Assessment of tissue viability: clinical demand and problems

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Introduction

Over the past decade it has become clear that chronic left ventricular dysfunction is not necessarily an irreversible process. In some patients recovery of function may occur dependent on the presence of dyssynergic yet viable myocardium. It has been hypothesized that chronic hypoperfusion may result in a down-regulation of myocardial contractility and this process can be reversed after adequate restoration of myocardial perfusion. To describe this concept, the term hibernation was coined by Diamond et al. However, no animal modes are currently available to study long-term hibernation. In addition, no serial studies in patients with hibernation have been performed to determine the chronicity of the disorder and whether the 'severity' of the hibernation is stable over a long period of time. Several studies have recently demonstrated that many regions with chronic contractile dysfunction have (near-)normal perfusion. In these situations, it is quite conceivable that recurrent episodes of ischaemia result in chronic depression of contractile function. Nonetheless, independent of the underlying pathophysiology, the detection of myocardial viability has now become an important aspect in the diagnostic work-up of patients with chronic left ventricular dysfunction. Only if viability can be demonstrated, are revascularization procedures justified, whereas absence of viability warrants conservative medical therapy or heart transplantation.

The present review article focuses on three important questions that are frequently raised on the topic of myocardial viability. First, which patients need viability assessment and what is the ensuing clinical demand? Second, what is the optimum method to detect viability, and third, what other factors determine recovery of left ventricular function after coronary revascularization or influence optimal assessment of functional recovery?

Patient selection for viability studies

In patients with relatively preserved left ventricular function (left ventricular ejection fraction >35%) and symptoms of angina pectoris, interfering with the daily life-style of the patient, coronary revascularization may be indicated without the need of viability studies. It is in the subgroup of patients with poor left ventricular function (≤35%) and symptoms of congestive heart failure (ischaemic cardiomyopathy) that viability studies are indicated. The therapeutic options in these patients include medical therapy, revascularization or heart transplantation. The latter option is still restricted due to the relative shortage of donor hearts.

Therefore the choice of therapy for the majority of these patients will be either medical therapy or revascularization, particularly since revascularization procedures in these patients are associated with an increased risk of periprocedural complications. But the improvement of both left ventricular ejection fraction and functional class in patients with dysfunctional but viable tissue undergoing revascularization justifies revascularization procedures in these patients.

Clinical demand

What is the estimated clinical demand for viability studies for Europe and the U.S.A. together? To provide an answer to this question one has to rely on several assumptions. First, viability measurements are mainly indicated in patients with a history of myocardial infarction; second, the mean annual infarction rate is 2 per 1000 in both Europe and the U.S.A. (combined population of 500 million inhabitants), and third, viability studies are warranted in about 10–15% of patients with chronic artery disease referred for conventional thallium-201 imaging. Based on these assumptions,
With PET several methods have been described, such as the study of washout of rubidium-82\(^{16,17}\), assessment of the water perfusible tissue-index\(^{18}\) and the assessment of oxidative metabolism with C11-acetate\(^{19,20}\). The method most widely used and tested is based on assessment of metabolism and perfusion using two different tracers; fluorine-18 labelled with deoxyglucose (FDG) and nitrogen-13 labelled with ammonia (NH3) are the two most commonly used tracers\(^{21,22}\). The combined use of these tracers allows the identification of two discriminant states of myocardial viability i.e. a match pattern (reduced N13-ammonia activity together with decreased FDG activity), or a mismatch pattern (reduced N13-ammonia activity with increased FDG activity). A match pattern corresponds with non-viable tissue, whereas a mismatch pattern is consistent with viable tissue\(^{21,22}\). Based on this concept, several studies have shown the capability of combined FDG/perfusion imaging to predict functional recovery following revascularization\(^{19,13,19,23-29}\).

