**U Vector Loop in Patients with Right Ventricular Hypertrophy, Right Bundle Branch Block, and Myocardial Infarction**

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U vector loops were obtained by electrical dissection from 53 patients, composed of 11 cases of right ventricular hypertrophy, 21 cases of right bundle branch block and 21 cases of myocardial infarction. The U loop of right ventricular hypertrophy and right bundle branch block resembled that of normal subjects. It had a shape like a small, slightly curved club and was inscribed in the direction of continuance of the terminal limb of the T loop. The U loop of myocardial infarction was frequently larger than normal U loops and began with a marked bend at the T-U junction and extended in various directions. It resembled that of left ventricular hypertrophy, but the U loop abnormality in myocardial infarction was usually more marked than in left ventricular hypertrophy. It was suggested that the U vector was directed toward the location of myocardial infarcts. But because of technical difficulty this could not be confirmed.

Since our previous study1) on U vector loop in normal subjects and in those with left ventricular hypertrophy, U vector loop was further studied in patients with right ventricular hypertrophy, right bundle branch block and myocardial infarction.

This part of the vector loop could only be studied by the method of differential vectorcardiography,2) because the U vector loop is very small and merges with the ST-T and P loops and the initial and terminal portions of the QRS loop.

**Materials and Methods**

U loop vectorcardiograms obtained from 53 patients were selected for this study. Vectorcardiograms were taken in all cases with the leads proposed by Frank.3) Employing our dissecting apparatus,2) the T-U vector loop (the part of the vector

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loop from the beginning of the T loop to the end of the U loop) and the U loop were dissected at higher magnification in addition to recording the usual whole vector loop. Simply taking pictures was not sufficient to reveal the direction of inscription of the U loop, and careful observation of the dissected U loop or T-U loop on the cathode-ray oscilloscope was usually necessary. Other details on the technique of taking vectorcardiograms were reported elsewhere.1

The U loop vectorcardiograms were selected to study 3 pathological conditions: the subjects were composed of 11 cases of right ventricular hypertrophy, 21 cases of right bundle branch block and 21 cases of myocardial infarction. They were diagnosed by the electrocardiogram and vectorcardiogram together by clinical findings and results of other clinical examinations. Cases of right ventricular hypertrophy and right bundle branch block were found among patients who had been hospitalized because of congenital heart diseases, various digestive diseases, hypertension, tuberculosis, diabetes, etc. The age of the patients of right ventricular hypertrophy ranged from 24 to 78. The causes of right ventricular hypertrophy in these patients were congenital heart diseases, respiratory diseases, etc. Complete right bundle branch block was found in 17 cases from 48 to 82 years of age and its cause was considered to be arteriosclerotic in most cases. Incomplete right bundle branch block was found in 4 cases from 26 to 66 years of age. Its cause was considered to be arteriosclerotic in some cases and a normal variant in other cases. The differentiation between right ventricular hypertrophy and right bundle branch block was made by conventional electrocardiographic and vectorcardiographic criteria, aided by chest roentgenogram and other clinical findings. During the course of this study more precise differentiation between these 2 conditions was not felt necessary, because both of them showed similar findings, as far as the U vector loop was concerned. Therefore, special examination such as cardiac catheterization to know the intraventricular pressure of the right ventricle was not attempted for differentiation.

Among cases of myocardial infarction, anterior infarcts were found in 7 cases, anteroseptal infarcts in 3 cases, anterolateral infarcts in 3 cases, a lateral infarct in 1 case, posterolateral infarcts in 3 cases, and posterior infarcts in 4 cases. Most of them were old infarcts, and a few were relatively recent, but very fresh infarcts were not included.

**Results**

The U vector loops from patients were frequently larger than those from normal subjects, but they were mostly still difficult to be recognized without the dissection technique. Generally, after the T loop was inscribed, the beam-spot appeared to stay for a moment at the T-U junction; then the U loop was inscribed much more slowly than the T loop.

*Right ventricular hypertrophy and right bundle branch block*

U loops from the patients with right ventricular hypertrophy and complete or incomplete right bundle branch block were similar and resembled those from normal subjects (Figs. 1, 3, 5 and 6). Namely, they had a shape like a small,
Fig. 1. Diagrams of the T-U vector loops in all the studied cases of right ventricular hypertrophy, of right bundle branch block and of myocardial infarction. Short solid lines with arrows on their tips show the U vector loops, and broken lines the T vector loops. Arrows indicate direction of inscription. S, F, and H denote left sagittal, frontal and horizontal planes.

slightly curved club and were inscribed almost in the direction of continuance of the terminal limb of the T loop. Slight bending occurred, especially in the sagittal plane, at the T-U junction, differentiating the U loop from the T loop.

