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**Electrocardiogram and Vectorcardiogram Reconstruction and its Application
to Clinical Diagnosis of Myocardial Infarctions
Complicated by Right Bundle Branch Block**

By

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INTRODUCTION

Much research has been performed on the electrocardiographic changes in right bundle branch block¹⁻¹²), and now it is well known that three different patterns of extremity lead electrocardiograms, the usual and the unusual types of Wilson block, and the rare type of bundle branch block, appear in the presence of block in the right bundle branch.

However, the reason why such varied patterns appear in right bundle branch block remains uncertain. For example, the question can be raised as to whether the rare type of bundle branch block and the unusual type of Wilson block are characteristic of an isolated block of the right bundle branch or of right bundle branch block complicated by other diseases as myocardial infarction^{13, 14}) or left posterior branch block⁸).

In general, these three patterns appear in association with the precordial lead electrocardiograms of right bundle branch block pattern. However, precordial lead electrocardiograms displaying the pattern of right bundle branch block do not necessarily appear in association with these three patterns of right bundle branch block in extremity lead electrocardiograms, but sometimes appear in association with the common type of bundle branch block when left bundle branch block is complicated by myocardial infarction of a certain location^{15, 16}).

The reason for the appearance of such an atypical instance also remains uncertain.

In a preceding article¹⁷) on left bundle branch block complicated by myocardial infarction, the reconstruction method indicated the possibility that the common type of bundle branch block may appear in association with a relatively tall R wave in right precordial leads and a deep S wave in left precordial leads, though it is not the typical pattern of complete right bundle branch block. However, is it not for such an atypical pattern of bundle branch block to appear in the presence of a block in the right bundle instead?

Since it is anticipated that the reconstruction method of Toyoshima and associates may offer data important for the settlement of these questions, reconstructions of the electrocardiograms and vectorcardiograms in isolated right bundle branch block and those in right bundle branch block complicated by left ventricular myocardial infarction were performed.

METHOD

The methods and principles of reconstruction were the same as those in the preceding reports on myocardial infarction¹⁸) and on left bundle branch block complicated by myocardial infarction¹⁷). From two different original normal patterns of the propagation process of ventricular activation, various types of the process of spread of ventricular

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activation in right bundle branch block were planned by delaying the onset of the right ventricular activation in an appropriate manner. The electrocardiograms and the vectorcardiograms were reconstructed based on these plans of the spread of ventricular activation.

In the case in which right bundle branch block was complicated by myocardial infarction, the electrocardiograms and vectorcardiograms were reconstructed by the same method as that reported in the preceding papers on myocardial infarction¹⁷⁾.

When the onset of the activation of the right ventricle is delayed in order to obtain the pattern of propagation process of ventricular activation in right bundle branch block, there are two possible processes. In one the anterior wall of the right ventricle is activated earlier than the posterior wall. In the other the process is reversed.

The propagation processes of the ventricular activation in right bundle branch block in the present study were planned taking both possibilities into account regardless of the experimental evidences of these possibilities. Similar to the classification of Myers and associates¹⁹⁻²⁴⁾, the following six locations in left ventricular myocardial infarction were included in this study: anteroseptal, anterolateral, anteroposterior, lateral, posterolateral and posterior positions. (See Fig. 1)

Every infarction of these locations was assumed to be transmural and the infarcted area was treated as a mere electric conductor.

In this report, infarcted areas were situated mainly in the left ventricle, and the right ventricle was infarcted only in the small region of septal margin in the cases of anteroseptal, anterolateral

Fig. 1. illustrates the positions of the infarcts to be complicated. From up to down, 1: Anteroseptal, 2: anterolateral, 3: anteroposterior, 4: lateral, 5: posterolateral, and 6: posterior infarctions. From readers left to right, right septal, right free endocardial, left septal, left free endocardial, frontal, left lateral, back-caudal and right lateral views of the heart.

and posterior myocardial infarctions. The electrocardiographic and vectorcardiographic changes in myocardial infarctions, in which the endocardial and septal muscles of the right ventricle are involved extensively as well as the left ventricular muscles, will be reported in a subsequent article on the rare type of bundle branch block.

