Training in Multimodality Imaging

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MULTIMODALITY IMAGING TRAINING LEVELS AND TIME REQUIREMENTS

LEVELS OF TRAINING:

Level I: Basic training required of all fellows to become competent consultants and is a prerequisite for further multimodality imaging (MMI) training. This does not qualify the trainee for independent practice as an imager.

- **Training Program Mandate:** All cardiology fellows should successfully complete level I training in Echocardiography, Nuclear Cardiology (SPECT), Cardiovascular CT, and Cardiovascular MRI. Optional training in vascular ultrasound may become available in the future through individualized collaboration with the vascular lab.

- **Rotation Requirements (over 3 years):** 7 months (3 months of Echo and 4 months of Multi-Modality Imaging). MMI rotations will include Nuclear Cardiology, CT, and MRI to collectively account for the required 2 months of Nuclear, 1 month of CT, and 1 month of MRI.

- **General Training Objectives:** Develop the knowledge required for the practicing integrated, patient-centric imaging which is aimed to help improve patient outcomes, while reducing cost, minimizing risk, and enhancing value.

- **General Training Goals for Level I Competency in Cardiac Imaging:**
  - Learn the basic physical principles underlying echocardiographic, nuclear, CCT, and CMR imaging modalities.
  - Recognize each modality’s respective advantages, limitations, and potential risks.
  - Be able to select the most appropriate imaging modality for any common clinical condition.
  - Develop competence in evidence-based and appropriateness-based application of each of these imaging methods in the clinical setting.
  - Integrate the results of noninvasive imaging with other components of the patients’ evaluation to create a comprehensive management plan.
  - Learn to identify complex settings in which consultation with an advanced
imaging specialist is required.

- Extend the clinical application of all the above mentioned principles to specific situations when noninvasive imaging is employed in conjunction with surgical and catheter-based interventional or electrophysiological procedures.

**Level II: Additional** training in 1 or more specific imaging modalities which qualifies the trainee for independent practice as an imager.

- **Training Program Mandate:** Level II training in any of the imaging modalities is optional. However, fellows should be allowed some flexibility in their rotation schedule to seek further level II training, particularly in echocardiography if that aligns with their future career goals. Pursuing Level II training in any imaging modality is contingent upon successful completion of all mandatory (Level I) training requirements.

- **Rotation Requirements (over 3 years):** An additional 3 months for Echo, an additional 2 months for Nuclear, at least 3 additional months for MRI, and at least 1 additional month for CT.

**Note:** Due to the additional training and time demands, Level II competency training in any imaging modality during the standard 36 month-fellowship will require approval by the clinical competency committee and program director.

**Level III:** This level of training usually requires additional experience beyond the standard 3-year cardiovascular fellowship and is therefore not applicable to the general cardiology fellows.

**Note:** Such training will require a dedicated subspecialty fellowship in multimodality imaging.

**GUIDING PRINCIPLES FOR TRAINING IN MULTIMODALITY NONINVASIVE CARDIOVASCULAR IMAGING:**

1. All fellows should understand the basic principles underlying echocardiographic, nuclear cardiology, CCT, and CMR imaging along with each modality’s limitations and potential risks as the basis for achieving mandatory Level I competency in all 4 modalities.

2. Due to increased cost and complexity, fellows should develop competence in practicing evidence-based, appropriate use of these technologies to provide safe,
high quality, and cost effective patient care in various situations.

3. All fellows should gain a deep understanding of appropriate use criteria (AUC) and be encouraged to link their logged procedures to the corresponding AUC.

4. Training in non-invasive imaging should not be biased toward the heavy utilization of a specific modality. Instead, fellows should be guided by the available technical resources and professional expertise to select the optimum test for each individual situation.

5. All fellows should become competent in integrating the results of noninvasive imaging with other components of the clinical evaluation for various cardiovascular diseases. Correlation of findings across multiple imaging modalities should be emphasized to enhance the understanding of the strengths and weaknesses of each modality. Common workstations that display images generated by multiple imaging modalities are required for this purpose.

6. Concurrent training across multiple imaging modalities is encouraged whenever possible. Training in subjects common to multiple modalities (e.g., radiation physics, image processing etc…) can be grouped to avoid duplication or repetition.

7. For adequate training, fellows should be granted hands on access to on-site facilities, or be provided with audiovisual resources and courses organized by subspecialty organizations. In specific situations, off-site collaboration with other programs may be considered.

