EFFECTS OF CORONARY ARTERY BYPASS SURGERY ON
REGIONS SHOWING PERSISTENT DEFECTS
IN THALLIUM MYOCARDIAL IMAGES

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The indications for revascularization surgery and its effects on myocardial regions showing persistent defects in thallium myocardial images are controversial.

The effects of aortocoronary bypass surgery on myocardial perfusion and wall motion in the regions with persistent defects were evaluated in 47 patients with thallium-201 single photon emission computed tomography and left ventriculography. In areas showing persistent thallium defects preoperatively the rate of improvement of perfusion was only 24% by postoperative thallium imaging, and 57% by wall motion analysis. These results were significantly inferior to those of regions with transient defects, which were 84% and 82%, respectively.

A persistent defect may not be a definitive marker of a non-viable scar, but the results of surgery on such regions were unsatisfactory. It is concluded, therefore, that revascularization surgery in regions with persistent defects is not always recommended and that the indications for surgery should be individually determined with operative risk balanced against benefits.

THALLIUM-201 myocardial perfusion scintigraphy has been demonstrated to be a useful technique for evaluating myocardial viability and, hence, predicting the response to revascularization surgery.1-4 It is agreed that myocardial regions showing reduced initial thallium uptake after exercise with delayed redistribution ("transient defect") represent ischemic but viable regions that can revert to normal after revascularization. On the other hand, persistent defects are generally considered to represent "fibrosis" or "scars" which show little response to revascularization. However, recent reports have suggested that persistent defects have some residual viable muscle and may respond to revascularization.1-3

In this study, we examined myocardial perfusion and wall motion after bypass surgery in regions that previously showed persistent defects and compared them to other regions that had

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normal perfusion or transient defects. We then tried to determine the effectiveness of revascularization surgery for these areas.

MATERIALS AND METHODS

Patients: Forty-seven patients (43 males, and 4 females) who had received aortocoronary bypass surgery (excluding patients with combined left ventricular aneurysmectomy) were studied before and one to 2 months after surgery. Investigations used thallium-201 single-photon emission computed tomography (SPECT) and coronary angiography combined with left ventriculography. Patients' ages ranged from 28 to 69 (mean 56 ± 9) years.

Coronary revascularization was performed for coronary arteries with more than 75% stenosis.

SPECT studies: All patients performed graded exercise on a bicycle ergometer, and the exercise was terminated when the patient noted chest oppression or leg fatigue, or there was more than 1 mm ST depression on the electrocardiogram, or the heart rate reached 80% of the predicted maximum. Two mCi of thallium-201 was injected intravenously one minute before the end of exercise. Then a SPECT scan was performed with a rotating gamma camera interfaced with a digital computer (General Electric: Max I 400T) described in detail elsewhere. Transaxial, short axis and long axis sections of the myocardium were obtained contiguously at 6 mm intervals in each plane. The delayed images of the same views were recorded approximately 3 hours after exercise.

Analysis of SPECT images: SPECT images were divided into 8 segments: anterobasal, anterior, apical, inferior, posterobasal, septal, anterolateral and posterolateral, as shown in Fig. 1. The anterobasal segment was excluded from this study because no correlation was seen between this segment and any coronary arteries. A total of 232 segments that were fed by diseased coronary arteries were divided into 3 groups depending on their preoperative scintigraphic findings evaluated by two independent observers. Group I consisted of the segments showing normal perfusion which had no perfusion defects on exercise images. Group II included the segments showing initial defects after exercise with delayed redistribution. Redistribution was further classified as complete or incomplete. Complete redistribution (Group IIa) was designated if initial defects normalized on the delayed images, and incomplete redistribution (Group IIb) if initial defects improved on the delayed images but there were still residual defects. Group III consisted of segments showing persistent defect which were unchanged after 3 hours.

TABLE I COMPARISONS OF SEVERAL FACTORS AMONG GROUPS

<table>
<thead>
<tr>
<th>Group</th>
<th>Number of total perfusion area</th>
<th>Number of area with transmural infarction</th>
<th>Number of diseased coronary artery</th>
<th>Graftability</th>
<th>Graft patency</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>91</td>
<td>5 (5%)*</td>
<td>65</td>
<td>88%</td>
<td>82%</td>
</tr>
<tr>
<td>II</td>
<td>88</td>
<td>11 (13)*</td>
<td>66</td>
<td>97*</td>
<td>86*</td>
</tr>
<tr>
<td>IIa</td>
<td>32</td>
<td>1 (3)</td>
<td>22</td>
<td>100</td>
<td>86</td>
</tr>
<tr>
<td>IIb</td>
<td>56</td>
<td>10 (18)</td>
<td>44</td>
<td>95</td>
<td>86</td>
</tr>
<tr>
<td>III</td>
<td>53</td>
<td>18 (34)</td>
<td>39</td>
<td>79</td>
<td>52</td>
</tr>
</tbody>
</table>

*: p < 0.01 compared with Group III

Analysis of regional wall motion: Coronary angiography and left ventriculography at rest were done within 2 weeks from SPECT studies in all patients pre- and postoperatively.