### Table 1  Negative and positive predictive values of 10 combined FDG PET studies (260 patients) to predict improvement of regional contractile function after revascularization

<table>
<thead>
<tr>
<th>Author</th>
<th>Number of patients</th>
<th>NPV (%) (segments)</th>
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<td>20</td>
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<td>Gropler et al.(^{19})</td>
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<td>85 (35/41)</td>
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<td>Tamaki et al.(^{25})</td>
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<td>76 (45/59)</td>
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<td>80 (40/50)</td>
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Weighted mean: 86 (261/302) 74 (295/396)

NPV = negative predictive value; PPV = positive predictive value.

Assessment of myocardial viability would be needed in 100 000–150 000 patients per year in Europe and the U.S.A. Of course, this is a rough estimate but it shows that expensive specialized techniques are not capable of fulfilling this requirement; instead more generally applicable techniques should be available to meet the clinical demand.

### Which technique should be used to assess viability?

The hibernating myocardium has been demonstrated to have several characteristics: cell membrane integrity, preserved glucose metabolism and inotropic reserve. These characteristics form the basis of the various techniques that are currently available for the assessment of myocardial viability in patients with chronic coronary artery disease. The currently most frequently used techniques include scintigraphic imaging with either positron emission tomography (PET) or single photon emission computed tomography (SPECT) and echocardiography during stepwise infusion of dobutamine. Newer techniques include magnetic resonance imaging and contrast echocardiography. The choice between these methods depends on the expertise and availability of resources, especially with expensive technologies such as PET and magnetic resonance imaging.

### Positron emission tomography

With PET several methods have been described, such as the study of washout of rubidium-82\(^{16,17}\), assessment of the water perfusible tissue-index\(^{18}\) and the assessment of oxidative metabolism with C11-acetate\(^{19,20}\). The method most widely used and tested is based on assessment of metabolism and perfusion using two different
mixture of normal myocardium and necrosis (without the potential to recover). In these segments, the additional information provided by the relative FDG uptake (increased or concomitantly decreased) may allow differentiation between segments with and without recovery.

Finally, it has been demonstrated recently that myocardial glucose utilization (as assessed by FDG PET during hyperinsulinaemic euglycemic clamping) was significantly higher in segments with recovery after revascularization as compared to the segments without recovery[14,32-34]. Further studies to determine whether assessment of myocardial glucose utilization alone (without determination of perfusion) allows differentiation between recovery/no recovery after revascularization, are necessary.

In addition, apart from the capacity to predict functional recovery following revascularization, FDG PET offers a long-term prognostic value as patients with a mismatch pattern are more prone to subsequent events than patients with a match pattern[14,32-34]. Prognosis improved dramatically when the patients with a mismatch pattern were revascularized.

Figure 1 shows the combined data from the studies by Eitzman et al.[32] and Di Carli et al.[14]. The authors evaluated cardiac mortality in 175 patients with severely depressed left ventricular function who underwent FDG imaging. Patients were followed for an average of 12 and 13.6 months, respectively. Ninety-two patients were treated medically and 83 patients were revascularized. The patients were subdivided into four groups: depending on the therapy and on the presence or absence of a mismatch pattern (Fig. 1). The highest mortality was observed in the group of patients with a mismatch pattern who were treated medically. Di Carli et al.[14] also demonstrated that angina and symptoms of congestive heart failure improved significantly in the group of patients with a mismatch who underwent revascularization, in contrast to the other groups.

**Single photon imaging: thallium-201**

Thallium-201 imaging relies on the principle that integrity of cell membrane is the hallmark of viable myocardium[31]. The clinically most accurate thallium-201 protocols are stress-redistribution-reinjection[29,35-40] and rest-redistribution[41-44].

**Stress-redistribution-reinjection**

The detection of viability by thallium-201 reinjection may be explained by the hypothesis that a sufficient concentration of thallium-201 chloride in the blood needs to be present to allow redistribution of thallium-201 to severe perfusion defects[47,48]. This hypothesis is supported by data from Kayden et al.[49] who showed that 38% of irreversible segments on stress-late (24-h) redistribution appeared viable when reinjection was performed after the acquisition of the 24-h redistribution images. Bonow et al.[50] compared the value of thallium-201 stress-redistribution-reinjection imaging with FDG
PET and showed concordance between the two approaches in 88% of segments regarding the presence or absence of viable myocardium. It also appeared that quantitation of thallium-201 activity is important, as the majority of mild-to-moderate (thallium-201 activity ≥50% of normal) fixed defects on the redistribution images and reinjection images were viable on FDG PET.

