Comparison of Left Ventriculography and Coronary Arteriography with Positron Emission Tomography in Assessment of Myocardial Viability

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Summary

Background: Assessment of viability of myocardium after an ischemic insult is an important clinical question that affects decisions pertaining to potential revascularization. The results of contrast left ventriculograms and coronary angiography were compared to positron emission tomography (PET) in 64 patients with coronary artery disease and reduced left ventricular function.

Hypothesis: The study was undertaken to determine the relative utility of the invasive studies in the assessment of viability.

Methods: Right anterior oblique ventriculograms were assessed for hypokinesis, akinesis, or dyskinesis in six segments. The PET scans were assessed for viability by visual estimation of fluorodeoxyglucose (FDG) uptake in six segments that corresponded to the segments analyzed on the ventriculograms.

Results: Of a total of 373 segments successfully analyzed by PET, 272 were judged to be viable (normal or hypokinetic) by contrast ventriculography. Of these, 253 (93%) were considered viable by PET. Of 177 segments deemed either normal or mild-to-moderately hypokinetic by ventriculography, 170 (94%) were viable by PET. Of 95 severely hypokinetic segments, 83 (84%) were viable by PET. Of 79 akinetic segments, 44 (56%) were considered viable by PET. For segments that were dyskinetic and thought to be nonviable by ventriculography, 19 of 22 (86%) were also considered nonviable by PET. For 294 segments for which a determination on viability was made based on the presence of wall motion on the ventriculogram (normal, hypokinetic, or dyskinetic; not akinetic), there was excellent agreement with PET (93%; p < 0.001). In 49 patients there was akinesis in no more than one segment in either the anterior or inferior territories, indicating the potential for assessment of viability by ventriculography in at least two of three segments in each territory. Coronary anatomy was analyzed to assess whether coronary patency could help in assessing viability. Segments supplied by patent arteries were more likely to be viable by PET than segments supplied by occluded arteries (p < 0.001). Akinetic segments were more likely to be supplied by occluded arteries (56 vs. 23, 72%). Dyskinetic segments were predominantly nonviable by PET (86%) and were usually supplied by occluded arteries (77%).

Conclusion: In patients in whom the assessment of viability is clinically relevant, the presence of systolic inward motion on the contrast left ventriculogram correlates well with segment viability by PET, while outward or dyskinetic movement correlates well with nonviability. Thus, the use of PET to assess viability in many patients may be unnecessary.

Key words: ventriculography, coronary angiography, viability, positron emission tomography, fluorodeoxyglucose, coronary artery disease, contrast

Introduction

Viability of myocardium in patients with coronary artery disease is an important clinical question related to the evaluation of the need for, or potential benefit from, revascularization by surgery or percutaneous coronary intervention. The question of viability can arise after an acute ischemic episode with documented Q-wave or non-Q-wave infarction, or during evaluation of a patient with established coronary artery disease and evidence of left ventricular dysfunction which may be due to “stunned” or “hibernating” myocardium. Left ventricu-
lar dysfunction may be manifested as hypokinesis, akinesis, or dyskinesis in the territory of coronary arteries that are diseased with either occlusion or stenosis, with or without collaterals.

The potential benefit from revascularization may be related to three factors. First, regardless of the contractile state of the myocardium, there is a question of whether ischemia, with or without symptoms of angina, can be produced by situations in which the blood supply to that segment, whether by collaterals or antegrade, is not adequate to meet increased myocardial oxygen demand (inducible ischemia). Second, if the coronary artery supplying the segment is stenosed, there is a question of whether subsequent occlusion of the vessel will result in myocardial infarction (jeopardized myocardium). This can be an important factor in subsequent prognosis. The third way in which viability is important is in the potential for improvement of segmental function subsequent to coronary revascularization. Assessment of myocardial viability has often been focused on the prediction of functional recovery, but it should also include the first two aspects of viability described above, that is, inducible ischemia and jeopardized myocardium.

