Thallium-201 myocardial scintigraphy in the left bundle branch block patient: the importance of left ventricular size

Jacqueline Celeste Hodge

Yale University

1986
THALLIUM-201 MYOCARDIAL SCINTIGRAPHY IN THE LEFT BUNDLE BRANCH BLOCK PATIENT: THE IMPORTANCE OF LEFT VENTRICULAR SIZE

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[Signature of author]

Jacqueline C. Hodge

(Printed name)

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(Date)
THALLIUM-201 MYOCARDIAL SCINTIGRAPHY IN THE
LEFT BUNDLE BRANCH BLOCK PATIENT:
THE IMPORTANCE OF LEFT VENTRICULAR SIZE

A Thesis Submitted to the Yale University School of Medicine
In Partial Fulfillment of the Requirements
for the Degree of Doctor of Medicine

by

Jacqueline Celeste Hodge
1986
To
Mother
and
Chandigarh
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THALLIUM-201 MYOCARDIAL SCINTIGRAPHY IN THE LEFT BUNDLE BRANCH BLOCK PATIENT: THE IMPORTANCE OF LEFT VENTRICULAR SIZE

Jacqueline Celeste Hodge

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The myocardial uptake of thallium-201 was compared between eighteen patients with electrocardiographic left bundle branch block (LBBB) and less than ten percent probability of coronary artery disease (CAD) and twenty-two normal patients (patients without CAD, without LBBB).

All patients exercised on treadmill and had thallium-201 scintigraphy in three views of the left ventricle (LV) -- left-anterior-oblique (LAO), left-lateral (LLAT), and anterior (ANT) -- were photographed at two time intervals, immediately post-exercise (stress images) and two to four hours post-exercise (delay images).

By both qualitative and quantitative analysis methods, the eighteen patients with LBBB could be divided into two groups: those with normal LV size (nine patients) and those with enlarged LV size (nine patients). Of those patients with normal LV size/LBBB, four out of nine (44%) had perfusion defects, with three of these four (75%) having small defects. Of those patients with enlarged LV size/LBBB, seven out of nine (78%) had perfusion defects, with five of the seven (71%) having large defects.
In comparing the lower-limit thallium-201 profiles of the three patient populations, statistically significant differences were found between: 1) patients with LBBB/enlarged LV and the normal patients in all three views, 2) patients with LBBB/normal sized LV and the normal patients in the ANT view, and 3) the two subpopulations of LBBB patients in the LLAT view.

Comparing these three sets of thallium-201 profiles on a segmental basis, statistically significant differences were found between all three populations, primarily in the region of the interventricular septum and/or anterior wall.

These results indicate that not only may positive thallium-201 scintigrams occur in patients with LBBB in the absence of CAD, but that positive scans tend to occur more often in patients with LBBB/enlarged LV than in patients with LBBB/normal sized LV, and that defects in the former group tend to be larger than defects in the latter group. Thus, LV size may be important in the analysis of a positive thallium-201 scintigram in patients with LBBB. A positive scintigram in patients with LBBB/normal sized LV is more suggestive of CAD than a similar scintigram in patients with LBBB/enlarged LV. Furthermore, a large defect in patients with LBBB/normal sized LV should raise a high index of suspicion for CAD, whereas in patients with LBBB/enlarged LV, a large defect is more likely to be due solely to LBBB.
INTRODUCTION

Several noninvasive myocardial imaging studies (4,6,9) performed in patients with electrocardiographic left bundle branch block indicate that these patients often have decreased radionuclide activity in the region of the interventricular septum in the absence of coronary artery disease. This pattern resembles that seen in patients with anteroseptal myocardial infarctions.

Other investigators (3,10) have argued that the abnormalities on thallium-201 studies in left bundle branch block patients are not false positives. They feel that these abnormalities usually are due to co-existing coronary artery disease. Furthermore, they believe that left bundle branch block alone will not cause abnormalities on thallium-201 scintigrams.

This controversy raises two questions. First, do some patients with lone left bundle branch block have falsely positive thallium-201 myocardial perfusion scintigrams? Secondly, if the thallium-201 scintigrams are falsely positive, how is the diagnosis of coronary artery disease established in the patient with left bundle branch block?

These contradicting reports in the literature are probably due to the method of analyzing thallium-201 studies. Previously, thallium-201 myocardial images were visually assessed. Today, however, this subjective method has been replaced by a more objective way of interpreting thallium-201 studies: quantitative analysis. As Berger et al (2) point out, quantitative analysis of thallium-201 studies is highly sensitive and specific for coronary artery disease. They found that whereas qualitative analysis of thallium-201 studies had an 85% sensitivity and 73% specificity for coronary artery disease,
quantitative analysis of thallium-201 studies had a 94% sensitivity and 90% specificity. Furthermore, quantitative analysis was far superior to qualitative analysis in predicting the presence of multi-vessel disease, 78% and 39% respectively.

