Postural Electrocardiographic Changes in Healed Myocardial Infarction

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An electrocardiographic study of 110 patients with old myocardial infarction was made. Change of posture, by causing rotation of the heart on its axes, frequently altered the evidence of infarction. These changes were most evident in posterior infarction. The "labeled" area did the following with respect to the exploring electrode: (1) disappeared, (2) if absent in the supine posture, the evidence appeared in one or more of the other postures, and (3) shifted from one exploring electrode position to another.

Since the introduction of unipolar leads, the changes in the human electrocardiogram associated with various postures have been clarified. Significant movement of the heart along its long and anterior-posterior axes has been detected by changes in the unipolar limb and multiple chest leads. Jones and co-workers observed that in normal subjects and in patients with right and left ventricular hypertrophy and right and left bundle branch block the heart becomes electrically more vertical in the left lateral posture, horizontal in the sitting posture, and in about one-half of the cases more horizontal and in one-half more vertical in the right lateral posture. In addition, rotation of the heart along the long axis was manifested by changes of position of the transitional zone in multiple chest leads.

In the present study, the effect of posture on the electrocardiogram has been extended to patients with old myocardial infarcts. The area of infarction was considered to be "labeled" by diagnostic QRS and T changes. It was possible to correlate movement of the labelled area with changes in the electrical axis and in the position of the transitional zone.

In the majority of cases of human myocardial infarction healing takes place between the first and second months. After healing, the electrocardiographic manifestations will depend upon the size and location of the resultant electrically dead scar. However, this area may be so situated or so small that there may be no effect recorded by the multiple exploratory leads now in use. Absence of electrocardiographic evidence of myocardial infarction in previously proved cases could be due either to morphologic healing without electrocardiographic residua, or to inappropriate orientation of the exploring electrodes to the electrically altered area.

Our study of the effects of change of body posture upon the electrocardiograms of patients with proved (clinical) infarction, and with or without electrocardiographic residua in the supine posture have confirmed the theoretic possibilities that the effects of a labeled area could be made (1) to disappear, (2) to appear in one or more postures, if absent in the supine, and (3) to shift from one exploratory lead to another.

Methods

One hundred and ten patients with a positive history and unequivocal electrocardiographic evidence of acute myocardial infarction were studied one month to nine years following the acute episode. The cases were selected in order to obtain an approximately equal number of those with anterior and those with posterior myocardial infarction. Electrocardiograms consisting of the standard limb leads, the augmented unipolar leads and the six standard precordial leads, using Wilson's central terminal, were taken with the patient in the following four postures: supine, left lateral, right lateral, and sitting erect. (The points were marked on the chest with indelible ink.) The patient was allowed to remain in each posture long enough before taking the electrocardiograms so as to eliminate or minimize any effect on heart rate and other cardiovascular dynamics due to the shift in posture.

The approximate QRS axis and the T axis in...
the standard leads in each posture were estimated by Dieuade's method and the extent of rotation of the electrical axis in comparison with the supine was thus determined. The electrical position of the heart was estimated from the augmented extremity leads. The extent of rotation about the long axis of the heart was determined by movement of the transitional zone and of the labeled area in the precordial leads. Using circumferential leads, Jones and associates have demonstrated that displacement of the anterior transitional zone was accompanied by an oppositely directed displacement of the posterior transition zone, substantiating the concept of rotation upon the long axis. It is possible that in some of the cases in the present series displacement of the transitional zone may have occurred without rotation on the long axis; however, for the purposes of this study, displacement of the transitional zone or labeled area will infer clockwise or counterclockwise rotation of the long axis. Changes with reference to the transverse axis can only be inferred.

The records were then carefully studied for evidence of significant changes associated with the changes from supine to other postures: The appearance or disappearance of a diagnostic Q and T wave in the extremity leads was considered to be significant. Changes in the precordial leads were considered to be significant when they showed a shift of positive findings from one precordial lead to another or the appearance or disappearance of a positive finding (a broad Q wave or a negative T wave), usually in V6.

**Results**

Of the 110 patients studied, 100 had some electrocardiographic evidence of an old myocardial infarct in one or more of the four postures. The remaining 10 patients had electrocardiograms which were within normal limits in all postures, despite the previous diagnostic electrocardiograms and clinical evidence of infarction.

