The Morphology of the ST-T Loop in Healed Myocardial Infarction*

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Abnormalities of the Terminal (ST-T) ventricular deflections have been properly analyzed in clinical electrocardiography, but less emphasis has been placed on the vectorcardiographic appearance of ventricular repolarization. According to Massie and Walsh,¹ narrow, elongated T loops have been found in acute myocardial infarction by some investigators, while others¹ have encountered small round T loops in chronic myocardial infarction. This is in keeping with the findings of Kaufman,² and Donzelot and Milanovich.³ Chu et al.⁴ have stressed that abnormal circular loops indicative of myocardial disease can be present even in the absence of characteristic electrocardiographic abnormalities. Although the importance of certain parameters such as rotation, QRS-T angle, magnitude, and length-to-width ratio has been stressed,⁵ it is interesting to note that the fine morphology of the repolarization process in myocardial infarction has not been thoroughly studied. In view of this fact, it was considered of interest to describe the vectorcardiographic characteristics of the highly magnified ST-T loop in healed myocardial necrosis.

Material and Methods

Spatial vectorcardiograms were recorded in 38 patients who had clinical, enzymatic and electrocardiographic evidence of myocardial infarction. The loops were obtained three months to five years after the acute episode. Sixteen patients had had more than one infarction. None of them had been taking digitalis, quinidine or diuretics for at least ten days. The cardiac rate at the time of recordings ranged from 65 to 100 per minute. The electrocardiograms were still abnormal at this time; this was considered a prerequisite.

The loops were obtained with the Frank system of electrode placement.¶ The horizontal leads were placed at the level of the fifth intercostal space. The right sagittal plane was employed. The T loops were amplified to more or less 1 mv=5 or 10 inches. Vectorcardiograms were projected on a large screen and all measurements performed on it. The vectorcardiographic diagnosis of myocardial infarction was made taking into consideration the changes in the QRS loop described by Hugenholtz et al.⁵

For this presentation, only the following parameters of the T loop were analyzed: 1) orientation; 2) rotation; 3) morphology, expressed by the ratio between the

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maximal length-width; 4) morphology expressed by the existence of abnormal delayed segments.

A T loop was considered normal if its orientation ranged from $355^\circ$ to $82^\circ$ in the horizontal plane; $20^\circ$ to $68^\circ$ in the frontal plane and $8^\circ$ to $90^\circ$ in the right sagittal plane (Fig. 1). For the purpose of this presentation, the normal T loop had to show counterclockwise rotation in the horizontal plane and clockwise in the right sagittal plane (Fig. 1). We are well aware, however, that rarely a reversed rotation can be seen in a few normal subjects with minor degrees of right bundle branch block. However, both QRS and T loops were required to have the same rotation in the horizontal and sagittal planes. The length-to-width ratio, calculated between the largest maximal T vector among the three planes, and the largest maximal width of the T loop in the three planes was considered to be abnormal if it was 2.6 or less.

The efferent loop of the normal T loop was always inscribed at a slower speed than the afferent limb. It is not infrequent to observe an initial area of delay, followed by a slight increase in speed, which in turn is followed by decreased velocity of inscription toward the apex of the loop (Fig. 1). Finally, the terminal half was inscribed at a much faster speed.

**RESULTS**

The ST-T loop was normal by standard vectorcardiographic criteria in six cases. In 18 patients, the terminal ventricular deflec-
tions were abnormally oriented, but showed normal morphology (Fig. 2). QRS and T loop rotation were discordant in 14 patients (Fig. 2). In six, the speed of inscription of the T loop did not show a marked difference between the first and terminal parts (Fig. 3 and 4). In other words, the afferent limb was not inscribed at a faster speed than the initial portions. This “ischemic” loop showed two types of variations. In one, both limbs were inscribed at the same speed practically from the very beginning (Fig. 3). In others, there was a very slow inscription of the first third of the efferent portion, as in the normal cases, and the rest of the efferent as well as the afferent limbs presented a uniform rate of recovery (Fig. 4). In both types of ischemic loop, the small area of delay seen in the apex of the T loop was not prominent.