RESULTS

The contour maps planning the processes of the spread of ventricular activation illustrated in Fig. 2 and Fig. 3 are those for the propagation processes which are assumed to occur in right

Fig. 2. illustrates two patterns of propagation process of ventricular activation in right bundle branch block. "A" is originated from a propagation process giving rise to a normal ECG of semihorizontal position and B, from that giving rise to a normal ECG of semivertical position. In both processes the anterior wall was assumed to be depolarized earlier than the posterior wall in the right ventricle.

Fig. 3. illustrates two patterns of propagation process of ventricular activation in right bundle branch block. "A" is originated from a propagation process giving rise to a normal ECG of semihorizontal position and B, from that giving rise to a normal ECG of semivertical position. Original processes are the same with those in the cases of Fig. 2. In both processes, the posterior wall was assumed to be depolarized earlier than the anterior wall in the left ventricle.

bundle branch block. They were originated from the two propagation processes of normal ventricular activation giving rise to electrocardiograms of semihorizontal and semivertical positions. The original processes and the electrocardiograms and vectorcardiograms resulting from them are the same with those reported in the preceding report on myocardial infarction¹⁸⁾. The propagation processes A in Fig. 2 and Fig. 3 are originated from the process giving rise to the electrocardiogram of semihorizontal position and B in Fig. 3 and Fig. 4, from that giving rise to the electrocardiogram of semivertical position. The processes in Fig. 2 were planned under the assumption that the anterior wall was activated earlier than the posterior wall in the right ventricle or the block-side ventricle. Those in Fig. 3 were planned under the assumption that the posterior wall was activated earlier than the anterior wall in the right ventricle.

The electrocardiograms and the vectorcardiograms in Figs. 4 and 5 were reconstructed based on the plans of the propagation process in Fig. 2 and Fig. 3 respectively. Those in upper rows of both Figs. 4 and 5 were from the plans A in Figs. 2 and 3, and those in lower rows, from the plans B in them.

When the anterior wall of the right ventricle was planned to be activated earlier than the posterior wall, the electrocardiograms, as seen in Fig. 4, displayed the rare type of bundle branch block in extremity leads, prominent R waves in right precordial leads, and deep S waves in left precordial leads characteristic of right bundle branch block.

Fig. 4. illustrates the reconstructed electrocardiograms and vectorcardiograms of right bundle branch block. These in upper row were reconstructed basing on the propagation process of ventricular activation illustrated in A of Fig. 2, and those in lower row, on propagation process in B of Fig. 2.

Fig. 5. illustrates the reconstructed electrocardiograms and vectorcardiograms of right bundle branch block. Those in upper row were reconstructed basing on the propagation process of ventricular activation illustrated in A of Fig. 3, and those in lower row, on the propagation process in B of Fig. 3.

On the other hand, when the posterior wall of the right ventricle was assumed to be activated earlier than the anterior wall, they displayed the usual type of Wilson block in extremity leads, while the precordial lead electrocardiograms remained in nearly the same configuration except that the tall R waves in right side precordial leads were more prominent than those in Fig. 4. (Fig. 5) In the former (Fig. 4), the S wave in lead VL was generally deeper than that in the latter, and the QRS complex in lead VF with the former activation process ended in a positive deflection in contrast to a negative deflection in the latter process. Thus the difference in extremity lead electrocardiographic pattern resulted.

The vectorcardiographic changes in both cases of right bundle branch block were quite similar to those reported by many authors²²⁾. Namely, the body of the QRS loop was always inscribed anteriorly to the right-inferior and the terminal portion was always inscribed anteriorly to the right as seen in Figs. 4 and 5.

Under the condition that the anterior wall was affected earlier by activation than the posterior wall in the right ventricle (hereafter this condition will be referred to as the first condition), the frontal plane QRS loop was inscribed more vertically than that under the condition that the posterior wall was affected earlier by activation than the anterior wall in the right ventricle (hereafter this condition will be referred to as the second condition).