Although thallium-201 reinjection imaging has a high sensitivity to predict functional recovery after revascularization, more recent studies have shown that the specificity of this approach is rather low, indicating that thallium-201 reinjection imaging may over-estimate functional recovery in some segments. The exact value of these segments (viable on thallium-201 imaging without recovery after revascularization) is currently unclear; it is possible that these segments contribute to relief of heart failure symptoms after revascularization, prevention of remodelling or improved prognosis.

Finally, several authors have investigated the use of an immediate reinjection protocol to shorten the procedure. Reinjection is performed immediately after obtaining the stress image and 1 h later a second scintigram is obtained. This procedure may eliminate the need for the additional 3–4 h redistribution imaging, offers reduced imaging time and may increase patient throughput. These data need to be confirmed by studies showing improvement of ventricular function in viable segments as assessed by this protocol.

**Rest-redistribution**

Several studies evaluated the use of thallium-201 rest-redistribution imaging to predict improvement of regional contractility after revascularization. Different criteria for viability are employed: ≥50% thallium-201 activity on the late image, the presence of significant redistribution (5% or 10% increase in activity) on the late image or the combination of both criteria. Most studies have employed the 50% activity criterion or the combination of both criteria; in clinical practice, redistribution is rarely observed. The predictive values of these studies are shown in Table 2. In addition, Diliszian et al. showed that FDG PET and thallium-201 rest-redistribution imaging yielded comparable information regarding viability. Iskandrian et al. studied 26 patients and showed that thallium-201 rest-redistribution identified 12 of 14 patients (86%) who demonstrated improvement of left ventricular ejection fraction of at least 5% after revascularization. Similar results were reported in other studies. At present, rest-redistribution is considered the first choice thallium-201 protocol when tissue viability is questioned. Stress-redistribution-reinjection is applied when information on both viability and exercise-induced ischaemia is required.

**Single photon imaging: technetium-99m labelled compounds**

Myocardial uptake of technetium-99m sestamibi parallels regional perfusion and provides adequate information for the detection of coronary artery disease. The uptake and retention of sestamibi is also dependent on cell membrane integrity and mitochondrial function (membrane potential), and may thus reflect cellular viability. The role of sestamibi for the detection of viable, hibernating myocardium however remains controversial. Diliszian et al. studied 54 patients with thallium-201 stress-redistribution-reinjection and rest-stress sestamibi (one day protocol) and observed a concordance of 70% on a segmental base. The agreement between the two techniques could be improved by either acquiring an additional redistribution image after the rest sestamibi injection or by quantitative analysis of the sestamibi activity in irreversible defects. It became apparent from this study that the cut-off level of 50% thallium-201 activity was also applicable for technetium-99m sestamibi, since a good correlation was found between viability/non-viability when this cut-off level was used for both techniques.

Three studies compared rest sestamibi imaging with FDG PET. Sawada et al. showed that 50% of the segments with a moderate or severe reduction in sestamibi uptake were viable on FDG PET. Similar

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**Table 2 Negative and positive predictive values of six combined thallium-201 rest-redistribution studies (93 patients) to predict improvement of regional contractile function after revascularization**