This retrospective study comparing eighteen patients with left bundle branch block and either low likelihood of coronary artery disease or insignificant coronary artery disease to twenty-two normal patients with normal electrocardiogram tracing and low likelihood of coronary artery disease, addresses these two questions.
MATERIALS AND METHODS

Patient Population

The initial study population consisted of forty patients identified by computer search. These patients met the following criteria: 1) had undergone exercise thallium-201 myocardial perfusion scintigraphy between January 1982 and December 1985 at Yale-New Haven Hospital in New Haven, Connecticut, Crawford Long Hospital in Atlanta, Georgia, or Medical Center Hospital in Burlington, Vermont, and 2) had left bundle branch block on baseline electrocardiogram. Patients who, in addition, had either normal coronary arteries on angiography or low pre-test likelihood of coronary artery disease were selected for the final study population.

The normal population, also identified by computer search, consisted of twenty-two patients. These patients, similarly having undergone exercise thallium-201 scintigraphy, satisfied the following criteria: 1) had no symptoms of coronary artery disease, engaging in the stress test only as a routine part of an insurance physical, 2) had both normal baseline and stress electrocardiograms, and 3) had, on the basis of criteria 1 and 2, a low pre-test likelihood of coronary artery disease. (These patients all had pre-test likelihoods between one and three percent.)

The initial study population consisted of twenty-five males and fifteen females, ages 32 to 71 years. Their clinical characteristics, angiography findings, and pre-test likelihood of coronary artery disease are listed in Table 1.

The normal population consisted of ten males and twelve females, ages 30 to 45 years.
Treadmill Exercise and Imaging Procedure

Patients were first connected to a twelve-lead electrocardiogram machine and then exercised on treadmill according to the multi-stage Bruce protocol. During the stress test, their cardiac status was monitored by frequent electrocardiogram readings. Patients discontinued exercising when they became fatigued or when they developed chest pain, hypotension, or ventricular arrhythmia.

At maximal exercise, 2 mCi of thallium-201 was administered intravenously and patients were asked to continue exercising for at least 60 additional seconds.

Immediately post-exercise, stress myocardial images were taken using a single crystal gamma camera (Siemens or Technicare). These images were taken in three planes: left-anterior-oblique, left-lateral, and anterior. Each image was acquired over a period of eight minutes, and between 500,000 and 600,000 counts were accumulated in the full field of view. Images were acquired in either 64x64 or 128x128 matrix and were stored on floppy disks. (Studies acquired in 128x128 matrix were converted into 64x64 matrix and then stored on new floppy disks.)

Two to four hours post-exercise, delayed myocardial images were obtained in each of the three planes in a similar manner.

Computer Processing and Quantitative Analysis

Images were processed and analyzed according to the computer algorithm described by Wackers et al (14).

In brief, after smoothing of the myocardial image, an elliptical reference region was drawn around both ventricles, and subsequently interpolative background correction was applied to the cardiac image.
By segmental mapping, the left ventricle was divided into 36 segments, each of 10 degree angles. Within each segment, average thallium-201 activity was assessed and displayed as a distribution profile.

The distribution profile for each patient was simultaneously displayed with the lower-limit-of-normal (mean minus two standard deviations) for the group of normal patients.

Similarly, the washout profile for each patient was simultaneously displayed with that for the group of normals.

A study was defined as normal if, on both the distribution and washout profiles, the patient's circumferential profile was greater than or equal to the established lower-limit-of-normal for the corresponding segments.

Coronary Angiography

Selective coronary angiography was performed within six months of thallium-201 testing. Angiograms were interpreted by two independent observers, each unaware of the findings on thallium-201 scintigrams.

Coronary artery stenosis was graded according to the most severe narrowing of the lumen. A coronary vessel was defined as normal if there was less than 50% narrowing of the diameter of the lumen. Patients with 50% or greater stenosis of a vessel were defined as having significant coronary artery disease.

Pre-test Likelihood of Coronary Artery Disease

Stepwise probability analysis was used to determine the pre-test likelihood of coronary artery disease. Based on patient age, sex, and
symptoms, a pre-test likelihood value was determined according to tables published by Diamond and Forrester (5) (Table 2).

Patient symptoms were grouped into four categories: typical angina, atypical angina, non-anginal chest pain, and asymptomatic. A patient was defined as having typical angina if he had substernal discomfort that was precipitated by physical exertion and if his symptoms were relieved by resting or by taking nitroglycerin. A patient was defined as having atypical angina if he had discomfort other than substernal, discomfort that was not precipitated by exertion, or discomfort that was not relieved by resting or nitroglycerin. If two or more of the above three characteristics were absent, the patient was defined as having non-anginal chest pain. An asymptomatic patient was defined as one who had no discomfort above the level of the diaphragm.

For the purpose of this study, a patient with left bundle branch block and a pre-test likelihood value of less than 10% was considered to have a low likelihood of coronary artery disease.

Statistical Analysis

The chi-square test was used to compare the difference in incidence of defects on thallium-201 scintigrams between two subpopulations of patients with left bundle branch block. A p value of less than 0.05 was considered significant.

The t-test was used to compare the differences between: 1) the lower-limit of thallium-201 profiles for all three patient populations, and 2) the lower-limit of thallium-201 profiles on a segmental basis for all three patient populations. Similarly, a p value of less than 0.05 was considered significant.
RESULTS

Final Study Population

The final study population consisted of eighteen patients with electrocardiographic left bundle branch block: eight patients with normal coronary arteries and ten patients with a low pre-test likelihood of coronary artery disease.