8. Trainee competency, as evaluated by the clinical competency committee, should serve as the primary determinant of sufficient training, rather than the time, exposure, or volume of imaging studies performed or interpreted.

9. By the conclusion of their training, all fellows should be able to identify complex settings in which consultation with a specialist in advanced cardiovascular imaging is required to select the most appropriate imaging approach that addresses the clinical question at hand.

10. Fellows will be provided with opportunities to pursue or facilitate Level II training in 1 or more imaging modalities, based on each fellow’s aptitude, interests, and career goals. More advanced competency beyond Level II typically requires additional training beyond the standard 3-year cardiovascular fellowship.

11. As medical school and residency training provides more advanced imaging training and a wider array of modalities is introduced in the future, fellows in cardiology should be progressively better prepared to understand, utilize, and perform cardiac imaging.

EVALUATION OF COMPETENCY:

To ensure quality, competency-based learning methods will be utilized whenever possible to ensure that successful graduation occurs on the basis of articulated and
rigorously evaluated competency rather than just the amount of time devoted to a particular skill or the number of procedures performed or interpreted during training. More specifically:

- Appropriate selection of the optimum modality on a case-by-case basis, judgment, acquisition, and interpretive skills should be evaluated in every trainee.

- Evaluation tools may include direct observation by faculty, in-training examinations, case logbooks, conference and case presentations, multisource evaluations, trainee portfolios, or simulation.

- Interaction with other physicians, patients, and laboratory support staff; initiative; reliability; decisions or actions that result in complications; and the ability to make appropriate decisions independently and follow up appropriately should be considered in these assessments.

- Trainees should maintain records of participation and advancement in the form of a Health Insurance Portability and Accountability Act (HIPAA)–compliant electronic database or logbook that meets ACGME reporting standards.

- Fellows should document clinical correlation with the other imaging, hemodynamic, invasive laboratory, surgical pathology, and outcomes data to enhance their understanding of the diagnostic utility and value of various imaging procedures.

- Finally, imaging experiences should be assessed against measures of quality with regard to test selection, performance, interpretation, and reporting to ensure an appreciation of the potential adverse consequences of suboptimal, redundant, or unnecessary testing.

- The teaching faculty should record and verify each trainee’s experiences, assess his or her performance, and document satisfactory achievement.

- The program director is responsible for confirming trainees’ experience and competence and reviewing the overall progress of individual trainees with the Clinical Competency Committee to ensure achievement of selected training milestones and to identify areas in which additional focused training may be required.
Echocardiography

A. ECHOCARDIOGRAPHY – CORE COMPETENCIES AND CURRICULAR MILESTONES BY ROTATION and COMPETENCY COMPONENT (COCATS 4)

YEAR 1 or MONTH 1-2

MEDICAL KNOWLEDGE
- **Level 1**: Know the physical principles of ultrasound and the instrumentation used to obtain images.
- **Level 1**: Know the limitations and potential artifacts of the echocardiographic examination.
- **Level 1**: Know the standard views included in a comprehensive transthoracic echocardiogram.

SYSTEMS-BASED PRACTICE
- **Level 1**: Work effectively and efficiently with the echocardiography laboratory staff

PROFESSIONALISM
- **Level 1**: Interact respectfully with patients, families, and all members of the healthcare team, including ancillary and support staff.

YEAR 2 or MONTH 2-3

MEDICAL KNOWLEDGE
- **Level 1**: Know the appropriate indications, including the appropriate use criteria, for: M-mode, 2-dimensional, and 3-dimensional transthoracic echocardiography; Doppler echocardiography and color-flow imaging; transesophageal echocardiography; tissue Doppler and strain imaging; and contrast echocardiography.
- **Level 1**: Know the standard views included in a comprehensive transesophageal echocardiogram.
- **Level 1**: Know the characteristic findings of cardiomyopathies.
- **Level 1**: Know the echocardiographic and Doppler findings of cardiac ischemia and infarction, and the complications of myocardial infarction.

PATIENT CARE AND PROCEDURAL SKILLS
- **Level 1**: Skill to perform and interpret a basic transthoracic echocardiographic examination.
- **Level 1**: Skill to integrate echocardiographic findings with clinical and other testing result in the evaluation and management of patients.
SYSTEMS-BASED PRACTICE
- **Level 1**: Incorporate risk/benefit, safety, and cost considerations in the use of ultrasound techniques.

