Resident Core Curriculum

Non-Invasive Cardiovascular Imaging

General Goals: The specific goals include objectives required for every level of training with graduate levels of supervision and responsibility. All aspects of non-invasive cardiovascular imaging are incorporated into the residency, including cardiac CT and MR, vascular CTA and MRA, and nuclear cardiology. The CV rotation will include imaging of both the heart and the peripheral vascular system. The junior experience will focus on vascular imaging, with transition to a more cardiac focused rotation for the more senior residents. During every training rotation, the resident will read the required literature and study the teaching file in non-invasive cardiovascular imaging. Over time, the resident will be progressively more knowledgeable about normal radiographic anatomy, physiology of cardivascular organs, and the radiological appearances of cardiovascular diseases. In addition, the resident will increasingly understand disease entities, their clinical presentations, and current modes of treatment. Overall the resident will receive training satisfying both ACR guidelines and ACC/AHA Level II guidelines in both Cardiac CT (CCT) and Cardiac MR (CMR). Level II training is the minimal level of training outlined by the ACC/AHA for independent interpretation of cardiac imaging.

Resident Daily Work Responsibilities (OVERALL BENCHMARKS/OBJECTIVES for Self-Evaluation)

1. Residents assigned to non-invasive cardiovascular imaging will be available for consultations by technologists, clinicians, and other health care providers, except during conference times, when the attending faculty will cover.
2. Resident questions will be referred to the supervising faculty covering non-invasive cardiovascular imaging.
3. Resident review of cases with the supervising faculty will be conducted as many times in the day as necessary to keep an efficient workflow.
4. All resident examinations will be dictated by the end of every working day.
5. Residents will check and sign his/her reports prior to final verification by supervising faculty.
6. Residents must be familiar with the operation of all imaging equipment.
7. Residents must acquire knowledge of radiation protection and ways to reduce radiation exposure to both patients and hospital personnel. The resident will be supervised to assure that safe practices are followed.
8. Residents will learn the techniques for performing high quality, state-of-the art diagnostic examinations. Examinations will be checked before the patient leaves the department if requested to do so by the supervising faculty.
9. Residents must become proficient at detecting abnormalities demonstrated by cross-sectional examinations and be able to generate meaningful differential diagnosis.
10. Residents will become knowledgeable about the use of different radiographic contrast agents (including their indications, contraindications, dosages, and side effects).
11. Residents will acquire an understanding of the proper preparation of patients for examinations and appropriate follow-up afterward. At the start of every working day, the resident will be familiar with the patient schedule and anticipate need for any procedures.

The resident will check requisitions for the next working day to evaluate for appropriateness of the requested procedure or if additional exams/protocols need to be performed. Absent clinical indication or seemingly inappropriate requests will be clarified and discussed with the referring physician.

12. Residents will do in-depth reading and study, along with a review of teaching file cases, to become knowledgeable about the normal anatomy and physiology of the cardiovascular system and the radiologic appearances of cardiovascular diseases, and gain a general understanding of the disease entities, their clinical presentations, and certain modes of treatment.
13. Residents will serve as a secondary consultant to referring physicians regarding non-invasive cardiovascular imaging. This will strengthen the confidence of the resident in the very important role every radiologist must perform throughout his/her career as a consultant to clinicians.
14. Residents on cardiac focused rotations are expected to be present at the scanner during acquisition, to have reviewed the studies independently, and have prepared a preliminary report prior to interpretation by an attending physician.
15. Residents will keep an independent log of all the cardiac cases which they have reviewed. The log will distinguish which studies the resident individually interpreted and was physically present for the acquisition of images.
16. Residents will become prepared to pass the certifying examination of the American Board of Radiology.
17. Residents will teach and share knowledge to medical students, radiologic technologist students, and junior residents.
18. Residents will participate in the preparation and presentation of imaging studies at the monthly Interesting Case Conference.

Supervising Faculty Responsibilities:

1. Supervising faculty will be available at all times for any questions or consultations needed by the resident.
2. Supervising faculty will review all cases with the residents before the end of the day.
3. Supervising faculty will provide the resident with constructive feedback in any problem areas encountered during the rotation.
4. Supervising faculty will verify resident-generated reports in a timely manner and inform the resident of any major changes made.

Educational Goals and Objectives (Second Year Residents):

Patient Care:

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- The overriding goal is to teach the resident to practice compassionate, appropriate and effective care for the treatment of disease.
- Adequately explain each examination to the patient in order to ensure that the patient feels comfortable and to provide patient care that is compassionate, appropriate, and effective

- Familiarity with the operation of imaging equipment
- Aware of the basic principles of radiation protection in order to reduce as much as possible the radiation dose to the patient and reduce exposure to healthcare providers
- Understand the indications for and contraindications to use of intravenous radiographic contrast, and be able to monitor its administration
- Recognize and treat reactions to intravenous contrast
- Understand the indications and contraindications to the different types of contrast, dosages, side effects, and the differences and relative merits of single and double contrast studies.
- Develop a knowledge of the preparation and aftercare required for the common examinations
- Use the PACS, voice recognition systems, and hospital information systems to become proficient in dictating reports of significant radiographic findings in a concise and clear manner
- Demonstrate the ability to recommend additional imaging studies as appropriate to better assess findings on non-invasive cardiovascular imaging studies
- Educational activities to foster development of a compassionate, appropriate and effective approach to patient care provided during this stage of training are:
    - One-on one mentoring during the rotation,
    - Interdepartmental conferences (ED, Vascular Conference)
    - Self-study of materials outlined in the reading list
    - Cardiovascular imaging case conferences in AM
    - Cardiovascular imaging didactic noon lectures
    - Monthly Cardiac Imaging noon unknown case conference
    - Annual cardiovascular lecture series.
    - Journal Clubs
    - Monthly QA conference
- Progress is monitored by :
    - 360° Multi source evaluations
    - Daily performance feedback by faculty
    - Radiation Safety Test
    - Global assessment
    - Review of Case log

Medical Knowledge:

- Proficient in the techniques to achieve high-quality diagnostic CT pulmonary angiography, CTA for mesenteric ischemia, CTA for acute dissection and trauma, and peripheral CTA of the upper and lower extremity in order to be prepared for the 1590 rotation.
- Proficient in understanding proper indications, protocoling, troubleshooting technical problems with image acquisition, interpretation, appropriateness in high risk patients, such as in pregnancy, renal failure, alternative studies, and dealing with contrast reactions and other complications
- Develop a knowledge of normal and abnormal anatomy of the cardiovascular system as demonstrated on contrast studies

