

Artefacts and pitfalls in MPI

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Myocardial perfusion imaging (MPI) is a valuable tool in the assessment of patients with cardiovascular disease. MPI plays an important role in cardiovascular disease diagnosis, prognostication, therapy assessment, and viability assessment. MPI is a complex physiologic imaging process, which exposes it to a number of potential pitfalls and artefacts that can limit the utility of the study. This presentation will review the pre-imaging, technical, patient-related, and heart-related artefacts and pitfalls that may compromise the performance and interpretation of MPI studies. It is essential to be aware of these factors, limit them wherever possible, and to recognize them when they do arise in clinical situations.

Preimaging

The first step in ensuring an optimal study is patient preparation. To limit gut activity adjacent to the heart, patients should be NPO or have only a light meal, depending on institution preference. If a pharmacologic stress with a vasodilator such as adenosine or dipyridamole is to be performed, the patient should abstain from medications containing methylxanthines and beverages, food (such as chocolate), and medications containing caffeine for 12-24 hours.

An IV line must be placed to reduce the possibility of an interstitial dose and to allow injection during exercise. An interstitial injection may compromise the study in three ways. Firstly, because less radiopharmaceutical is taken up by the myocardium, counting statistics are lowered, resulting in a poorer quality study. Secondly, if the interstitial injection occurs during the second phase of a same day study, the resultant second scan will be predominated by activity from the first injection. Thus ischemia induced during a stress study may be masked, a significant error. Thirdly, an interstitial injection can lead to altered distribution of the radiopharmaceutical, such as uptake in lymph nodes, which may be mistaken for malignancy. Another potential error related to the injection that can inappropriately result in an evaluation for malignancy is contamination. A final issue related to the injection is the use of a port device which may act as a reservoir for the radiopharmaceutical.

Technical

Once the ECG has been established, the duration of the cardiac cycle, represented by the R-R interval, must be properly recognized by the camera system prior to beginning imaging. If changes in the length of the cardiac cycle occur during the acquisition, there may be frames in the cardiac cycle that do not have adequate counts. This can manifest as flickering artefact on the raw cine data. In addition to causing a potentially unreliable assessment of wall motion and ejection fraction on the gated study, the perfusion images and assessment of wall thickening may also be compromised by this uneven distribution of counts among the time frames.

The detrimental effects of arrhythmias can be reduced by using the beat rejection capabilities offered by most commercial systems. This software acquires data around an acceptance window, or range of acceptable beats. This allows the system to acquire data within a more stable R-R interval and provide a better quality study. For pronounced arrhythmias however, this approach may be inadequate to eliminate artefacts. In this case, an additional non-gated perfusion study may be required.

A number of quality control (QC) procedures are critical to provide optimum camera performance, and thus ensure the diagnostic utility of myocardial perfusion studies. SPECT studies require additional QC testing and image correction beyond that required for routine planar imaging. The SPECT corrections that may cause the most significant negative effects on reconstructed data are centre of rotation, multi-head registration, and tomographic uniformity. Other useful SPECT QC testing may include pixel size calibration, tilt angle check, and SPECT phantom reconstruction. Where a transmission image is acquired for attenuation correction, testing of emission-transmission alignment should also be considered.

Quality control testing should be performed according to the guidelines and at the recommended frequency of the camera manufacturer, and in accordance with the National Electrical Manufacturers Association (NEMA) recommendations for implementing SPECT instrumentation quality control. A thorough review of SPECT QC testing is provided in the references (3), and is not included here.

A number of technical errors may occur during the processing phase of MPI. The short, horizontal long, and vertical long axis images are generated according to the limits and axis selection of the user.

These should be chosen carefully to ensure that the entire myocardium is included and the axis angles are correct.

Patient related

Patient motion is a common source of artifact on MPI studies. Movement of 1 pixel could cause a detectable defect but this was rarely clinically significant, whereas movement of 2 or more pixels always caused a detectable artefact, and it was felt this could be clinically significant in 5% of cases (4). The technologist performing the study should ensure the patient is relaxed and comfortable prior to the start of acquisition to limit the possibility of motion throughout the scan. Observation of the patient during the acquisition is also recommended to ensure the patient remains still. Prone imaging may also be introduced to reduce patient motion.