PRACTICE-BASED LEARNING AND IMPROVEMENT
- **Level 1**: Identify knowledge and performance gaps and engage in opportunities to achieve focused education and performance improvement.

PROFESSIONALISM
- **Level 1**: Know and promote adherence to guidelines and appropriate use criteria.

YEAR 2 or MONTH 4-5

MEDICAL KNOWLEDGE
- **Level 2**: Know the echocardiographic findings of pericardial disease, pericardial effusion, and pericardial constriction.
- **Level 2**: Know the techniques to evaluate cardiac masses and suspected endocarditis.
- **Level 2**: Know the techniques to evaluate diseases of the aorta.
- **Level 2**: Know the techniques to assess pulmonary artery pressure and diseases of the right heart.
- **Level 2**: Know the use and characteristic findings in the evaluation of patients with systemic diseases involving the heart.
- **Level 2**: Know the indications for, and the echocardiographic findings in, patients with known or suspected cardioembolic events.
- **Level 2**: Understand the principles and applications of 3-dimensional echocardiography.
- **Level 2**: Recognize and treat the potential complications of stress, contrast, and transesophageal echocardiography.

INTERPERSONAL AND COMMUNICATION SKILLS
- **Level 2**: Communicate with and educate patients and families across a broad range of cultural, ethnic, and socioeconomic backgrounds.
- **Level 2**: Communicate testing results to physicians and patients in an effective and timely manner.

YEAR 3 or MONTH 5-6

MEDICAL KNOWLEDGE
- **Level 2**: Know the techniques to quantify cardiac chamber sizes and evaluate left and right ventricular systolic and diastolic function and hemodynamics.
- **Level 2**: Know the use of echocardiographic and Doppler data to evaluate native and prosthetic valve function and diseases.
• **Level 2:** Know the characteristic findings of basic adult congenital heart disease.
• **Level 2:** Know key aspects of contrast echocardiography including interpretation, administration techniques, and safety information.

**PATIENT CARE AND PROCEDURAL SKILLS**
• **Level 2:** Skill to perform and interpret a comprehensive transthoracic echocardiographic examination.
• **Level 2:** Skill to perform and interpret a comprehensive transesophageal echocardiographic examination.
• **Level 2:** Skill to recognize pathophysiology, quantify severity of disease, identify associated findings, and recognize artifacts in echocardiography.
• **Level 2:** Skill to interpret stress echocardiography.
• **Level 2:** Skill to incorporate stress hemodynamic information in the management of complex valve disease or hypertrophic cardiomyopathy.
• **Level 2:** Skill to perform and interpret basic 3-dimensional echocardiography.
• **Level 2:** Skill to perform and interpret contrast echocardiographic studies.
• **Level 2-3:** Skill to utilize echocardiographic techniques during cardiac interventions, including intraoperative transesophageal echocardiography.
• **Level 2-3:** Skill to utilize advanced 3-dimensional echocardiography during guidance of procedures and/or surgery.

**SYSTEMS-BASED PRACTICE**
• **Level 2:** Participate in echocardiographic quality monitoring and initiatives.

**INTERPERSONAL AND COMMUNICATION SKILLS**
• **Level 2:** Communicate detailed information on cardiac anatomy for surgical planning or guidance of interventional procedures.

**B. TRAINING GUIDELINES IN REGULAR ECHOCARDIOGRAPHIC PROCEDURES**
• Each fellow is expected to complete a minimum of three months of echocardiography, preferably prior to the end of their second year of general cardiology training to meet level 1 requirements and 6 months of training by the end of their fellowship to meet level 2 training.
• The core competencies and curricular milestones outlined in the latest COCATS 4 document will serve as the basis for structuring each rotation and assessing progress.
• The core competencies and curricular milestones commensurate with each fellow's level of training (by year or month) will be provided to them and to the teaching faculty at the beginning of every rotation to ensure training is properly channeled toward meeting these goals.
• Fellows on the Echo rotation will receive direct supervision and hands-on training in the performance of transthoracic echocardiography by designated senior sonographers.
To meet the procedural volume and quality standards required for level I training in echocardiography, each fellow has to successfully **perform 75 complete, or near complete transthoracic examinations and participate in their interpretation** by the end of their third echo month. In addition, every fellow will need to partially or completely **interpret an additional 75 studies** within the same timeframe.