The sagittal plane QRS loop under the second condition was rounder and the terminal portion was inscribed more anteriorly than that under the first condition. The direction of the inscription of the QRS loop was clockwise under both conditions in the frontal plane, whereas it was counterclockwise under the second condition and a figure-eight under the first condition in the sagittal plane. In the horizontal plane, the inscription was varied between clockwise, counterclockwise or figure-eight under both conditions.

Electrocardiographic and vectorcardiographic changes in right bundle branch block complicated by myocardial infarction to be described will be separated into two cases. The first change includes the cases originating from the propagation process of the ventricular activation giving rise to the electrocardiograms of the semihorizontal electrical heart position, and the other change includes the

Fig. 6A. illustrates the reconstructed electrocardiograms of right bundle branch block complicated by each of six myocardial infarctions of different positions illustrated in Fig. 1. From up to down: Anteroseptal, anterolateral, posterolateral and posterior myocardial infarctions. The pattern of propagation process used for reconstruction of these electrocardiograms is that illustrated in A of Fig. 2.

Fig. 6B. illustrates the reconstructed electrocardiograms of right bundle branch block complicated by each of six myocardial infarctions of different positions illustrated in Fig. 1. The pattern of propagation process used for reconstruction of these electrocardiograms is that illustrated in B of Fig. 2.

cases originating from the propagation process giving rise to the electrocardiograms of the semivertical heart position. The former case will be called case I, and the latter, case II.

1. *Electrocardiographic changes in right bundle branch block complicated by old myocardial infarction in the cases I and II under the first condition (Figs. 6A and 6B).*

Extremity lead ECG: In both cases, the appearance of the rare type of bundle branch block was not disturbed by the complication of myocardial infarction of any positions other than the posterior position. When posterior myocardial infarction was complicated, the S wave in lead V_F , in conjunction with lead III, became deep, and the R wave in lead V_L , in conjunction with the R wave in lead I, became large reflecting the effect due to infarction, in both cases and often displayed the IR and IIS pattern.

Even in the rare type of bundle branch block, the electrocardiographic feature in lead II is different according to the position of the infarcted area. In anteroseptal and anterolateral infarction, the QRS complex in lead II displayed a positive wave while in anteroposterior and posterolateral infarction, it was negative. In lateral myocardial infarction the wave was intermediate.

The QRS complex in lead V_1 was characterized by a tall and almost complete monophasic R wave in all instances except anteroseptal infarction, in which the slight Q wave preceded the tall R wave.

Precordial lead ECG: In anteroseptal infarction, Q waves were observed in leads V_2 through V_4 and to a slight degree in lead V_1 . In anterolateral infarction, they were observed in leads V_3 to V_6 .

In anteroposterior infarction, Q waves were observed in leads V_3 through V_6 , and in lateral infarction, in leads V_5 and V_6 .

In posterolateral and posterior infarctions, Q waves appeared in leads V_5 and V_6 or only in lead V_6 according to the extent of the infarcted area.

As a result, in right bundle branch block complicated by myocardial infarction, the Q phenomenon characteristic of old myocardial infarction was seen in all leads over the infarcted area as in an uncomplicated myocardial infarction. This is contrary to myocardial infarction complicated by left bundle branch block.

Reciprocal effects, for example, enlargement of the R waves in leads V_1 through V_3 in uncomplicated myocardial infarctions of lateral, posterolateral and posterior positions, were also observed distinctly in these leads.

Between cases I and II, no characteristic differences were observed.

2. Electrocardiographic changes in right bundle branch block complicated by old myocardial in-

Fig. 7A. illustrates the reconstructed electrocardiograms of right bundle branch block complicated by each of six myocardial infarctions of different positions in Fig. 1. The pattern of propagation process used for reconstruction of these electrocardiograms is that illustrated in A of Fig. 3.

Fig. 7B. illustrates the reconstructed electrocardiogram of right bundle branch block complicated by each of six myocardial infarctions of different positions in Fig. 1. The pattern of propagation process used for reconstruction of these electrocardiograms is that illustrated in B of Fig. 3.

farction in cases I and II under the second condition (Figs. 7A and 7B).

