INTRODUCTION
(Srichai 2018; Mitra 2102; Patel 2013)

- Multiple-gated acquisition (MUGA) scanning uses radio-labelled red blood cells to scan right and left ventricular images in a cine loop format that is synchronized with the ECG, which requires a regular rhythm for accuracy.

- Right and left ventricular systolic wall motion, ejection fraction, ventricular volumes, stroke volume ratios, diastolic function, pulmonary blood volumes, regurgitant fractions, and exercise response can be derived from the data acquired by the gamma camera (Scheiner 2002; Ritchie 1995). However, in the current era, the test is primarily for a left ventricular ejection fraction (LVEF) determination, when transthoracic echocardiography (TTE) has been inadequate, and cardiac magnetic resonance imaging (CMR) precision is not demanded.

INDICATIONS FOR A MUGA SCAN
(Srichai 2018; Mitra 2102; Patel 2013; Corbett 2008; Friedman 2009)

- In the course of cardiotoxic chemotherapy and/or subsequent to radiation to the anterior or left chest, when TTE has not been helpful and CMR is not available, to evaluate left ventricular systolic function (Zamorano 2016; Plana 2014; Patel 2013; Yancy 2013):
  - Prior to cardiotoxic chemotherapy, and subsequently for monitoring and follow up (see cardio-oncology section under Additional Information)
  - For radiation to the anterior or left chest, left ventricular function assessment at baseline, 5 years post inception, and every 5 years thereafter (Lancellotti 2013)

- To evaluate biventricular or left ventricular function in a patient with CAD, valvular heart disease, myocardial disease, or congenital heart disease, in any of the following scenarios:
  - When ventricular function is required for management and/or post therapeutic/post interventional/post-operative follow up, and echocardiography or other required concomitant imaging has proven inadequate (e.g. COPD, obesity) for an adequate determination of ejection fraction (Yancy 2013; Patel 2013)
  - With new, worsening, intractable (Mitra 2012) or other major status change in congestive heart failure (CHF), when TTE or other required concomitant imaging
has proven inadequate (e.g. COPD, obesity interfering with TTE) (Fihn 2012; Yancy 2013; Patel 2013)
- In the presence of significant resting wall motion abnormalities or distorted geometry (Patel 2013)
- For accurate verification of ejection fraction in meeting criteria for an implantable cardioverter defibrillator (ICD) and/or cardiac resynchronization therapy (CRT) implantation (Krahn 2008)

- As an alternative form of stress imaging instead of myocardial perfusion imaging, based upon similar necessity criteria for the evaluation of coronary artery disease, recognizing some prohibitive limitations with respect to (Ritchie 1995; Corbett 2008; Friedman 2009):
  - Localization of ischemia (superior with MPI)
  - Quantitation of myocardium at risk (superior with MPI)
  - Requirement for ability/safety with performance of exercise or with inotropic stimulation
  - Lack of interpretability when
    - Resting MUGA images are poor
    - ECG-related issues are present (affecting wall motion or gating technique)
      - Complete left bundle branch block
      - Ventricular pacing or ICD
      - Ventricular pre-excitation (e.g. Wolff Parkinson White)
      - Atrial fibrillation
      - Frequent ectopy, irregular rhythm

**Additional Information**

**Imaging Surveillance for Cardiotoxic Chemotherapy**
(Plana 2014; Zamorano 2016; Maleszewski 2018; Herrmann 2014)

**TTE is the method of choice** for the evaluation of patients before, during, and after cancer therapy. Ideally accuracy prefers that 3D and global longitudinal strain (GLS) are part of the exam, and serum troponin (Tn) should also be measured. However, GLS and Tn might not have been performed, in which case determinations might need to be made with left ventricular ejection fraction (LVEF) only. *Serum troponin (Tn) and GLS abnormalities constitute an abnormal assessment of LV function, because their abnormalities frequently herald an imminent fall in LVEF* (Plana 2014; Zamorano 2016).

**CMR** is recommended when TTE has been unreliable and/or candidacy for cardiotoxic chemotherapy based upon LVEF is questionable (Plana 2014). MUGA can also be considered when TTE is inadequate and CMR is not available.

**MUGA** is accurate and reproducible, but lacks information about pericardium and valves, incurs repeated radiation exposure, and is inaccurate during an irregular cardiac rhythm (Plana 2014).
**Surveillance guidelines** are somewhat complex, possibly beyond the scope of this guideline, especially in patients with additional risk factors for LV dysfunction (Herrmann 2014). As with all guidelines, adequate information for complex decisions might be impractical to acquire. However, if the reader requires more rigorous recommendations, they are summarized concisely in the table below. **Necessity determinations might not require strict adherence to this table at this time, but it is here to serve as a helpful reference for the reader, if desired.**

**TTE Surveillance Strategy for Cardiotoxic Chemotherapy (Optional Information)**  
(Plana 2014; Herrmann 2014; Zamorano 2016; Maleszewski 2018)