<table>
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<th>Author</th>
<th>Number of patients</th>
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<td>Udeshon et al.</td>
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<td>75 (15/20)</td>
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<td>Ragosta et al.</td>
<td>21</td>
<td>77 (27/33)</td>
<td>57 (81/141)</td>
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<tr>
<td>Allieri et al.</td>
<td>13</td>
<td>70 (14/20)</td>
<td>92 (92/100)</td>
</tr>
<tr>
<td>Charney et al.</td>
<td>10</td>
<td>92 (11/12)</td>
<td>90 (19/21)</td>
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<td><strong>Weighted mean:</strong></td>
<td></td>
<td><strong>76 (123/161)</strong></td>
<td><strong>76 (260/340)</strong></td>
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NPV = negative predictive value; PPV = positive predictive value.
findings were reported by Altehoefer et al. and Soufer et al. Six other studies compared rest-redistribution thallium-201 imaging with sestamibi imaging[42,43,66-69]. Two studies[43,69] showed a good agreement between thallium-201 imaging and technetium-99m sestamibi imaging, while four other studies[42,66-68] were consistent in showing that sestamibi was less accurate in the detection of myocardial viability. However an independent 'gold standard' for viability (i.e. recovery of function after revascularization) was not available in five of these studies. The two studies[43,69] showing a good agreement between both techniques again emphasized the value of using the 50% cut-off level for both techniques.

Finally, several studies compared sestamibi imaging with functional outcome after revascularization[42,43,70-72]. In the study by Marzullo et al[70], 22 patients were studied with a rest sestamibi protocol and improvement of contractile function was assessed 11 ± 2 weeks after revascularization. In this study, the sensitivity and specificity were 73% and 55%, respectively. Other studies by Marzullo et al.[71] and Maublant et al.[72] indicated suboptimal prediction of functional recovery after revascularization by sestamibi. In contrast, Udelson et al.[43] showed a high sensitivity and specificity for the detection of functional recovery after revascularization: 94% and 86%, respectively. In addition, more recent studies suggested that the administration of nitrates (orally or intravenously) may enhance the accuracy of sestamibi to predict functional recovery after revascularization[73,74]. Nonetheless, the majority of the studies demonstrate that sestamibi tends to overestimate myocardial necrosis. More studies are needed to fully elucidate the role of sestamibi in the detection of myocardial viability in patients with chronic coronary artery disease. Other technetium-99m labelled imaging agents such as tetrofosmin (Myoview)[75] and furfusmin (Q-12) have not been exclusively studied for viability assessment yet. For technetium-99m teboroxime, the experience indicates that this compound is not suitable for viability assessment[70].

**Single photon imaging: iodinated fatty acids**

Radioiodinated free fatty acids have been clinically applied since the beginning of the 1980s[77,78]. At that time, most studies were performed in Europe and the used compounds were primarily iodoalkyl fatty acids (hexadecanoic acid and heptadecanoic acid), followed by iodophenyl fatty acids. The feasibility of iodine-123 iodophenylpentadecanoic acid (IPPA) has been extensively studied in Europe[79], and is still undergoing Phase III clinical trials in the U.S.A. to assess myocardial viability[80]. The metabolism of this long-chain fatty acid is different in normal from ischaemic myocardium. The clearance is bi-exponential, most of the clearance is early due to β-oxidation and the slow clearance is due to incorporation into triglyceride and phospholipid pools. The clearance in ischaemic myocardium is slow due to predominant incorporation of the fatty acid into the phospholipid and triglyceride pools. This pattern of differential 'washout' may, therefore, be used by serial imaging to determine the presence of hibernating myocardium. Henrich et al.[81] studied patients with chronic myocardial infarction and found a reasonable concordance between myocardial uptake of FDG and IPPA in areas with persistent thallium-201 defects. Methyl-branched fatty acids have been predominantly studied in Japan[82]. These compounds show prolonged retention in the myocardium and are ideally suited for tomographic imaging. The potential role of iodinated fatty acids (iodoalkyl, iodophenyl, and methyl-branched fatty acids) in the assessment of myocardial viability following reperfusion has been addressed in several studies[83-85]. These studies showed restored metabolism in successfully reperfused myocardium and persistent metabolic abnormalities in non-reperfused infarcted regions, indicating the capability of radioiodinated fatty acids to assess myocardial viability.

