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Patient Motion During Cardiac PET Imaging

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Cardiac positron emission tomography (PET) myocardial perfusion imaging (MPI) utilization has increased consistently throughout the United States over the past 10 years. This expansion is attributed to multiple advantages, including higher diagnostic accuracy, faster scan protocols, lower patient and staff radiation exposure, and fewer artifacts, resulting in fewer false-positive studies as well as the value of myocardial blood flow assessment. The use of attenuation correction has virtually eliminated attenuation artifact. However motion artifact with cardiac PET does occur. This happens when a patient literally moves during the rest or stress data acquisition, potentially producing inconclusive or false-positive results.

This whitepaper will examine patient motion during PET imaging with Rubidium-82 (Rb-82), the characteristic appearance of motion artifacts, the consequential impact on clinical interpretation and finally suggestions for prevention.

Cardiac SPECT vs. PET Motion Artifact

Although motion artifact occurs with both SPECT and PET, motion artifact presents distinct challenges in cardiac PET. First, continuous data acquisition in PET imaging precludes frame-by-frame motion correction capabilities that are available with SPECT. Consequently, motion artifacts manifest more frequently in the processed PET images for interpretation. Furthermore, the absence of rotating projection images in PET eliminates a valuable tool for motion identification available in SPECT imaging.

Recognizing PET Motion Artifact

Patient motion occurs during the 7-minute rest or stress acquisition. Generally, motion occurs more frequently with stress as the patient is more uncomfortable after administration of pharmaceutical stress agents. The defect is generally concise ("slit-like") in appearance as well as opposite contralateral defects, but can also be mistaken for ischemia. The degree to which the patient moves affects the appearance on processed images, as described below.

Mild Patient Motion

Mild patient motion generally occurs at the apical segments only and is characterized by "contralateral defects," generally anterior and inferior. In **Figure 1**, the defect is antero/septal and infero/lateral and spares the rest of the slices. This appearance can occasionally be interpreted as consistent with ischemia, but if myocardial blood flow is normal, it is reassuring that this is an artifact.

