A COMPARISON OF UNIPOLAR LEADS OBTAINED WITH THE METHODS OF WILSON AND GOLDBERGER

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Wilson *et al.* in 1934 introduced a method of obtaining unipolar leads representing the potential variations of a single electrode, by using as an indifferent electrode a central terminal that was obtained by connecting the lead wires of the three extremities through non-inductive resistances of 5000 ohms. It is assumed that this central terminal has a potential of zero, the assumption being based on Einthoven's equilateral triangle theory and Kirchoff's law. Although it has been shown (Dolgin *et al.*, 1949) that this central terminal is not a truly indifferent electrode and may show some potential, this method has proved to be the most practical one for obtaining unipolar leads.

Goldberger in 1942 introduced a modification of Wilson's method for obtaining unipolar limb leads by omitting the resistances between the extremities and the central terminal, and disconnecting the lead wire of the explored extremity from the central terminal. According to Goldberger, an amplification of 50 per cent of the potential of the corresponding Wilson unipolar limb lead is thus obtained.

Various studies (Bryant and Johnston, 1946; Bryant *et al.*, 1949; Griffeath and Sokolow, 1951) have been made, comparing the unipolar limb lead electrocardiograms taken by the method of Goldberger with corresponding curves taken after modifying this method by the introduction of 5000 ohm resistances between the limb electrodes and the central terminal. In these studies differences in the amplitude of the deflections were found in under 10 per cent of the cases. Kisch (1948) in one case compared the Goldberger unipolar limb leads with the corresponding Wilson limb leads and found that the ratio between them was inconstant, varying from limb to limb. Rappaport and Williams (1949) analysed the methods of Wilson and Goldberger from a theoretical mathematical point of view, and concluded that the Goldberger method gave better results when used with the Wilson central terminal.

We are reporting a comparative study between Wilson's unipolar limb leads (VR, VL, VF) and Goldberger's augmented unipolar limb leads (aVR, aVL, aVF). The purpose of the study is: to determine (1) whether the (assumed) 1:1·5 ratio between Wilson's leads and Goldberger's augmented leads is valid; and (2) whether there are differences in the form and direction of the deflections recorded by the two methods.

Method of study. Fifty patients showing abnormal cardiograms were studied. They were taken by a Cambridge string galvanometer, recording consecutively the three Wilson unipolar limb leads and the three Goldberger's augmented unipolar limb leads. In addition the three standard limb leads and the six unipolar præcordial leads (V1–V6) were taken. Special care was given to proper preparation of the skin. In every one of the 300 tracings, attention was paid to the standardization (1·0 MV=10 mm.). The waves of the ventricular complex, Q, R, S, and T were measured (a magnifying lens being used) in at least three consecutive cardiac cycles, and appropriate corrections were made for eventual errors in the standardization. The mean value of each wave in three consecutive cycles in Wilson's and Goldberger's leads were calculated and the ratio between them determined—VR/aVR, VL/aVL, and VF/aVF.

Results

The results are summarized in the table. The mean ratio between the corresponding waves recorded from the same limb with the two methods was found to be inconstant and to vary considerably. Thus, for example, the following results were obtained for the right arm: QaVR/QVR= $1{\cdot}51 \pm 0{\cdot}22$; RaVR/RVR=$2{\cdot}02 \pm 0{\cdot}84$; SaVR/SVR=$1{\cdot}56 \pm 0{\cdot}09$; TaVR/TVR=$1{\cdot}86 \pm 0{\cdot}67$. Except for very few instances, marked variations of this ratio were found from case to case, as may be seen from the wide spread of the limits of the true mean.

Furthermore, the mean ratio of the identical waves obtained from the different limbs was also found to show variations; for example, in the case of the R waves the following results were obtained: RaVR/RVR=$2{\cdot}02 \pm 0{\cdot}84$; RaVL/RVL=$1{\cdot}75 \pm 0{\cdot}82$; RaVF/RVF=$1{\cdot}65 \pm 0{\cdot}45$.

In two instances a significant discrepancy in the form of the waves was found. In the first an upright T of 0·4 mm. was seen in aVL, while it was isoelectric in VL; in the second a Q of 0·6 mm. was seen in aVL while it was absent in VL.

TABLE

Deflection	Leads	No. of observations	Mean of ratio	Standard deviation	Standard error of the mean	The true mean is likely to lie within the limits of
Q	AVR/VR	28	1·51	0·22	±0·04	1·4–1·6
Q	AVL/VL	20	1·93	0·87	±0·19	1·5–2·3
Q	AVF/VF	16	2·47	1·68	±0·42	1·6–3·3
R	AVR/VR	34	2·02	0·84	±0·15	1·7–2·3
R	AVL/VL	46	1·75	0·82	±0·12	1·5–2·0
R	AVF/VF	49	1·65	0·45	±0·06	1·5–1·8
S	AVR/VR	20	1·56	0·09	±0·02	1·5–1·6
S	AVL/VL	16	1·68	0·28	±0·07	1·5–1·8
S	AVF/VF	28	1·75	0·34	±0·07	1·6–1·9
T	AVR/VR	45	1·86	0·67	±0·10	1·7–2·1
T	AVL/VL	39	1·99	1·13	±1·18	1·6–2·4
T	AVF/VF	47	2·03	0·84	±0·12	1·8–2·3

Comment

As seen from the results the ratio between the waves of the ventricular complex obtained by the Wilson unipolar leads and the Goldberger augmented unipolar leads varies from lead to lead and from wave to wave. Thus the assumption that there is a constant ratio of 1:1·5 between the potentials recorded by Wilson's unipolar leads and Goldberger's augmented leads could not be verified in our series. The ratio of 1:1·5 was derived from calculations based on the concept of Enthoven's equilateral triangle, the heart being equidistant from each angle, and accordingly it was concluded that the central terminal of Wilson equals zero.

Goldberger modified the Wilson method by eliminating the 5000 ohms resistances and by disconnecting the electrode of the explored limb from the central terminal. With this procedure each extremity was coupled with a central terminal of a different potential, obtained by omitting a different angle of the triangle for each lead. This is in contrast with the Wilson method in which the same central terminal is used for each extremity. Furthermore, elimination of the 5000 ohm resistances from the central terminal may increase the distorting effect of inequalities in the skin resistances. These factors may account for the inconsistency and variations in the potentials recorded by the two methods in our series.

Summary

Wilson's and Goldberger's unipolar limb leads were compared in 50 cases with abnormal electrocardiograms.

The ratio between the potentials recorded by the two methods was found not to be 1:1·5. No constant relationship was found between the potentials recorded by the two methods, though the ratio generally lay between 1:1·5 and 1:2·0.

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