In recent years, several institutions have gained experience with FDG imaging in combination with either planar scintigraphy or single photon emission computed tomography (SPECT) using 511 keV collimators[86-91]. These approaches allow FDG imaging to be carried out in centres that do not have access to PET equipment. The initial results with 511 keV collimators were obtained with planar scintigraphy. After Van Lingen et al.[86] validated this approach in phantom studies, considerable experience has been obtained with planar FDG imaging in patients with coronary artery disease[86,87,93]. Kallf et al.[93] compared FDG PET with planar FDG imaging, and showed good agreement between the two approaches in the identification of viable myocardium.

In addition to planar FDG scintigraphy, FDG SPECT has been evaluated extensively[88-91]. In two feasibility studies, the image quality of FDG SPECT was evaluated in normal individuals and in patients with coronary artery disease[88,94]. In the FDG SPECT studies, myocardial FDG uptake is compared with regional perfusion assessed with either resting thallium-201 SPECT or technetium-99m sestamibi[88-91] or technetium-99m tetrofosmin[93]. The latter two approaches allow dual isotope imaging, thereby reducing misalignment between perfusion and FDG images. An example of a FDG-perfusion mismatch is demonstrated in Fig. 2.

Several studies have compared FDG PET with FDG SPECT[89,90,96]. showing a good agreement between PET and SPECT in the differentiation between viable and non-viable myocardium. Martin et al.[90] evaluated myocardial viability in nine patients with...
FDG PET and FDG SPECT. On PET imaging, eight patients had an FDG-perfusion match, while four patients had additional regions of FDG-perfusion mismatch. Visual analysis revealed no differences between FDG PET and SPECT with regard to the number, size and location of the matches and mismatches. Two other studies confirmed these findings. The main shortcomings of these comparative studies are the lack of outcome after revascularization.

Preliminary data in 25 patients undergoing revascularization, however, showed a positive predictive value for improvement of contractile function after revascularization of 73% and a negative predictive value of 87%. These data are well in line with the aforementioned FDG PET results. In another study, FDG SPECT was compared with low-dose dobutamine echocardiography and thallium-201 stress-reinjection SPECT in 17 patients with depressed left ventricular function (mean left ventricular ejection fraction 38 ± 11%) undergoing revascularization. The agreement for the detection of viability between FDG SPECT and thallium-201 reinjection was 70%, between low-dose dobutamine echocardiography and thallium-201 reinjection 76%, and between FDG SPECT and low-dose dobutamine echocardiography 80%. In this study, the sensitivities for FDG SPECT, low-dose dobutamine echocardiography and thallium-201 stress-reinjection were 89%, 85% and 93%, respectively, whereas the specificities were, respectively, 77%, 63% and 43%. Thus, cardiac FDG imaging with SPECT appears a promising technique and may allow the use of FDG in centres without PET equipment. At the same time, it is important to consider that FDG SPECT still requires the presence of a nearby cyclotron for the FDG production and also that the costs of FDG are considerable.

**Dobutamine echocardiography**

The use of a low-dose dobutamine infusion (5–15 μg · kg⁻¹ · min⁻¹) to enhance systolic contraction in dysynergic regions during echocardiography has been proposed as an alternative method for the assessment of myocardial viability in patients with chronic ischaemic heart disease. The hallmark for viability is the improvement of contractility of a dysynergic segment after adrenergic stimulation. Experimental studies have confirmed that the contractile reserve of dysynergic but viable segments can be recruited after moderate inotropic stimulation. Thus, in the absence of myocardial ischaemia, myocardial contractility in dysynergic but viable segments will enhance and lead to appearance or improvement of myocardial thickening. Many studies have determined the value of low-dose dobutamine echocardiography for the detection of functional recovery after revascularization in patients with chronic coronary artery disease. The results from these studies indicate that low-dose dobutamine echocardiography seems adequate to detect recovery of contractile function after revascularization, with an accuracy comparable to that of the nuclear tests. Nonetheless, the sensitivity of dobutamine echocardiography appears lower than that of the nuclear techniques, in particular in the patients with an extremely poor left ventricular function. Preliminary data suggest that in these patients the myocardium may...
have lost its contractile reserve due to severe ultrastructural damages; in these patients nuclear imaging may be more sensitive for the detection of viable myocardium than dobutamine echocardiography.