Among those 22 patients not selected to be a part of the final study population, five were excluded because they had a significant amount of coronary artery disease, nine were excluded because they had more than a 10% pre-test likelihood of coronary artery disease, and six were excluded because of insufficient clinical data. In addition, two patients were excluded because the floppy disks containing their studies were unavailable.

Interpretation of Scintigrams

Normal Limits

The thallium-201 scintigrams of the twenty-two normal patients with less than 3% likelihood of coronary artery disease were reviewed and defined as normal studies. Based on their distribution profiles, three normal data bases were generated by computer processing. Assuming a Gaussian distribution the lower-limit-of-normal range was defined as "mean minus two standard deviations." Each normal data base defined the lower-limit of normal for thallium-201 distribution in a given plane i.e. left-anterior-oblique, left-lateral, anterior.
Abnormal Image

An abnormal image was defined as one in which the patient's thallium-201 distribution profile was less than the lower-limit-of-normal profile in more than 5 adjacent 10\degree segments.

Patients with Left Bundle Branch Block

On quantitative analysis of the thallium-201 scintigrams, 11 of the 18 patients with left bundle branch block were found to have defects i.e. the distribution of thallium-201 was below the lower-limit-of-normal. Ten of these defects were localized to the interventricular septum and/or anterior portion of the left ventricle. One patient had an apical defect.

Size of Left Ventricle

Based on visual analysis of the analog images, there appeared to be differences in left ventricle size: nine patients had normal sized left ventricles and nine patients had enlarged left ventricles (Figures 1 and 2).

Quantitative Assessment of Left Ventricle Size

The size of the left ventricle in patients with left bundle branch block was determined by calculating the number of pixels in a selected region of interest of the left-anterior-oblique stress image. (The number of pixels in a region is proportional to the size of the region.) However, since not all patient studies were acquired with the same camera or at the same magnification, it was necessary to correct for the difference in lens field size.

To determine the lens field size for the left-anterior-oblique stress images, the number of pixels was computed along both the x-axis and the y-axis. The actual number of pixels was then multiplied or divided by the appropriate correction factor to determine the corrected number of pixels (Table 4).
Pixel counts for the eighteen patients ranged from 176 to 398. For those patients with apparently normal sized left ventricles on analog image displays, pixel counts ranged from 176 to 280, mean = 233 ± 35. For those patients with apparently enlarged left ventricles, pixel counts ranged from 294 to 398, mean = 388 ± 27.

Of the patients with normal sized left ventricles, 3 had normal coronary arteries and 6 had a low likelihood of coronary artery disease. Among the patients with enlarged left ventricles, 5 had normal coronary arteries and 4 had a low probability of coronary artery disease.

Re-evaluating the thallium-201 studies with respect to left ventricle size, 4 of the 9 patients with left bundle branch block/normal sized left ventricles and 7 of the 9 patients with left bundle branch block/enlarged left ventricles had defects. In patients with left bundle branch block/normal sized left ventricles, 3 of the defects were small and 1 was large. In patients with left bundle branch block/enlarged left ventricles, 2 of the defects were small and 5 were large.

In comparing the patients with left bundle branch block to the normal patients, there was a significant difference (p < .001) in the occurrence of defects on thallium-201 studies. Whereas 11 of the 18 patients with left bundle branch block had defects on visual assessment of thallium-201, by definition, none of the normal patients had defects.

Comparing the two subpopulations of patients with left bundle branch block, there was no significant difference between: 1) those patient with any defect and those patients without defects (p = .70), or 2) those patients with large defects and those patients without defects (.20 ≤ p ≤ .30), or 3) those
patients with small defects and those patients without defects ($0.95 \leq p \leq 0.99$), or 4) those patients with large defects and those patients with small defects ($0.50 \leq p \leq 0.70$).

Distribution Profiles

For each subpopulation of left bundle branch block patients, those with normal sized left ventricles and those with enlarged left ventricles, three sets of thallium-201 distribution profiles, representing the mean minus two standard deviations, were generated (Figures 3 and 4). These profiles depict the lower-limit of thallium-201 distribution for each subpopulation in a given plane.

Three graphs were constructed summarizing the thallium-201 distribution profiles for the three patient populations i.e. those patients with left bundle branch block/normal sized left ventricles, those with left bundle branch block/enlarged left ventricles, and the normal patients. Each graph contained the three thallium-201 distribution profiles -- one for each patient population -- corresponding to a given image plan (Figure 5).

Visual Comparison of Lower-Limit Profiles

In the left-anterior-oblique view, visual assessment of the thallium-201 lower-limit distribution profiles showed an obvious difference in the thallium-201 uptake among the three patient populations. This difference was most appreciated in the septal region ($0^0-240^0$). In the region of the lateral wall ($240^0-360^0$) there was little difference between the three patient populations.

As expected, the normal population had an overall greater thallium-201 uptake than did those patients with left bundle branch block/enlarged left
ventricle. In the septal region, the normal population had greater thallium-201 uptake than patients with left bundle branch block/normal sized left ventricles. However, in the lateral wall segments, the situation was reversed. Thus, the overall thallium-201 uptake was not greatly different between these two populations.

There appeared to be a difference between thallium-201 uptake in left bundle branch block patients based on left ventricle size. Whereas patients with left bundle branch block/normal sized left ventricles had an overall thallium-201 distribution profile closely resembling the profile of the normal population, patients with left bundle branch block/enlarged left ventricles had markedly less thallium-201 uptake than either the normal population or the group of patients with left bundle branch block/normal sized left ventricles.