The shape of the repolarization loop expressed as the length-to-width ratio was abnormal eight times. In these cases, the ratio was extremely low (2.6 or less). The speed of inscription in these cases could be normal (Fig. 5) or could be most bizarre. In the latter cases, it was not unusual for the ST-T loop to show initial, medial and terminal uniformity of inscription with widespread area of greater velocity among them (Fig. 6).
DISCUSSION

The ST-T loop in chronic myocardial infarction can show different degrees of abnormalities, or on the contrary it can be perfectly normal. This is in keeping with the well known, but not completely understood fact that T loop changes, characteristic of myocardial ischemia, may disappear in the months following the infarction or may persist and even be replaced by secondary T loop changes.1

Abnormal orientation with abnormal rotation of the T loop can represent an altered sequence of repolarization perhaps due to the anomalous depolarization. This would thus represent one form of repolarization conduction defect.

For the purpose of this presentation we have considered that both QRS and T loops should have a similar type rotation. However, in normal hearts, the rotation of QRS and T loops is not identical. This is more evident in infants and children rather than in adults.7 It seems that in man the time sequence of repolarization is altered in such a way that there is no absolute uniformity in the relationship of depolarization and repolarization.

The spatial orientation of the QRS and T loops will not coincide exactly, so that there is a normal range of angular deviation between the corresponding maximal vectors.13 Calculations of the true spatial QRS-T angle (not planar projections) can be of help in differentiation between normal and abnormal.1 Unfortunately, this is not easy to perform unless special instruments are used. Values obtained by certain tables, as the one devised by Helm and Fowler,14 are of help only if planar projections are obtained simultaneously. This
parameter was not studied in the present communication.

In chronic myocardial infarction, the ST-T loop can show abnormal orientation with normal morphology (Fig. 2). In other occasions, the abnormal T loop can be elongated with a more or less uniform speed of inscription of both afferent and efferent limbs (Fig. 3 and 4). There are two vectorcardiographic types of ischemic ST-T loops, each one of them corresponding to a specific electrocardiographic pattern. For instance, vectorcardiographic uniform speed of inscription from the very beginning of ventricular repolarization (Fig. 3) corresponds to those T waves in which the initial limb presents a slight upward convexity and which are followed, in turn, by a sharp apex and an upward, convex, terminal portion. The apex corresponds more or less to the middle portion of repolarization. The T loop which is initially slow and only after a period of time shows uniform speed of inscription (Fig. 4) also has an electrocardiographic equivalent. These would be the T waves which occur in a moment in which the direction of repolarization is not grossly altered at a time when its progression is retarded probably at the deeped layers of the myocardium. If there is reversal in the direction of this process in some fibers of the most superficial muscle, the net result would be the inscription of a diphasic T wave, the first part of which is more prolonged than the terminal parts. The apex will thus not be placed at mid-repolarization.

The importance of the morphology of the T loop expressed as the ratio between maximal length-to-width has been stressed by several authors. Wide or circular T loops have been observed in myocardial infarction, as well as in other diverse conditions. A circular T loop was seen in 18 per cent of 500 vectorcardiograms taken from patients with presumptive heart disease. However, it should be stressed that other processes such as tachycardia and autonomic imbalance can produce similar T loops in normal adults or children.

Several mechanisms are probably implicated in the genesis of the circular ST-T loops. For instance, some cases of myocardial infarction can show marked divergence of the instantaneous T vectors resulting in a round loop. At times this is a direct consequence of a poor contribution of the necrotic area to repolarization. In other cases it is conceivable that this divergence can represent a true repolarization conduction defect.

The study of the fine morphology can be of help in differentiating the normal wide T loop frequently found in children from the one observed in chronic myocardial infarction. Whereas in the former cases the normal rate of inscription is maintained, in some cases of infarction the terminal portions can be inscribed as slow or even slower than the initial (Fig. 6). Occasionally the areas of delay are separated by zones in which there is apparently a normal rate of inscription. There is only one known condition in which the terminal portions of repolarization are inscribed at a slower speed than the initial ones. Katz and Pick have observed this unusual type of repolarization abnormality in electrocardiograms recorded in dying patients some of whom had intraventricular dissociation.

The abnormalities of the T loop are more complex and less understood than QRS changes. This is probably so because the fine morphology and rate of inscription have been insufficiently studied. Yet, it should be stressed that repolarization in general is a more complex process than depolarization. It is possible that the uncertainties and complexities are due to our poor knowledge of repolarization in general. For instance, ventricular depolarization is usually considered to start at a single area. On the contrary because the recovery process propagates very slowly, one should not look for a single area from which repolarization would spread throughout the ventricles. According to Hoffman and Cranefield it is possible that each area.
which repolarized before some adjoining zone could contribute to the repolarization of that adjoining area. Hence repolarization would be a propagated process originating in several foci.