To be a candidate for level II training in echocardiography, fellows have to first meet all the level I core competencies and curricular milestones outlined in this document. Each fellow will then have to be physically signed off on meeting those skills by the clinical competency committee and/or the training program director preferably by the end of their second year of training to make room for additional training geared toward Level II competency.

Once the above pre-requisites are met, the procedural volume and quality standards required for level II training in echocardiography, will consist of successfully **performing and interpreting an additional 75 complete transthoracic examinations** under appropriate, though less intense supervision. Each fellow will also need to **fully, and correctly interpret an additional 75 transthoracic studies** by their graduation date.

C. TRAINING GUIDELINES IN SPECIAL ECHOCARDIOGRAPHIC PROCEDURES

- Fellows on the Echo rotation will receive direct supervision and hands-on training in the performance of transesophageal, and rest and stress echocardiographic examinations including 3D and contrast echocardiography by a collaborative effort between senior sonographers and imaging faculty.

- Initial exposure to TEE and other special echocardiographic procedures may begin during the latter part of level 1 training (during second year of fellowship or after completion of first 2 echo rotations) as long as the fellow is on track toward timely completion of their core competencies and curricular milestones.

- Minimum training for independent performance and interpretation of TEE is a level II competence and shall **not** be started until level I training in regular echocardiography is completed.

- Level II training in TEE requires the supervised performance and interpretation of at least 100 multiplanar studies in addition to **50 successful esophageal intubations**.

- Similar to TEE, initial exposure to stress echocardiography may begin during the latter part of level 1 training, as long as the fellow is on track toward timely completion of their core competencies and curricular milestones. However because of the difficulty in interpreting segmental wall-motion and/or perfusion abnormalities developing during stress echocardiography, achieving basic competence in this area is an objective of Level II training and generally requires participation in and interpretation of at least 100 stress echocardiograms under the supervision of a Level III–trained physician.
• Fellows completing Level II training should have the requisite skills to perform and interpret contrast-enhanced echocardiograms under the supervision of a Level III echocardiographer trained in contrast imaging.

• Level II training should prepare fellows to apply 3D echocardiography appropriately and expose them to basic image acquisition and interpretation.

• Level II training in echocardiography should include knowledge of the principles and potential applications of strain echocardiography.
NUCLEAR CARDIOLOGY

A. NUCLEAR CARDIOLOGY – CORE COMPETENCIES AND CURRICULAR MILESTONES BY ROTATION and COMPETENCY COMPONENT (COCATS 4)

MONTH 1 of the MMI rotations

MEDICAL KNOWLEDGE
- **Level 1:** Know the indications for myocardial perfusion imaging and the appropriate selection of exercise versus pharmacologic stress testing.
- **Level 1:** Know the principles and use of pretest probability and sequential probability analysis to assess post-test probability.

PROFESSIONALISM
- **Level 1:** Interact respectfully with patients, families, and all members of the healthcare team—including ancillary and support staff.

MONTH 2-4 of the MMI rotations

MEDICAL KNOWLEDGE
- **Level 1:** Know the principles of SPECT and radionuclide ventriculography image acquisition and display, including the standard tomographic planes and views.
- **Level 1:** Know the properties and use of standard perfusion tracers.
- **Level 1:** Know the mechanism of pharmacologic stress agents, methods of their administration, and safety issues in using the agents.
- **Level 1:** Know the protocols for administration of standard perfusion agents and the influence of the clinical situation on choice of imaging protocol.
- **Level 1:** Know the use of nuclear cardiology in the assessment of ventricular function.
- **Level 1:** Know the protocols for the use of perfusion imaging to assess myocardial viability.

PATIENT CARE AND PROCEDURAL SKILLS
- **Level 1:** Skill to select the appropriate imaging study.
- **Level 1:** Skill to integrate perfusion imaging findings with clinical and other test results in the evaluation and management of patients.
- **Level 1:** Skill to identify results that indicate a high-risk state.

SYSTEMS-BASED PRACTICE
- **Level 1:** Incorporate risk/benefit and cost considerations in the use of radionuclide imaging techniques.
PRACTICE-BASED LEARNING AND IMPROVEMENT
- **Level 1:** Identify knowledge and performance gaps and engage in opportunities to achieve focused education and performance improvement.

PROFESSIONALISM
- **Level 1:** Know and promote adherence to guidelines and appropriate use criteria.