- Become knowledgeable about the different contrast agents available and begin to recognize abnormalities that are demonstrated on cross-sectional studies and other imaging modalities
- List the risk factors for allergic reaction to intravenous contrast media
- State the proper assessment and treatment for allergic reactions to contrast media
- Recognize and develop a knowledge of the differential diagnoses of the more common abnormalities encountered in the cardiovascular system
- Demonstrate the ability to recognize and describe common medical conditions depicted on non-invasive cardiovascular imaging studies
- Develop a knowledge of proper indications, protocoling, troubleshooting technical problems with image acquisition, interpretation, and appropriateness in high risk patients such as in pregnancy and renal failure
- Familiarity with the basics of MRA interpretation
- Educational activities to improve medical knowledge provided during this stage of training are:
    - Review of rotation goals and objectives (at beginning of rotation)
    - One-on one mentoring during the rotation
    - Self-study of materials outlined in the reading list
    - Cardiovascular imaging case conferences in AM
    - Cardiovascular imaging didactic noon lectures
    - Monthly Cardiac Imaging noon unknown case conference
    - Annual cardiovascular lecture series.
    - Journal Clubs
    - Interdepartmental conferences (ED, Vascular, HCC, pediatric congenital heart)
    - Monthly QA conference
- Progress is monitored by :
    - 360° Multi source evaluations
    - Daily performance feedback by faculty
    - Conference Attendance Record
    - American College of Radiology inservice exam

Practice-Based Learning and Improvement:

- Develop ability to investigate their own patient care
- Show evidence of independent study using textbooks, learning materials from reading list, and journal articles
- Demonstrate appropriate follow up of interesting cases
- Research interesting cases as directed by faculty
- Identify, rectify, and learn from personal errors
- Incorporate feedback into improved performance
- Efficiently use electronic and print sources to access information
- Appraisal and assimilation of scientific evidence and improvements in patient care
- Educational activities to foster learning practice-based learning provided during this stage of training are:
    - One-on one mentoring during the rotation,
    - Self-study of teaching modules provided by the faculty during the rotation,

    - Cardiovascular imaging case conferences in AM
    - Cardiovascular imaging didactic noon lectures
    - Monthly Cardiac Imaging noon unknown case conference
    - Annual cardiovascular lecture series.
    - Journal Clubs
    - Monthly QA conference
- Progress is monitored by :
    - 360° Multi source evaluations
    - Annual Self Assessment evaluations

Interpersonal and Communication Skills:

- Effective information exchange between patients, their families and other health care professionals is taught and enforced during every step of NICV training.
- Patient confidentiality and HIPAA compliance are key concepts.
- Communicate with the patient and family members before during and after the examination to ensure that patient remains comfortable and informed about progress.
- Communicate effectively with all members of the health care team (technologists, medical students, fellows, residents, allied health providers, support staff, and attending physicians/radiologists)
- Call results to the referring physicians and show ability to interact with referring physicians
- Interact with clinicians when reviewing cases involving radiographs and non-invasive cardiovascular imaging studies and show ability to provide preliminary readings, follow up with attending radiologists, formulate a diagnostic plan for complex cases, and communicate any changes to referring clinicians
- Educational activities to foster learning practice-based learning provided during this stage of training are:
    - One-on one mentoring during the rotation,
    - Self-study of teaching modules provided by the institution (Patient confidentiality/HIPAA)
    - Discussion during resident meetings
- Progress is monitored by :
    - 360° Multi source evaluations
    - American Board of Radiology oral exam
    - Performance feedback by faculty

Professionalism:

- Goal is to develop an unwaivering commitment to
        - Ethical principles
        - Carrying out professional activities
        - Being sensitive to diverse patient populations
- Demonstrate respect for patients, families, and all members of the healthcare team and be able to discuss significant radiology findings
- Explain the impact of the radiology findings on patient care, including what imaging studies may/may not be appropriate
- Respect patient confidentiality at all times

- Present oneself as a professional in appearance and communication
- Demonstrate a responsible work ethic with regard to work assignments
- Educational activities to foster professionalism and etiquette provided during this stage of training are:
    - One-on one mentoring during the rotation,
    - Self-study of online modules provided by the institution
    - Discussion during resident meetings
    - Conference attendance
- Progress is monitored by :
    - 360° Multi source evaluations
    - Conference attendance record
    - Performance feedback by faculty

System-Based Practice:

- Goal is to teach awareness and responsiveness to the larger context and system of health care
- The resident will be taught to effectively call on the system resources to provide care of optimal value. Focus will be on the resident to be:
- Able and willing to participate in clinical conferences in which imaging studies are used to guide patient care/evaluations and be able to demonstrate understanding of how imaging relates to the clinical care of the patient
- Demonstrate knowledge of the ACR practice guidelines and technical standards for non-invasive cardiovascular imaging
- Demonstrate knowledge of ACR appropriateness criteria and cost effective imaging evaluation of common disorders
- Show ability to interact with clinicians regarding cost effective and streamlined evaluation for differing clinical entities
- Demonstrate the ability to interpret quality vascular studies on call and whether remediation will be required. If time permits, attend cardiac imaging procedures and readout to begin logging cases
- Educational activities to enhance systems-based practice provided during this stage of training are:
    - One-on one mentoring during the rotation,
    - Self-study of online modules provided by the institution (eg. Billing, reimbursement)
    - Discussion during resident meetings
    - Discussion during QA meetings
- Progress is monitored by :
    - 360° Multi source evaluations
    - Performance feedback by faculty
    - Global assessment
    - Annual self-assessment evaluations
    - Semi-annual program director review
    - Attendance monitoring at QA meetings

Monitoring and Assessment of Resident Performance

The resident's progress will be monitored by the attending radiologists on the service on a daily basis and immediate feedback will be given. Toward the end of each rotation, the resident will receive an evaluation of performance from each attending. Deficiencies or substandard performance will be discussed personally and privately with the resident and will be brought to the attention of the Residency Program Director by the attending radiologist if deemed necessary. Residents are evaluated monthly by faculty. Resident performance is also evaluated through direct observation, case logs, multi-source professional evaluations, structured case discussion, review of patient outcomes, and other performance evaluation methods as outlined in detail above.