Precordial lead ECG: Changes in precordial lead electrocardiograms were nearly the same as those under the first condition except that the R

waves in right precordial leads were more prominent than those under the first condition. Appearance of Q waves in leads over the infarcted area was also not precluded.

Extremity lead ECG: On the contrary, the electrocardiographic patterns in extremity leads were markedly different from those under the first condition. In antero-septal and anterolateral myocardial infarctions, a pattern close to the rare type of bundle branch block was seen, and in antero-posterior infarction, a pattern with deep negative wave in leads I and II and small positive or bi-phasic wave in lead III occurred.

In posterior myocardial infarction, the main deflection was positive in lead I and negative in lead III and displayed a pattern resembling the unusual type of Wilson block or, under certain circumstances, the common type of bundle branch block.

In antero-septal, anterolateral and antero-posterior infarctions, VL displayed a Q wave and in posterior and posterolateral infarctions, VF displayed a Q wave similar to those in uncomplicated myocardial infarction. In most instances, VR showed qR or entirely positive deflection.

3. *Vectorcardiographic changes in right bundle branch block complicated by myocardial infarction in cases I and II under the first condition. (Figs. 8A and 8B).*

The characteristics of the vectorcardiographic

Fig. 8A. illustrates the reconstructed vectorcardiograms of right bundle branch block complicated by each of six myocardial infarctions of different positions in Fig. 1. The pattern of propagation process used for reconstruction of these vectorcardiograms is that illustrated in A of Fig. 2.

Fig. 8B. illustrates the reconstructed vectorcardiograms of right bundle branch block complicated by each of six myocardial infarctions of different positions in Fig. 1. The pattern of propagation process used for reconstruction of these vectorcardiograms is that illustrated in B of Fig. 2.

changes in right bundle branch block in which the mid to terminal portion is inscribed anteriorly to the right inferior were not modified by complication of left ventricular myocardial infarction of any position.

The terminal portion especially was scarcely displaced from its original position of inscription even after the complication of myocardial infarction. Only in posterior myocardial infarction, in which the right posterior ventricular muscles were infarcted as well as left ventricular muscles, the terminal portion was slightly displaced superiorly from its original position, but it still remained inferiorly to the right anterior. In antero-septal infarction, the initial force was inscribed displacing to the posterior from its original position in isolated right bundle branch block. In anterolateral infarction the initial portion (the portion from first stage to the sixth stage) was significantly displaced to the right, and in antero-posterior infarction the initial force and the body were displaced distinctly to the right.

In lateral infarction changes were nearly the same but not so significant as in antero-posterior infarction. In posterolateral infarction, the initial through the mid portion was displaced to the right and somewhat anteriorly, and in posterior infarction, it was displaced anteriorly to the superior from the original position in isolated right bundle branch block. Between case I and case II, no

particular difference was observable.

The direction of inscription of the QRS loop was variable according to the position of the infarcted area. In anteroseptal and anteroposterior infarctions, it was clockwise in the frontal and horizontal planes and counterclockwise or a figure-eight followed by a terminal clockwise inscription in the sagittal plane. In anteroseptal and lateral infarctions, the direction was not simple. But the terminal portions were inscribed clockwise in three planes. In posterior and posterolateral infarction, the direction of inscription was clockwise in the horizontal plane, and in most of the cases it was also clockwise in the sagittal plane as a result of forward displacement of the initial force. In the frontal plane, it was complicated, but the terminal portion was inscribed counterclockwise.

4. *Vectorcardiographic changes in right bundle branch block complicated by myocardial infarction in cases I and II under the second condition (Figs. 9A and 9B).*

The trend of the changes was nearly the same as that under the first condition. The terminal portion was inscribed anteriorly to the right and somewhat superiorly in myocardial infarction of any position. The position of the inscription of the terminal loop was scarcely displaced after the

Fig. 9A. illustrates the reconstructed vectorcardiograms of right bundle branch block complicated by each of six myocardial infarctions of different positions in Fig. 1. The pattern of propagation process used for reconstruction of these vectorcardiograms is that illustrated in A of Fig. 3.