INTERPERSONAL AND COMMUNICATION SKILLS
- **Level 1:** Communicate effectively and timely with patients, families, and referring physicians.

ADDITIONAL 2 months of the MMI rotation (dedicated to Nuclear Cardiology)

MEDICAL KNOWLEDGE
- **Level 2:** Know the principles of radiation safety and how to minimize radiation exposure.
- **Level 2:** Know the quality control issues, how to review raw data, and recognize artifacts.
- **Level 2:** Know the indications for PET imaging and use of PET tracers.

PATIENT CARE AND PROCEDURAL SKILLS
- **Level 2:** Skill to perform and interpret gated stress-rest perfusion study.
- **Level 2:** Skill to perform and interpret a radionuclide ventriculography study.

SYSTEMS-BASED PRACTICE
- **Level 2:** Work effectively and efficiently with the nuclear laboratory staff.
- **Level 2:** Participate in laboratory quality monitoring and initiatives.

INTERPERSONAL AND COMMUNICATION SKILLS
- **Level 2:** Communicate test results in a comprehensive and user-friendly manner.
CARDIOVASCULAR MRI

A. CARDIOVASCULAR MRI – CORE COMPETENCIES AND CURRICULAR MILESTONES BY ROTATION and COMPETENCY COMPONENT (COCATS 4)

MONTH 1-3 of the MMI rotations

MEDICAL KNOWLEDGE

- Level 1: Know the principles of cardiovascular magnetic resonance image acquisition.
- Level 1: Know the principles of safety and contraindications for cardiovascular magnetic resonance imaging.
- Level 1: Know the uses, potential side effects, and contraindications of using gadolinium-based contrast agents in cardiovascular magnetic resonance imaging.
- Level 1: Know the indications for cardiovascular magnetic resonance to assess left and right heart chamber sizes and function.
- Level 1: Know the cardiovascular magnetic resonance indications for assessment of myocardial viability.
- Level 1: Know the cardiovascular magnetic resonance indications and characteristic findings of myocardial ischemia.
- Level 1: Know the cardiovascular magnetic resonance indications and characteristic findings of acute myocardial infarction.
- Level 1: Know the cardiovascular magnetic resonance indications and characteristic findings of acute coronary syndromes and other causes of myocardial injury.
- Level 1: Know the cardiovascular magnetic resonance indications and differential findings in cardiomyopathies of uncertain cause.
- Level 1: Know the cardiovascular magnetic resonance indications to assess diseases of the pericardium.
- Level 1: Know the cardiovascular magnetic resonance indications to evaluate valvular heart disease.
- Level 1: Know the cardiovascular magnetic resonance indications for left atrial and pulmonary vein mapping prior to ablation of atrial fibrillation.

SYSTEMS-BASED PRACTICE

- Level 1: Incorporate risk/benefit and cost considerations in the use of cardiovascular magnetic resonance testing.

PROFESSIONALISM

- Level 1: Know and promote adherence to guidelines and appropriate use criteria.
MONTH 4 of the MMI rotations

MEDICAL KNOWLEDGE
- **Level 1**: Know the cardiovascular magnetic resonance indications and characteristic findings of myocardial masses and thrombi.
- **Level 1**: Know the cardiovascular magnetic resonance indications for evaluation of adult congenital heart disease including identification of coronary artery anomalies.
- **Level 1**: Know the cardiovascular magnetic resonance indications to detect and evaluate diseases of the aorta and peripheral arteries.

PATIENT CARE AND PROCEDURAL SKILLS
- **Level 1**: Skill to appropriately order and integrate the results of cardiovascular magnetic resonance testing with other clinical findings in the evaluation and management of patients.
- **Level 1**: Skill to interpret cardiovascular magnetic resonance tissue characterization (late gadolinium enhancement) to distinguish the etiology of cardiomyopathy and acute myocardial injury.

PRACTICE-BASED LEARNING AND IMPROVEMENT
- **Level 1**: Identify knowledge and performance gaps and engage in opportunities to achieve focused education and performance improvement.

PROFESSIONALISM
- **Level 1**: Practice within the scope of expertise and technical skills.