Reading List:

1. Valji K. Vascular and Interventional Radiology, 2nd edition , Saunders, 2006 (relevant chapters for this rotation only)(Book in radiology library available)
2. Kaufman JA, Lee MJ. Vascular and Interventional Radiology: The Requisites, 1st edition, Mosby 2003 (relevant chapters for this rotation only)(Book in radiology library available)
3. Prokop M, Galanski M, Schaefer-Prokop C, Van der Moolen A. Spiral and Multislice Computed Tomography of the Body. Thieme Publishing Group, 2002. (relevant chapters for this rotation only) (book in radiology library available)
4. Wittram C, Maher MM, Yoo AJ, Kalra MK, Shepard JO, McLoud TC. "CT Angiography of Pulmonary Embolism: Diagnostic Criteria and Causes of Misdiaganosis". Radiographics 2004; 24: 1219-1238.
5. Han D, Lee KS, Franquet T, Muller NL, Kim TS, Kim H, Kwon OJ, Byun HS. "Thrombotic and Nonthrombotic Pulmonary Arterial Embolism: Spectrum of Imaging Finding." Radiographics 2003; 23:1521-1539.

Educational Goals and Objectives (Third Year Residents):

The objectives above as well as the following:

Patient Care:

- Understand the physics of radiation protection and how to apply it to routine studies
- Obtain consent for more complex procedures and answer all questions the patient may have
- Develop a knowledge of the preparation and aftercare required for more complex procedures
- Continue to improve skills for performing non-invasive cardiovascular examinations, and tailor examinations to answer all questions being asked by the clinician; anticipate those questions that should have been asked but were not

- Demonstrate knowledge of indications for the examinations requested (when the reason for the examination is not clear, the resident will effectively communicate with the patient and referring physician until clarified)
- Familiarity with available and relevant medical records and how to access them for the purposes of patient care
- Protocol cases, in consultation with the attending, to assure that the examination is appropriate and of sufficient quality to address the clinical concerns of the patient and referring physician
- Review all studies with the supervisor faculty attending
- Provide preliminary reports to all referring clinicians if needed before the final review of cases (when there is a significant discrepancy between the preliminary reading and final reading, the resident will notify the referring clinician immediately)
- Educational activities to foster development of a compassionate, appropriate and effective approach to patient care provided during this stage of training are:
    - One-on one mentoring during the rotation,
    - Interdepartmental conferences (ED, Vascular, HCC, nuclear cardiology, pediatric congenital heart)
    - Self-study of materials outlined in the reading list
    - Cardiovascular imaging case conferences in AM
    - Cardiovascular imaging didactic noon lectures
    - Monthly Cardiac Imaging noon unknown case conference
    - Annual cardiovascular lecture series.
    - Journal Clubs
    - Monthly QA conference
- Progress is monitored by :
    - 360° Multi source evaluations
    - Daily performance feedback by faculty
    - Radiation Safety Test
    - Global assessment
    - Review of Case log

Medical Knowledge:

- Recommend the appropriate study based on the clinical scenario and understand the relative strengths of each modality (eg. CT versus MRI versus ultrasound versus angiography)
- Familiarity with the anatomy and pathology of the organs examined in every case
- Familiarity with imaging findings of common and uncommon acute and chronic cardiovascular diseases, the basics of a variety of therapies, and indications including stent grafting and bypass surgery
- Identify pathology in order to interpret routine non-invasive cardiovascular studies with accuracy, appropriate to the level of training when presenting to the attending
- Distinguish between normal and abnormal cardiovascular anatomy to level of training when presenting to the attending
- Detect abnormalities while the procedures are in progress, such as 1) disease recognition skills will continue to increase on plain radiographs and contrast studies, and 2) begin to develop meaningful differential diagnoses for the pathology that is found

- Focus on advanced vascular imaging with CT and MR and basics of cardiac CT and MR
- Interpret advanced vascular CT and MR exams of the thoracic and abdominal vessels as well as run-off vessels for vascular disease
- Understand the physics of cardiac CT and MR with respect to image optimization
- Understand protocoling, MR sequence selection, imaging acquisition troubleshooting and contrast media injection protocols
- Familiarity with image post-processing of CTA and MRA data including MPR, MIPs, volume rendering, vessel tracking and analysis
- Educational activities to improve medical knowledge provided during this stage of training are:
    - Review of rotation goals and objectives (at beginning of rotation)
    - One-on one mentoring during the rotation,
    - Self-study of materials outlined in the reading list
    - Cardiovascular imaging case conferences in AM
    - Cardiovascular imaging didactic noon lectures
    - Monthly Cardiac Imaging noon unknown case conference
    - Annual cardiovascular lecture series.
    - Journal Clubs
    - Interdepartmental conferences (ED, Vascular, HCC, pediatric congenital heart)
    - Monthly QA conference
- Progress is monitored by :
    - 360° Multi source evaluations
    - Daily performance feedback by faculty
    - Conference Attendance Record
    - American College of Radiology inservice exam

Practice-Based Learning and Improvement

- Goal is to further develop ability to investigate their own patient care
- Demonstrate appropriate follow up of interesting cases
- Research interesting cases as directed by faculty
- Identify, rectify, and learn from personal errors
- Incorporate feedback into improved performance
- Efficiently use electronic and print sources to access information
- Appraisal and assimilation of scientific evidence and improvements in patient care
- Demonstrate evidence of independent reading and learning through use of printed and electronic resources
- Follow up on abnormal or interesting cases through personal communication with the referring physician or patient medical records
- Competent in using PACS, voice recognition systems, and the patient information systems in the daily accomplishment of the workload and instruct others in their use
- Log cardiac cases, be present for the acquisition of as many cases and cardiac readouts as possible
- Educational activities to foster learning practice-based learning provided during this stage of training are:
    - One-on one mentoring during the rotation,

    - Self-study of teaching modules provided by the faculty during the rotation,
    - Cardiovascular imaging case conferences in AM
    - Cardiovascular imaging didactic noon lectures
    - Monthly Cardiac Imaging noon unknown case conference
    - Annual cardiovascular lecture series.
    - Journal Clubs
    - Monthly QA conference
    - Attendance of interdepartmental conferences (Vascular, ED, Hepatoma, Nuclear Cardiology, Cardiac Imaging)
- Progress is monitored by:
    - 360° Multi source evaluations
    - Annual Self Assessment evaluations

Interpersonal and Communication Skills:

- Goal is to further improve effective information exchange between patients, their families and other health care professionals is taught and enforced during every step of NICV training.
- Patient confidentiality and HIPAA compliance are key concepts.
- Communicate with the patient and family members before during and after the examination to ensure that patient remains comfortable and informed about progress.
- Communicate effectively with all members of the health care team (technologists, medical students, fellows, residents, allied health providers, support staff, and attending physicians/radiologists)
- Call results to the referring physicians and show ability to interact with referring physicians
- Interact with clinicians when reviewing cases involving radiographs and non-invasive cardiovascular imaging studies and show ability to provide preliminary readings, follow up with attending radiologists, formulate a diagnostic plan for complex cases, and communicate any changes to referring clinicians
- Further components of learning are:
    - Appropriately obtain informed consent
    - Produce concise reports that include all relevant information
    - Communicate effectively with all members of the healthcare team
    - Communicate effectively the results of studies to referring clinicians whenever needed (for emergent studies, this will be accomplished in a timely manner)
    - Effectively convey the findings of examinations through accurate dictation of reports
- Educational activities to foster learning practice-based learning provided during this stage of training are:
    - One-on one mentoring during the rotation,
    - Self-study of teaching modules provided by the institution (Patient confidentiality/HIPAA)
    - Discussion during resident meetings
- Progress is monitored by :
    - 360° Multi source evaluations
    - American Board of Radiology oral exam
    - Performance feedback by faculty

Professionalism:

- Goal is to enhance and further develop an unwaivering commitment to
    - Ethical principles
    - Carrying out professional activities
    - Being sensitive to diverse patient populations
- Demonstrate respect for patients, families, and all members of the healthcare team and be able to discuss significant radiology findings
- Explain the impact of the radiology findings on patient care, including what imaging studies may/may not be appropriate
- Respect patient confidentiality at all times
- Present oneself as a professional in appearance and communication
- Demonstrate a responsible work ethic with regard to work assignments
- Educational activities to foster professionalism and etiquette provided during this stage of training are:
    - One-on one mentoring during the rotation,
    - Self-study of online modules provided by the institution
    - Discussion during resident meetings
    - Conference attendance
- Progress is monitored by :
    - 360° Multi source evaluations
    - Conference attendance record
    - Performance feedback by faculty

Systems-Based Practice:

- Goal is to further teach and enhance awareness and responsiveness to the larger context and system of health care
- The resident will be taught to effectively call on the system resources to provide care of optimal value.
- Focus will be on the resident to be:
- Able and willing to participate in clinical conferences in which imaging studies are used to guide patient care/evaluations and be able to demonstrate understanding of how imaging relates to the clinical care of the patient
- Demonstrate knowledge of the ACR practice guidelines and technical standards for non-invasive cardiovascular imaging
- Demonstrate knowledge of ACR appropriateness criteria and cost effective imaging evaluation of common disorders
- Show ability to interact with clinicians regarding cost effective and streamlined evaluation for differing clinical entities
- Familiarity with departmental procedures, contrast safety, and sedation required in the performance of examinations
- Use appropriate language in communicating to clinicians through reports or consultations so proper management decisions can be made
- Thorough dictations will be made with indications, techniques, findings, and conclusions
- Dictate and correct reports in a timely fashion to avoid delay in patient disposition

- Make suggestions to improve methods and systems utilized in radiology whenever appropriate Able and willing to participate in multi-disciplinary clinical conferences in which imaging studies are used to guide patient care/evaluations and be able to demonstrate understanding of how imaging relates to the clinical care of the patient
- Demonstrate the ability to interpret quality vascular studies on call and whether remediation will be required. If time permits, attend cardiac imaging procedures and readout to begin logging cases
- Educational activities to enhance systems-based practice provided during this stage of training are:
    - One-on one mentoring during the rotation,
    - Self-study of online modules provided by the institution (eg. Billing, reimbursement)
    - Discussion during resident meetings
    - Discussion during QA meetings

- Progress is monitored by :
    - 360° Multi source evaluations
    - Performance feedback by faculty
    - Global assessment
    - Annual self-assessment evaluations
    - Semi-annual program director review
    - Attendance monitoring at QA meetings

Monitoring and Assessment of Resident Performance

The resident's progress will be monitored by the attending radiologists on the service on a daily basis and immediate feedback will be given. Toward the end of each rotation, the resident will receive an evaluation of performance from each attending. Deficiencies or substandard performance will be discussed personally and privately with the resident and will be brought to the attention of the Residency Program Director by the attending radiologist if deemed necessary. Residents are evaluated monthly by faculty. Resident performance is also evaluated through direct observation, case logs, multi-source professional evaluations, structured case discussion, review of patient outcomes, and other performance evaluation methods as outlined in detail above.

Reading List:

1. Higgins CB, de Roos A. MRI and CT of the Cardiovascular System. Lippincott Williams & Wilkins; 2nd edition 2005 (Book in radiology and NICV library available).
2. Miller S. Cardiac Imaging: The Requisites. Mosby 2nd edition, 2004. (Book in radiology and NICV library available)
3. Lee VS. Cardiovascular MR Imaging: Physical Principles to Practical Protocols. Lippincott Williams & Wilkins; 1st edition 2005 (for residents interested in in depth physics of cardiovascular MRI) (Book in NICV library available).

4. Norton PT, Nancey NC, Caovan DB, Gay SB, Kramer CM, Jeun BS, Hiatt MD, Tatieny KC. "Cardiac MRI: The Bascis." 2006: University of Virginia, Dept. of Radiology. http://www.med-ed.virginia.edu/courses/rad/cardiacmr/index.html

Educational Goals and Objectives (Fourth Year Residents):

The above objectives as well as the following:

Patient Care:

- Perfect diagnostic examination techniques and be very skilled and efficient in performing and interpreting all diagnostic procedures performed
- Demonstrate knowledge of indications for the examinations requested (when the reason for the examination is not clear, the resident will effectively communicate with the patient or referring physician until clarified)
- Familiarity with available medical records and how to access them for the purposes of patient care
- Protocol cases, in consultation with the attending, to assure that the non-invasive cardiovascular examination is appropriate and of sufficient quality to address the clinical concerns of the patient and referring physician
- Review all studies with the supervising faculty attending
- Provide preliminary reports to all referring clinicians if needed before the final review of cases (when there is a significant discrepancy between the preliminary reading and final reading, the resident will notify the referring clinician immediately)
- Educational activities to foster development of a compassionate, appropriate and effective approach to patient care provided during this stage of training are:
    - One-on one mentoring during the rotation,
    - Interdepartmental conferences (Nuclear Cardiology, Cardiac Catheterization, Echocardiography, pediatric congenital heart)
    - Self-study of materials outlined in the reading list
    - Cardiovascular imaging case conferences in AM
    - Cardiovascular imaging didactic noon lectures
    - Monthly Cardiac Imaging noon unknown case conference
    - Annual cardiovascular lecture series.
    - Journal Clubs
    - Monthly QA conference
- Progress is monitored by :
    - 360° Multi source evaluations
    - Daily performance feedback by faculty
    - Radiation Safety Test
    - Global assessment
    - Review of Case log

