Mechanical Inscription of the Vectorcardiogram

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A modification of the vectorcardiographic method of studying electrical events is presented. Simultaneous scalar leads, taken by any vector lead system, are first recorded. The important time intervals, difficult or impossible to read from the loop itself, are measured from these tracings. Proper pairs of the scalar leads can then be rapidly integrated into vector loops by an easily constructed drawing board based on the pulley system. This instrument is described in detail. It is demonstrated that loops so derived do not appear to differ in their important characteristics from electronically integrated loops.

The CLINICAL usefulness of the vectorcardiogram is most obviously limited by its inability to record satisfactorily temporal relationships such as P-R and Q-T intervals, heart rate, and types of irregularity. Practical considerations, such as a heavy investment in expensive electronic equipment, processing time, and the need of trained personnel also restrict its use. It is believed that the method to be described will adequately answer these objections until the higher frequency deflections, not recordable on direct-writing apparatus or in mechanically inscribed loops are proven to be of diagnostic importance.

The first requirement is a two-channel recording electrocardiograph with a paper speed of at least 50 mm. per second. The scalar electrocardiograms so recorded may be used for determining the important time relationships referred to above. The choice of a vectorcardiographic lead system may be left to the discretion or bias of the investigator. All such systems currently in vogue have electrodes so placed that the scalar components in any plane allegedly recorded along axes at right angles to each other. The magnetic plates which deflect the beam of electrons in the cathode ray tube are, therefore, at right angles. This same geometric principle has been utilized in designing a drawing board by means of which a vector loop can be derived from a pair of simultaneously recorded electrocardiograms. A writing point is deflected by two chains, pulling it along two axes at right angles. Each chain is attached through a pulley system to a pointer which traces the scalar electrocardiograms.

Description of Apparatus

Figure 1 illustrates the complete device. The choice of materials is to some extent arbitrary. The baseboard of our model is of $\frac{5}{8}$ inch plywood. A 12 inch square plate of $\frac{1}{8}$ inch plexiglass is screwed to this as a drawing board since the soft plywood is otherwise pitted by constant pecking with a sharp pencil point. The 1 inch square blocks (1-7, fig. 1) on which the pulleys are mounted were cut from brass square stock. The pulleys were machined from $\frac{3}{4}$ inch brass round stock and are set on washers so as to turn freely. The beaded chain* connecting the pencil holder (S) and tracing arms (W) is $\frac{3}{16}$ inch and moves easily in the pulleys. Both chains are 36 inches long and have an adjustable coupling attaching a 9 inch length of No. 000 Brass safety chain, whose links will fit the eye hooks on the stylus. This arrangement permits varying the effective length of the bead chain as necessary simply by catching the adjustable couple at any point.

The pencil holder or guide (S) is a 1$\frac{1}{2}$ inch length of plexiglass round stock bored to fit loosely the size pencil to be used. A 2$\frac{1}{2}$ by 2$\frac{1}{2}$ inch plate of $\frac{1}{16}$ inch plexiglass is cemented

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to the bottom of the stylus to give it stability, and a small hole, large enough to admit a pencil point, is bored in its center. Two 1/4 inch eye screws are screwed into the stylus at right angles to which the link chain is hooked. A third eye screw bisects the remaining angle on the stylus, and a heavy rubber band keeps the chains taut by stretching between the third eye screw and pulley block 2. The band can be attached to the same screw that anchors the bead chain.

The scanning table (T) to which the electrocardiograms are fastened with Scotch tape, is supported by blocks 8 and 9, 13\(\frac{3}{8}\) inches long, and cut from 1 inch square brass stock. The table itself is 5\(\frac{1}{2}\) by 3 inches and of 1/8 inch plexiglass, and is screwed to each brass block by two flat-head screws. This carriage is guided by a track made of two 1/2 inch aluminum angles 4 inches long. Block 10 is stationary and is bored to fit a 1/2 inch brass rod (A) threaded 13 threads to the inch. Half inch round brass collars lock this rod to blocks 9 and 8 so that turning the attached plastic handle moves the entire carriage along the track.

The pointers (W) are of 1/16 inch plexiglass 3\(\frac{3}{8}\) by 3\(\frac{3}{8}\) inches. A tiny hole is made about 3\(\frac{3}{16}\) inch from the end and filled with India ink, and these dots are used for precise alignment of the arm with the electrocardiogram.
under it. The pointers are screwed to a \( \frac{3}{8} \) inch plastic plate which is screwed to blocks 1 and 7 (left inset, fig. 1). Blocks 2 and 6 are fixed to the baseboard and act as a bearing for the screws B which, when turned, move the pointers at right angles to the edge of the scanning table. The ends of the bead chain are anchored in blocks 2 and 6 by screws and a coupling ring. The chains are looped around one or two pair of pulleys, depending upon whether one wishes the motion of the pointers to be amplified two or four times at the pencil guide (left inset, fig. 1). The blocks 1 and 7 to which the pointers are attached run in tracks of the same \( \frac{3}{8} \) inch aluminum angles. Plastic handles are attached to the shaft of the screws B with a No. 10 set screw. The traversing nuts (blocks 1 and 7) must be closely fitted to the guide rails throughout this length to avoid play. These two rails must be carefully aligned with each other and at right angles to the direction of travel of the scanning table. Cost of materials does not exceed $12.00 and mechanical skill required for construction is minimal. For these reasons, it is preferred to the device described by Shillingford and Brigden\(^1\) for the same purpose but which requires a light source and optical system.