Fig. 9B. illustrates the reconstructed vectorcardiograms of right bundle branch block complicated by each of six myocardial infarctions of different positions in Fig. 1. The pattern of propagation process used for reconstructions of these vectorcardiograms is that illustrated in B of Fig. 3.

complication of myocardial infarction.

Characteristics of the complication of myocardial infarction under the second condition were that the initial through mid portions were displaced away from the infarcted area like that under the first condition. Portion displaced was different depending on the position and the extent of the infarcted area, as seen in Figs. 9A and 9B.

The degree of deformation of the QRS loop was also variable depending on the position and the extent of the infarcted area. It was largest in posterolateral, posterior, anteroposterior and lateral infarctions. Among them, anteroposterior infarction was the largest and lateral and posterior infarction were the smallest in the extent of the infarcted area.

In anteroseptal infarction, the initial portion of the QRS loop (the portion from the first to the fifth stage) was displaced posteriorly somewhat to the left in the horizontal and sagittal planes. In the frontal plane, no particular change was seen. In anterolateral infarction, the initial force (the portion from the first to the sixth stage) was significantly displaced to the right posterior in the polyogram, but not so remarkably in the cube system method.

In anteroposterior infarction, the initial through mid portions were displaced significantly to the right and the deformation was most remarkable in the frontal and sagittal planes especially in case II. In

case II, the direction of the inscription was very complicated in the frontal plane QRS loop.

In lateral infarction, the initial through mid portions were displaced to the right and somewhat anteriorly. The deformation of the loop was most significant in the frontal and sagittal planes.

In posterolateral and posterior infarctions, the initial through mid portions were displaced anteriorly to the right-superior, especially in posterolateral infarction, and changes of the direction of inscription occurred in the sagittal and horizontal planes and occasionally in the frontal plane. In posterolateral infarction, the initial force displaced to the superior was impressive in comparison to the change under the first condition.

The direction of inscription was variable depending upon the position of the infarct. In antero-septal and anterolateral and anteroposterior infarctions, it was clockwise in the frontal plane, and counterclockwise in the sagittal plane. In the horizontal plane, it was a figure-eight followed by a terminal clockwise inscription in most of cases, but the QRS loop registered by the cube-system method displayed an occasional clockwise inscription in antero-septal or anterolateral infarction. In lateral infarction, the direction was nearly the same as that in anteroposterior infarction. In posterior and posterolateral infarctions, however, it was very complicated as a result of significant forward displacement of the initial portion. In the sagittal plane it was often clockwise or a figure-eight.

The most important of the findings in the electrocardiogram and vectorcardiogram was that the configuration of the terminal portion was not altered even in the presence of left ventricular myocardial infarction.

DISCUSSION

On the extremity lead electrocardiogram:

It is well known that the various patterns of the extremity lead electrocardiogram appear in right bundle branch block such as the usual and the unusual type of Wilson block and the rare type of bundle branch block. Among these, the usual type of Wilson block is the most common.

The reason why such varied patterns appear is not yet established. In the preceding report on bundle branch block²⁶⁾, the authors assumed that the rare type of bundle branch block would appear if the anterior wall of the right ventricle was acti-

vated earlier than the posterior wall of the right ventricle for a certain reason, for example, due to the complication of posterior myocardial infarction.

This assumption was confirmed in the present study. But as to myocardial infarction as a cause of such a special process of right ventricular activation, the results of the present study were not necessarily identical to the assumption by the authors. It is surmised that the infarcted area of the posterior free ventricular wall must be very small to produce the rare type of bundle branch block, if such a special process of the spread of right ventricular activation results from posterior myocardial infarction. When the infarcted area is extensive, the results are different depending upon the position and the extent of the infarct as seen in Figs. 6A and 6B and Figs. 7A and 7B.

When the infarcted area is extended predominantly into the right ventricular posterior wall in posterior infarction, the features of the extremity electrocardiograms display the patterns of the usual type or the unusual type of Wilson block and, in some conditions, the pattern resembles the common type of bundle branch block. On the contrary, when the infarct extends predominantly into the lateral wall of the left ventricle, the pattern similar to the rare type of bundle branch block appears.