Most of the studies have used low-dose dobutamine infusion to detect viable myocardium. During the infusion of higher dosages of dobutamine (30–40 µg·kg⁻¹·min⁻¹), it is also possible to induce ischaemia, resulting in reversal of the initial improvement in wall thickening. This pattern, called a biphasic response, has recently been demonstrated to be superior in the prediction of improvement of contractile function after revascularization⁹⁴⁴.

Despite these good results, the technique is limited in that transthoracic echocardiography may not always provide a sufficient image quality and that sometimes the endocardial and epicardial contours are difficult to define. To overcome these problems, several studies have demonstrated the feasibility of transoesophageal low-dose dobutamine echocardiography⁹⁰⁷–⁹⁰⁹,¹¹⁰.

Finally, in a broader context, the lack of infarct expansion or regional thinning may also be indirect markers of viable myocardium. A recent study has demonstrated that segments with a reduction in end-diastolic wall thickness of ≥30% are unlikely to show improvement in mechanical function after revascularization of healed Q-wave anterior myocardial infarctions (predictive value 87%)⁹¹¹.

Despite the aforementioned limitations, dobutamine echocardiography appears useful in the assessment of tissue viability.

**Contrast echocardiography**

Contrast echocardiography is a promising technique, but at the present time requires intracoronary administration of micro air bubbles¹¹². These bubbles remain entirely within the intravascular space and reflect the status of the microvascular perfusion in that region¹¹². Clinical studies have shown that, in patients with acute myocardial infarction, the extent of the collateral bed supplied by collateral flow (as depicted by contrast echocardiography) is a good predictor of functional recovery after coronary angioplasty¹¹³. Importantly, no correlation is seen between angiographic appearance of collaterals and the spatial extent of collateral perfusion defined by contrast echocardiography¹¹³. Early studies were done in patients with occluded infarct-related arteries with injection of microbubbles into the contralateral artery¹¹⁴. More recent studies showed similar conclusions in patients with open infarct-related arteries¹¹⁵. Experimental studies, however, have shown that in the absence of coronary vasodilation (such as dipyridamole), the region of 'no-flow' underestimates infarct size in the presence of patent infarct artery¹¹⁶. However, in the presence of a coronary vasodilator, the perfusion defect size corresponds to the infarct size, while the regions with contrast depict viable myocardium¹¹⁶.

**Magnetic resonance imaging**

Magnetic resonance imaging has been proven valuable in the detection of a wide range of pathophysiological entities such as flow, perfusion, wall motion, and cardiac metabolism¹¹⁷–¹¹⁹. Magnetic resonance imaging may also be useful to identify viable myocardium. Perrone–Filardi et al.¹²⁰ showed that reduced end-diastolic wall thickness and absent systolic wall thickening, measured with magnetic resonance imaging, did not exclude the presence of viable myocardium, measured with FDG and thallium-201 reinjection. Baer et al.¹²¹, however, showed that the combination of low-dose dobutamine infusion during magnetic resonance imaging measurements can identify viable myocardium. The authors compared FDG PET with magnetic resonance imaging during low-dose dobutamine infusion in 35 patients with chronic coronary artery disease. Criteria for viability with magnetic resonance imaging included a positive response during dobutamine (improved systolic wall thickening) or an end-diastolic wall thickness ≥5.5 min. Using FDG PET as the gold standard, they found a sensitivity of 81% and a specificity of 95% for magnetic resonance imaging to detect viable myocardium. To date, the technique is only sparsely used for the detection of myocardial viability, possibly because of the relatively long scanning time and relatively high costs of the equipment. Recent developments, like myocardial tagging (allowing quantification of changes in wall motion during dobutamine infusion) and assessment of metabolism with magnetic resonance spectroscopy¹¹³, may further enhance the use of this modality in the assessment of myocardial viability.