**Location of Myocardial Infarction.** Of these 100 patients there was electrocardiographic evidence of old infarction in the anterior or anteroseptal region in 41, in the posterior wall in 47, and in both anterior and posterior walls in 12.

**Abnormal Left Axis Deviation.** Arbitrarily setting the normal range of position of the electrical axis of QRS as 0 to + 90 degrees, it was found that abnormal left axis deviation occurred in the supine posture in 45 cases. There were no cases of abnormal right axis deviation. Of the 45 showing abnormal left axis, 25 were posterior infarcts, 19 anterior, and 1 anterior and posterior.

**Changes in the Average Electrical Axis.** The average electrical axis of the QRS complexes in the 100 cases was +10 degrees in the supine posture, +21 in the left lateral, +16 in the right lateral and +4.5 degrees in the sitting posture.

**Changes in the QRS and T Axes.** Table 1 summarizes the direction of the shift of the QRS and T axes from the supine to the other postures.

<table>
<thead>
<tr>
<th>Posture</th>
<th>Axis</th>
<th>Direction of Axis Shift</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>To Left</td>
</tr>
<tr>
<td>Left Lateral</td>
<td>QRS</td>
<td>28 cases</td>
</tr>
<tr>
<td></td>
<td>T</td>
<td>24 cases</td>
</tr>
<tr>
<td>Right Lateral</td>
<td>QRS</td>
<td>36 cases</td>
</tr>
<tr>
<td></td>
<td>T</td>
<td>24 cases</td>
</tr>
<tr>
<td>Sitting</td>
<td>QRS</td>
<td>55 cases</td>
</tr>
<tr>
<td></td>
<td>T</td>
<td>26 cases</td>
</tr>
</tbody>
</table>

The assumption of either the right or left lateral postures tended to make the electrical axis become more vertical, whereas in the sitting posture it tended toward the horizontal. The shift of the T axis was independent of the QRS axis.

**Rotation about the Long Axis.** The direction of rotation about the long axis of the heart is summarized in table 2. In two-thirds of the cases there was no significant change.* When significant rotation occurred in either the right or left lateral postures it was more frequently counterclockwise, whereas in the sitting posture it was more frequently clockwise. The shift of the transition zone coincided with that of the labeled area. Further correlation shows that when the heart tends to become more vertical, counterclockwise rotation occurs twice as frequently as clockwise rotation; on the other hand, when the heart tends to become more horizontal rotation occurs as frequently clockwise as counterclockwise.

**Apparent Shift of Old Infarction.** Of the 100 cases studied, 27 showed significant changes in the electrocardiogram with shift in posture.

* A significant change in the precordial leads was one in which the transitional zone and the labeled area moved one precordial position to the right or left.
POSTURAL CHANGES IN HEALED MYOCARDIAL INFARCTION

Table 2.—Direction of Rotation of the Heart on Its Long Axis (As Seen from Below) in 77 Cases of Myocardial Infarction Associated with Changes in Posture from the Supine

<table>
<thead>
<tr>
<th>Posture</th>
<th>Direction of Rotation on Long Axis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Clockwise</td>
</tr>
<tr>
<td>Left Lateral</td>
<td>12 cases</td>
</tr>
<tr>
<td>Right Lateral</td>
<td>8 cases</td>
</tr>
<tr>
<td>Sitting</td>
<td>18 cases</td>
</tr>
</tbody>
</table>

Changes were considered to be due to rotation of the heart on its long axis.

Of the total of 27 cases, 11 were anterior infarcts, 13 posterior, and 3 combined anterior and posterior.* In the 8 cases in which evidence of an old infarct disappeared or was less diagnostic this was associated with the electrical axis becoming more vertical in 5 cases, more horizontal in 2, and no change in axis in 1. Six of these cases were old posterior infarcts, 1 anterior, and 1 anterior and posterior. Clockwise rotation occurred in 3 cases and counter-clockwise rotation in 2. There was no constant relationship between the change in direction of the QRS electrical axis and the direction of rotation on the long axis.