**Use of Apparatus**

One cycle of a two-lead electrocardiogram is clipped out and attached to the scanning table with Scotch tape. A piece of paper on which the loop is to be drawn is aligned with the edge of the plexiglass drawing board and fastened in place with Scotch tape. The length of the two chains is adjusted so that they impinge on the pencil guide at right angles and are held taut by the pull of the rubber band. The last vertical time line on the electrocardiographic record which crosses both simultaneously recorded tracings before ventricular electrical activity has begun is moved under the two dots on the pointers by moving the scanning table. Each pointer is then moved so that the black dots overlie the exact spot where the tracings cross the time line. A pencil mark is made through the hole in the pencil guide to mark the zero point of the QRS loop. The scanning table is then moved until the black dots touch the next time line. The pointers are adjusted as before and the first movement of the loop indicated by a second pencil mark. At equal time intervals the process is repeated until both electrocardiograms have returned to the baseline and the QRS loop is completed. The setting of the pointers must always be made by moving them in from the

![Diagram of electrocardiogram](http://circ.ahajournals.org/)

**Fig. 2.** The interruptions of the electronic loops occur every 0.004 second, and the direction of rotation is indicated by the sharp end of the light streaks. The dots in the mechanical QRS loops are at .01 second intervals and the T loop is indicated by a beaded line. The pairs to be examined are adjusted to the same approximate size to facilitate comparison. P loop is omitted on mechanical tracings. The orientation of all loops in the same plane is similar: (1) Frontal: the patient's left is on the reader's right. (2) Transverse: anterior chest is towards bottom of illustration and patient's left is on the reader's right. (3) Sagittal: anterior chest is on the reader's right.
same direction to avoid lag as the pencil guide changes direction. The procedure is then continued until the T loop is also completed. We have found a paper speed of 50 mm. per second with readings on and half way between the vertical time lines (.01 second intervals) adequate speed to record the characteristic shape, clinically important vectors, and direction of rotation of the majority of loops. Finally, a vertical and horizontal axis is drawn through the zero point to establish a reference system and the successive points numbered and connected with straight lines. The average time required, after some practice, is about seven minutes per loop.

Figure 2 demonstrates a comparison between six loops electronically recorded (kindly supplied by Dr. William F. Milnor of Johns Hopkins University) and their counterparts mechanically derived by the method just described. The same scalar leads were used for both electronic and mechanical integrations. In every case it is seen that the direction of rotation, general shape, and orientation of the loops are about as close as any successively recorded vectorcardiogram cycles.

LIMITATIONS OF THE METHOD

Since only one-fourth as many points are recorded in the above mechanically derived loops, slight, brief changes in direction and magnitude are not reproduced. The significance of these changes, however, is still unknown.2

Since each component of each vector is recorded, not as a straight line, but as an arc on the circumference of a wide circle with blocks 4 and 5 their center and their radius the length of chain between these blocks and the stylus, each vector direction is slightly distorted and its magnitude shortened. The larger the component, the greater amount of the circle it will involve and consequently the greater the inaccuracy. On the other hand, errors on the two arcs are opposite in direction and tend to cancel each other. Figure 2 confirms that this is not a serious defect.

If vectors of no shorter duration than .01 second are traced, the peak of a tracing may occasionally be bracketed by the arbitrarily chosen points and the maximum extent of the loop not drawn. This is easily recognized during transcription, however, and the missing peak may be included in the loop with an approximate timing of the event.

In practice, different colors are used for the zero point, for the QRS, and for the ST-T loops, and the points are lightly numbered as they are written to avoid confusion.

Some care must also be exercised in selecting complexes to be used. The one chosen should not include a shifting baseline, and the initial vectors from two complexes from the same patient will not be reproducible unless the take-off of the QRS always bears the same temporal relationship to the last time line while the electrocardiogram is still isopotential.

Actually the mechanical loops present one advantage over some electronically integrated photographed loops in that the P, QRS, and T loops can be artificially separated so that superimposition of the three, which sometimes makes it difficult to read the initial and terminal QRS forces, is eliminated. Experience has shown that students seem to grasp the significance of the vector loop more quickly when the integrative process can be visualized.

SUMMARY

A simple, inexpensive, easily built mechanical device for integrating two simultaneously recorded electrocardiograms into a vector loop is described. It is demonstrated that the loops so derived bear a close relationship in their important features to those electronically written and photographically recorded.

SUMARIO ESPAÑOL

Una modificación del método vectorcardiográfico de estudiar los acontecimientos eléctricos se presenta. Derivaciones escalares simultáneas, tomadas por cualquier sistema de derivaciones vectoriales, son por primera vez registradas. Los intervalos de tiempo importantes, difíciles o imposibles de leer de la misma onda, se miden en estos trazados. Pares propios de derivaciones escalares pueden ser rápidamente integrados a ondas vectores por
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medio de una tabla de dibujo fácilmente construida y basada en un sistema de poleas. Este instrumento se describe en detalle. Se demuestra que ondas obtenidas de esta manera no aparecen diferir en sus características importantes de ondas electronicamente integradas.

REFERENCES