Similarly, in the left-lateral view there was a marked difference in the thallium-201 distribution profiles of the three groups in the anterior wall segments (0°-240°). There was no difference among the three groups in the inferior and posterolateral segments.

In the anterior wall segments, thallium-201 uptake was greatest in the normal patients and least in patients with left bundle branch block/enlarged left ventricles. There was an appreciable difference in thallium-201 uptake between the normal population and patients with left bundle branch block/normal sized left ventricles. However, this difference was less than the difference between the two subpopulations of left bundle branch block patients.

In the anterior view, the thallium-201 distribution profiles of the three populations exhibited greater differences in the inferior and apical segments (0°-240°) and little difference in the anterolateral and anterobasal segments (240°-360°).
In the inferior and apical segments, the thallium-201 uptake was greatest in the normal population. The thallium-201 distribution profiles were similar for both subpopulations of left bundle branch block patients.

Statistical Analysis on a Segmental Basis

For each of the forty patient studies, fifteen values were computed; twelve values representing the average thallium-201 uptake in each quadrant of the three planes, and three values representing the average thallium-201 uptake for each plane (Table 5). All values were entered into the Kaypro-16 computer system. The t-test was used to assess the differences in: 1) average thallium-201 uptake in each quadrant between the three populations and, 2) average thallium-201 uptake in each plane between the three populations.

The quadrants were determined according to the axis along which the valve plane ran. In the left-anterior-oblique view the valve plane bisected the image along the 0°-180° axis. The four quadrants were selected as: quadrant 1 - 0°-90°, quadrant 2 - 90°-180°, quadrant 3 - 180°-270°, and quadrant 4 - 270°-0°. In the left-lateral view, the valve plane bisected the image along the 315°-135° axis. The quadrants were defined as follows: quadrant 1 - 45°-135°, quadrant 2 - 135°-225°, quadrant 3 - 225°-315°, and quadrant 4 - 315°-45°. In the anterior view the valve plane bisected the image along the 45°-225° axis. Since this is perpendicular to the valve plane for the left-lateral view, the quadrants for the anterior view were defined as those for the left-lateral view (Figure 6).
The average thallium-201 uptake for each quadrant was computed by estimating the value of each of the nine points within the quadrant and taking the average. In determining the average thallium-201 uptake, the stress thallium-201 counts were used.

The average thallium-201 uptake for each view was computed by summing the average thallium-201 uptake in each of the four quadrants and dividing by four.

In comparing the overall lower-limit of thallium-201 profiles, significant differences in thallium-201 uptake were found:

1) In the left-anterior view between those patients with left bundle branch block/enlarged left ventricle and the normal patients;

2) In the left-lateral view between those patients with left bundle branch block/enlarged left ventricle and the normal patients, and between the two subpopulations of patients with left bundle branch block, and;

3) In the anterior view between those patients with left bundle branch block/normal sized left ventricle and the normal patients, and between those patients with left-bundle branch block/enlarged left ventricle and the normal patients.

On a segmental basis, statistically significant differences in the thallium-201 uptake were found:

I. In the left-anterior-oblique view between:

A. Those patients with left bundle branch block/normal sized left ventricle and the normal patients in the interventricular septal and inferolateral segments (quadrants 1, 2, and 3);

B. Those patients with left bundle branch block/enlarged left ventricle and the normal patients in the region of the interventricular septum (quadrants 1, 2, and 3);
C. The two subpopulations of left bundle branch block patients in the apical septal and inferolateral segments (quadrants 2 and 3).

II. In the left-lateral view between:

A. Those patients with left bundle branch block/normal sized left ventricle and the normal patients in the anterobasal segment (quadrant 1);

B. Those patients with left bundle branch block/enlarged left ventricle and the normal patients in the anterobasal and posterobasal segments (quadrants 1 and 4, and);

C. The two subpopulations of left bundle branch block patients in the anterior and apical segments (quadrants 1 and 2).

III. In the anterior view between:

A. Those patients with left bundle branch block/normal sized left ventricle and the normal patients in the anterobasal, anterolateral, apical and inferior segments (quadrants 1, 3, and 4, and);

B. Those patients with left bundle branch block/enlarged left ventricle and the normal patients in the anterobasal, anterolateral, apical, and inferior segments (quadrants 1, 3, and 4) (Figures 7 and 8).

Refer to Table 6 for a listing of the probability values of the one-tailed t-test.
DISCUSSION

In summary, this quantitative study indicates that patients with left bundle branch block can indeed have abnormal thallium-201 myocardial perfusion scintigrams in the absence of coronary artery disease. In eleven of eighteen patients with left bundle branch block, decreased thallium-201 uptake was detected on scintigram, compared to a lower-limit-of-normal derived from twenty-two normal patients. Statistical analysis demonstrated a significant difference ($p < .001$) between these two patient groups.

Furthermore, both qualitative and quantitative methods indicate that when abnormalities on thallium-201 studies do occur in patients with left bundle branch block, they tend to be localized to the interventricular septum and/or anterior wall.

On visual analysis of the scintigrams, ten of the eleven patients (91%) had abnormalities localized to these regions. Only one patient had an apical defect.