In the 14 cases in which evidence of an old infarct appeared, the electrical axis became

Fig. 1. Serial electrocardiograms showing complete electrocardiographic "healing." Leads 1, 2, and 3, the augmented unipolar leads, and three precordial leads are shown. Under A are the diagnostic findings of the acute anterior infarction. The same patient three years later in the supine position is shown in B. C shows a shift in axis in the sitting position, but still no evidence of the old infarct. In none of the postures could evidence of an old infarct be elicited. Discussion in text.

Considering the supine as the standard posture, in 8 cases it was found that evidence of an old infarct disappeared in the limb leads in one or more of the other postures assumed. Similarly, in 14 cases evidence of an old infarct which was not present in the limb leads appeared in one or more of the other postures. Significant changes in the precordial leads were present in 9 instances, 4 of which had also showed changes in the limb leads. The precordial

* Approximately the same proportion as the total number studied.
more vertical in 8, more horizontal in 5 and unchanged in 1. Eight of these cases were anterior infarcts, 5 posterior, and 1 combined anterior and posterior. There was clockwise rotation on the long axis in 9 and counterclockwise in 3. Of the 8 cases of anterior infarction in this group significant changes occurred always in association with the electrical axis becoming more vertical, with clockwise rotation in 6 and counterclockwise rotation in 1. Four of the 5 posterior infarcts showed significant changes associated with the electrical axis becoming more horizontal, while in the fifth there was no axis change associated with clockwise rotation on the long axis. (There was correlation between shifts of the electrical axis and direction of rotation on the long axis in that clockwise rotation occurred as the heart became vertical in the anterior infarcts.)

Of the 9 cases which showed significant changes in the precordial leads there were 4 cases in which evidence of an infarct moved medially over the precordium with change in the acute infarct are no longer present in the supine or other postures.

Figures 2, 3, and 4 demonstrate cases in which evidence of an old infarct in the supine position disappeared with change of posture. In figure 2, the deep Q and inverted T present in lead III and in aVF are absent in the sitting posture. In this case the QRS axis became more horizontal (from -20 degrees in the supine to -30 degrees in the sitting posture), and there was clockwise rotation on the long axis (as viewed from below).
In figure 3, the Q wave present in lead III and in aV_F in the supine is absent in the left and right lateral postures, as the QRS axis shifts from −4 degrees in the supine to 68 degrees in the left and 30 degrees in the right lateral postures. Slight clockwise rotation on the long axis occurs.

In figure 4, the deep Q present in aV_F in the supine disappears in the right lateral posture as the QRS axis becomes more vertical (supine, −16 degrees; right lateral, 0 degrees). There is also clockwise rotation on the long axis so that the terminal T-wave inversion seen in V_6 in the supine moves laterally over the precordium and is not present in the right lateral posture.

Figures 5 and 6 demonstrate cases in which positive evidence of an old infarct not present in the standard supine posture appeared with posture change. In Figure 5 a definite Q wave appears in aV_F in the sitting posture as the QRS axis becomes more horizontal (supine, 5 degrees; sitting, −20 degrees). There is clockwise rotation on the long axis.

In figure 6, a deep Q and more marked inversion of T appear in aV_L in the left lateral posture as the QRS axis becomes more vertical (supine, 45 degrees; left lateral, 78 degrees). There is also clockwise rotation on the long axis so that terminal T wave inversion appears in V_6 in the left lateral posture.

Figure 7 demonstrates a case showing marked changes in the precordial leads associated with clockwise rotation from supine to left lateral posture. The deep QS and T present in V_4 in the supine are present in V_6 in the left lateral. There are insignificant changes in the limb leads.

**Discussion**

Variations in the position of the heart are usually referred to in relation to its three axes. (1) Rotation around the anteroposterior axis of the heart results in the long axis becoming more horizontal or vertical. (2) Clockwise rotation on the long axis causes the right ventricle to become more anterior as the left ventricle...
becomes posterior, whereas in counterclockwise rotation on the long axis the left ventricle becomes more anterior. (3) With reference to the transverse axis of the heart the apex may rotate forward or backward. Of course any combination of rotation about these axes may occur.

It has been recognized since the earliest days of electrocardiography that the posture of the patient exerts a varying effect upon the positions in the electrical field of the body and changes in the configuration of various complexes result.