From the facts that the extremity lead electrocardiograms always displayed the rare type of bundle branch block when the right bundle branch block was complicated by left ventricular myocardial infarction of antero-septal, anterolateral, or anteroposterior position, it may be surmised that the clinical electrocardiogram in left ventricular myocardial infarction of anterior aspect may also cause the rare type of bundle branch block in most of the cases.

Noteworthy is the fact that the reconstruction of the electrocardiograms and the vectorcardiograms in the present study was performed with no respect to the passive changes of the spread of ventricular activation which may occur in the peripheral muscles of the infarct. Thus the infarcted area of old myocardial infarction was treated as a mere volume conductor and was not treated as influential in the conduction rate in the peripheral muscles. Therefore, it is not effective in changing the general course of the spread of ventricular activation.

For example, in posterior myocardial infarction, if the transmission of the activation wave from left

ventricular muscles to the right posterior wall is disturbed as a result of infarction and there is no possibility that the posterior wall of the right ventricle is activated earlier than the anterior wall of the right ventricle, the electrocardiographic changes as seen in Figs. 7A and 7B under the second condition will not be observable in practice. Also the pattern resembling the common type of bundle branch block will not be observed in a clinical electrocardiogram of the patient of such an anatomical heart position as in our heart model. But if this is not so, there will be the possibility of the appearance of a pattern resembling the common type of bundle branch block in right bundle branch block complicated by posterior myocardial infarction.

From the finding that the extremity lead electrocardiograms always displayed the rare type of bundle branch block when right bundle branch block was complicated by left ventricular myocardial infarction of anteroapical, anterolateral, or anteroposterior position, it may be surmised that the clinical electrocardiogram in right bundle branch block complicated by left ventricular myocardial infarction of anterior aspect displays almost always the rare type of bundle branch block independently of the electrical heart position so long as the heart takes the same anatomical position as that used for the measurement of the solid angles in our series of the reports.

On the unipolar lead electrocardiogram:

The most characteristic of the changes of precordial leads in right bundle branch block complicated by myocardial infarction is that the Q waves are also observed in the leads over the infarcted area. These findings were in good agreement with those in the reports by Wilson and associates⁽¹⁰⁾.

The reason for this would be as follows: The ventricular muscles participating in depolarization in the early stage of ventricular activation in right bundle branch block are the left ventricular muscles alone and the position of the infarcted area is assumed to localize in the left ventricle in all cases. Therefore, the lead point over the infarcted area is obliged to face the opening or the "window" of the equivalent electric double layer in an early stage of ventricular activation. At this instant the equivalent electric double layer is induced at the boundary of the activated and unactivated regions of ventricular muscles and the opening is broken

out around the infarct. As there is no other effective equivalent double layer in the right ventricle at that instant, the potential at a point over the infarcted area is predominantly negative and the Q wave appears in the lead from that point.

On the contrary, the potential at a given point opposite the infarcted area, for example at lead-points V_2 and V_3 in posterior myocardial infarction, is more predominantly positive at this instant than that in isolated right bundle branch block, and the so-called reciprocal effect appears in the lead from that point.

From this reason, the reciprocal effect is more or less variable in its magnitude according to the condition of the spread of ventricular activation and the position of the lead-point. For example, the reciprocal effects at V_2 and V_3 in posterior myocardial infarction are usually larger when the posterior wall of the right ventricle is activated earlier than the anterior wall of the right ventricle.

Analogous findings are observable at various lead-points in myocardial infarctions of various positions. Conversely, in posterior myocardial infarction complicated by left bundle branch block the reciprocal effect is precluded because the right ventricular muscle had been already activated at the instant when the left ventricular muscles around the infarcted area participated in activation.

According to Myers and associates⁽²³⁾, the Q waves in right precordial leads V_2 and V_3 in anterior myocardial infarction are supposed to occur as a manifestation of extension of the infarct into the septum. An abnormal initial downward deflection in lead V_2 is also supposed to be observed in association with an infarct involving the apical one-half of the anterior wall, but not extending into the septum.