By quantitative analysis, both subpopulations of patients with left bundle branch block consistently differed from the normal population in these two regions.

Thus, it appears that in patients with left bundle branch block, left ventricle size is not a factor in determining the anatomical location of the defect. Regardless of left ventricle size, defects in these patients remain localized to the septum and/or anterior wall.

Left ventricle size does appear to be important however, in determining the size of the defect and the frequency with which defects occur. On quantitative comparison of the patients with left bundle branch block, those
patients with enlarged left ventricles had significantly different thallium-201 uptake from those patients with normal sized left ventricles. These differences occurred in the septal, anterior, and apical segments.

Although on quantitative comparison of these two groups there was no significant difference in the occurrence of abnormal thallium-201 scintigrams between left bundle branch block patients with normal sized left ventricles and those with enlarged left ventricles, the data suggests the following: 1) defects are more likely to occur in left bundle branch block patients with enlarged left ventricles than in those with normal sized left ventricles and, 2) when defects do occur in patients with left bundle branch block, they tend to be large in patients with enlarged left ventricles and small in patients with normal sized left ventricles.

It is reasonable to assume that the difference between these two subgroups of left bundle branch block patients would approach statistical significance, given a larger study population. However, it is difficult to obtain a large study population because the left bundle branch block patient with insignificant or low probability of coronary artery disease is rare.

Concluding that patients with left bundle branch block may have falsely positive thallium-201 studies poses a dilemma in establishing the diagnosis of coronary artery disease in these patients. As Wackers pointed out, findings on electrocardiogram are of limited value in diagnosing coronary artery disease in these patients (11). Although the presence of Cabrera's sign, Chapman's sign, or initial notching of the QS complex on electrocardiogram are considered to be diagnostic of acute myocardial infarction in patients with left bundle branch block, Wackers found that these criteria lacked sensitivity and predictive value. Furthermore, he found that these criteria were subject to considerable interobserver variability.
Few studies have addressed this problem, primarily due to the controversy existing around falsely positive scans in patients with left bundle branch block. For example, Wackers et al (17) found that of 32 patients with left bundle branch block and no evidence of myocardial infarction, all had normal resting thallium-201 scintigrams. Hence, they (16) concluded that thallium-201 scintigraphy was adequate in diagnosing coronary artery disease in patients with left bundle branch block. McGowan et al (9) in examining twenty-seven patients using potassium-43 and rubidium-81 concluded that left bundle branch block could produce falsely positive thallium-201 scintigrams. Several other investigators reported occasional nondiagnostic thallium-201 scintigrams in patients with left bundle branch block (6).

These disparities can be explained by: 1) different imaging agents, 2) different methods of interpreting thallium-201 scintigrams, and 3) differences in equipment.

Although the majority of studies in the literature examining patients with left bundle branch block involve the use of thallium-201, there have been studies (McGowan et al) using other isotopes. Discrepancy between studies may be due to differences in isotope distribution and to different abilities of the isotopes to contrast normal and abnormal regions.

Probably the most important cause of disparity between earlier studies and more recent studies is the use of quantitative methods to interpret thallium-201 scintigrams today. Previous visual interpretation of thallium-201 scintigrams was subject to interobserver variability. Several investigators (2,8,14) have commented on the increased accuracy and reproducibility of results in using a quantitative method for analysis of thallium-201 scintigrams.
Newer up-to-date equipment has improved the quality of thallium-201 images. Thus, more accurate results have been obtained.

Why defects on thallium-201 scintigrams occur in patients with lone left bundle branch block is unknown. Some investigators (6,15) have commented on possible etiologies.

Hirzel et al (6), in carrying out thallium-201 scintigrams and regional blood flow measurements in 7 dogs during right atrial and right ventricle pacing, found that all 7 dogs had normal thallium-201 activity in the septal region in response to right atrial pacing, but that 6 of the 7 dogs had decreased thallium-201 activity in the septal region in response to right ventricle pacing (artificially induced left bundle branch block). They concluded that septal defects in patients with left bundle branch block do not necessarily suggest coronary artery disease. Furthermore, they proposed that impaired septal blood flow in left bundle branch block may be due to prolonged compression of the septal arteries that occurs as a consequence of asynchronous septal contraction.

Wackers et al (15) commented on the presence of clinical and subclinical cardiomyopathy in symptomatic and asymptomatic patients with left bundle branch block, respectively. On assessing left ventricular function in 26 asymptomatic patients with left bundle branch block, they found that 9 had abnormal (< 50%) resting left ventricular ejection fraction, 19 had abnormal exercise left ventricular ejection fraction, and 4 had normal resting and exercise left ventricular ejection fraction. This suggested that left ventricular dysfunction is not due to abnormal conduction i.e. left ventricular dysfunction is a distinct entity that may occur in patients with left bundle branch block. This raises the question as to whether left
ventricular dysfunction could be responsible for defects on thallium-201 scintigraphy in patients with left bundle branch block.

Clinical Implications

1. A positive thallium-201 scan in a symptomatic patient with left bundle branch block does not necessarily indicate the presence of coronary artery disease. However, in these patients a septal and/or anterior wall defect is more likely to be due to left bundle branch block than defects in other regions. Conversely, defects in regions other than the septum and anterior wall are more likely to be due to coronary artery disease.