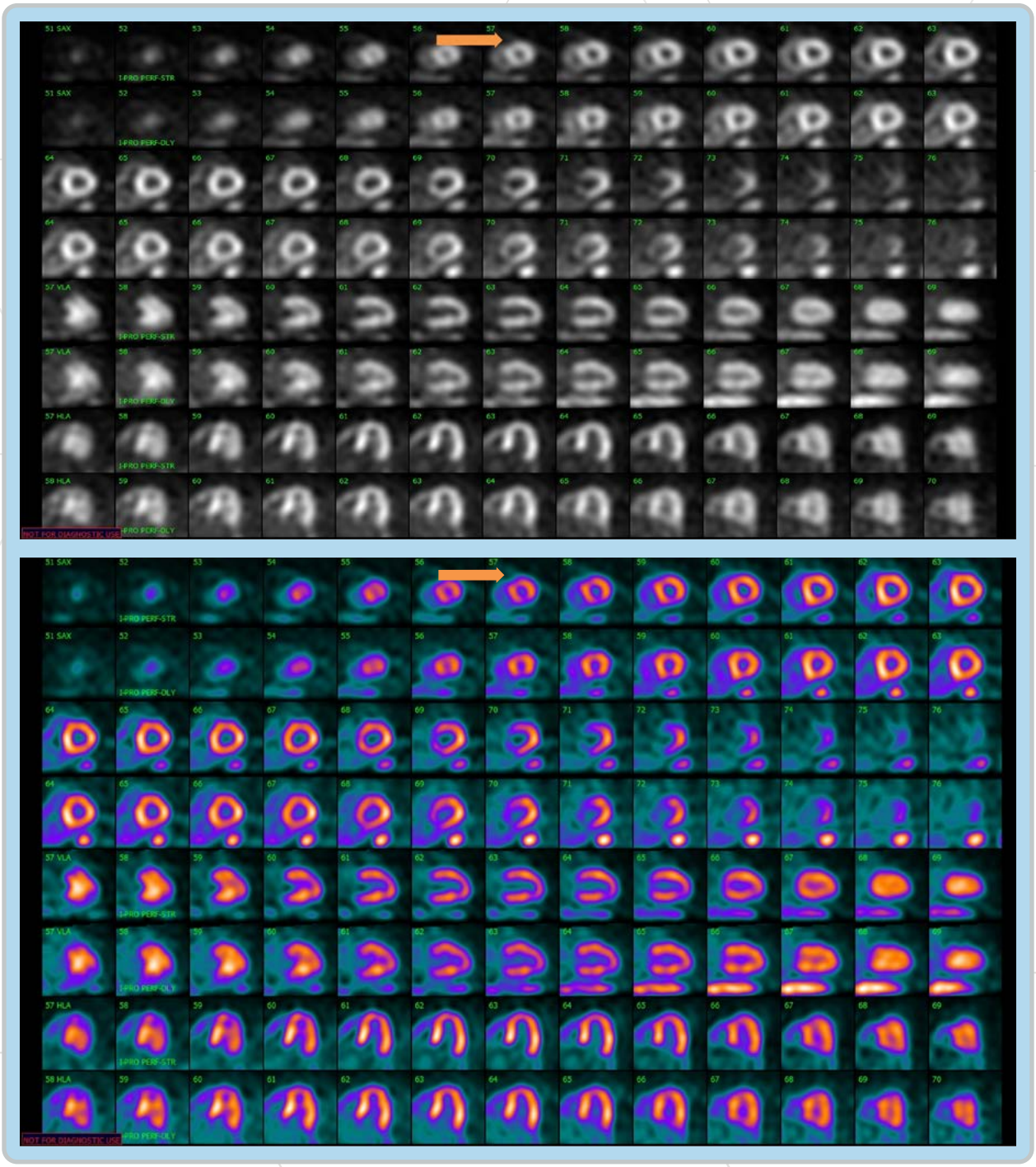

Figure 1: Rest/stress myocardial perfusion imaging with apical motion artifact. See the arrow on both gray scale and cool color. The rest of perfusion is normal. The study can be considered normal with apical motion artifact.

Moderate Motion Artifact

Moderate motion artifact can encompass the entire left ventricle from apex to base or at least to the mid-ventricular region. It, too, is characterized by contralateral defects such as antero/septal and infero/lateral or antero/lateral and infero/septal defects (see **Figure 2**). A defect of this size may also affect quantification, but if so, it is generally 1-3 slices and in line.

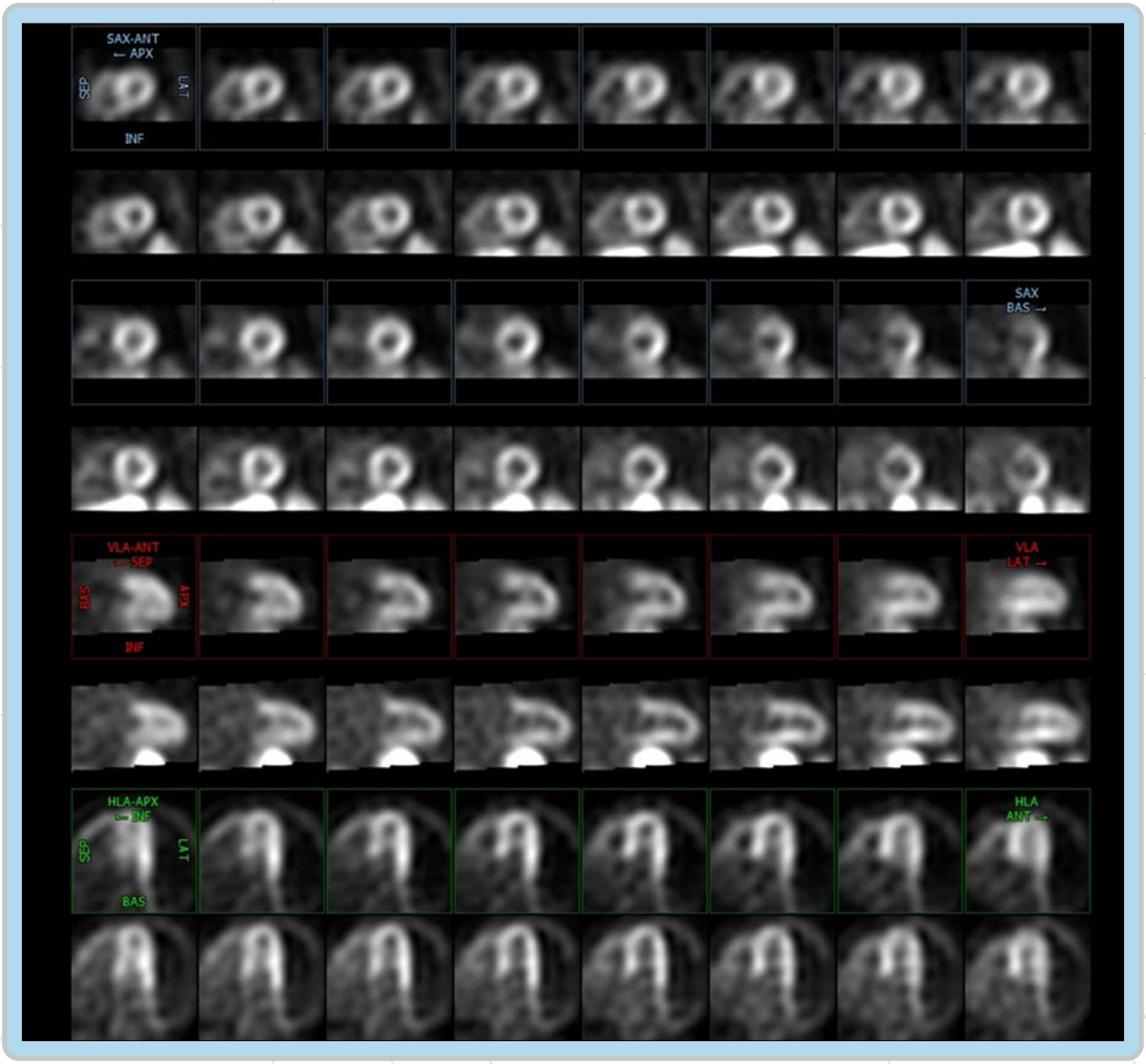

Figure 2: The rest/stress perfusion study demonstrates moderate motion artifact with anterior and inferior defects (contra-lateral). The study can be considered normal or probably normal with moderate motion artifact especially if myocardial blood flow is normal.