Assessment of viability has been undertaken by various imaging techniques including left ventriculography in combination with nitroglycerin or catecholamine administration or postextrasystolic potentiation. More recently, dobutamine echocardiography, radionuclide ventriculography, nuclear perfusion imaging, and positron emission tomography (PET) have been used for detection of viability. There is no established reference standard for viability, but PET has been proposed as the standard in that the demonstration of continued uptake of fluorodeoxyglucose (FDG) indicates preserved metabolic activity and tissue at risk of ischemia or infarction, and potentially capable of functional recovery. The contrast ventriculographic techniques are less commonly used for assessment of viability because of their invasive nature which precludes easy achievement of repeat studies. However, since almost all patients in whom viability is an issue are studied by coronary arteriography, left ventriculography can be performed at the same time and information on contractile function and viability should be available from the resting ventriculogram, even without the augmentation techniques that have been used previously. If the results of coronary arteriography can be correlated with contrast ventriculography to identify regions at risk of inducible ischemia and those that will recover function, the need for additional noninvasive imaging studies may be reduced. The purpose of the present paper is to evaluate to what extent analysis of regional wall motion on resting left ventriculogram, combined with coronary arteriography, provides information regarding viability, using PET FDG scans as a reference standard. By analyzing ventriculograms for segmental wall motion and comparing this analysis to the results of PET FDG scans, we have tested the hypothesis that any inward systolic motion on the ventriculogram identifies viable myocardium, while dyskinesis (outward systolic motion) indicates nonviable. The coronary anatomy was analyzed to determine whether viability information could be obtained in segments with no motion (akinesis).

Materials and Methods

The study included 64 patients (59 men, mean age 55 years) with regional wall motion abnormalities, who were candidates for coronary revascularization and who underwent both PET and cardiac catheterization with coronary arteriography and left ventriculography. Positron emission tomography was performed a mean of 24 days after diagnostic cardiac catheterization. There was no important change in clinical status between the two studies. All patients had coronary artery disease documented by coronary arteriography.

Left Ventriculography

Left ventriculograms were performed in the right anterior oblique view and analyzed by a single observer blinded to the results of PET. The ventriculograms were recorded on a 30’ right anterior oblique view on 35 mm cine film and analyzed on a Vanguard projector. Each of six segments (anterobasal, anterolateral, anteroinferior, mid-inferior, and inferobasal) were assessed for each patient as to whether they were normal, mild-to-moderately hypokinetic (referred to subsequently as hypokinetic), severely hypokinetic, akinetic, or dyskinetic. For this purpose, the inferior wall from the mitral valve annulus to the apex was divided approximately into thirds, as was the anterior wall from the aortic root to the apex. End-systolic and end-diastolic frames were drawn onto overlaying transparent paper from the film screen and were used to help in classification of each segment. Determination of segmental function was primarily subjective, and the drawn outlines were used as confirmatory evidence of the subjective evaluation of the cine film. Using these outlines combined with subjective evaluation of the cine film, a segment was classified according to whether the major part of the segment (> 50%) moved inward during systole. Segmental wall motion was classified as follows: excursion < 2 mm for akinesis, 2 to 5 mm for severe hypokinesis, 5 to 10 mm for hypokinesis, and > 10 mm for normal; or moved outward > 2 mm for dyskinesis.

Figure 1 Diagram of segmental analysis of left ventriculogram in right anterior oblique view. AV = aortic valve, MV = mitral valve, AB = anterobasal, IB = inferobasal, AL = anterolateral, MI = mid inferior, AA = anteroinferior, IA = inferolateral.

a Generally supplied by left anterior descending artery.
b Generally supplied by right coronary artery.
Any ventriculographic segment that was either normal, hypokinetic, or severely hypokinetic was considered to be viable. Segments that were akinetic were deemed unknown. Segments that were clearly dyskinetic were deemed not viable.

Coronary Arteriography

Coronary arteriography was performed using standard Judkins techniques with multiple views and recording on 35 mm cine film. The arteriograms were analyzed by a single observer blinded to the results of PET. Disease was classified as significant when there was > 50% diameter stenosis. The angiograms were also analyzed for collaterals.

