A TWIN OSCILLOSCOPIC VECTORCARDIOGRAPH

BY

A. J. V. CAMERON,* T. D. V. LAWRIE, AND J. H. WRIGHT

From the Department of Cardiology, Royal Infirmary, Glasgow

Received December 20, 1958

Any constant electrical force can be regarded as a vector quantity and can be represented by a straight line with magnitude, polarity, and direction in space. A force that is continually varying in magnitude and direction can be represented by a succession of such vectors drawn from a common origin or zero point. The free ends of these vectors can then be joined to form a loop. This loop begins with the onset of the force and returns to its origin when that force ceases.

The fundamental concept of vectorcardiography is that the varying electrical field of the heart can be considered in this way and that a three-dimensional vector loop can be constructed around a hypothetical electrical centre of the heart. At any instant the summation of electrical activity of the heart may be represented by a vector. The spatial vector loop or vectorcardiogram is traced out by the free ends of a continuous succession of these instantaneous vectors drawn from a common origin. This loop indicates from moment to moment the orientation and magnitude of the mean cardiac vectors. In the normal cardiac cycle there are three vector loops, the P loop representing atrial depolarization, the QRS loop representing ventricular depolarization, and the T loop representing repolarization.

In practice a three-dimensional loop cannot be recorded directly and is usually analysed by means of its two-dimensional projections on suitable planes of the body such as the frontal, horizontal, and sagittal. Ordinary scalar electrocardiographic leads lying in these planes, when given vector direction, can be regarded as linear projections of the respective planar loops and vector loops can be constructed from suitably chosen leads.

All vectorcardiograms are, in fact, derived from scalar electrocardiograms and as the vectorcardiogram is a spatial representation of the cardiac electrical field, it is necessary to select three leads representing X, Y, and Z co-ordinates. Pairs of these leads, XY, YZ, and ZX, define the planar vectorcardiograms which are projections of the spatial vectorcardiogram.

Einthoven introduced the string galvanometer for the study and measurement of the electrical currents generated by the heart muscle, and thus helped to lay the foundations of electrocardiography. His concept of the equilateral triangle and the measurement of the resultant manifest vector in the frontal plane was based on physical and mathematical principles, which formed a basis for vectorcardiography. His work on this subject was limited by the lack of a suitable recording instrument.

In 1920, Mann constructed a monocardiogram, based on the principles of Einthoven's equilateral triangle, by using photographic enlargements of the standard limb leads. These enlargements were measured at intervals of 0·01 sec. and the measurements of the voltages were so arranged that at any moment the voltage of lead II equalled the algebraic sum of leads I and III. By plotting these points at 0·01 sec. intervals, and joining them up he obtained a curve or loop which he called the monocardiogram. This was a laborious procedure and in 1938 he devised the monocardiograph for constructing the loop instrumentally. This instrument consisted of four parts.

* Present address—Western Infirmary, Glasgow.

1. An amplifier, which amplified the currents obtained from the surface of the body.
2. A galvanometer, which responded simultaneously to these currents, corresponding to the three leads of the electrocardiogram.
3. An optical system, which magnified the deflection of the galvanometer.
4. A camera.

The introduction of oscilloscopic recording was the next great advance in vectorcardiography. By this means it was possible to take two leads in one plane acting vectorially at right angles to each other and to apply them to the X and Y plates of a cathode ray oscilloscope. The spot then traced the loop, being activated by both transverse and vertical lead voltages. Several workers, apparently unaware of each others work, used the cathode ray oscilloscope for recording the vectorcardiogram. (Schellong, 1939; Wilson and Johnston, 1938; and Hollmann and Hollmann, 1939.)

Since then, several groups in Europe, Duchosal and Sulzer (1949), Rochet and Vaastesaeger (1944), Donzelot *et al.* (1950), Jouve *et al.* (1950), and Burger and van Milaan (1946, 1947, 1948), and in America, Burch *et al.* (1953), Grishman and Scherlis (1952), Milnor *et al.* (1953), and Frank and Schmitt, have employed instruments of their own design. The variations in instruments are wide and relate mainly to attempts to study the particular aspects of the problems of vectorcardiography in which each group is interested. Some instruments are also unduly restricted in the choice of component leads and polarity.