When the infarct involves the left anterior free wall, the effect of the septal infarct is balanced by the opposite effect of the left free ventricular wall and fails to present the Q wave in lead V_1 . When the lesion extends further into the left lateral wall, the Q wave in lead V_2 also fails to occur.

In anteroapical infarction, the Q wave is observed in one or more leads of V_1 through V_4 and when the infarct involves the left lateral apical wall, the Q wave appears in V_2 through V_5 or V_6 also. Q waves in V_1 and V_2 are a sign of predominant septal infarction and Q waves in lead V_2 and the leads to the left of V_2 are not neces-

sarily a sign of septal infarction. Q waves in V_3 and V_4 are supposed to occur as a manifestation of anterior or anterolateral infarction of the left ventricle.

The authors' results of reconstruction of the electrocardiograms were in good agreement with the findings in Myers' report. In the present study of right bundle branch block complicated by left ventricular myocardial infarction, Q waves in leads V_1 through V_4 were observed in antero-septal infarction, and in anterolateral infarction Q waves appeared in V_2 and the leads to the left of V_2 , and in lateral infarction, in the leads to the left of V_5 . That is, Q waves in V_1 and V_2 gradually disappear in sequence as the position of the infarct displaces to or extends into the left lateral wall.

The Q wave in lead V_F was characteristic of posterolateral and posterior infarction and occasionally of anteroposterior infarction. Among these, in anteroposterior infarction, the deep negative deflection corresponding to the Q phenomenon was preceded by a small or rudimentary r wave, and in posterior infarction, the Q wave was recorded as very small depending upon the conditions of the spread of ventricular activation.

The most important reason for this discrepancy is that the lead-point of V_F in the present study is situated on the point of the left axillary line at the level of the umbilicus. This position is somewhat too high and too anterior to reflect the effect of posterior infarction in comparison with the normal position, thus making manifestation of the Q wave in posterior and anteroposterior infarction difficult.

On the vectorcardiogram:

As the process of the spread of ventricular activation in right bundle branch block in the present study has been planned in such a manner that the right ventricular muscles are activated later than the left ones, the terminal portion of the QRS loop was inscribed almost always independently of the left ventricular infarct, and accordingly the terminal portion was not displaced even if myocardial infarction was complicated. However, when the infarct involved the right ventricular muscles as well as left ventricular muscles, for example as in posterior infarction, the terminal portion was more or less displaced from its original position in uncomplicated right bundle branch block.

Therefore, the portion of the QRS loop dis-

placed by complication of myocardial infarction is from the initial to the mid-portion.

In general, the endocardial activation in the left ventricle occurs in the early stage of ventricular activation in right bundle branch block. Therefore, the "window" or an opening of the electric double layer appears at a portion of the infarcted area in a relatively early stage of the ventricular activation.

This opening of the electric double layer gives an electric effect directed away from the infarcted area. This is the reason why the initial portion of the QRS loop is inscribed away from the infarcted area in left ventricular myocardial infarction complicated by right bundle branch block.

However, as seen in the results of the present study, the direction of the displacement of the initial force of the QRS loop is not necessarily same in every vectrocardiographic reference system even if the position of myocardial infarction is identical.

The reason for this is in the difference of the manifest vector resulting from the difference of the reference system. Even if the same electric force with a single source and sink is given in a certain volume conductor, the manifest vector is different according to the kind of reference system of the vectorcardiogram. This principle in the electric field of single source and sink is also applicable to the electric force generated in the heart. Accordingly, the initial portion of QRS loop may be inscribed in different directions with different reference systems.

The direction of displacement of the initial force in antero-septal infarction in the cube reference system was markedly different from that in the polygraphy because the deformation of the manifest vector of the electric force of each unit area of the ventricular surface is marked in the cube reference system at the region of the anterior ventricular surface in contrast to scarce deformation in the polygraphy.