For analysis of the relationship between coronary artery patency and segmental function and viability, the anterior segments of the ventriculogram were considered to be supplied by the left anterior descending system, including diagonals. Where there was correlation with coronary anatomy, anterolateral segment function was related to circumflex obtuse marginal disease. The inferior segments were considered to be supplied by the right coronary artery. Where there was correlation with coronary anatomy, the mid inferior segment was related to circumflex disease. Arteries were classified as occluded when there was no antegrade flow (Thrombolysis in Myocardial Infarction [TIMI] 0), subtotally occluded when there was critical stenosis (> 90%) with slow antegrade flow (TIMI 1–2), or patent when antegrade flow was normal at rest (TIMI 3), regardless of the degree of stenosis. Arteries with patent grafts were considered to be patent.

Representative examples of patients with significant coronary artery disease and left ventricular wall motion abnormalities are shown in Figures 2 and 3.

Positron Emission Tomography

Positron emission tomography imaging was performed using a whole body tomograph (Siemens 951/31R, Siemens Medical Solutions, Inc., Iselin, N.J., USA). A 15-min transmission scan was performed after positioning of the patient and an oral glucose load. A 20 mCi intravenous dose of nitrogen-13 (N-13) ammonia was administered for assessment of myocardial perfusion. Images were obtained for a 20-min period starting 5 min after injection. After decay of the N-13 ammonia, 10 mCi of FDG was given intravenously. Forty min after injection images were acquired for a 20 min period. The transaxial images were reoriented along the major axis of the heart and resliced to yield long- and short-axis images. The PET images were analyzed in blinded fashion by an observer not familiar with the clinical history or the findings of ventriculography or coronary arteriography. The FDG uptake was assessed for determination of viability in 16 segments of the left ventricle and was scored as normal (1), mildly reduced (2), moderately reduced (3), or severely reduced (4). Segments with scores ≤ 2 were considered viable. Six of the 16 segments were identified as corresponding approximately to the 6 segments viewed in the right anterior oblique left ventriculogram. These segments were apical-inferior, mid-inferior, basal-inferior, basal-anterior, mid-anterior, and apical-anterior. The other 10 segments analyzed (basal-, mid-, and apical-septum; basal- and mid-anterior septum; basal-, mid-, and apical-lateral; and basal- and mid-posterior) relate to aspects of the ventricle that are not seen on the routinely performed right anterior oblique ventriculogram. Abnormalities in the five septal regions are usually related to lesions in the left anterior descending coronary artery and are generally associated with abnormalities in the anterior regions seen on the right anterior oblique ventriculogram. Abnormalities in the five posterior and lateral segments are generally related to lesions in the circumflex system, diagonal branches of the left anterior descending, or posterolateral branches of the right coronary artery, and are usually associated with abnormalities on the ventriculogram that involve the mid-anterior region (circumflex or diagonals), inferior region (circumflex or posterolateral branch of the right coronary artery), or both (circumflex).

Statistics

Fisher’s exact test was used to assess statistical significance of differences between the proportion of segments supplied by patent or occluded arteries that were viable by PET or ventriculography, or of the concordance in determining viability between PET and ventriculography. In addition, McNemar’s test was performed to assess whether the number of false negatives for viability by ventriculography (with PET as the standard of reference) was significantly different from the number of false positives. The normal approximation to the binomial distribution was used to calculate the 95% confidence limits for the proportions of segments in various subgroups.

Results

The results of the viability assessment from angiograms and PET images are summarized in Table I. Of a total of 384 segments reviewed, 11 were not analyzed by PET for technical reasons. Of 373 segments analyzed by PET, 272 were assessed as viable by left ventriculography. Of these, 253 (92%) were read as viable by PET. Of 177 segments deemed either normal or hypokinetic by ventriculography, 170 (96%) were viable by PET. Of 95 severely hypokinetic segments, 83 (87%) were read as viable by PET.

Of 79 akinetic segments in 51 patients, 44 (56%) were considered viable by PET. For segments that were dyskinetic and believed not to be viable by ventriculography, 19 of 22 (86%) were considered nonviable by PET.