Medical Knowledge:

- Develop a thorough knowledge of the differential diagnosis of abnormalities encountered in non-invasive cardiovascular studies
- Relate the imaging findings to the clinical condition and its pathology
- Understand the clinical management of the conditions encountered
- Familiarity with the anatomy of the organs examined in every case
- Familiarity with imaging findings of common acute and chronic non-invasive cardiovascular diseases
- Identify pathology in order to interpret non-invasive cardiovascular imaging studies with accuracy appropriateness to the level of training when presenting to the attending
- Distinguish between normal and abnormal cardiovascular anatomy with excellent accuracy according to the level of training when presenting to the attending and demonstrate improvement compared to the prior rotation
- Become proficient in detecting abnormalities on plain radiographs and contrast studies while in progress
- Development of appropriate differential diagnostic lists will be well advanced
- Know the proper preparation of patients for diagnostic procedures and the appropriate follow-up afterwards
- Act as a consultant in non-invasive cardiovascular radiology to the clinical services
- Obtain a broad understanding of cardiovascular diseases, their clinical features, radiographic manifestations, and current modes of treatment
- Complete a minimum of 50 exams each of CCT and CMR performed and primarily interpreted and a minimum of 150 cases each of CCT and CMR reviewed with mentor
- Complete 40 hrs each of CME for CCT and CMR with some of the time covered by current lectures in the radiology curriculum including: physics, anatomy, physiology, and pathology and independent study if accreditation as ACC/SCMR Level II reader is desired by resident and elective cardiac rotation time is chosen.
- Assist in covering vascular imaging studies as needed per clinical workload
- Be present at the CT and MR scanner for all cardiac studies with regards to ECG gating, protocol selection, MR sequence selection and parameter manipulation (e.g. TE, TR, TI, FOV, etc), pharmaceutical administration, contrast media injection protocols, and general image optimization including artifact troubleshooting
- Development of advance image post-processing including cardiac volumetric and functional calculations, analysis of velocity encoded imaging, and coronary vessel tracking and analysis
- Attend nuclear cardiology daily checkout and supplement didactic and viewbox teaching with background reading as outlined in the nuclear cardiology curriculum.
- Observe the acquisition and processing of nuclear cardiology studies
- Focus on cardiac imaging, including cardiac CT and MR as well as nuclear cardiology. Residents must attend nuclear cardiology checkout at the scheduled time Monday through Friday
- Educational activities to improve medical knowledge provided during this stage of training are:
    - Review of rotation goals and objectives (at beginning of rotation)
    - One-on one mentoring during the rotation,

    - Attendance of daily nuclear cardiology readouts
    - Self-study of materials outlined in the reading list and literature list in addendum
    - Cardiovascular imaging case conferences in AM
    - Cardiovascular imaging didactic noon lectures
    - Monthly Cardiac Imaging noon unknown case conference
    - Annual cardiovascular lecture series.
    - Journal Clubs
    - Interdepartmental conferences (Nuclear Cardiology, Cardiac Catheterization, Echocardiography, pediatric congenital heart)
    - Monthly QA conference
- Progress is monitored by :
    - 360° Multi source evaluations
    - Daily performance feedback by faculty
    - Conference Attendance Record
- American College of Radiology inservice exam

Practice-Based Learning and Improvement:

- Goal is to further develop ability to investigate their own patient care
- Demonstrate appropriate follow up of interesting cases
- Research interesting cases as directed by faculty
- Identify, rectify, and learn from personal errors
- Incorporate feedback into improved performance
- Efficiently use electronic and print sources to access information
- Appraisal and assimilation of scientific evidence and improvements in patient care
- Demonstrate evidence of independent reading and learning through use of printed and electronic resources
- Follow up on abnormal or interesting cases through personal communication with the referring physician or patient medical records
- Competent in using PACS, voice recognition systems, and the patient information systems in the daily accomplishment of the workload and instruct others in their use
- Log cardiac cases, be present for the acquisition of as many cases and cardiac readouts as possible
- Educational activities to foster learning practice-based learning provided during this stage of training are:
    - One-on one mentoring during the rotation,
    - Self-study of teaching modules provided by the faculty during the rotation,
    - Cardiovascular imaging case conferences in AM
    - Cardiovascular imaging didactic noon lectures
    - Monthly Cardiac Imaging noon unknown case conference
    - Annual cardiovascular lecture series.
    - Journal Clubs
    - Monthly QA conference
    - Attendance of interdepartmental conferences (Vascular, ED, Hepatoma, Nuclear Cardiology, Cardiac Imaging)
- Progress is monitored by:
    - 360° Multi source evaluations

- Annual Self Assessment evaluations

Interpersonal Skills:

- Goal is to further improve effective information exchange between patients, their families and other health care professionals is taught and enforced during every step of NICV training.
- Patient confidentiality and HIPAA compliance are key concepts.
- Communicate with the patient and family members before during and after the examination to ensure that patient remains comfortable and informed about progress.
- Communicate effectively with all members of the health care team (technologists, medical students, fellows, residents, allied health providers, support staff, and attending physicians/radiologists)
- Call results to the referring physicians and show ability to interact with referring physicians
- Interact with clinicians when reviewing cases involving radiographs and non-invasive cardiovascular imaging studies and show ability to provide preliminary readings, follow up with attending radiologists, formulate a diagnostic plan for complex cases, and communicate any changes to referring clinicians
- Further components of learning are:
  - Appropriately obtain informed consent
  - Produce concise reports that include all relevant information
  - Communicate effectively with all members of the healthcare team
  - Communicate effectively the results of studies to referring clinicians whenever needed (for emergent studies, this will be accomplished in a timely manner)
  - Effectively convey the findings of examinations through accurate dictation of reports
  - Assist with supervision and teaching of medical and radiology technologist students
- Educational activities to foster learning practice-based learning provided during this stage of training are:
  - One-on one mentoring during the rotation,
  - Self-study of teaching modules provided by the institution (Patient confidentiality/HIPAA)
  - Discussion during resident meetings
- Progress is monitored by :
  - 360° Multi source evaluations
  - American Board of Radiology oral exam
  - Performance feedback by faculty

Professionalism:

- Goal is to enhance and further develop an unwaivering commitment to
  - Ethical principles
  - Carrying out professional activities
  - Being sensitive to diverse patient populations
- Demonstrate respect for patients, families, and all members of the healthcare team and be able to discuss significant radiology findings

- Explain the impact of the radiology findings on patient care, including what imaging studies may/may not be appropriate
- Respect patient confidentiality at all times
- Present oneself as a professional in appearance and communication
- Demonstrate a responsible work ethic with regard to work assignments
- Educational activities to foster professionalism and etiquette provided during this stage of training are:
    - One-on one mentoring during the rotation,
    - Self-study of online modules provided by the institution
    - Discussion during resident meetings
    - Conference attendance
- Progress is monitored by :
    - 360° Multi source evaluations
    - Conference attendance record
    - Performance feedback by faculty

Systems-Based Practice:

Goal is to further teach and enhance awareness and responsiveness to the larger context and system of health care

- The resident will be taught to effectively call on the system resources to provide care of optimal value. Focus will be on the resident to be:Able and willing to participate in clinical conferences in which imaging studies are used to guide patient care/evaluations and be able to demonstrate understanding of how imaging relates to the clinical care of the patient
- Demonstrate knowledge of the ACR practice guidelines and technical standards for non-invasive cardiovascular imaging
- Demonstrate knowledge of ACR appropriateness criteria and cost effective imaging evaluation of common disorders
- Show ability to interact with clinicians regarding cost effective and streamlined evaluation for differing clinical entities
- Familiarity with departmental procedures, contrast safety, and sedation required in the performance of examinations
- Use appropriate language in communicating to clinicians through reports or consultations so proper management decisions can be made
- Thorough dictations will be made with indications, techniques, findings, and conclusions
- Dictate and correct reports in a timely fashion to avoid delay in patient disposition
- Make suggestions to improve methods and systems utilized in radiology whenever appropriate Able and willing to participate in multi-disciplinary clinical conferences in which imaging studies are used to guide patient care/evaluations and be able to demonstrate understanding of how imaging relates to the clinical care of the patient
- Demonstrate the ability to interpret quality vascular studies on call and whether remediation will be required. If time permits, attend cardiac imaging procedures and readout to begin logging cases

- Educational activities to enhance systems-based practice provided during this stage of training are:
    - One-on one mentoring during the rotation,
    - Self-study of online modules provided by the institution (eg. Billing, reimbursement)
    - Discussion during resident meetings
    - Discussion during QA meetings
- Progress is monitored by :
    - 360° Multi source evaluations
    - Performance feedback by faculty
    - Global assessment
    - Annual self-assessment evaluations
    - Semi-annual program director review
    - Attendance monitoring at QA meetings

Monitoring and Assessment of Resident Performance

The resident's progress will be monitored by the attending radiologists on the service on a daily basis and immediate feedback will be given. Toward the end of each rotation, the resident will receive an evaluation of performance from each attending. Deficiencies or substandard performance will be discussed personally and privately with the resident and will be brought to the attention of the Residency Program Director by the attending radiologist if deemed necessary. Residents are evaluated monthly by faculty. Resident performance is also evaluated through direct observation, case logs, multi-source professional evaluations, structured case discussion, review of patient outcomes, and other performance evaluation methods as outlined in detail above.

Reading List:

1. Higgins CB, de Roos A. MRI and CT of the Cardiovascular System. Lippincott Williams & Wilkins; 2nd edition 2005 (Book in radiology and NICV library available).
2. Miller S. Cardiac Imaging: The Requisites. Mosby 2nd edition, 2004. (Book in radiology and NICV library available)
3. Lee VS. Cardiovascular MR Imaging: Physical Principles to Practical Protocols. Lippincott Williams & Wilkins; 1st edition 2005 (for residents interested in in-depth physics of cardiovascular MRI) (Book in NICV library available).
4. Ohnesorge B, Flohr TG, Becker CR, Knez A, Reiser MF. Multi-slice and Dual-source CT in Cardiac Imaging. Springer 2nd ed. 2006. (Book in NICV library available).
5. Kramer CM, Hundley WG. Atlas of Cardiovascular Magnetic Resonance Imaging: Expert Consult - Online and Print: Imaging Companion to Braunwald's Heart Disease (Imaging Techniques to Braunwald's Heart Disease). Saunders 2009. (Book in NICV library available).
6. Cardiac MR Article List (see addendum)

Other Requirements/Expectations

CTA/MRA Call

1232 Call:

The 1232 call resident (Upper Level Swing Shift) will interpret and dictate CTA and MRA studies performed from 5p - 8p during the weekdays (M-F). The 1232 resident will send the dictations to the cue of the on call Vascular Imaging attending. The on call Vascular Imaging attending is the vascular attending *covering the following day* (in dark blue on NCV schedule). The 1232 resident will protocol all CTA and MRA presented to them during their shift. If the 1232 has a concern or question regarding a protocol or the interpretation of study, they are to contact the on call attending.

On weekends, the 1232 resident will continue to protocol, interpret and dictate CTA studies from 8a - 9p Sat and Sun. They will also be responsible for interpretation of MRA studies performed during the weekend hours. The 1232 call resident should *send studies to the on call attending covering Vascular Imaging for the entire weekend* (in dark blue on attached schedule). If there is a question regarding a study during this time, the resident should contact the on call attending covering Vascular imaging for the weekend.

1590 Call:

The 1590 call resident will continue to interpret and dictate CTA studies performed from 8p - 8a during weekday and weekends. The 1590 resident *will send the dictations to the cue of the Vascular Imaging attending covering the following day* (in dark blue on attached schedule). If there are any questions with a study, they should contact the on call attending.

Additionally, the 1590 resident will protocol vascular MRA. The resident will give preliminary reads on these studies when asked by the clinical team, similar to MR for other divisions. If the resident feels uncomfortable with the prelim, then the on call attending (attending on vascular imaging the next day) should be contacted. They must dictate the preliminary interpretation and send it to the on call attending's cue. Alternatively, they may dictate the full study and send it to the attending's cue.

Please send dictations to the attending's cue rather than using the dummy cue. Remember to NOT include the attending's name when in the preliminary state. The attending will add his name at the time of final signing. The call schedule will be posted in the NCV reading room. It will also be available on the intranet, at

https://www.healthsystem.virginia.edu/intranet/radiology/FacultyResidentDailyWorkSchedules/NCVHome.cfm

Vacation Policy

Residents may request vacation up to two weeks prior to the beginning of the rotation. The primary resident on the rotation requires coverage at all times. If there are multiple residents on the service for a given rotation, the need for coverage will be at the discretion of the division. As

per residency policy, residents are not allowed more than 1 week total away from the rotation over the course of their residency. Additionally, residents are highly discouraged from taking vacation during their first rotation as preparation for 1590 call is paramount.

