Radionuclide Imaging in Congestive Heart Failure

Assessment of Viability, Sarcoidosis, and Amyloidosis

John P. Bois, MD, Panithaya Chareonthaitawee, MD*

KEYWORDS

• Amyloidosis • Cardiac imaging • Radionuclide • Sarcoidosis • Viability

KEY POINTS

- ^{18}F-fluorodeoxyglucose (^{18}F-FDG) PET has the highest sensitivity for detection of myocardial viability.
- Viability assessment helps to guide clinical decision making in patients with moderate-to-severe ischemic cardiomyopathy but its exact role and impact on revascularization outcomes remain uncertain.
- Cardiac PET with ^{18}F-FDG and myocardial "perfusion" imaging has tremendous diagnostic and prognostic potential for cardiac sarcoidosis.
- 99m-Technetium pyrophosphate and 3,3-diphosphono-1,2-propanodicarboxylic acid demonstrate preferential transthyretin-related amyloidosis (ATTR) uptake and may be helpful in distinguishing between ATTR and amyloid light-chain amyloidosis.

INTRODUCTION

The diverse etiologies of myocardial diseases pose diagnostic and therapeutic challenges in patients with congestive heart failure. In specific cardiomyopathies, such as sarcoidosis and amyloidosis, precise identification of the underlying etiology is paramount to treatment choice and outcome. In other situations, such as moderate-to-severe ischemic cardiomyopathy, myocardial viability assessment has important implications for revascularization (**Box 1**). The need for precise identification of these entities has led to intense efforts to develop and refine radionuclide imaging techniques for their assessment. The current review outlines the pathophysiology of each entity, highlights the associated clinical challenges, describes established and emerging radionuclide imaging techniques, and compares them with nonradionuclide imaging modalities.

ASSESSMENT OF MYOCARDIAL VIABILITY IN ISCHEMIC CARDIOMYOPATHY

Despite therapeutic advances, the high morbidity and mortality of ischemic cardiomyopathy persist.[1] At the same time, potential revascularization benefits on survival, functional status, and myocardial contraction must be weighed against the greater periprocedural risks and possible lack of benefit in these patients. Past studies have demonstrated better outcomes with revascularization in patients with versus without viability by noninvasive imaging,[1] but recent trials have not confirmed these prior observations. Although controversy lingers

Disclosures: The authors have nothing to disclose.
Division of Cardiovascular Diseases, Mayo Clinic, 200 First Street Southwest, Rochester, MN 55905, USA
* Corresponding author.
E-mail address: Chareonthaitawee.Panithaya@mayo.edu

Cardiol Clin 34 (2016) 119–132
http://dx.doi.org/10.1016/j.ccl.2015.07.014
0733-8651/16/$ – see front matter

Box 1
Myocardial viability assessment

- Fluorine-18 deoxyglucose PET has the highest sensitivity for detection of myocardial viability.
- Each imaging modality has inherent strengths and weaknesses.
- Viability assessment helps to guide clinical decision making in patients with moderate-to-severe ischemic cardiomyopathy, but its exact role and impact on revascularization outcomes remain uncertain.

on the role of noninvasive viability testing, the pathophysiology of dysfunctional but viable myocardium and the available techniques for its assessment are discussed herein.

Pathophysiology of Dysfunctional but Viable Myocardium

Both hibernating and stunned myocardium exhibit reversible contractile dysfunction and have distinct pathophysiologic definitions. In hibernation, chronically reduced myocardial blood flow leads to adaptive or protective left ventricular (LV) systolic dysfunction, which may improve with revascularization. In myocardial stunning, the pathophysiologic mechanism is the temporary impediment of coronary blood flow that leads to transient contractile dysfunction, which may persist for hours to months even after restoration of flow.[1] Although these 2 entities have distinct pathophysiologic and histologic definitions, in the clinical setting, they may represent the same pathophysiologic process, and may be indistinguishable. Their potential improvement in function with revascularization underscores the role of noninvasive imaging to differentiate between viable myocardium and scar.

Single Photon Emission Computed Tomography

The most common single photon emission computed tomography (SPECT) tracers for viability assessment are thallium-201 (^{201}Tl)[2] and technetium-99m (^{99m}Tc)-based agents.[3] Viability assessment with ^{201}Tl relies on an electromechanical gradient across the intact (viable) cell membrane,[4,5] and on redistribution, whereby ^{201}Tl uptake is initially high in normal myocytes but decreases rapidly within hours as ^{201}Tl returns to the blood pool and becomes available for hibernating/ischemic segments. Two main ^{201}Tl protocols are used for viability: rest–redistribution and stress–redistribution. The definition of viability by ^{201}Tl requires at least 1 of the following: (1) 50% or greater radioactivity in the hypocontractile segments relative to the maximal radioactivity (usually in a normally contracting area), and/or (2) an increase in the relative radioactivity between the initial and redistribution images of at least 1 grade on a standard 5-point semiquantitative visual scale. The ^{201}Tl rest–redistribution protocol has greater sensitivity than the stress–redistribution protocol for predicting contractile recovery after revascularization, but specificity is low (**Fig. 1**, **Table 1**). Over the past decade, use of ^{201}Tl for viability assessment has decreased, likely related to the lower specificity, higher patient radiation exposure (approximately 20–30 mSV), longer duration of the complete study, and lower image quality, especially in patients with a larger body habitus.

Similar to ^{201}Tl, myocardial cellular uptake and retention of ^{99m}Tc requires maintenance of an electrochemical gradient across the cell membrane.[13] Two main ^{99m}Tc viability protocols have been developed: the rest with nitrate enhancement and the rest–stress protocols. Sensitivity of ^{99m}Tc to identify contractile recovery after revascularization is less than that of other noninvasive techniques (see **Fig. 1**, **Table 1**), but specificity is higher than that of ^{201}Tl. Similar to ^{201}Tl, ^{99m}Tc use for viability assessment has also been declining, likely related to similar reasons as for ^{201}Tl, although the radiation exposure associated with ^{99m}Tc is less. Major advantages and disadvantages of SPECT are listed in **Table 1**.

PET

Positron Emission Tomography (PET) with the glucose analog, ^{18}F-fluorodeoxyglucose (^{18}F-FDG), has traditionally been considered the gold standard for the identification of viable myocardium. Viability assessment with ^{18}F-FDG depends on the shift in substrate metabolism from free fatty acids, when flow is normal, to the use of glucose, when oxygen supply is compromised by reduced flow. Ischemic and hibernating cells, therefore, demonstrate relatively increased ^{18}F-FDG uptake compared with scar tissue, and to normal myocytes. ^{18}F-FDG PET viability imaging requires concomitant myocardial perfusion imaging, usually with either ^{13}N-ammonia, or rubidium-82 (^{82}Rb). Proper patient preparation is crucial to diagnostic ^{18}F-FDG image quality, and usually requires a combination of insulin and glucose administration to decrease free fatty acid levels and maximize myocardial ^{18}F-FDG uptake.[14]