Fig. 2. Distribution of the T-U junction vectors of cases of right ventricular hypertrophy (A), of right bundle branch block (B) and of myocardial infarction (C).

The T-U junction vectors with the T vector discordant to QRS vector are indicated by open circles while others are indicated by closed circles (Cf. Fig. 3 of reference 1). A transverse bar at the left lower corner of the figure indicates the magnitude of 0.1 mv. S, F, and H denote left sagittal, frontal, and horizontal planes.

When the end of the U loop is considered as the null point of the whole vector loop, the T-U junction vector, namely, the vector from the null point to the junction between the T loop and the U loop, was directed in most cases
to the left, inferiorly, and mostly anteriorly, as in the normal U loop. The vector of most cases was distributed in the quadrants from 0 to +90 degrees in the frontal and horizontal planes and from +90 to ±180 degrees in the left sagittal plane (Fig. 2A).

In such a U loop configuration it was presumed that the direction of the U vector, i.e., the vector from the null point to the point corresponding to the peak of the U wave, was almost the same as the T-U junction vector according to the reason stated in the previous report on the normal U loop.\textsuperscript{1)}

Compared with the U loop of the normal subjects in more detail, the U vector (or T-U junction vector) of right ventricular hypertrophy seemed to have a slightly rightward direction occasionally (cases 1, 4, 7 and 8 in Fig. 1, Fig. 4). In such cases a slight bending from the terminal limb of the T loop occurred frequently at the T-U junction. In other cases a slight bending occurred also because the U vector kept the normal direction, while the T loop was directed slightly posteriorly (cases 9 and 11 in Fig. 1). All of these changes were not conspicuous, giving an impression of similarity with the normal U loop.

Occasionally the U loop of right bundle branch block showed a finding...
Fig. 4. Another example of the T-U loop of right ventricular hypertrophy. Figure arrangements and abbreviations are the same as in Fig. 3.

Fig. 5. An example of the T-U loop of right bundle branch block. Figure arrangements and abbreviations are the same as in Fig. 3.
which formed a definite exception to the above statement. In such cases the direction of the U vector (T-U junction vector) was out of the above-mentioned range and a more or less conspicuous bending occurred at the T-U junction (cases 21, 23, 24 and 31 in Fig. 1). Mostly the T loop showed also some of the abnormal features. Occasionally a bending occurred at the T-U junction because the T loop was inscribed in an abnormal direction, while the U loop still kept its normal features in direction and configuration (cases 13, 27 and 29 in Fig. 1).

Myocardial infarction

In contrast to the U loop of right ventricular hypertrophy and right bundle branch block, the U loop from patients with myocardial infarction showed definite abnormalities (Figs. 1, 8, 9 and 10). The U loop began usually with a marked bend at the T-U junction and extended in various directions. Frequently a small circus-like turning occurred at the beginning, i.e., close to the T-U junction. In many cases the U loop still resembled a small curved club, but usually it was much larger than the normal U loop. Occasionally the U loop itself showed a definite bending as in case 45 of Fig. 1. In such cases the U vector and the T-U junction vector were definitely different. However, such cases were not many, and in most cases the exact point of the tip of the U loop was not clearly defined because of its arc-like shape.
Fig. 7. The relation between the U vector and the site of myocardial infarcts. The site of infarcts was determined by the findings of electrocardiograms and vectorcardiograms. Note that the U vector directs oppositely to the Q vector rather than to the T vector in most of the cases.

Fig. 8. An example of the T-U loop of myocardial infarction. A case of a strictly anterior myocardial infarct. Figure arrangements and abbreviations are the same as in Fig. 3. Note the U vector is directed anteriorly.
Fig. 9. Another example of the T-U loop of myocardial infarction. A case of an extensive anterior infarct.
Figure arrangements and abbreviations are the same as in Fig. 3. Note the U vector is directed anteriorly.

Fig. 10. Another example of the T-U loop of myocardial infarction. A case of inferior and anterolateral infarcts.
Figure arrangements and abbreviations are the same as in Fig. 3. Note the U vector is directed inferiorly and anteriorly to the left.
Eventually it could be defined rather arbitrarily, but the U vector determined by this way did not differ too much from the T-U junction vector in direction in most cases. Therefore, the direction of the T-U junction vector is shown in Fig. 2 instead of that of the U vector.