<table>
<thead>
<tr>
<th>Suspected/Detected LV Status at Baseline, During, or After Completion of Therapy (LVEF is minimum information, GLS and Tn can reveal early LV dysfunction prior to LVEF)</th>
<th>Type I</th>
<th>Type II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suspected/Detected LV Status at Baseline, During, or After Completion of Therapy (LVEF is minimum information, GLS and Tn can reveal early LV dysfunction prior to LVEF)</td>
<td>Type I Anthracyclines: Doxorubicin, Epirubicin, Idarubicin Mitoxantrone (Asnani 2018)</td>
<td>Type II Trastuzumab, Labatinib, Pertuzumab, Sorafenib, Sunitinib, Bevacizumab, Bortezomib **</td>
</tr>
<tr>
<td>Normal: EF is ≥ 55%, troponin is negative, and global longitudinal strain (GLS) &gt; lower limit of normal*</td>
<td>Normal assessment: Assess after a cumulative dose &gt; 200mg/M² (or its anthracycline equivalent) and prior to each additional 50 mg/M², and completion of therapy, and 6 months later, and for cumulative dose &gt; 300 mg/M² include assessment at 1 year and at 5 years post completion of therapy. (Zamorano 2016)</td>
<td>Normal assessment: Assess every 3 months during therapy and at 6 months post completion of therapy</td>
</tr>
<tr>
<td>Abnormal: any one of:</td>
<td>Abnormal assessment: Assess after every cycle, and re-assess for verification 2-3 weeks later if a drop in LV function has been detected/suspected: assess 6 months post completion of therapy, followed by re-assessment every 6 months until stable, and for cumulative dose &gt; 300 mg/M² include assessment at 1 year and 5 years post completion of therapy. (Zamorano 2016)</td>
<td>Abnormal assessment: Assess after every cycle, and re-assess for verification 2-3 weeks later if a drop in LV function has been detected /suspected: assess 6 months post completion of therapy, and if still not stable re-assess every 6 months until stable.</td>
</tr>
<tr>
<td>o GLS reduced ≥ 10-15% below normal (about 20 is normal*, labs vary)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>o Troponin positive</td>
<td></td>
<td></td>
</tr>
<tr>
<td>o LVEF started &lt; 55%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>o During therapy LVEF drops below 55% AND ≥ 5 points for a symptomatic ≥ 10 points for an asymptomatic patient. (Maleszewski 2018)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* GLS of (negative) 20 is generally normal, but individual labs vary (Collier 2017).
** Imatinib, rarely cardiotoxic, does not require surveillance of LV function (Floyd 2018).
First Pass Radionuclide Angiography
(Friedman 2009)

First pass radionuclide ventriculography provides similar information by radiotracer blood pool scanning, but requires only a single pass of isotope through the heart, made possible by rapid, high count rate acquisition, achievable with certain multi-crystal gamma cameras. Its indications are essentially the same as for MUGA, also referred to as equilibrium radionuclide angiography, which requires time (i.e. multiple cardiac cycles) for isotope circulation.

Combination of Other Studies with MUGA

Abdomen CT/Pelvis CT/Chest CT/Neck MRI/Neck CT with MUGA – known tumor/cancer for initial staging or evaluation before starting chemotherapy or radiation treatment.

Abbreviations

- CMR  Cardiac Magnetic Resonance Imaging
- CT   Computed Tomography Imaging
- ECG  Electrocardiogram
- GLS  Global longitudinal strain (measurement of left ventricular function)
- mg   Milligrams
- MUGA Multiple Gated Acquisition (nuclear scan of ventricular function)
- PAC  Premature atrial contraction
- PVC  Premature ventricular contraction
- sqM  Square meters of body surface area
- Tn   Troponin
- TTE  Transthoracic echocardiography
- WPW  Wolf Parkinson White Syndrome (electrical pre-excitation)
REFERENCES


Floyd J, Cardiotoxicity of nonanthracycline cancer chemotherapy agents. UpToDate, May 2018. Available at: https://www.uptodate.com/contents/cardiotoxicity-of-nonanthracycline-cancer-chemotherapy-agents?search=cardiotoxicity%20chemotherapy&source=search_result&selectedTitle=1~150&usage_type=default&display_rank=1#. Retrieved June 13, 2018


Ritchie JL, Bateman TM, Bonow RO, et al Guidelines for clinical use of cardiac radionuclide imaging, report of the American College of Cardiology/American Heart Association Task Force on Assessment of Diagnostic and Therapeutic Cardiovascular Procedures (Committee on Radionuclide Imaging) developed in collaboration with the American Society of Nuclear Cardiology. *JACC.* 1995;25(2):521-547.


Srichai MB, Danias PG, Lima J. Tests to evaluate left ventricular function. UpToDate. Waltham, MA; April, 2018. Available at: https://www.uptodate.com/contents/tests-to-evaluate-left-ventricular-systolic-function?search=indications%20for%20muga%20radionuclide%20left%20ventriculography&source=search_result&selectedTitle=1~150&usage_type=default&display_rank=1 Retrieved May 23, 2018