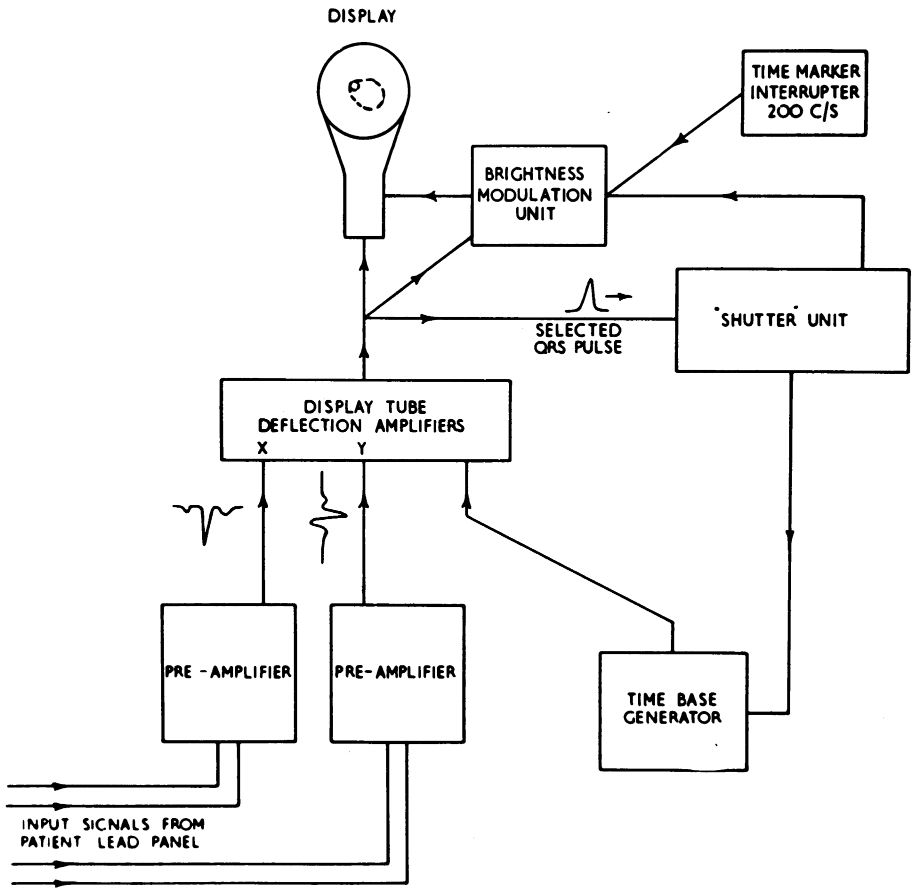

FIG. 1.—Diagram showing main features of vectorcardiograph. For further details see text.