Such features of the U loop of myocardial infarction resembled those of left ventricular hypertrophy. Actually we could not differentiate myocardial infarction from marked left ventricular hypertrophy by the U loop alone. However, generally abnormal features of the U loop were more marked in myocardial infarction and none of our cases of myocardial infarction showed a completely normal U loop, while in left ventricular hypertrophy the U loop itself kept normal features in a fair number of cases, although few retained normal features if the whole T-U loop was considered. In Fig. 2C the T-U junction vector shows normal direction in some projections of some cases of myocardial infarction, but rather accidentally. This could be guessed by the fact that such cases were mostly indicated by the open circle in this figure, which meant that the T vector was discordant to the QRS vector. Actually none of these cases showed a normal direction of the T-U junction vector in all of the 3 projections.

Grouping by the location of myocardial infarcts determined by the vectorcardiogram and electrocardiogram, it was found that in many cases the U vector was directed toward the location of myocardial infarcts (Figs. 7, 8, 9, and 10). Furthermore, the direction of the U vector was opposite to the Q vector rather than to the T vector in most of them. However, there were too many exceptions to allow it as a general statement.

**Discussion**

The finding that the U vector tended to point toward the location of myocardial infarcts is interesting. Furthermore, a tendency that the direction of the U vector was found to be related more to the Q vector than to the T vector might mean that the U vector has a relation with myocardial destruction, reversible or irreversible. However, since the U loop is minute, the measurement of the T-U junction vector or of the U vector could not be very exact. Therefore, we cannot attach a deep significance in these findings alone especially since there were several exceptions. But several previous authors proposed that the electrocardiographic U wave abnormality was related to organic changes in the myocardium. For instance, Palmer had this opinion by finding U wave inversion in patients with hypertension, with coronary sclerosis, and with certain valvular changes. We can at least say that our findings are consistent with such a proposal.
A similar impression was given in our previous study on the U loop of left ventricular hypertrophy. Hypertension has been emphasized by several authors as another factor inducing U loop or U wave abnormalities. Georgopoulos and associates found a direct correlation between arterial pressure levels and negativity of U waves in electrocardiograms of hypertensive patients. In the previous study of ours it was also found that even in the initial stage of left ventricular hypertrophy, the U loop showed abnormality. And the more marked the left ventricular hypertrophy, the more abnormality tended to be found in the U loop. However, differently from Georgopoulos and associates, we cannot think that this factor is the only one. No certain relationship could be found between the level of systemic blood pressure and the direction of the U vector or any other features of the U loop in the previous study. Rather the U vector pointed in various directions. It was felt more likely that marked left ventricular hypertrophy caused more myocardial change such as myocardial fibrosis in various parts of the heart, which oriented the U vector in various directions. It must be presumed then that widely distributed myocardial change, even if composed of small patches, induces the U vector abnormality. In our present study on myocardial infarction the cause of the U loop abnormality could not be attributed to hypertension, because none of our cases of infarction showed marked hypertension at the time of vectorcardiographic study. Slight hypertension was found in 2 cases. Presumably there are at least 2 factors to induce U loop or U wave abnormality and in each actual case of myocardial infarction or of left ventricular hypertrophy these 2 factors played their roles in various intensity and combination so that a simple relationship could not be found.

There seemed to be a slight rightward tendency of the T-U junction vector of right ventricular hypertrophy. For the above-mentioned reason we probably cannot attach a deep significance in it again.

The factor of myocardial change may be the reason that the patients with right bundle branch block more often showed exception in the direction of the U vector than normal subjects and the patients with right ventricular hypertrophy, when all of them were considered to show principally the same direction of the U vector. Most of our patients with right bundle branch block were elderly and the right bundle branch block could be considered to be caused by coronary sclerosis. Therefore, it was reasonable to presume that in some of these patients the myocardial change was so marked as to induce the abnormal direction of the U vector.
SUMMARY

(1) U-loop vectorcardiograms were obtained from 53 patients by the method of differential vectorcardiography. The subjects were composed of 11 cases of right ventricular hypertrophy, 21 cases of right bundle branch block and 21 cases of myocardial infarction.

(2) The U loop of right ventricular hypertrophy and of complete or incomplete right bundle branch block resembled that of normal subjects. Namely, it had a shape like a small, slightly curved club and was inscribed in the direction of continuance of the terminal limb of the T loop. A few cases of right bundle branch block showed a definite exception to this statement.

(3) The U loop of myocardial infarction began with a marked bend at the T-U junction and extended in various directions. It resembled also a small curved club, but was sometimes much larger than normal U loops. Namely, it resembled that of left ventricular hypertrophy. But the U loop abnormality in myocardial infarction was usually more marked than in left ventricular hypertrophy.

(4) In reviewing the U loop abnormality in ventricular hypertrophy, bundle branch block and myocardial infarction at least 2 factors could be thought of to cause the U loop abnormality: hypertension and organic changes in the myocardium.

REFERENCES