In addition to taking steps before and during the acquisition to limit patient motion, the technologist must review the raw data in cine mode afterwards to assess for motion. A decision must then be made as to whether additional steps are required. Minimal motion may be ignored, whereas more moderate motion should be corrected with the aid of the manufacturer's motion correction software. However, there are limitations to the degree of motion that can be corrected using software, and large amounts of motion will necessitate repeating the acquisition.

Attenuation of photons by the patient's body is responsible for one of the most prevalent artefacts in myocardial perfusion imaging. Large body habitus results in generalized decreased counts, creating a noisier, and therefore less diagnostic, image. This can be mitigated by using a weight-based dosing regimen. Even more troublesome however, is focal attenuation. Typically this is due to breasts in women and the diaphragm in men, although lateral chest wall fat can also lead to focal attenuation artefacts.

Breast attenuation usually results in an apparent perfusion defect along the anterior wall of the left ventricle, although depending on body habitus, the lateral wall, septum, and even the apex can be affected. It sometimes can be difficult to distinguish breast attenuation artefact from a true defect. Clues to the artefactual nature of the abnormality include:

1. The defect is fixed (unchanged between rest and stress imaging)
 - this alone does not point to an artefactual origin, but a fixed defect along with normal motion and thickening on the gated study does favour breast attenuation
2. Appreciation of the size and density of the breasts
 - this can be evaluated by observing the raw data in cine format. Further, it is important that the patient's body parameters, including bra size, be recorded on the patient's data sheet, along with whether there has been prior breast surgery, such as mastectomy or implants. If the patient has a breast prosthesis, it should be removed prior to imaging.
3. The defect may not conform to an expected coronary artery distribution.
 - Large abdomens result in attenuation of the inferior wall. This is more commonly seen in men, resulting in sex differences in typical myocardial perfusion patterns,

Activity in subdiaphragmatic organs can interfere with evaluation of perfusion in two general ways. Firstly, it can result in apparent increased activity in the adjacent inferior wall as a result of scatter and volume averaging. This can mask a true defect in the inferior wall, or may lead to normalization problems throughout the remainder of the myocardium, due to the increased activity in the inferior wall. Less intuitively, this adjacent "hot" activity can result in apparent decreased activity in the adjacent myocardium. This results from the reconstruction algorithm used in filtered back projection (FBP). FBP attempts to limit the star artefact that arises from a simple superposition of back projections of the data from the multiple angle acquisitions of a SPECT study. FBP utilizes a ramp filter, in which the weighting applied increases linearly as a function of frequency in the frequency domain (like a ramp). In the spatial domain, this is represented by a decaying oscillation function, such that a negative weighting is applied at short distances away from a hot object. This results in the artefactual decreased activity adjacent to hot objects. It is important to wait an adequate amount of time between injection of the radiopharmaceutical and imaging to allow subdiaphragmatic activity to clear.

Heart related

Left bundle branch block (LBBB) is a conduction abnormality in which the cardiac electrical signal cannot pass through the left bundle branch. In this situation conduction to the left ventricle comes from the right ventricle, and is delayed. This results in paradoxical septal motion (towards the right) on

gated studies. More importantly, it can result in a septal defect on perfusion imaging, which may be mistaken for myocardial infarction or ischemia, depending on whether the artefactual defect is fixed or reversible.

In hypertrophic cardiomyopathy, there is thickening of the myocardium, often particularly involving the septum. This can result in significant increased activity in the septum, which results in the activity in the other walls appearing decreased. This may lead to the erroneous diagnosis of widespread perfusion abnormalities. This phenomenon can also be seen in the setting of hypertension, though it is less frequently seen and is typically less severe in this circumstance.

If there is decreased perfusion to all walls, the abnormalities may not be recognized, particularly if the decrease is of a similar magnitude throughout (so-called "balanced ischemia"). Still, while the sensitivity for identifying multi-vessel disease in patients with 3-vessel disease is only approximately 60%, there is usually some abnormality present, so that the identification of some degree of coronary artery disease in this setting remains high, at 95-98%.

It is essential that the presence of dextrocardia be recognized by both the technologist and the reporting physician. This situation may not be known when the patient presents for a myocardial perfusion study. Because of the altered orientation of the heart within the thorax, a 180° SPECT acquisition will have to range from -135° to +45°. The orientation will also have to be taken into account during the processing.

Further Reading

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