In 1909 Grau pointed out that persons with long narrow hearts showed a small and tall . The effect of rotation of the heart, especially around its long axis, as an important cause of changes in the standard leads has long been established. In 1931 Nathanson studied the effect of change in pos-

![Image]

Fig. 4. Positive evidence of an old posterior infarct present in lead 3 and the foot lead in the supine position (A) disappears in the right lateral position (B). The precordial leads further show clockwise rotation in the right lateral position so that evidence of lateral involvement also disappears. Insert shows posterior infarct (stippled); upper arrow represents rotation on the long axis, lower arrow QRS axis shift. The lateral rotation is also shown in the second insert representing a cross-section of the heart as viewed from above. (R, right ventricle; L, left ventricle).

tion of the heart in the chest and upon the form of the electrocardiogram.

Katz and Robinov have shown that changes within the chest account for variations in the electrocardiogram with the shift from the recumbent to the upright posture. The rotation of the heart about its various axes, displacement of the heart as a unit without rotation, and alteration in the contour of the chest cavity are also significant. The summation of these factors produces essential varia-

In 60 cases from the supine to the left and right lateral. In the left lateral the QRS axis in most cases shifted toward the right although some became more left. In the right lateral there was no change in 30 per cent and the rest went equally to right and to left. Mayerson found a shift of the axis to the right in the upright posture.

Kountz in revived perfused human hearts in normal position found that a shift of the heart to the right caused relative left axis
deviation while rotation to the left caused right axis deviation. Rotation of the heart clockwise caused right axis deviation, while counterclockwise rotation caused left axis deviation.

Numerous continental authors have stressed the importance of the effect of standing on the T waves and have indicated that changes are due to a lack of cardiac reserve. Alterations in coronary blood flow have been postulated by some. Sigler found T-wave alterations in 33 normal subjects when the recumbent and standing postures were compared. He also pointed out changes in the sitting posture. The T-wave changes are presumed to be caused by changes in direction of repolarization.

More recently Master and Gardberg and Ashman have further correlated electrocardiographic patterns and the position of the heart. Jones and Feil found that in left and right bundle branch block lateral postures frequently cause gross rotation of the electrical axis to the right. They stressed the importance of posture

![Diagrams](image)

**Fig. 5.** Equivocal evidence of an old posterior infarct as seen in the foot lead in the supine position (A) becomes more diagnostic in the sitting position (B). Insert shows posterior infarct (stippled); upper arrow represents rotation on long axis, lower arrow, QRS axis shift.

In our series, on the assumption of the left and right lateral postures, the QRS axis shifted to the right approximately twice as frequently as to the left. Likewise, the average electrical axis for the QRS shifted 11 degrees and 6 degrees to the right in the left and right lateral postures, respectively, while shifting 5.5 degrees to the left in the sitting posture. The degree of shift in the electrical axis was the same in those cases showing significant electrocardiographic differences as in those in which there was no significant change.

The average electrical axis for the QRS in the supine posture (10 degrees) showed a marked shift toward the horizontal as compared to the value of 58 degrees usually given for young adults. Goldberger states that electrically the heart lies more horizontal after anterior infarction and more vertical after posterior infarction. However, of the 45 cases showing
abnormal left axis deviation, 25 had posterior infarcts, 19 anterior and 1 anterior and posterior. Mallory and co-workers present data to suggest that infarction per se may lead to cardiac hypertrophy, the average weight of hearts the seat of old myocardial infarction being 503.5 Gm. However, it should be pointed out that the hypertrophy and left axis shift may just as well be a consequence of such accompanying factors as hypertension and valvular disease which tend to cause left ventricular hypertrophy.

According to Levine, during the normal aging process, the left ventricle becomes slightly hypertrophied. Shipley and Hallaran in a study of 200 normal men and women between the age of 20 and 35 found an electrical QRS axis of less than 30 degrees in 10 per cent of the cases. In a study of people over sixty years of age left axis deviation was found in 71 per cent of 300 cases, 61.6 per cent of whom had fluoroscopic evidence of enlargement of the heart. Similarly in a group of 100 people over 70, 62 per cent showed left axis deviation. In 33 cases which subsequently developed left bundle branch block Jones and Feil found an average QRS axis of -6 degrees. With left bundle branch block the axis became -18 degrees.