**What are the other factors that affect the degree of improvement of left ventricular function after coronary revascularization?**

Additional factors, besides the presence of viable myocardium, that influence recovery of function or the optimal assessment of recovery after revascularization are listed in Table 3.

1. The technique used to detect recovery of left ventricular function. Most studies have relied on visual analysis of wall motion assessed by two-dimensional echocardiography. Few studies have used radionuclide ventriculography to measure wall motion, while this technique already allows a more objective analysis. In the future, more sophisticated techniques, such as quantitative assessment based on the centreline method available with contrast ventriculography or magnetic resonance imaging, may allow more precise evaluation of left ventricular function after the revascularization.
Table 3  Factors that affect recovery of left ventricular function after revascularization and/or determine optimal assessment of recovery

1. The method of assessment of recovery.
2. The timing of post-revascularization assessment.
3. The magnitude of (pre-revascularization) viable myocardium.
4. Surgical aspects.
5. Associated primary cardiomyopathy.
6. Left ventricular dilatation.

(2) The timing of the assessment of recovery. Early assessment after surgery (6–12 weeks) may underestimate the improvement, possibly because of residual myocardial stunning. Assessment at 4–6 months is probably preferable.[122]

(3) The amount of viable myocardium. It is conceivable that a certain critical mass of viable myocardium is necessary to result in improvement of left ventricular ejection fraction after revascularization. Tillisch et al.[103] showed that improvement of left ventricular ejection fraction only occurred in patients with two or more viable segments (using a 12-segment model, i.e. >16% of the left ventricular) on FDG PET, whereas the patients with one viable segment did not improve in function. Preliminary data from our own group showed a linear relationship between the amount of viability (assessed by FDG SPECT) and the change in left ventricular ejection fraction after revascularization.[123]

(4) Surgical aspects. First, the coronary anatomy must permit revascularization. Second, if the patient suffers from peri-operative necrosis the beneficial effect of revascularization will be negated. Third, the skills of the surgeon and the completeness of the revascularization are important. Finally, early graft closure may prohibit viable myocardium to recover after the revascularization.

(5) The presence of unrelated primary cardiomyopathy.[114]. In these patients left ventricular dysfunction is not due to myocardial ischaemia, hence revascularization will not improve left ventricular function.

(6) Left ventricular chamber size as an important determinant of recovery of function. Left ventricular dilatation is due to both infarct expansion and remodelling: therefore, even myocardial segments with normal perfusion may have systolic dysfunction. The degree of left ventricular dilatation beyond which left ventricular dysfunction becomes irreversible is not clear. It is important that future studies should include quantitative measurement of left ventricular volume in addition to assessment of left ventricular ejection fraction and regional wall motion. Moreover, it appears that accurate assessment of viability and prediction of recovery of function after revascularization is most difficult in patients with poor left ventricular function and severely dilated ventricles. Clearly, more studies are needed to determine the precise value of the different viability techniques in these patients.

Conclusions

It is important to realize that patients who require viability studies are those with chronic, severe, ischaemic left ventricular dysfunction (left ventricular ejection fraction ≤ 35%). Patients with viable myocardium are likely to show improvement in contractile function after coronary revascularization. Depending on several factors, the degree of improvement may be considerable. Furthermore, improvement of left ventricular function may be associated with improvement in survival and improvement in symptoms of congestive heart failure. Therefore, in patients with viable tissue, revascularization may be an alternative to heart transplantation.

The techniques of choice are dobutamine echocardiography or SPECT imaging with either thallium-201, sestamibi or FDG. SPECT imaging with iodinated fatty acids to assess viability has not been validated in extenso and needs further study. PET is particularly useful in patients with ischaemic cardiomyopathy and severely dilated left ventricles. In addition, PET can be used when there is difficulty in the results of dobutamine echocardiography or SPECT imaging. The use of magnetic resonance imaging for the detection of viability remains to be established in larger clinical trials.

References


[40] Ragosta M, Beller GA, Watson DO, Kaul S, Gimble JW. Quantitative planar rest-redistribution TI-201 imaging in
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