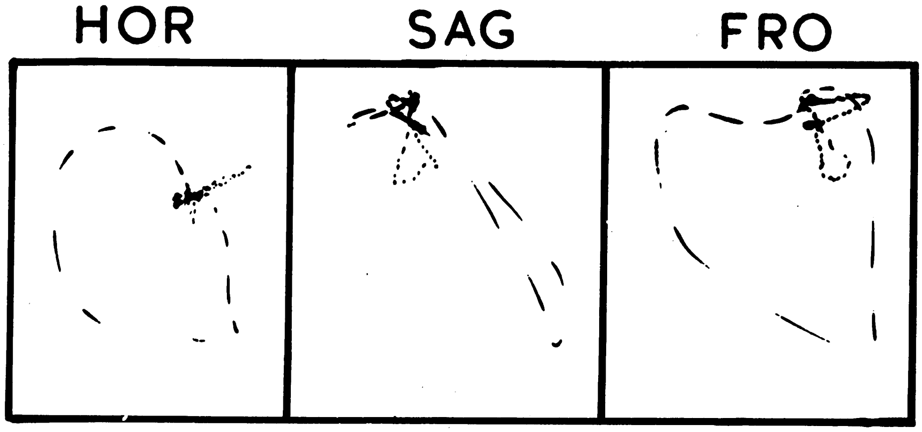

FIG. 2.—Vectorcardiograms from a case of mitral stenosis to illustrate time-marking at 200 cycles per second and direction of rotation of QRS loop (see text). P loops, due to atrial hypertrophy, are well seen in the sagittal and frontal projections. The magnification was 1½ times standard.

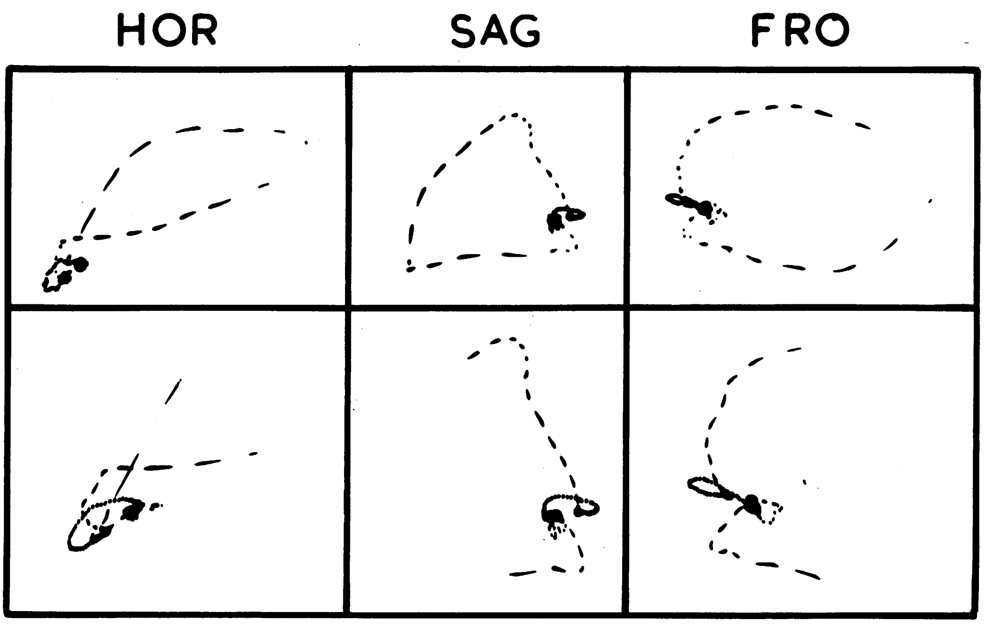

FIG. 3.—Vectorcardiograms from a case of anteroseptal myocardial infarction. The top row is at a magnification of twice standard, the bottom row of thrice standard, to show details of the isoelectric point and P and T loops. HOR=horizontal, SAG=sagittal, FRO=frontal. All vectorcardiograms were taken by the cube system (Grishman and Scherlis).

Good photographic records have been hard to obtain because of central halation obscuring the initial and terminal parts of the loop and the difficulty in having satisfactory control of the photographic exposures, especially with rapid heart rates.

With these and other problems in mind, it was decided to design an instrument primarily for vectorcardiographic research. It was thought that simultaneous recording of at least two vector loops was desirable. Lead connections, switching and polarity arrangements were made as versatile as possible. A combination of visual and automatic recording was devised, together with time-marking and direction-marking of loops. We should like to present certain details of the instrument that we have designed, in co-operation with the Cambridge Instrument Company, Ltd.