![Figure 6](http://circ.ahajournals.org/)

Fig. 6. Positive evidence of an old infarct appears in the left arm lead as posture is changed from supine (A) to left lateral (B). The precordial leads indicate clockwise rotation so that an inverted T appears in V₄. Insert shows anterior infarct (solid); upper arrow represents rotation on long axis, lower arrow, QRS axis shift. Second insert shows lateral rotation.

Presumably the tendency to left axis deviation found in our series is merely a result of the factors which operate in those hearts predisposed to myocardial infarction. Certainly hypertension and myocardial ischemia due to progressive coronary artery disease are prominent factors in these hearts.

The degree of shift in position of the heart in various postures varied greatly in individual cases. Changes in the electrocardiogram depended upon the relative mobility of the heart.
and other mediastinal structures and the electrical conductivity of tissues contiguous to the heart in so far as the distribution of cardiac action potentials are affected.\(^{33,34}\)

Of the 110 cases studied it was possible to elicit evidence of an old infarct in 100. In the other 10 cases, despite some degree of change in position of the heart with respect to the electrodes brought on by postural change, the scar was so situated or so small so as to produce no electrocardiographic manifestation of an old infarct. Of the remaining 100 cases, positive electrical evidence of an old infarct was present in 73 cases in all postures with no significant change despite varying degrees of rotation about the various axes. In 27 cases there was significant movement of the labeled area associated with rotation of the heart on one or more of its axes. However, the degree of axis shift was not the determining factor in producing significant changes as the degree of shift was equally as great in those cases in which significant changes did not appear.

In 8 cases the scar was so situated that electrocardiographic evidence disappeared in one or more postures as the position of the heart was altered by postural change with a consequent shift of the infarcted area from an electrically effective zone. Similarly in 14 cases there was a shift of the infarcted area; the electrocardiogram showed no evidence of infarction in the standard supine posture while this became evident as the scar moved into the electrical field with posture change. In 9 instances there was significant rotation of the heart on its long axis, clockwise or counterclockwise, so that positive findings shifted in the chest leads. Especially in lead V\(_6\) evidence of lateral involvement appeared or disappeared.

**CLINICAL IMPLICATIONS**

In a significant number of cases of old infarction, change in posture can alter the electrocardiogram so that there may be more or less evidence of the old infarct.

The necessity for correlating the precordial...
and limb leads is emphasized. In no case did all the evidence of an anterior infarct disappear with respect to all twelve leads. Diagnostic signs of an old anterior wall infarct were present in one or more of the twelve leads in the various postures although diagnostic changes may have disappeared from one or more but not all of the leads. Thus, the diagnosis could still be made in all postures where twelve leads were used.

On the other hand, in the posterior infarcts diagnostic signs did disappear in one or more postures so that the diagnosis could not be made in every position despite the use of twelve leads. This presumably indicates that the electrocardiographic survey of anterior wall lesions are given in table 3. Figure 8 indicates the magnitude and direction of change of the ventricular gradients before and after posture change which resulted in significant alteration in appearance of the electrocardiogram.

The cases shown in figures 2, 3, and 4 showed significant alteration in the contour of the electrocardiogram with disappearance of diagnostic evidence of old posterior infarction, associated with posture change. In the case in figure 2, the ventricular gradient occupied an abnormal position in the first sextant as expected in posterior wall infarction.39 In the sitting posture this shifted toward a more normal position in the sixth sextant with clockwise rotation; at the same time the diagnostic Q wave in the foot