Core Knowledge Presentation Topics

Overview
The CV rotation will include imaging of both the heart and the peripheral vascular system. The focus of the rotation will vary depending on the resident's level of training and type of rotation (required or elective) as outlined below. The junior experience will focus on vascular imaging, with transition to a more cardiac focused rotation for the more senior residents. A joint read out with cardiology will continue for both cardiac CT and cardiac MR. This will occur at a predetermined time each day. Residents on rotations with a cardiac focus are expected to be present at the scanner during acquisition and to have reviewed the studies independently and have prepared a preliminary report prior to interpretation by an attending physician. All residents will keep an independent log of all the cardiac cases which they have reviewed. This log should also distinguish which studies the resident individually interpreted and was physically present for the acquisition of images.

Residents who wish to qualify for accrediation by the ACC/SCMR as a level II cardiac CT and MR reader will have to choose cardiac imaging as an elective during the 4th year and will nedd to meet the following requirements:

Cardiac CT and MR Education

- Minimum of 50 exams each of CCT and CMR performed and primarily interpreted
- Minimum of 150 cases each of CCT and CMR reviewed with mentor
- 40 hrs each of CME for CCT and CMR. Some of this time will be covered by current lectures in the radiology curriculum.
    - Lectures
        - Physics
        - Anatomy
        - Physiology
        - Pathology
    - Independent study
        - Teaching file
        - Web-based
        - Case Review books
        - DVD
        - Required reading
- Written and oral assessment of knowledge base and skill set

Addendum:

The following Cardiac MR Reading List is available to all residents wishing to gain more knowledge in cardiac MRI:

CMR Article List *=10 most important

Adabag AS, Maron BJ, Appelbaum E, Harrigan CJ, Buros JL, Gibson CM, et al. Occurrence and frequency of arrhythmias in hypertrophic cardiomyopathy in relation to delayed enhancement on cardiovascular magnetic resonance. J Am Coll Cardiol 2008 Apr 8;51(14):1369-74.

Aletras AH, Tilak GS, Natanzon A, Hsu LY, Gonzalez FM, Hoyt RF, Jr., et al. Retrospective determination of the area at risk for reperfused acute myocardial infarction with T2-weighted cardiac magnetic resonance imaging: histopathological and displacement encoding with stimulated echoes (DENSE) functional validations. Circulation 2006 Apr 18;113(15):1865-70.

*Assomull RG, Prasad SK, Lyne J, Smith G, Burman ED, Khan M, et al. Cardiovascular magnetic resonance, fibrosis, and prognosis in dilated cardiomyopathy. J Am Coll Cardiol 2006 Nov 21;48(10):1977-85.

Assomull RG, Lyne JC, Keenan N, et al. The role of cardiovascular magnetic resonance in patients presenting with chest pain, raised troponin and unobstructed coronary arteries. Eur Heart J 2007;28(10):1242-1249.

Baer FM, Theissen P, Schneider CA, et al. Dobutamine magnetic resonance imaging predicts contractile recovery of chronically dysfunctional myocardium after successful revascularization. J Am Coll Cardiol 1998;31:1040-1048.

Bove CM, DiMaria JM, Voros S, Conaway MR, Kramer CM. Dobutamine response and myocardial infarct transmurality: functional improvement after coronary artery bypass grafting – initial experience. Radiology 2006;240:835-841.

Choi CJ, Haji-Momenian S, DiMaria JM, et al. Infarct involution and improved function during healing of acute myocardial infarction: the role of microvascular obstruction. J Cardiovasc Magn Reson 2004;6(4):917-25.

Choi KM, Kim RJ, Gubernikoff G, et al. Transmural extent of acute myocardial infarction predicts long-term improvement in contractile function. Circulation 2001;104:1101-7.

Corti R, Fayad ZA, Fuster V et al: Effects of lipid-lowering by simvastatin on human atherosclerotic lesions: a longitudinal study by high-resolution, noninvasive magnetic resonance imaging. Circulation 104:249-252, 2001

Cury RC, Shash K, Nagurney JT, Rosito G, Shapiro MD, Nomura CH, et al. Cardiac magnetic resonance with T2-weighted imaging improves detection of patients with acute coronary syndrome in the emergency department. Circulation 2008 Aug 19;118(8):837-44.

*Friedrich MG, Abdel-Aty H, Taylor A, Schulz-Menger J, Messroghli D, Dietz R. The salvaged area at risk in reperfused acute myocardial infarction as visualized by cardiovascular magnetic resonance. J Am Coll Cardiol 2008;51:1581-7.

Friedrich MG, Sechtem U, Schulz-Menger J, Holmvang G, Alakija P, Cooper LT, et al. Cardiovascular magnetic resonance in myocarditis: A JACC White Paper. J Am Coll Cardiol 2009 Apr 28;53(17):1475-87.

Hombach V, Grebe OC, Merkle N, et al. Sequelae of acute myocardial infarction regarding cardiac structure and function and their prognostic significance as assessed by magnetic resonance imaging. Eur Heart J 2005;26:549-557.

Hundley WG, Hamilton CA, Thomas MS, et al. Utility of fast cine magntetic resonance imaging and display for the detection of myocardial ischemia in patients not well suited for second harmonic stress echocardiography. *Circulation*. 1999;100:1697-1702.

Hundley WG, Morgan TM, Neagle CM et al. Magnetic resonance imaging determination of cardiac prognosis. *Circulation*. 2002:2328-2333.

Ingkanisorn WP, Kwong RY, Bohme NS, Geller NL, Rhoads KL, Dyke CK, et al. Prognosis of negative adenosine stress magnetic resonance in patients presenting to an emergency department with chest pain. J Am Coll Cardiol 2006 Apr 4;47(7):1427-32.

*Kim RJ, Fieno DS, Parrish TB et al. Relationship of MRI delayed contrast enhancement to irreversible injury, infarct age and contractile function. Circulation 1999; 100:1992-2002.

*Kim RJ, Wu E, Rafael A et al. The use of contrast-enhanced magnetic resonance imaging to identify reversible myocardial dysfunction. N Engl J Med 2000; 343:1445-1453.