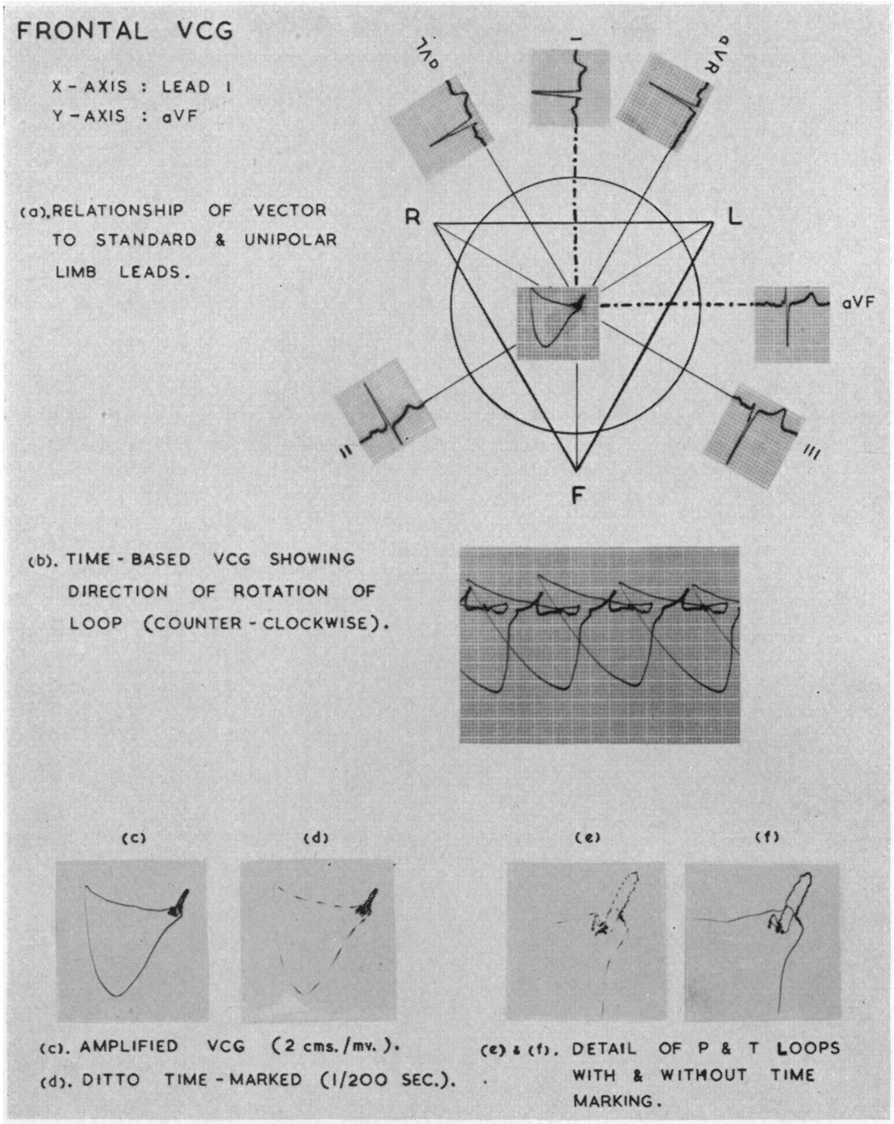

FIG. 4.—Vectorcardiograms from a case of hypertensive heart disease, taken by the unipolar system of Donzelot *et al.* (1950) with electronegative convention.

The basic features of the machine are shown in Fig. 1. Cardiac electromotive forces from the patient (scalar components or leads) are fed into three pre-amplifiers. These are of the balanced type with step amplification and a maximum gain sufficient to give 10 cm. per millivolt on the display tube. Correction factors can thus be applied to any scalar component of the vectorcardiogram as desired. The appropriate signals are then passed into the amplifiers of two cathode ray oscilloscopes and applied to the X and Y plates of the tubes. Suitable combinations of two of the three signals produce the frontal, horizontal, or sagittal loops and any two of these may be viewed simultaneously. Alternatively, one vector loop and one scalar component can be displayed.