In general, there was excellent agreement (93%) between PET and ventriculography whenever a determination on viability could be made by ventriculography (p < 0.001). The number of false positives for viability by ventriculography (with PET as the standard of reference) was significantly higher than the number of false negatives (19 vs. 3, p < 0.001). A viability determination could be made by the presence of hypokinesis or dyskinesis on the ventriculogram in 294 of 373 segments (79%).
Of the 64 patients, 42 had triple-vessel disease, 11 had double-vessel disease, and 11 had single-vessel disease. All patients with significant circumflex system disease also had disease in the left anterior descending or right coronary systems, or both.

Analysis of the relation between coronary anatomy, function, and PET is also summarized in Table I. Of 79 segments classified as akinetic by ventriculography, 56 were supplied by occluded (53) or subtotally occluded (3) arteries, all but 3 with collaterals. Since the number of subtotally occluded arteries (TIMI 1 or 2 flow) is small, these are included with occluded arteries for subsequent analysis (Table I). Of the 56 segments supplied by occluded arteries, an equal number (28) of segments were deemed viable and nonviable by PET. Of 23 akinetic segments supplied by patent vessels, 16 were viable, 7 were nonviable.

Of 95 severely hypokinetic segments, 47 were supplied by occluded vessels, all but one with collaterals (39 viable by PET), and 48 by patent vessels without collaterals (44 viable by PET). For hypokinetic segments, there was a greater proportion of patent vessels (38 patent vs. 23 occluded; all viable by PET), and for normal segments most were supplied by patent vessels (85 patent vs. 31 occluded; all except 7 viable by PET). Dyskinetic segments were more likely to be supplied by occluded arteries (17/22, 77%).

The difference between the proportion of dyskinetic segments (nonviable) by ventriculography supplied by occluded arteries (77%) and the proportion of normal or hypokinetic...
segments (viable by ventriculography) supplied by occluded arteries (37%) was statistically significant (p < 0.001). Of 300 segments deemed viable by PET, 181 were supplied by patent arteries, 119 by occluded arteries, all but 1 with collaterals. Of 174 segments supplied by occluded vessels, 55 (32%) were nonviable by PET, whereas of 199 segments supplied by patent vessels, only 18 (9%) were nonviable. This difference was statistically significant (p < 0.001).

There was complete concordance in all six segments for contrast ventriculography and PET in 14 of the 64 patients. In these 14 patients, both contrast ventriculography and PET indicated either viability in all segments (11 patients) or viability in most segments, but nonviability because of dyskinesis in one or two segments (3 patients). In 49 patients, there was no more than one akinetic segment in either the anterior or inferior territories, indicating the potential for assessment of viability by ventriculography in at least two of three segments in each territory.

Discussion

This comparison of contrast ventriculography and PET shows a good correlation between segmental myocardial viability assessed by contrast ventriculography and that assessed by PET. This high correlation is achieved by careful attention to detection of any inward or outward systolic motion of the endocardial outline on contrast ventriculography. When there was enough motion for the segment to be designated normal or hypokinetic, as opposed to severely hypokinetic or akinetic,
there was nearly 100% concordance in this study. The correlation with severe hypokinesis was also high, which indicates that the vast majority of segments that show any inward systolic movement by contrast ventriculography can be considered to be viable to some degree.

On the other hand, when a segment is akinetic by ventriculography, determination of viability cannot reliably be made, and approximately half of the segments are viable by PET. When there is dyskinesis (paradoxical motion) by ventriculography, most of the segments are not viable.

Correlation with coronary anatomy indicates that segments supplied by patent arteries are more likely to be viable by PET (60%) than segments supplied by occluded arteries, while nonviable segments are more likely to be supplied by occluded arteries (77%). Akinetic segments were more likely to be supplied by occluded arteries (72%), although slightly more likely to be viable (56%) than nonviable by PET. Assessment of collaterals appears to be unhelpful in this study, since these were present with almost all occluded arteries whether or not there was viability. Intuitively, the absence of collaterals would imply nonviability, but there were not enough such patients in this study to validate this.