Kim WY et al Coronary magnetic resonance angiography for the detection of coronary stenoses. N Engl J Med 2001;345:1909

*Kramer CM, Barkhausen J, Flamm SD, et al. Standardized cardiovascular magnetic resonance imaging (CMR) protocols, society for cardiovascular magnetic resonance: board of trustees task force on standardized protocols. J Cardiovas Magn Reson 2008;10:35.

Kribben A, Witzke O, Hillen U, et al. Nephrogenic systemic fibrosis: pathogenesis, diagnosis and therapy. J Am Coll Cardiol 2009;53:1621-1628.

Kwong RY, Schussheim AE, Rekhraj S et et.al .Detecting acute coronary syndrome in emergency department with cardiac magnetic resonance imaging.*Circulation*. 2003;107:531-537.

Kim HW, Klem I, Shah DJ, et al. Unrecognized non-Q-wave myocardial infarction: prevalence and prognostic significance in patients with suspected coronary disease. PLosS Med 2009;6(4):e1000057.

*Klem I, Heitner JF, Shah DJ, et al. Improved detection of coronary artery disease by stress perfusion cardiovascular magnetic resonance with the use of delayed enhancement infarction imaging. J Am Coll Cardiol 2006;47:1630-1638.

Lund GK, Stork A, Muellerleile K, et al. Remodeling and analysis of infarct resorption in patients with reperfused myocardial infarcts by using contrast enhanced MR imaging. Radiology 2007;245:95-102.

Maceira AM, Joshi J, Prasad SK, Moon JC, Perugini E, Harding I, et al. Cardiovascular magnetic resonance in cardiac amyloidosis. Circulation 2005 Jan 18;111(2):186-93.

Mahrholdt H, Goedecke C, Wagner A, Meinhardt G, Athanasiadis A, Vogelsberg H, Fritz P, Klingel K, Kandolf R, Sechtem U. Cardiovascular magnetic resonance assessment of human myocarditis: a comparison to histology and molecular pathology. *Circulation*. 2004**;**109:1250-1258.

Mollet NR, Dymarkowski S, Volders W, Wathiong J, Herbots L, Rademakers FE, et al. Visualization of ventricular thrombi with contrast-enhanced magnetic resonance imaging in patients with ischemic heart disease. Circulation 2002 Dec 3;106(23):2873-6.

McCrohon JA, Moon JC, Prasad SK, et al. Differentiation of heart failure related to dilated cardiomyopathy and coronary artery disease using gadolinium-enhanced cardiovascular magnetic resonance. *Circulation*. 2003**;**108:54-59.

Nagel E, Lemkuhl HB, Bocksch W, et al. Noninvasive diagnosis of ischemia-induced wall motion abnormalities with the use of high-dose dobutamine stress MRI. *Circulation*. 1999;99:763-770.

*Nandular KR, Dwamena BA, Choudhri AF, Nadular MR, Carlos RC. Diagnostic performance of stress cardiac magnetic resonance imaging in the detection of coronary artery disease. J Am Coll Cardiol 2007;50:1343-53.

Rickers C, Wilke NM, Jerosch-Herold M, Casey SA, Panse P, Panse N, et al. Utility of cardiac magnetic resonance imaging in the diagnosis of hypertrophic cardiomyopathy. Circulation 2005 Aug 9;112(6):855-61.

Rogers WJ, Kramer CM, Geskin G, et al. Early contrast enhanced MRI predicts late functional recovery after reperfused MI. *Circulation* 1999;99:744-750.

Schwitter J, Wacker CM, van Rossum AC, et al. MR-Impact: comparison of perfusion-cardiac magnetic resonance with single-photon emission computed tomography for the detection of coronary artery disease in a multicenter, multivendor, randomized trial. Eur Heart J 2008;29:480-489.

Simonetti OP, Kim RJ, Fieno DS et al. An improved MR imaging technique for the visualization of myocardial infarction. Radiology 2001; 218:215-223.

Smedema JP, Snoep G, van Kroonenburgh MP, van Geuns RJ, Dassen WR, Gorgels AP, et al. Evaluation of the accuracy of gadolinium-enhanced cardiovascular magnetic resonance in the diagnosis of cardiac sarcoidosis. J Am Coll Cardiol 2005 May 17;45(10):1683-90.

Soriano CJ, Ridocci F, Estornell J, Jimenez J, Martinez V, De Velasco JA. Noninvasive diagnosis of coronary artery disease in patients with heart failure and systolic dysfunction of uncertain etiology, using late gadolinium-enhanced cardiovascular magnetic resonance. J Am Coll Cardiol 2005 Mar 1;45(5):743-8.

Steel K, Broderick R, Gandla V, et al. Complementary prognostic value of stress myocardial perfusion and late gadolinium enhancement imaging by cardiac magnetic resonance in patients with known or suspected coronary artery disease. Circulation 2009;Sep 21:Epub

Tandri H, Castillo E, Ferrari VA, Nasir K, Dalal D, Bomma C, et al. Magnetic resonance imaging of arrhythmogenic right ventricular dysplasia: sensitivity, specificity, and observer variability of fat detection versus functional analysis of the right ventricle. J Am Coll Cardiol 2006 Dec 5;48(11):2277-84.

Wagner A, Mahrholdt H, Holly TA et al. Contrast-enhanced MRI and routine single photon emission computed tomography (SPECT) perfusion imaging for detection of subendocardial myocardial infarcts: an imaging study. *Lancet*. 2003;361:374-379.

*Weinsaft JW, Kim HW, Shah DJ, Klem I, Crowley AL, Brosnan R, et al. Detection of left ventricular thrombus by delayed-enhancement cardiovascular magnetic resonance prevalence and markers in patients with systolic dysfunction. J Am Coll Cardiol 2008 Jul 8;52(2):148-57.

*White JA, Yee R, Yuan X, Krahn A, Skanes A, Parker M, et al. Delayed enhancement magnetic resonance imaging predicts response to cardiac resynchronization therapy in patients with intraventricular dyssynchrony. J Am Coll Cardiol 2006 Nov 21;48(10):1953-60.

*Wu KC, Zerhouni EA, Judd RM, et al. Prognostic significance of microvascular obstruction by magnetic resonance imaging in patients with acute myocardial infarction. *Circulation*. 1998;97:765-772.

Yuan C, Mitsumori LM, Ferguson MS et al: In vivo accuracy of multispectral magnetic resonance imaging for identifying lipid-rich necrotic cores and intraplaque hemorrhage in advanced human carotid plaques. Circulation 104:2051-2056, 2001

Updated 5/30/2012