**SUMMARY**

The morphology of the enlarged ST-T loop (1 mv=5 or 10 inches) was studied in 38 patients with chronic myocardial infarction. Spatial repolarization was normal by standard vectorcardiographic criteria in six cases. In 16, the T loop was located in an abnormal position. Fourteen of the latter cases showed divergence between QRS and T loop rotation. This could represent one form of repolarization conduction defect.

An ischemic ST-T loop characterized by a more or less uniform speed of inscription of its afferent and efferent portions was seen in six cases. Eight patients showed an abnormal, low, length-to-width ratio, resulting in a circular ST-T loop. The terminal portions of repolarization could be inscribed as slowly as the efferent loop in these cases. This specific type of abnormality could well be another type of repolarization conduction defect.

**RESUMEN**

Hemos estudiado la morfología del asa ST-T aumentada (1MV=12,5 o 25 cms.) en 38 pacientes con infarto crónico del miocardio. La repolarización espacial en 6 de estos casos parecía ser normal, dentro del criterio vectorcardiográfico estándar.

En 16 el asa ST presentaba una localización anormal. Entre estos últimos casos, 14 mostraban divergencias en la rotación de QRS y T. Esta particularidad puede ser indicio de un defecto de conducción de la repolarización.

En seis casos se observó un asa ST-T de tipo isquémico caracterizada por una velocidad de inscripción mas o menos uniforme de sus ramas ascendente y descendente. En 8 pacientes se comprobó una relación baja entre la longitud y latitud, dando lugar a una asa ST-T de forma circular. Las porciones terminales de la repolarización pudieron ser inscritas tan lentamente como el asa aferente en estos casos. Este tipo específico de anormalidad bien puede ser otra variedad de defecto de conducción de la repolarización.

**RéSUMÉ**

La morphologie d'une boucle ST-T agrandie (1 mv=12,5 ou 25 cm.) a été étudiée chez trente-huit malades ayant un infarctus myocardique ancien. Le repolarisation spatiale est normale d'après les critères vectorcardiographiques habituels dans six cas. Dans seize, la boucle T est située dans une position anormale. Quatorze des derniers cas ont montré des divergences entre la rotation des boucles QRS et T. Ceci peut représenter une forme de troubles de conduction dans la repolarisation. Une boucle ST-T ischémique caractérisée par une vitesse d'inscription plus ou moins uniforme dans ses portions afferente et efferente a été observée dans 6 cas. Huit malades ont un rapport longueur-largeur anormalement bas, ce qui donne une boucle ST-T circulaire. Les parties terminales de la repolarisation peuvent être inscrites aussi lentement que la boucle afferente dans ces cas. Ce type particulier d'anomalie peut être tout aussi bien un autre type de trouble de conduction dans la repolarisation.

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ASPERGILLOSIS SECONDARY TO PULMONARY TUBERCULOSIS

In this discussion, comments are restricted to the secondary form. Decreased local and generalized resistance appear to be contributory factors in the occurrence of the disease. Debilitating diseases, prolonged use of antibiotics and chemotherapy, use of corticosteroids and "anti-tumor" drugs and irradiation all seem to be predisposing factors. Demonstration of hyphae in sputum, growth of the organisms on culture, morphologic characteristics of the culture and microscopic examination of the cultures aid in the diagnosis. Aspergilll are ubiquitous and are frequent contaminants in clinical specimens. It has often been suggested that specimens for culture should be obtained by bronchoscopy. Eosinophils may be seen in some patients. The authors have developed a skin test in the hope that it may be an asset in the diagnosis. Results have been gratifying. The test was positive in 16 of 20 cases of proved aspergillosis in their series. There was one case in which the skin test was negative, but an aspergilloma was removed surgically. They have also had cases in whom the skin test turned negative spontaneously. The implications of these are subjects for further study. The authors are of the opinion that the reaction to the skin test is of the delayed hypersensitivity type. This hypersensitivity may be transient, unlike the reaction to the tuberculin skin test. This may explain why some persons who had positive reactions initially were later found to have negative reactions.


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