There are important clinical implications relating to the likelihood of infarction or reinfarction (jeopardized myocardium) in the presence of a patent artery. Although a segment supplied by an occluded artery may be viable with regard to improvement in function after revascularization or inducible ischemia, it is very unlikely to infarct unless the collateral supply is also at risk due to critical lesions in the artery supplying the collaterals. Although arterial patency cannot reliably be used to determine viability in an akinetic segment, it may be important in clinical decision-making regarding revascularization.

The primary implication of these findings is that when the ventriculogram shows any inward systolic endocardial motion in an individual segment, the segment can, for practical clinical purposes, be considered viable. When the issue is of practical clinical significance, such segments are therefore worthy of consideration for revascularization, particularly if the artery supplying the segment is patent. On the other hand, when there is dyskinesis, nonviability is implied. In patients in whom only one segment was akinetic by ventriculography in either the anterior or inferior territories, so that at least two segments in each coronary territory could be assessed for viability, PET would be unnecessary for assessing viability in more than three quarters of the patients (49/64). This may have important consequences relating to the cost of investigating individual patients.

**Limitations of the Study**

The ventriculographic and coronary analysis was performed qualitatively rather than quantitatively. The study was performed to establish the clinical utility of the commonly performed resting contrast ventriculogram in the assessment of viability. Since this is routinely analyzed qualitatively, and sophisticated quantitative techniques are not readily available, the addition of a quantitative analysis to this study would probably not be contributory. Likewise, quantitative analysis of the coronary anatomy would not contribute significantly to the evaluation of the correlation between coronary patency and viability.

A limitation of the ventriculogram performed in only the right anterior oblique view is the fact that function in the septum cannot be assessed, and function in the posterior and lateral walls is inadequately assessed. Analysis of septal function may not be essential since revascularization is generally not applicable to this territory and wall motion abnormalities in the septal region are generally due to left anterior descending
disease and therefore associated with anterolateral and/or anteroseptal abnormalities. Analysis of posterior and lateral wall function by left anterior oblique ventriculography would not have significantly contributed to this study since all patients with circumflex disease also had significant left anterior descending or right coronary disease, or both. For the clinical application of the results of this study, if there is important circumflex disease, left anterior oblique ventriculography should be performed and any inward motion of the posterior endocardium can be used to imply viability in this territory.

It is also worth noting that some assessment of posterior wall motion can be achieved from analysis of the right anterior oblique view by attention to the anterolateral and mid inferior segments. When these are abnormal in the absence of apical or basal inferior involvement, circumflex disease can sometimes be inferred. Lateral wall motion abnormalities can also be inferred at times from coronary angiography. For example, in the right anterior oblique projection, the obtuse marginals tend to crinkle during systole and straighten in diastole if there is motion. In the left anterior oblique projection, these same vessels move back and forth during systole and diastole. These signs can be suggestive of viable disease in this distribution.

Foster et al. assessed the relationship between systolic thickening and endocardial motion by echocardiography to perfusion evaluated by thallium scintigraphy to show that viability can be evaluated in the majority of myocardial segments using a combination of these two techniques without the need for PET. In the present study we have focused only on the functional status of myocardial segments as assessed by contrast ventriculography and on the extent to which viability can be evaluated by this technique alone. Evaluation of the role of adjunctive functional or perfusion studies to establish the optimal or most cost effective way of assessing viability was not part of this study. This could be the subject of further studies on this issue, together with analysis of follow-up data to confirm viability in individual segments by establishing the presence of inducible ischemia, reinfarction, or functional improvement after revascularization.

Conclusion

Positron emission tomography gives information that is very different from that obtained by contrast ventriculography and can clearly tell us about viability in situations where focusing only on function may not be sufficient. However, it is a costly procedure which is not readily available to everyone and which should be reserved for patients in whom such information is necessary but not obtainable by other methods. In this study, it is demonstrated that in many patients in whom the issue of viability is clinically relevant, careful attention to the presence or absence of endocardial systolic inward or outward motion in analyzing the readily available contrast left ventriculogram may give all the information that is needed to make an informed and clinically relevant decision regarding viability. Analysis of the coronary anatomy does not give additional information regarding viability but may be important in clinical decision making regarding revascularization.

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