2. Thallium-201 scintigrams may be helpful in evaluating patients with left bundle branch block for coronary artery disease. Both thallium-201 distribution profiles and left ventricle size must be available.

3. Because it appears that defects on thallium-201 studies occur less often in patients with left bundle branch block/normal sized left ventricle than in patients with left bundle branch block/enlarged left ventricle, a defect in the former group should arouse a higher index of suspicion for coronary artery disease than a similar defect in the latter group.

4. Because it appears that large defects on thallium-201 studies rarely occur in patients with left bundle branch block/normal sized left ventricle, a large defect on thallium-201 studies in these patients should raise a high index of suspicion for coronary artery disease.

5. This study provided data to establish the lower-limit-of-normal thallium-201 distribution in patients with left bundle branch block with normal sized left ventricle and enlarged left ventricles. Their profiles could be used prospectively in patients with left bundle branch block suspected of having coronary artery disease.
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<tr>
<td>*P.F.</td>
<td>35</td>
<td>M</td>
<td>S/P MI, typical chest pain</td>
<td>100</td>
</tr>
<tr>
<td>T.S.</td>
<td>64</td>
<td>M</td>
<td>asymptomatic</td>
<td>6.9</td>
</tr>
<tr>
<td>*T.I.</td>
<td>54</td>
<td>M</td>
<td>typical angina</td>
<td>95% LAD</td>
</tr>
<tr>
<td>*W.M.</td>
<td>61</td>
<td>M</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>*Y.H.</td>
<td>63</td>
<td>M</td>
<td>typical angina</td>
<td>93.8</td>
</tr>
<tr>
<td>B.M.</td>
<td>46</td>
<td>M</td>
<td>asymptomatic</td>
<td>5.1</td>
</tr>
<tr>
<td>*B.B.</td>
<td>--</td>
<td>M</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>B.C.</td>
<td>--</td>
<td>M</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>D.J.</td>
<td>--</td>
<td>M</td>
<td>S/P CABG X3-</td>
<td>17.3</td>
</tr>
<tr>
<td>*L.P.</td>
<td>60</td>
<td>F</td>
<td>atypical chest pain</td>
<td>17.3</td>
</tr>
<tr>
<td>*L.H.</td>
<td>--</td>
<td>M</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>M.M.</td>
<td>41</td>
<td>M</td>
<td>asymptomatic</td>
<td>5.1</td>
</tr>
<tr>
<td>M.E.</td>
<td>--</td>
<td>M</td>
<td>--</td>
<td>insignificant CAD</td>
</tr>
<tr>
<td>*P.M.</td>
<td>--</td>
<td>F</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>*P.M.</td>
<td>55</td>
<td>M</td>
<td>--</td>
<td>significant CAD of circumflex</td>
</tr>
<tr>
<td>S.F.</td>
<td>--</td>
<td>M</td>
<td>--</td>
<td>100</td>
</tr>
<tr>
<td>V.R.L.</td>
<td>32</td>
<td>M</td>
<td>asymptomatic</td>
<td>50% circumflex, 30% RCA</td>
</tr>
<tr>
<td>W.F.</td>
<td>--</td>
<td>F</td>
<td>--</td>
<td>1.7</td>
</tr>
<tr>
<td>*A.C.</td>
<td>65</td>
<td>M</td>
<td>--</td>
<td>90% PDA</td>
</tr>
<tr>
<td>B.B.</td>
<td>68</td>
<td>F</td>
<td>--</td>
<td>100</td>
</tr>
<tr>
<td>*B.D.</td>
<td>62</td>
<td>M</td>
<td>--</td>
<td>28</td>
</tr>
<tr>
<td>B.R.</td>
<td>51</td>
<td>M</td>
<td>typical angina</td>
<td>100</td>
</tr>
<tr>
<td>*C.E.</td>
<td>51</td>
<td>F</td>
<td>--</td>
<td>insignificant CAD</td>
</tr>
<tr>
<td>*E.J.</td>
<td>68</td>
<td>M</td>
<td>--</td>
<td>0</td>
</tr>
<tr>
<td>*G.A.</td>
<td>71</td>
<td>F</td>
<td>--</td>
<td>60.9±84.5</td>
</tr>
<tr>
<td>K.Ha.</td>
<td>59</td>
<td>M</td>
<td>chest pain</td>
<td>&lt;10</td>
</tr>
<tr>
<td>P.E.</td>
<td>51</td>
<td>F</td>
<td>atypical chest pain</td>
<td>3</td>
</tr>
<tr>
<td>*P.C.</td>
<td>52</td>
<td>F</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>*P.R.</td>
<td>49</td>
<td>M</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>S.M.</td>
<td>48</td>
<td>F</td>
<td>--</td>
<td>&lt;10</td>
</tr>
<tr>
<td>*S.H.</td>
<td>60</td>
<td>F</td>
<td>chest pain</td>
<td>80</td>
</tr>
<tr>
<td>S.L.</td>
<td>54</td>
<td>F</td>
<td>chest pain</td>
<td>&lt;10</td>
</tr>
</tbody>
</table>