ADDITIONAL 3 months of the MMI rotation (dedicated to Cardiovascular MRI)

PATIENT CARE AND PROCEDURAL SKILLS
- **Level 2**: Skill to interpret regional and global left and right ventricular wall motion and ejection fraction.
- **Level 2**: Skill to interpret vascular diseases of the aorta (e.g., intramural hematoma, dissection, coarctation, and aneurysm).
- **Level 2**: Skill to identify and characterize myocardial masses.
- **Level 2**: Skill to identify and characterize pericardial disease.
- **Level 2**: Skill to identify and diagnose basic congenital heart disease in adults.
- **Level 2**: Skill to identify and diagnose complex adult congenital heart disease, including quantification of intracardiac shunting, and anomalous coronary arteries.
- **Level 2**: Skill to perform and interpret cardiovascular magnetic resonance stress testing.

SYSTEMS-BASED PRACTICE
- **Level 2**: Participate in cardiovascular magnetic resonance quality monitoring and initiatives.
INTERPERSONAL AND COMMUNICATION SKILLS

- **Level 2**: Communicate testing results to physicians and patients in an effective and timely manner.

B. TRAINING GUIDELINES IN CARDIOVASCULAR MRI

- Each fellow is expected to complete level I training in cardiovascular MRI by the conclusion of their 4th month of the multimodality imaging rotation.
- The core competencies and curricular milestones outlined in the latest COCATS 4 document will serve as the basis for rotation structure and progress assessment.
- The core competencies and curricular milestones commensurate with each fellow's level of training (by year or month) will be provided to them and to the teaching faculty at the beginning of every rotation to ensure training is properly channeled toward meeting these goals.
- Over the first four months of the MMI rotation, fellows will gain exposure to the basic methods and applications of CMR through direct involvement in at least 25 cases (preferably 50) mentored by MRI faculty and dedicated technicians. This should provide fellows with the basic (Level 1) background knowledge in CMR required for the practice of adult cardiology, appropriate patient referral for CMR evaluation, and report interpretation, but not for the practice of or independent clinical interpretation of CMR studies.
- To be a candidate for level II training in CMR, fellows have to successfully complete all the level I core competencies and curricular milestones outlined in this document and be on track for completing their level II training in Echocardiography by the end of their 3 year fellowship.
- Level II trainees must receive at least 3 additional months of dedicated CMR training (where 1 month is defined as 4 weeks and 1 week is defined as 35 hours) to develop a clear understanding of CMR physics and how it relates to image acquisition, sequence building, and troubleshooting common issues that may come up during image acquisition and post-processing.
- To satisfy level II training requirements, fellows should actively participate in daily CMR study performance and interpretation under the direction of Level II or (preferably) Level III CMR faculty. This entails interpreting at least 150 CMR examinations, 50 or more of which need to be either acquired by the fellow or directly supervised by them. For all studies in which other cardiac imaging data are available, such information should be correlated with CMR data.
CARDIOVASCULAR CT

A. CARDIOVASCULAR CT – CORE COMPETENCIES AND CURRICULAR MILESTONES BY ROTATION and COMPETENCY COMPONENT (COCATS 4)

MONTH 1-3 of the MMI rotations

MEDICAL KNOWLEDGE
- **Level 1:** Know the principles of cardiovascular computed tomographic scanning and the scanning modes.
- **Level 1:** Know the appropriate indications for cardiovascular computed tomography for screening or evaluating symptoms in patients with suspected cardiac disease.
- **Level 1:** Know the indications, potential adverse effects, prevention, and treatment of complications of iodinated contrast agent use in cardiovascular computed tomographic studies.

PATIENT CARE AND PROCEDURAL SKILLS
- **Level 1:** Skill to recognize and treat contrast-related adverse reactions.

SYSTEMS-BASED PRACTICE
- **Level 1:** Incorporate appropriate use criteria, risk/benefit, and cost considerations in the use of cardiovascular computed tomography and alternative imaging modalities.

PROFESSIONALISM
- **Level 1:** Work effectively in an interdisciplinary cardiovascular computed tomographic imaging environment.
- **Level 1:** Reliably obtain patient informed consent, ensuring that patients understand the risks and benefits of, and alternatives to, cardiovascular computed tomographic testing.
- **Level 1:** Know and promote adherence to clinical practice guidelines.

INTERPERSONAL AND COMMUNICATION SKILLS
- **Level 1:** Communicate testing results to physicians and patients in an effective and timely manner.

MONTH 4 of the MMI rotations

MEDICAL KNOWLEDGE
- **Level 1:** Know the risks and safety measures for cardiovascular computed tomographic scanning, including radiation reduction strategies.
• **Level 1:** Know the characteristic cardiovascular computed tomographic images of normal cardiac chambers and great vessels, normal coronary arteries and veins, and normal variants.