Regional wall motions were assessed according to the American Heart Association (AHA) classification. The wall motion in each segment was scored on a scale from 0 to 2 (0 = akinesis or dyskinesis, 1 = hypokinesis, and 2 = normokinesis). Septal segments were excluded because reduction of septal motion was frequently reported after successful aortocoronary bypass surgery.

The results of the interpretation of segmental SPECT images and wall motions were correlated with the corresponding grafted arteries, as shown in Fig. 2. Gifts of the left anterior descending artery would be expected to provide perfusion to the septal, anterior and, in most cases, apical segments; left circumflex artery grafts would supply the antero- and posterolateral segments; and right coronary artery grafts, the posterobasal and inferior segments. In some cases, perfusion areas showed individual differences depending on variations of coronary anatomy.

For statistical analysis, Student's t test for paired or unpaired data and chi-square test with Yate's correction for determination of differences between proportions were employed.

RESULTS

Preoperatively, transmural myocardial infarction with documented Q waves on the electrocardiogram was significantly frequent in Group III (p < 0.01). Surgical accessibility of the vessels (graftability) was not significantly different among the groups, but graft patency was signifi-

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Fig. 3. Changes in pre- and postoperative images in each group.

**TABLE II** PRE- AND POSTOPERATIVE CHANGES OF WALL MOTION SCORES SHOWN BY MEAN ± STANDARD DEVIATION

<table>
<thead>
<tr>
<th>Total area</th>
<th>Wall motion score</th>
<th>Area with normal or improved postoperative wall motion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre op</td>
<td>Post op</td>
</tr>
<tr>
<td>I</td>
<td>61</td>
<td>1.65 ± 0.48**</td>
</tr>
<tr>
<td></td>
<td>&lt;1&gt;</td>
<td>1.84 ± 0.37**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>p &lt; 0.005</td>
</tr>
<tr>
<td>II</td>
<td>55</td>
<td>1.56 ± 0.60**</td>
</tr>
<tr>
<td></td>
<td>&lt;3&gt;</td>
<td>1.76 ± 0.43*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>p &lt; 0.005</td>
</tr>
<tr>
<td>IIa</td>
<td>17</td>
<td>1.76 ± 0.44</td>
</tr>
<tr>
<td></td>
<td>&lt;3&gt;</td>
<td>1.88 ± 0.33</td>
</tr>
<tr>
<td></td>
<td></td>
<td>p &lt; 0.005</td>
</tr>
<tr>
<td>IIb</td>
<td>37</td>
<td>1.46 ± 0.65</td>
</tr>
<tr>
<td></td>
<td>&lt;3&gt;</td>
<td>1.70 ± 0.46</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt;1.68 ± 0.58&gt;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>p &lt; 0.005</td>
</tr>
<tr>
<td>III</td>
<td>23</td>
<td>1.09 ± 0.67</td>
</tr>
<tr>
<td></td>
<td>&lt;8&gt;</td>
<td>1.39 ± 0.50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt;1.13 ± 0.35&gt;</td>
</tr>
</tbody>
</table>

*: p < 0.01, **: p < 0.005, compared with Group III
< >: areas with ECG evidence of transmural infarction

Significantly poorer in Group III (p < 0.01) (Table I).

The effects of surgery on myocardial perfusion and wall motion were evaluated only in the segments perfused by patent grafts confirmed by postoperative coronary angiography. The segments with apparent perioperative infarction judged by electrocardiograms and MB-CPK values were excluded.

**Myocardial perfusion**: A total of 169 segments were perfused by patent grafts. Changes in SPECT images after surgery are shown in Fig. 3. In Group I, 62 of 67 segments (93%) maintained normal perfusion postoperatively. Sixty-five of 77 segments (84%) in Group II with transient defects showed normal perfusion on the postoperative scan. However, only 6 of 25 segments (24%) of Group III showed normal or improved perfusion. Hence, the response of Group III to surgery was significantly inferior to that of Groups I and II (p < 0.01 and p < 0.01).

On the other hand, electrocardiographic evidence of transmural infarction did not always indicate irreversible damage.

**Wall motion**: Both pre- and postoperative...
Fig. 4. SPECT images and wall motion. This patient had a history of anterior myocardial infarction and three bypass grafts of the left anterior descending artery, diagonal branch and circumflex branch. However, only the graft of the left anterior descending artery was patent. SPECT images (upper panel) showed persistent defect in the anterior region (arrows) both pre- and postoperatively. The wall motion of the corresponding area (arrows in middle panel) analyzed by automatic processing method of cineventriculogram developed by Fujita et al. showed slight improvement. Segmental motion from the geometric center of gravity of the cavity expressed as percent shortening was plotted over the entire circumference and the anterior segments (arrows in lower panel) showed improvement in percent shortening. PRE: preoperative; POST: postoperative; E: exercise image; D: delayed image; EF: left ventricular ejection fraction.

