Vectorcardiogram of the 'Man-Frog'

A. SKOWRON, P. GATHIRAM

SUMMARY

New experimental evidence is adduced to show that the hypothesis of the single instantaneous equivalent or resultant cardiac vector—which forms the basic concept of vectorcardiography — no matter whether this is produced by a dipole or a combination of dipoles, or a multipole, is no longer tenable. Chest electrodes from a man and from a frog are connected simultaneously to an oscilloscope — the one to the vertical and the other to the horizontal plates — and the resulting display observed. It consists of a loop, the interpretation of which is discussed, and the conclusion is reached that the presently held vector theory appears to be of historical value only. Nevertheless, electrocardiograms and 'vectorcardiograms' will continue to be of the greatest clinical value, albeit on a purely empirical basis.

S. Afr. Med. J., **48**, 1095 (1974).

'Many people find theories much more amusing than facts. Now these facts may be certain—but the hypotheses may be wrong.'

A. V. Hill: *Trails and Trials in Physiology.*[1]

To hardly any other field does Professor Hill's quotation apply more than to the theory of electrocardiography. Some are openly critical and reject the theory in its entirety. Wolferth[2] states that Einthoven's and Wilson's assumptions upon which they based their hypotheses 'are mostly untested', and proposes the view that clinical electrocardiography is an offspring of empiricism and not of science.

Abildskov[3] maintains that the present status of electrocardiography has developed largely without consideration of the nature of the processes whose effects are being recorded, and that the present status of diagnostic cardiology has been achieved despite severe limitations of pertinent knowledge. He ascribes this to the necessity to use oversimplified assumptions concerning the geometry of the volume conductor and the properties of the body and of the heart—and also to the limitations which were dictated by the inadequacy of the instruments available to the pioneers. He foresees major changes in diagnostic electrocardiography based on a deeper understanding of the subject.

Geselowitz[4] states quite unequivocally: 'There is no single equivalent generator'. If this is true, and it is well supported, then the whole basis of vectorcardiography falls away and what was thought to be a scientific concept is reduced to pure empiricism. If no single equivalent vector exists, then not even a multipole substituted for one or more dipoles can produce a single equivalent cardiac vector.

Rijlant[5] says that the dipole hypothesis, which was thought to satisfy the need of a causal interpretation of the distribution of potentials at the surface of the body 'has now been definitely refuted' since Yeh *et al.*[6] have shown the quantitatively important magnitude of quadrupoles and octopoles. The magnitude of the singularities of the surface distribution of potentials is greater than was thought in the past. He continues: 'The urgent need for revision cannot be ignored any more'.

Other workers had the same feeling, and, while not abandoning the single equivalent vector, have attempted to produce better correlation of theoretical and actual vector loops by 'correcting' the lead systems and proposing new ones. The originators of the oscilloscope method are Schellong,[7] Hollmann,[8] and Wilson and Johnston,[9] whose methods were simple but did not produce good clinical correlation. Variations in the theories arose and other well-known electrode placements aiming to correct these discrepancies were proposed by Frank, Grishman, Burger, Helm, Schmitt and Simonson, and McFee and Johnston, to mention only a few. The references to these works are too numerous to mention here. There the matter rests and unanimity has not been achieved.

This in itself suggests that the fundamental vector hypothesis on which all these new variations are based does not explain the real nature of the process being recorded. One is asked to accept it in good faith like a dogma which does not require proof. Therefore the varieties of new hypotheses all suffer from the same weakness as the original single equivalent vector hypothesis on which they are based. Nevertheless, investigators continue to amuse themselves by devising yet other and newer theories and hypotheses using the same unproved dogma as a basis.

In order to find a way out of this veritable theoretical maze of arguments, geometrical constructions, axes, projections, lead field concepts, equivalent vectors and other figmental ideas without physical existence, it is necessary to leave the field of speculation and return to experimental evidence. Our whole theory of electrocardiography rests on a single experiment undertaken three-quarters of a century ago with necessarily primitive methods, which relies on 'mostly untested hypotheses'. The experiment itself cannot be faulted. It was correct as far as it went. The explanation was, however, wrong.

EXPERIMENTAL EVIDENCE

The following experiments were therefore devised in an attempt to gather with modern instruments more evidence

Department of Physiology, University of Durban-Westville, Durban
A. SKOWRON, F.R.C.S., B.SC. ENG.
P. GATHIRAM, B.SC. HONS

Date received: 28 January 1974.

as to the nature of the electrical processes being measured. It was decided from the outset not to assume anything and to exclude all preconceived ideas. One therefore begins without any hypothesis at all, not knowing what to expect, just as Einthoven did in 1903.