A time base deflection can be superimposed on the display tube. In this way the vector loop can be made to move across the screen during its generation. This is often useful in the analysis of the

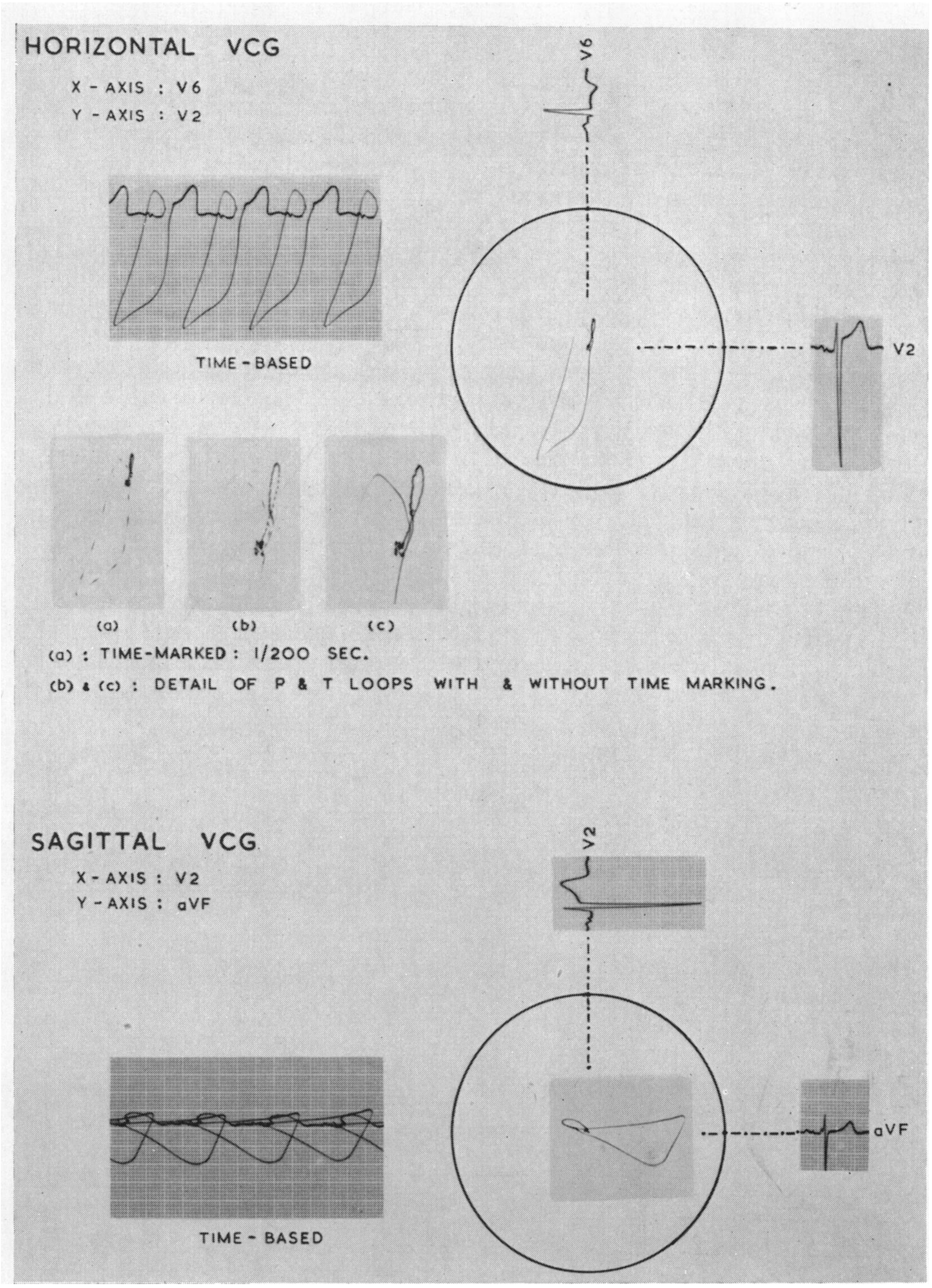

FIG. 5.—Vectorcardiograms from a case of hypertensive heart disease, taken by the unipolar system of Donzelot *et al.* (1950) with electronegative convention.

initial and terminal portions of the loop which tend to be obscured in the central halo. It is also helpful in determining the direction of rotation of the loop. A scalar signal along with the time base provides a display of the scalar electrocardiogram.