Data were available in 139 segments. Segmental wall motions were analyzed in relation to the preoperative thallium study. The wall motions improved in all groups postoperatively. However, the grade of improvement was significantly lower in Group III compared to Groups I and II (p < 0.005 and p < 0.01) (Table II).

There were no significant differences of the above mentioned factors between Groups IIa and IIb.

**DISCUSSION**

Previous data, as in our present study, demonstrated that the areas showing transient defects were highly reversible, and the vessels to these areas were most suitable for bypass surgery. On the other hand, surgical indications for areas with persistent defects are still controversial because the effects of surgery on these areas are not adequately evaluated.
Myocardial perfusion: Gibson et al\textsuperscript{1} divided the persistent defects semiquantitatively into two groups and showed that 45% of the preoperative moderate persistent defects and 21% of the severe persistent defects improved postoperatively. Liu et al\textsuperscript{2} concluded that 75% of the regions with persistent defects reverted to normal after percutaneous transluminal coronary revascularization. Their studies were performed by planar imaging. Our study using SPECT showed that 19 of 25 segments (76%) with persistent defects failed to respond to revascularization surgery. This result was similar to that of "severe" persistent defect in the classification of Gibson et al. The results reported by Liu et al were so good that there was no difference in the rates of improvement between transient and persistent defects. This might be due to the fact that the patients had symptomatic single vessel disease, as pointed out by the authors themselves. The presence of chest pain should be considered a clue to the presence of viable (ischemic) myocardium. In contrast to planar imaging, the tomographic approach used in this study allows clear separation of each myocardial segment due to the elimination of the superimposition of adjacent myocardial segments, and segmental analysis appears to be more accurate\textsuperscript{5,8,9}.

Correlation between myocardial perfusion and wall motion: As expected, the improved wall motion correlated with improved myocardial perfusion, although the anatomic regions of SPECT images did not completely correspond with the ventriculograms. Among the segments showing preoperative abnormalities both in perfusion and wall motion, 12 of 19 segments (63%) with improved perfusion, but 5 of 18 segments (28%) with unchanged or worsened perfusion, were associated with improved wall motion (p < 0.05). However, this is not true if limited to the regions with persistent defects. Of 23 segments with preoperative persistent defects, 13 (57%) demonstrated normal or improved wall motion postoperatively. Five segments showed concomitant improved perfusion, but 8 did not. Even severe wall motion abnormalities may improve without improvement of perfusion, as shown in Fig. 4. Rozanski et al\textsuperscript{3} showed that reversibility of severe wall motion abnormalities after revascularization was predicted if these regions demonstrated the presence of redistribution. Conversely, Liu et al\textsuperscript{2} and Berger et al\textsuperscript{4} found that the persistent defects, when associated with preserved wall motion, could be predicted to resolve after surgery. In the present study, neither persistent defect nor severe wall motion abnormality per se was a definitive marker of non-viable myocardium, and the segments with persistent defects had more chance of improved wall motion than perfusion, although the improvement had a significantly lower score than that of the regions with transient defects.

Incomplete redistribution vs persistent defect: Surgical benefits to the regions with incomplete redistribution (Group IIb) are the same as those to the regions with complete redistribution (Group IIa). The defects showing incomplete redistribution appear to be a mixture of ischemia and scarring\textsuperscript{1} and are, in fact, frequently associated with old transmural myocardial infarction. The defects with considerable viable tissue represent incomplete redistribution (Group IIb). If viable muscle is scarce, the segments may represent persistent defects because the coronary blood is reduced to such minimal levels that no redistribution is evident or redistribution occurs too slowly to be detected within 3 hours. Wiener et al\textsuperscript{11} pointed out that the true state of myocardial viability would only be known by obtaining 24-hour redistribution images. Thus, there is a wide spectrum of persistent defects depending on the amount of residual viable tissue. It is difficult to distinguish between viable and non-viable persistent defects by visual criteria of SPECT images alone. Our SPECT studies may possibly underestimate the presence of myocardial viability. This is one of the potential reasons for a significant difference in the rates of improvement between perfusion and wall motion in the regions showing persistent defects preoperatively (24% vs 57%, p < 0.05). An important next step is to develop more sensitive ways to select really viable persistent defects. A quantitative or metabolic approach using positron emission tomography may be useful for this purpose\textsuperscript{12–14}.

Implications: A persistent defect documented by SPECT may not be a definitive marker of non-viable scarring and therefore a persistent defect alone does not preclude consideration of therapeutic intervention. However, the results of surgery on these areas were unsatisfactory; the rate of graft patency was 52% and, even if the vessels perfusing such areas were successfully grafted, the rate of improvement of regional perfusion was only 24% and that of wall motion was 57%. Accordingly, at present, indications
for bypass surgery to these areas should be determined individually with consideration of operative risks balanced against benefit. The patient's age, number of grafts placed, duration of time on bypass, experience of surgeons and others are factors to be considered.

REFERENCE


6. AHA committee: A reporting system of patients evaluated for coronary artery disease. Circulation 51 (June), 1973