Experiment 1

A man and a frog are simultaneously connected to an oscilloscope through suitable preamplifiers. On the man two electrodes only are placed on the skin of the chest vertically above and below the heart, and they are connected to the vertical plates of the oscilloscope. On the frog two electrodes are placed on the skin horizontally on either side of the heart and connected to the horizontal plates. A loop display results and this is photographed.

The arrangement is shown in Fig. 1 and the photograph of the loop in Fig. 2.

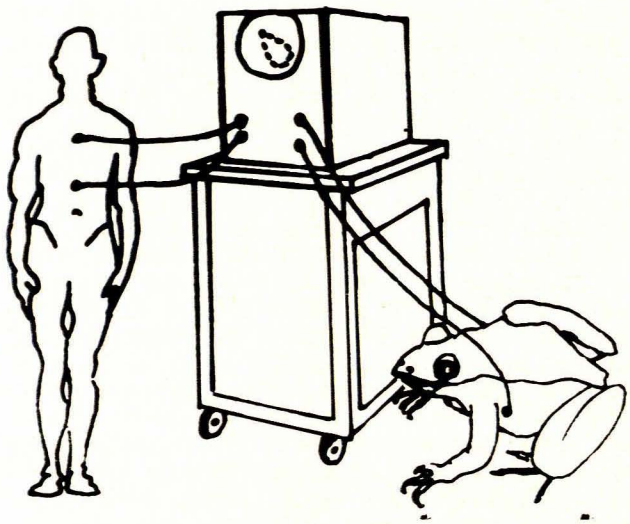

Fig. 1. Man connected to vertical plates of oscilloscope, frog connected to horizontal plates of oscilloscope.

Instrumentation: Tektronix Storage Oscilloscope Type 564B, 2 Tektronix Type 3A3 amplifiers, and 2 Tektronix Preamplifiers Type RM122. The trace was blanked at 1-millisecond intervals by a Tektronix saw tooth generator Type 162. The loop was photographed with a Tektronix Oscilloscope camera type C-12.

Discussion: What does the loop obtained mean? It obviously is not a vectorcardiogram of the man's heart, because only a single pair of electrodes was connected to the man. For a similar reason it is not a vectorcardiogram of the frog—and yet it looks like a vectorcardiogram.

It is necessary to go back to the beginning and to realise that the electrodes on the man's thorax record nothing more than a varying potential, which is impressed on the vertical plates. The electrodes on the frog's thorax act in a corresponding fashion. It has been shown[10] that such a loop will be also obtained if any two separate

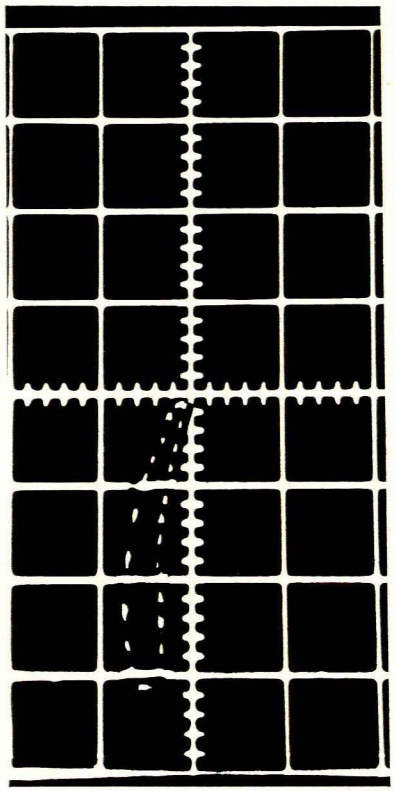

Fig. 2. Loop from arrangement in Fig. 1, partly from man and partly from frog.

varying voltages from whatever sources are impressed on the X-plates and the Y-plates on an oscilloscope.

One must therefore conclude that the loop shown in Fig. 2 is an X-Y loop representing two varying voltages.

Experiment 2

The two frog electrodes are now removed and transferred to the man, occupying the same relative positions on his chest as they did on the frog, i.e. on either side of the heart.

A new loop is displayed as shown in Fig. 3. The question now arises—is this loop a vectorcardiogram? The positions of the electrodes are more or less such that one lead is recorded horizontally and the other vertically. By all the tenets of vectorcardiography this loop should now be a vectorcardiogram, albeit not necessarily a 'corrected' one. The refinements are beside the point—it is the principle which matters—and in principle this is an orthogonal frontal vectorcardiogram.