*Indicates that patient was excluded from the final study population

NCA = normal coronary arteries, CAD = coronary artery disease, LAD = left anterior descending artery, RCA = right coronary artery, PDA = posterior descending artery, CABG = coronary artery bypass graft, -- = data not available

Table 1
Clinical Data, Angiography Findings, and Pre-test Likelihood of Coronary Artery Disease for Initial Study Population
Table 2

Pre-test Likelihood of Coronary Artery disease

<table>
<thead>
<tr>
<th>Age</th>
<th>Asymptomatic</th>
<th>Non-anginal Chest pain</th>
<th>Atypical Angina</th>
<th>Typical Angina</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Men</td>
<td>Women</td>
<td>Men</td>
<td>Women</td>
</tr>
<tr>
<td>30-39</td>
<td>1.7±0.6</td>
<td>0.3±0.1</td>
<td>4.8±1.6</td>
<td>0.7±0.4</td>
</tr>
<tr>
<td>40-49</td>
<td>5.1±1.5</td>
<td>0.9±0.3</td>
<td>13.1±3.7</td>
<td>2.6±1.0</td>
</tr>
<tr>
<td>50-59</td>
<td>9.0±2.5</td>
<td>2.9±0.9</td>
<td>20.1±5.1</td>
<td>7.8±2.4</td>
</tr>
<tr>
<td>60-69</td>
<td>11.4±3.1</td>
<td>6.9±2.0</td>
<td>26.4±6.2</td>
<td>17.3±4.7</td>
</tr>
</tbody>
</table>
Table 3A

Visual Assessment of Thallium-201 Scintigrams
For Patients with Left Bundle Branch Block

<table>
<thead>
<tr>
<th>Perfusion Defect</th>
<th>Patients with LBBB-normal sized LV</th>
<th>Patients with LBBB-enlarged LV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large</td>
<td>1/9 (11%)</td>
<td>5/9 (56%)</td>
</tr>
<tr>
<td>Small</td>
<td>3/9 (33%)</td>
<td>2/9 (22%)</td>
</tr>
<tr>
<td>None</td>
<td>5/9 (56%)</td>
<td>2/9 (22%)</td>
</tr>
</tbody>
</table>
### Table 3B

Anatomical Location of Myocardial Perfusion Defects on Thallium-201 Scintigraphy in Patients with Left Bundle Branch Block

#### Patients With Normal sized LV/LBBB:

<table>
<thead>
<tr>
<th>Patient</th>
<th>Perfusion Defect</th>
</tr>
</thead>
<tbody>
<tr>
<td>S.L.</td>
<td>--</td>
</tr>
<tr>
<td>P.E.</td>
<td>--</td>
</tr>
<tr>
<td>J.B.</td>
<td>small septal/anterior wall</td>
</tr>
<tr>
<td>T.S.</td>
<td>--</td>
</tr>
<tr>
<td>S.F.</td>
<td>small septal/anterior wall</td>
</tr>
<tr>
<td>M.E.</td>
<td>--</td>
</tr>
<tr>
<td>B.M.</td>
<td>--</td>
</tr>
<tr>
<td>M.M.</td>
<td>large anterior wall</td>
</tr>
<tr>
<td>V.R.L.</td>
<td>small anterior wall</td>
</tr>
</tbody>
</table>

#### Patients with Enlarged LV/LBBB:

<table>
<thead>
<tr>
<th>Patient</th>
<th>Perfusion Defect</th>
</tr>
</thead>
<tbody>
<tr>
<td>S.M.</td>
<td>--</td>
</tr>
<tr>
<td>B.R.</td>
<td>large inferior septal</td>
</tr>
<tr>
<td>K.H.</td>
<td>large inferior septal</td>
</tr>
<tr>
<td>K.Ha.</td>
<td>--</td>
</tr>
<tr>
<td>D.J.</td>
<td>small low septal</td>
</tr>
<tr>
<td>W.F.</td>
<td>large low anterior wall</td>
</tr>
<tr>
<td>B.C.</td>
<td>large anterior wall/anterior septal</td>
</tr>
<tr>
<td>B.B.</td>
<td>small apical</td>
</tr>
<tr>
<td>J.R.</td>
<td>large anteroseptal</td>
</tr>
<tr>
<td>Patient</td>
<td>Actual # of pixels</td>
</tr>
<tr>
<td>---------</td>
<td>--------------------</td>
</tr>
<tr>
<td>S.L.</td>
<td>194</td>
</tr>
<tr>
<td>P.E.</td>
<td>199</td>
</tr>
<tr>
<td>J.B.</td>
<td>488</td>
</tr>
<tr>
<td>T.S.</td>
<td>894</td>
</tr>
<tr>
<td>S.F.</td>
<td>256</td>
</tr>
<tr>
<td>M.E.</td>
<td>246</td>
</tr>
<tr>
<td>B.M.</td>
<td>249</td>
</tr>
<tr>
<td>M.M.</td>
<td>277</td>
</tr>
<tr>
<td>V.R.L.</td>
<td>280</td>
</tr>
<tr>
<td>S.M.</td>
<td>338</td>
</tr>
<tr>
<td>B.R.</td>
<td>398</td>
</tr>
<tr>
<td>K.H.</td>
<td>415</td>
</tr>
<tr>
<td>K.Ha.</td>
<td>981</td>
</tr>
<tr>
<td>D.J.</td>
<td>334</td>
</tr>
<tr>
<td>W.F.</td>
<td>328</td>
</tr>
<tr>
<td>B.C.</td>
<td>329</td>
</tr>
<tr>
<td>B.B.</td>
<td>319</td>
</tr>
<tr>
<td>J.R.</td>
<td>1392</td>
</tr>
</tbody>
</table>