For the same reasons, the difference in the direction of the displacement of the initial force between the cube system and the polygraphy was also significant in anterolateral infarction. In this condition, however, concomitant involvement of the left lateral ventricular muscles, where the deformation of the manifest vector of each unit area's electric force is not so significant, produces a lesser degree of deformation of the resultant manifest

vector. Consequently, the difference in the displacement of the initial force of the QRS loop between both systems is less remarkable than that in anteroseptal infarction. In myocardial infarctions

Fig. 10. illustrates the orthogonal projections (thick arrows) of the electric forces resulting from the infarcted area and their manifest vectors by means of polyography (fine arrows) and by cube reference system method (fine dotted arrows).

of other positions, the displacement of the initial force was not so markedly different as those in anteroseptal and anterolateral infarctions.

Fig. 10 illustrates the manifest vector resulting from the infarcted area. The fine stretched lines in the figure are the manifest vectors represented by the polyography; the fine dotted lines stand for those by the cube reference system; and the thick lines are the component vectors of this electric force projected on the three planes of rectangular coordinate system according to the concept of orthogonal projection.

The values for the orthogonal projections of these electric forces were calculated from the vectors of unit area's electric forces using a special method. Details will be reported elsewhere. These manifest vectors of the electric forces do not always display true direction and magnitude of displacement, because these electric forces do not always participate in the construction of the vectorcardiogram with their total efficiency but sometimes only with partial efficiency depending upon the conditions of the spread of the ventricular activation and the position of the infarcted area. However, the general tendency of the changes may be visualized from these manifest vectors in Fig. 10. That is,

the initial force of the QRS loop is displaced in different directions according to the position of the infarcted area as illustrated in Fig. 10. In anteroposterior infarction, the initial segment is displaced to the right and somewhat posteriorly and superiorly; in lateral infarction, to the right anteriorly and somewhat superiorly; and in posterior and posterolateral infarctions, superiorly to the anterior from the original position in isolated right bundle branch block.

SUMMARY

1. The electrocardiograms and the vectorcardiograms in right bundle branch block and those in right bundle branch block complicated by left ventricular myocardial infarction were obtained by the reconstruction method of Toyoshima and associates.

2. The standard extremity leads in right bundle branch block always displayed the rare type of bundle branch block when the anterior wall of the right ventricle was assumed to be activated earlier than the posterior wall, and displayed the usual type of Wilson block when the posterior wall of the right ventricle was activated earlier than the anterior wall.

3. The right precordial leads in right bundle branch block always presented tall late R waves and the left precordial leads showed rS patterns as characteristically reported in right bundle branch block. These patterns appeared regardless of whether the anterior or the posterior wall of the right ventricle was activated earlier or from which of the semihorizontal or semivertical electrical heart positions they originated.

4. The vectorcardiogram in right bundle branch block consistently presented characteristic features. That is, the mid through the terminal portions were always inscribed anteriorly to the right.

5. When left ventricular myocardial infarctions were artificially produced, the Q waves, which are characteristically observed in the leads over the infarcted area in uncomplicated myocardial infarction, also appeared distinctly in the leads over the infarcted area.

6. When the anterior wall of the right ventricle was assumed to be activated earlier than the posterior wall in right bundle branch block, the extremity lead electrocardiograms remained in the

rare type of bundle branch block even after the complication of anteroseptal, anterolateral, anteroposterior or lateral myocardial infarction. They changed, however, to the usual type of the Wilson block after the complication of posterior myocardial infarction.

7. When the posterior wall of the right ventricle was assumed to be activated earlier than the anterior wall in right bundle branch block, the extremity lead electrocardiogram changed to the rare type of bundle branch block after the complication of anteroseptal or anterolateral myocardial infarction, and to the unusual type of Wilson block or to the pattern resembling the common type of bundle branch block after the complication of posterior myocardial infarction.

8. When right bundle branch block is complicated by myocardial infarction the initial portion of the QRS loop of the vectorcardiogram was displaced away from the infarcted area, but the terminal portion was scarcely displaced in most of left ventricular infarctions and was always inscribed anteriorly to the right.

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