• **Level 1:** Know when to request help with interpretation of difficult studies, such as patients with complex congenital heart disease.

**PATIENT CARE AND PROCEDURAL SKILLS**
• **Level 1:** Skill to appropriately utilize cardiovascular computed tomography in the evaluation and management of patients with known or suspected cardiovascular disease.

• **Level 1:** Skill to integrate cardiovascular computed tomographic findings with other clinical information in patient evaluation and management.

**PRACTICE-BASED LEARNING AND IMPROVEMENT**
• **Level 1:** Identify knowledge and performance gaps and engage in opportunities to achieve focused education and performance improvement.

• **Level 1:** Utilize point-of-care educational resources (e.g., guidelines, appropriate use criteria, and clinical trial results).

**ADDITIONAL months of the MMI rotation (dedicated to Cardiovascular CT)**

**MEDICAL KNOWLEDGE**
• **Level 2:** Know the indications and protocols for beta-adrenergic blocking drugs and nitroglycerin during cardiovascular computed tomographic studies.

• **Level 2:** Know the principles of cardiovascular computed tomographic scan collimation, temporal resolution, table speed, field of view, and window and level view settings.

• **Level 2:** Know the principles of post-processing methods for cardiovascular computed tomographic scanning.

• **Level 2:** Know the algorithms used for reconstruction, and recognize and isolate causes of artifacts.

• **Level 2:** Know the principles of quantitative coronary artery calcium scoring.

• **Level 2:** Know normal chest anatomy and common incidental extra cardiac findings.

• **Level 2:** Know the characteristic cardiovascular computed tomographic findings of coronary atherosclerosis including plaque morphology and assessment of stenosis severity.

• **Level 2:** Know the characteristic cardiovascular computed tomographic findings of anomalous coronary arteries and other common congenital anomalies.

• **Level 2:** Know the characteristic cardiovascular computed tomographic findings in postoperative cardiac surgical patients including internal mammary artery and saphenous vein bypass grafts.

• **Level 2:** Know the characteristic cardiovascular computed tomographic findings of acquired and congenital valvular disease.
• **Level 2:** Know the characteristic cardiovascular computed tomographic findings of left atrial and pulmonary and coronary venous abnormalities.

• **Level 2:** Know the characteristic cardiovascular computed tomographic findings of pericardial disease.

• **Level 2:** Know the characteristic cardiovascular computed tomographic findings of cardiomyopathies and infiltrative myocardial diseases.

• **Level 2:** Know the differential diagnosis of cardiac masses identified by cardiovascular computed tomography.

• **Level 2:** Know the characteristic cardiovascular computed tomographic findings of common diseases of the aorta and great vessels.

• **Level 2:** Know the characteristic cardiovascular computed tomographic findings of pulmonary embolism and primary and acquired pulmonary vascular diseases.

**PATIENT CARE AND PROCEDURAL SKILLS**

• **Level 2:** Skill to independently perform and interpret cardiovascular computed tomography.

**B. TRAINING GUIDELINES IN CARDIOVASCULAR CT**

• Each fellow is expected to complete level I training in cardiovascular CT by the conclusion of their 4th month of the multimodality imaging rotation.

• The core competencies and curricular milestones outlined in the latest COCATS 4 document will serve as the basis for rotation structure and progress assessment.

• The core competencies and curricular milestones commensurate with each fellow’s level of training (by year or month) will be provided to them and to the teaching faculty at the beginning of every rotation to ensure training is properly channeled toward meeting these goals.

• Over the first four months of the MMI rotation, fellows will gain familiarity with CCT through a mentored interpretative experience of at least 50 studies with other imaging correlation. The mentored interpretive experience may include studies from an established teaching file of CCT cases, CD/DVD, and online training. This should provide fellows with the minimal (Level 1) introductory experience necessary to gain familiarity with CCT but does not provide sufficient competence for independent interpretation of CCT images.

• Fellows should attend lectures on the basic concepts of CCT and, in parallel, utilize self-study reading material.

• To be a candidate for level II training in CCT, fellows have to successfully complete all the level I core competencies and curricular milestones outlined in this document and be on track for completing their level II training in Echocardiography by the end of their 3 year fellowship.

• Clinical study volumes are currently insufficient for Level II certification in CCT as defined by the COCATS 4 document.