. 1A). Moreover, $-aVR$ accurately retains all of the specific features of aVR, but these now fall entirely into the same directional patterns as its two adjacent leads. Thus, a major new importance is provided to this altered aVR lead, since all its characteristics are related easily, directly, and correctly to the accompanying changes in adjacent traditional Leads I and II. And the routine use of Lead $-aVR$ will result in valuable new types of information that have not been available using aVR in the standard ECG presentation.

A direct comparison of all electrocardiographic features of aVR (seen here as $-aVR$) can be seen and compared accurately, simultaneously, and directly with all other frontal plane leads. This eliminates the standard, laborious calculated comparison of individual lead values such as T, ST, etc., in aVR, since these have always been regarded as a separate entity. This type of difficulty in clearly establishing the relative importance of aVR is evident in even very recent articles,^{2,3} in both of which it would have been quite simple if $-aVR$ had been available.

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Figure 1. ECG lead angles and associated lead nomenclature. (A) Hexaxial lead system in the frontal plane. The electrical ECG angle for the traditional lead aVR is -150 degrees, which places it well outside the common site for the rest of the standard frontal plane leads from aVL to lead III (or from lead angles -30 to $+120$), and makes any concept of its relationship to the other traditional leads a difficult one. However, the change of aVR by complete electrical inversion will enter the same lead, inverted by 180 degrees (now called $-aVR$ in the hexaxial lead system), and it fits directly between leads I and II at 30 degrees and permits an appropriate relationship with all other frontal leads. (B) Suggested 12-lead ECG presentation. The leads in the frontal and horizontal planes are sequentially presented in separate rows. The sequential lead angles for the frontal plane are provided in parentheses for descriptive purposes only and would not be included in the formal 12-lead presentation.

The T in Lead aVR is now often described as having unusual, unique and almost mystical diagnostic properties, perhaps due to the position of Lead aVR directly into the left ventricle or for other unknown

reasons, but there has been no evidence available to support this property of aVR. Such a unique property of aVR changes or their strength can easily be validated in any ECG containing Lead $-aVR$, since

a direct comparison with all frontal leads is now available. Should the T in aVR be indeed unique, there should be only a major T in $-aVR$, perhaps with some minor T changes on the two adjacent leads, Leads I and II (Fig. 1). The results should be interesting, definitive, and provide a direct understanding of the importance and value of aVR.

Another point to be made here is that the most new information to be obtained with $-aVR$ (such as ST- or T-wave changes) is in the relation with its two adjacent leads I and II, and that these three leads are much closer together (30 degrees apart) and provide more detailed evidence of the extent of the illness than simply those changes of Leads I and II, separated by 60 degrees (Fig. 1).

This approach leads directly to the second major improvement which can be made to the standard ECG. This change is also badly needed, and can be easily established. It is in the overall order of lead presentation, so that all six frontal plane leads are shown in a sequential, angular order (Fig. 1). The standardized ECG was of particular new interest and importance at its inception since it added three new leads (aVR, aVL, aVF) to the basic (I, II, and III) leads of Einthoven, and thus supplied three new positions for the evaluation of the ECG.

However, for little known reason in the development of the standardized ECG, the traditional Leads I, II, and III were grouped separately from the new unipolar Leads (aVR, aVL, and aVF). It is difficult to understand the reason for this type of grouping, since the angular relationship of the new unipolar leads and the basic Leads I, II, and III was known at that time and was defined more specifically thereafter. It is interesting that in each of the 30-degree steps in the angular presentation, there is a regular alteration between the historic Einthoven Leads (I, II, and III) and the unipolar leads. Nevertheless, the separate grouping of the traditional and unipolar leads has been maintained to this day, with the loss of a more valuable presentation of an angular presentation.

Over the years since the standardized ECG was set up, repeated attempts for its angular revision were proposed but never accepted. For specific examples, one of the authors here (AJM) proposed the adoption of this complete angular ECG frontal plane relationship in 1958, but this was rejected with the explanation that an understanding of this new format "would be too difficult to be accepted." It was also recommended and recorded in great detail by the other author in 1979 using complete

angular ECG frontal plane relationships in several patients with clinical ECG changes. The ST, T, etc., alterations which had occurred appeared in associated contiguous leads with a progressive increase to a maximum and then to a minimum. The existing ECG format also misses the extent and sensitivity of the full ECG response, since leads I, II, and III are separated by 60 degrees from lead to lead instead of by 30 degrees for all six leads (Fig. 1).

Repeated suggestions have been made for the adoption of an overall angular presentation and $-aVR$, and this was also presented⁴ as recently as 5 years ago in great detail, showing the historical background, and the important advantages of an orderly, frontal lead display, including $-aVR$. But there has continued to be no active interest in altering the standard ECG format other than in Sweden, where the angular ECG is used exclusively. The reason for continually avoiding a modern revision of the standard ECG into a very appropriate and valuable presentation is not clear, but it is most probably due to the enormous existing volume of standard ECG material in all clinical reports, medical articles, and books.

Change can be difficult, but both these revisions would add greatly to the value and reliability of the ECG. It is quite probable that a more rapid acceptance of each of these revisions can proceed more easily than expected, due not only to the clinical necessity of $-aVR$, but also due to the great rewards provided from an angular format.

While this New Format ECG will be scientifically useful, there will also be a number of other benefits. The extensive ECG memorization of electrocardiography, particularly from unrelated leads, will be much diminished.

The new patterns of an ECG in the complete angular frontal plane should be a pleasure to view and understand, particularly as changed patterns are present in several adjacent leads. Moreover, angular presentation of ECG at each 30 degrees will show a much more detailed appearance of the extent of changes and severity of ECG changes. And this should also permit digital analysis of the magnitude and size of the particular ECG alterations. And it should be a pleasure to classify each ECG lead by its scientifically correct numerical angular position, instead of its historically correct names of I, II, III, aVR, aVL, and aVF.

The described revisions of the standard ECG are most logical and valuable, and should be carried out. This should begin now with $-aVR$

substitution due to its clinical importance and its simplicity of change. The addition of a totally angular ECG system (including $-aVR$) should be initiated, too. It might be helpful to initially retain the printed names for the traditional leads (I, II, III, aVR , aVL , and aVF) as well as the angular degrees for each Lead (Fig. 1), but it seems most probable that all traditional cardiologists as well as younger cardiologists will easily assimilate and appreciate the updated, revised, and more logical lead system.

We plan to recommend these changes in the standard ECG format as highlighted in this editorial to the national cardiology societies throughout the world, to the International Society for Holter and Noninvasive Electrocardiology (ISHNE), and to the

major ECG manufacturers, for we believe these changes are logical and correct, and, if instituted, they will improve clinical electrocardiography.

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