A directional time marker can be introduced to break the trace at intervals of 50 or 200 cycles per second. The vector loop then appears as a series of dashes. Each dash has a thin tail and a thick head, the movement of the spot being from tail to head. This device gives a time scale and also indicates precisely the direction of rotation of the loop (Fig. 2 and 3).

A camera is incorporated in the instrument and the loops can be photographed under visual control with or without the aid of a triggering mechanism. The records are taken on 60 millimetre photographic paper or film. In addition to single frame records of the loops, it is also possible to take continuous records on moving film (Fig. 4 and 5).

The technical difficulties of photographic recording have been largely overcome by two electronic circuits, one for brightness modulation and the other for automatic triggering. The brightness modulator causes the trace to be brightened when the spot is moving rapidly and dimmed when it is moving slowly or is static. This largely eliminates central halation and ensures that both the rapid QRS loop and the slower T loop are equally clearly defined. The triggering device causes the trace to be visible for one complete cardiac cycle and to be extinguished for the succeeding two cycles. The duration of the visible tracing is shown by a pilot light on the control panel. Thus, the operator can easily work the mechanical shutter of the camera during the off period. During photography the loop can be seen through an observation panel on the front of the instrument.

The lead connections have been made versatile. Any desired combination of unipolar or bipolar leads can be applied to the pre-amplifiers and polarity can also be adjusted to suit the required convention. The choice of reference frames is, therefore, completely optional.

The instrument is mounted on casters, and may be wheeled to the bedside.

Summary

A brief account of the theory of vectorcardiography and methods of recording vectorcardiograms is given.

A new vectorcardiograph is described. Illustrative tracings are shown.

We should like to thank Dr. M. C. Marsh, Mr. H. Beck, and Mr. G. P. Naylor, of the Cambridge Instrument Company, Ltd., for their co-operation in the design and construction of this instrument.

References

Burch, G. E., Abildskov, J. A., and Cronvich, J. A. (1953). *Spatial Vectorcardiography.* Henry Kimpton, London.
Burger, H. C., and van Milaan, J. B. (1946). *Brit. Heart J.*, **8**, 157.
——, —— (1947). *Brit. Heart J.*, **9**, 154.
——, —— (1948). *Brit. Heart J.*, **10**, 229.
Donzelot, E., Milovanovich, J. B., and Kaufmann, H. (1950). *Etudes Pratiques de Vectographie.* Paris.
Duchosal, P. W., and Sulzer, R. (1949). *La Vectocardiographie.* Karger, Basle.
Frank, E. Personal communication.
Grishman, A., and Scherlis, L. (1952). *Spatial Vectorcardiography.* Saunders, Philadelphia.
Hollmann, H. E., and Hollmann, W. (1939). *Z. klin. Med.*, **134**, 732.
Jouve, A., Buisson, P., Albouy, A., Velasque, P., and Bergier, G. (1950). *La Vectocardiographie en Clinique.* Masson, Paris.
Mann, H. (1920). *Arch. intern. Med.*, **25**, 283.
—— (1938). *Amer. Heart J.*, **15**, 681.
Milnor, W. R., Talbot, S. A., and Newman, E. V. (1953). *Circulation*, **7**, 545.
Rochet, J., and Vastesaeger, M. M. (1944). *C. R. Soc. Biol.* Paris, **138**, 992.
Schellong, F. (1939). *Grundzüge einer klinischen Vektorkardiographie des Herzens.* Springer, Berlin.
Schmitt, O. Personal communication.
Wilson, F. N., and Johnston, F. D. (1938). *Amer. Heart J.*, **16**, 14.