The four electrodes are at all times unaware of and indifferent to what they are supposed to be measuring. They are not influenced by whether the potential differences they indicate are produced by a dipole or several dipoles, or by a multipole, or by one heart or two hearts, or whether the two hearts are close together or separated

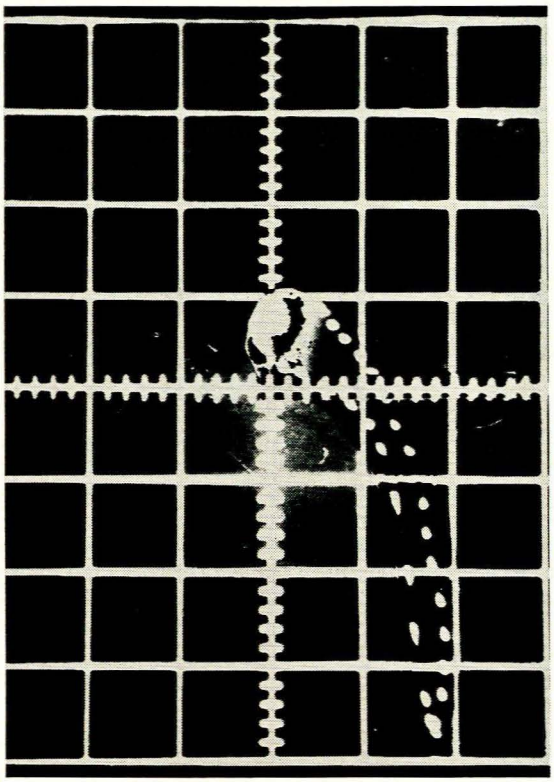

Fig. 3. Loop recorded from man only.

by several feet. They record differences of potential—no more, no less, and no matter how they originate.

It is now necessary for the observer to regard the situation with the same detachment:

1. Two loops on an oscilloscope are produced in both cases by four electrodes.
2. These loops can only be produced by two differences of potential.
3. These potential differences occur, for example, on human skins and on frog skins.
4. The first loop cannot be a vectorcardiogram.
5. It must in fact be an X-Y recording of 2 skin potentials on separate skins.
6. The second loop is also an X-Y recording of 2 skin potentials, but this time on the same skin.

Why then will vectorcardiographers term the second loop a vectorcardiogram and not the first loop? This is the weakness in their argument, and is what Wolferth refers to as a 'hypothesis which is untested.'

It has already been shown by Taccardi and Marchetti[11] that different skin potentials can be measured on the skin and that several positive and several negative areas exist on the skin at the same time, which vary with the cardiac cycle. When 2 electrodes are placed anywhere on the skin, a difference of potential will be measured between them. The 'vectorcardiogram' is therefore nothing but a recording of two skin potentials. Because these surface potentials are different in health and in disease, they do, however, serve as an excellent empirical diagnostic criterion. It has never been proved that they combine into any equivalent vector, and their very appearance as separate local areas of polarity speaks for itself and shows that they have not so combined.

CONCLUSION

The classical hypotheses and theories of electrocardiography are, as Rijlant claims, in urgent need of revision. They have never been proved, and experimental evidence has accumulated to show that they are incorrect. 'Many people find theories more amusing than facts. Now these facts may be certain—but the hypotheses may be wrong.' It is suggested that more experimental facts and less theory be brought into play in order to arrive at a revised system which is scientifically sound and acceptable and standard practice, which vectorcardiography is not. It is understandable that sentiment prevails and a certain commendable reluctance exists to avoid critical discussion of the work of the pioneers. But they would no doubt welcome progress and advancement in the same way as they themselves have contributed to and advanced this science. Further experimental work will in no way detract from their merit of having been the first to show the way.

If the loop on the man's chest is a vectorcardiogram, then the loop of the 'man-frog' must also be a vectorcardiogram — *a reductio ad absurdum.*

We wish to thank Professor J. Booyens for his encouragement and the excellent research facilities he made available, and Mrs L. Lawes for the photography.

REFERENCES

1. Hill, A. V. (1965): *Trails and Trials in Physiology*. London: Edward Arnold.
2. Wolferth, C. C. (1957): Circulation, **16**, 321.
3. Abildskov, J. A. (1964): Amer. J. Cardiol., **14**, 285.
4. Geselowitz, D. B. (1964): *Ibid.*, **14**, 301.
5. Rijlant, P. *in* Luisada, A. A. ed. (1961): *Encyclopaedia of the Cardiovascular System*, vol. 5. New York: McGraw-Hill.
6. Yeh, G. C. K., Yeh, J. and Martinek, Ann (1957): New York Acad. Sci., **65**, 1003.
7. Schellong, F. (1936): F. Verh. Dtsch. Ges. Inn. Med., **48**, 288.
8. Hollmann, H. E. (1938): Z. Klin. Med., **134**, 732.
9. Wilson, F. N. and Johnston, F. D. (1938): Amer. Heart J., **16**, 14.
10. Skowron, A. (1968): Brit. Heart J., **30**, 735.
11. Taccardi, B. and Marchetti, G. (1965): *Proceedings of the International Symposium on the Electrophysiology of the Heart*, p. 257 - 280. Oxford: Pergamon Press.