### Table 3.—Changes in Ventricular Gradient in 5 Cases Which Showed Postural Alteration in the Electrocardiogram

<table>
<thead>
<tr>
<th>Posture</th>
<th>Fig. 2</th>
<th>Fig. 3</th>
<th>Fig. 4</th>
<th>Fig. 6</th>
<th>Fig. 7</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>G</td>
<td>Sitting</td>
<td>Left</td>
<td>G</td>
<td>Left</td>
</tr>
<tr>
<td>Magnitude</td>
<td>13.5</td>
<td>15.8</td>
<td>15.5</td>
<td>13.6</td>
<td>12.1</td>
</tr>
<tr>
<td>Direction</td>
<td>-15</td>
<td>4.5°</td>
<td>-20°</td>
<td>-35°</td>
<td>-15°</td>
</tr>
<tr>
<td>( \Delta QRS ) Magnitude</td>
<td>9.7</td>
<td>10.9</td>
<td>5.0</td>
<td>1.2</td>
<td>7.1</td>
</tr>
<tr>
<td>( \Delta QRS ) Direction</td>
<td>-16.5°</td>
<td>-13°</td>
<td>-13°</td>
<td>1.5°</td>
<td>65°</td>
</tr>
<tr>
<td>Angle Between G and ( \Delta QRS ) Positive: G to left of ( \Delta QRS )</td>
<td>1.5°</td>
<td>17.5°</td>
<td>-21.5°</td>
<td>-100°</td>
<td>-9°</td>
</tr>
<tr>
<td>( \Delta A ) Magnitude</td>
<td>3.8</td>
<td>6.6</td>
<td>11.1</td>
<td>14.0</td>
<td>5.3</td>
</tr>
<tr>
<td>( \Delta A ) Direction</td>
<td>-11.5°</td>
<td>36.5°</td>
<td>-76°</td>
<td>-39°</td>
<td>-28°</td>
</tr>
</tbody>
</table>

1 unit = 4 microvolt seconds.

with six precordial leads and unipolar limb leads is adequate for the diagnosis of anterior wall lesions. In contradistinction this type of survey is probably not adequate for the diagnosis of posterior infarcts in any or all postures. The recent work of Myers35 with posterior chest leads may correct this deficiency.

**The Ventricular Gradient**

In an attempt to correlate these changes with the ventricular gradient,36,37 the gradients were calculated for the cases illustrated in figures 2, 3, 4, 6, 7, using 4 microvolt seconds as a unit.38 In order to obtain greater accuracy in determination of the gradient, the complexes were projected and photographed at exactly 100 times magnification. The values obtained lead disappeared. Thus, the gradient reflected the changes which took place in the electrocardiogram.

In the case shown in figure 3, the gradient remained in its abnormal position in the sixth sextant although the angle between G and \( \Delta QRS \) and the diagnostic electrocardiographic changes became less marked in the lateral postures. Thus, when the heart became electrically vertical the aVF reflected nontransmural involvement with delayed repolarization of the posterior wall. In the supine posture the foot lead had reflected transmural infarction.

In the case illustrated in figure 4, the ventricular gradient decreased in magnitude while remaining in the same sextant although the heart had rotated electrically in the right lat-
eral posture. In this case, as in the case shown in figure 3, the diagnostic Q waves had disappeared although the gradient remained distinctly abnormal.

In the case shown in figure 6, the gradient lay in the fifth sextant as a result of the old anterior infarct. The angle between G and AQRS is abnormal. With electrical rotation, the angle between G and AQRS was reduced but the gradient shifted farther toward the third sextant. The electrocardiographic changes became more diagnostic of old infarction.

In the case shown in figure 7, the ventricular gradient changed only slightly in the left lateral posture, although the electrocardiogram became more positive with marked clockwise rotation.

In general it may be said that rotation of the area of infarction altered the projection of the vector forces upon the frontal plane and modified the gradient. However, Katz's contention appears to apply, namely, that the ventricular gradient derived from summated vectors may change only slightly while there is great change in the form of the QRS complexes.

SUMMARY

This work was undertaken in order to determine the effect of posture on the electrocardiograms of patients with healed myocardial infarction. The study confirmed the theoretic possibilities that the effects of the scarred area could be made (1) to disappear (2) if absent in the standard position, to appear in one or more postures (3) to shift from one exploratory lead to another.

In 100 cases showing evidence of an old myocardial infarction, significant changes in the electrocardiogram occurred with change in posture from the supine in 27. In 8 (6 posterior infarcts, 1 anterior, 1 combined) evidence of an old infarct disappeared in one or more of the other postures. In 14 (8 anterior, 5 posterior, 1 combined) evidence of an old infarct appeared in the shift from supine. The precordial leads showed significant movement of an old infarction laterally in 5 cases and medially in 2.

The ventricular gradient in 5 significant cases showed no constant correlation with electrocardiographic changes.

Electrocardiographic evidence of an old myocardial infarction may be greatly altered by postural changes in a significant number of instances. The twelve lead electrocardiogram is probably adequate in the diagnosis of anterior wall lesions. In old posterior infarcts posture change produced evidence of lesions which were otherwise not recognizable.

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