<sup>1</sup> corrected # of pixels = actual # of pixels divided by 4, then multiplied by 6/5

<sup>2</sup> corrected # of pixels = actual # of pixels divided by 4

<sup>3</sup> corrected # of pixels = actual # of pixels multiplied by 6/7
Table 6
P Values for One-tailed t-test
Comparing the Average Thallium-201 Uptake

<table>
<thead>
<tr>
<th>Patient Populations</th>
<th>LAO View</th>
<th></th>
<th></th>
<th></th>
<th>LLAT View</th>
<th></th>
<th></th>
<th>ANT View</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Q1</td>
<td>Q2</td>
<td>Q3</td>
<td>Q4</td>
<td>LAO</td>
<td>Q1</td>
<td>Q2</td>
<td>Q3</td>
<td>Q4</td>
</tr>
<tr>
<td>L vs N</td>
<td>0.030</td>
<td>0.001</td>
<td>0.008</td>
<td>0.440</td>
<td>0.09</td>
<td>0.001</td>
<td>0.292</td>
<td>0.092</td>
<td>0.270</td>
</tr>
<tr>
<td>E vs N</td>
<td>0.006</td>
<td>0.000</td>
<td>0.273</td>
<td>0.272</td>
<td>0.099</td>
<td>0.000</td>
<td>0.098</td>
<td>0.268</td>
<td>0.033</td>
</tr>
<tr>
<td>L vs E</td>
<td>0.254</td>
<td>0.028</td>
<td>0.038</td>
<td>0.287</td>
<td>0.161</td>
<td>0.039</td>
<td>0.047</td>
<td>0.310</td>
<td>0.166</td>
</tr>
</tbody>
</table>
**FIGURE 1.**, ., S., 02/17/84

TOT CT = 532886    CELL CT: MAX = 532    MIN = 0    AV = 130    LAO

LT = 0.5
UT = 100.5
DUAL BUF

COMMAND: _
COMMAND: LAO 1
COMMAND: LAO 3

8 MIN 0 SEC

**FIGURE 1.**, ., S., 02/17/84

TOT CT = 605183    CELL CT: MAX = 879    MIN = 0    AV = 147    LT LAT

LT = 0.5
UT = 100.5
DUAL BUF

COMMAND: _
COMMAND: LAO 1
COMMAND: LAT STRESS
COMMAND: LAT DEL

8 MIN 0 SEC

**FIGURE 1.**, ., S., 02/17/84

TOT CT = 561202    CELL CT: MAX = 629    MIN = 0    AV = 137    ANT

LT = 0.5
UT = 100.5
DUAL BUF

COMMAND: _
COMMAND: ANT STRESS
COMMAND: ANT DELAYED

8 MIN 0 SEC
FIGURE 4A  -STRESS  
MYOCARDIAL PERFUSION ANALYSIS

**LAO**

- INITIAL  □ DELAYED  — MINIMUM LIMIT OF UPTAKE (N= 9)

FIGURE 4B  -STRESS  
MYOCARDIAL PERFUSION ANALYSIS

**LLAT**

- INITIAL  □ DELAYED  — MINIMUM LIMIT OF UPTAKE (N= 9)

FIGURE 4C  -STRESS  
MYOCARDIAL PERFUSION ANALYSIS

**ANT**

- INITIAL  □ DELAYED  — MINIMUM LIMIT OF UPTAKE (N= 9)
Figure 5
Thallium-201 Distribution Profiles for 3 Patient Populations

--- = Group of Normal Patients
.... = Group of Patients with LBBB/Normal sized LV
--- = Group of Patients with LBBB/Enlarged LV
Figure 6

Definition of Quadrants for 3 Imaging Planes

LEFT ANTERIOR OBLIQUE

LE F T LATERAL

ANTERIOR
Results of Statistical Analysis on Segmental Basis

**LEFT ANTERIOR OBLIQUE**

A. ![Diagram A](image)
B. ![Diagram B](image)
C. ![Diagram C](image)

**LEFT LATERAL**

A. ![Diagram A](image)
B. ![Diagram B](image)
C. ![Diagram C](image)

**ANTERIOR**

A. ![Diagram A](image)
B. ![Diagram B](image)
C. ![Diagram C](image)

N = Normal patients
L = Patients with left bundle branch block/normal sized LV
E = Patients with left bundle branch block/enlarged LV
* = Quadrants where statistically significant differences exist between the 2 populations being compared
Anatomical Segments of Ventricle Corresponding to 3 Imaging Planes

**LEFT ANTERIOR OBLIQUE**

- 1. Basal septal
- 2. Apical septal
- 3. Anterolateral
- 4. Anterobasal
- 5. Anterior
- 6. Apical
- 7. Inferoapical
- 8. Inferior
- 9. Posterobasal
- 10. Inferolateral
- 11. Posterolateral
- 12. Right ventricular

LV = Left ventricle
RV = Right ventricle
REFERENCES


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