Severe Motion Artifact

Severe motion artifact affects the entire ventricle from apex to base. It, too, is generally characterized by contralateral defects, anterior and inferior. However, it can also distort the appearance of the left ventricle, spuriously resulting in an abnormal transient ischemic dilation (TID) ratio that might be interpreted as consistent with ischemia. In addition, one of the other two defects (usually inferior) appears more severe than the other. This finding makes interpretation difficult as ischemia can not be excluded, and the patient may require re-imaging (see **Figure 3**)

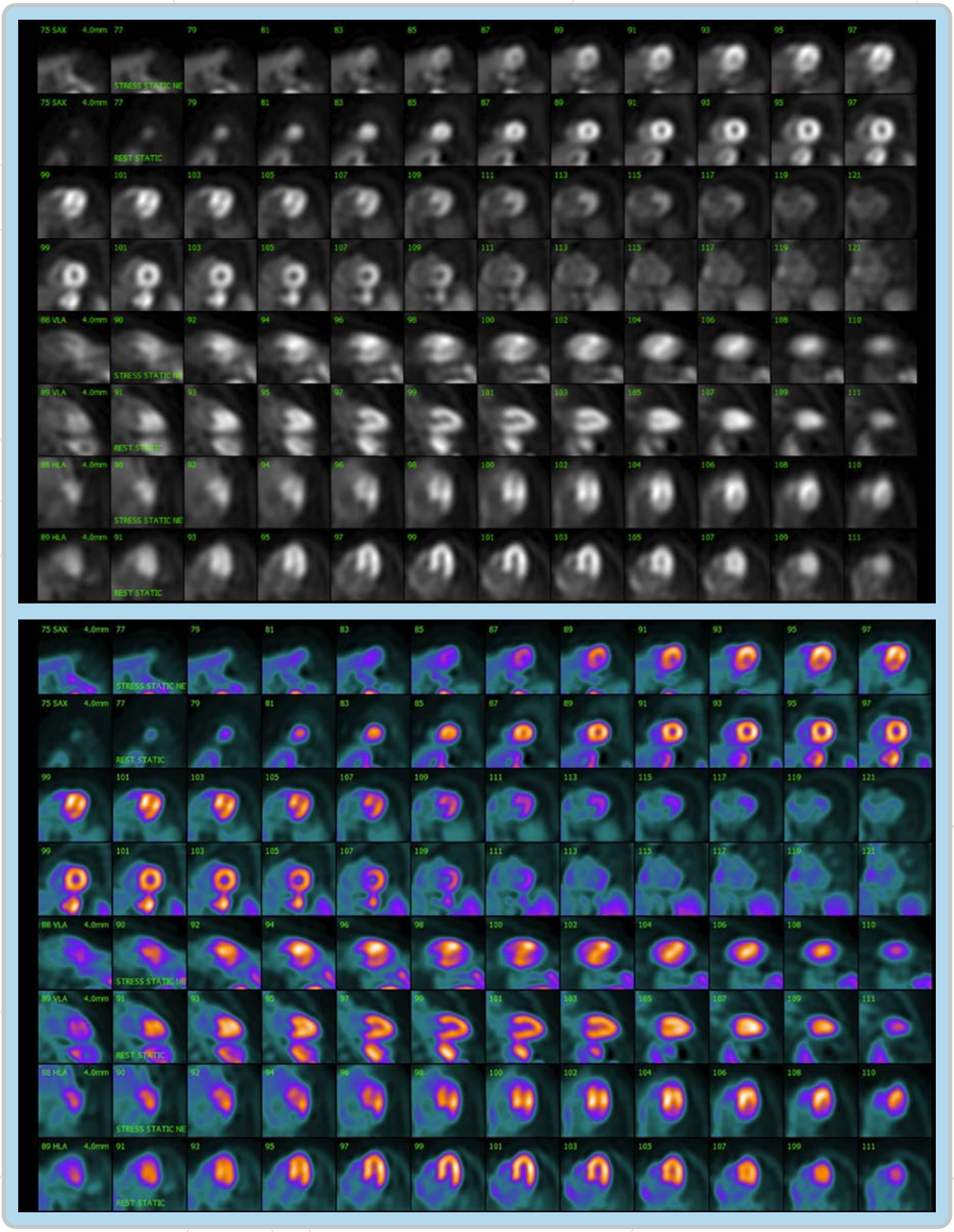

Figure 3: Rest/stress perfusion imaging in both gray and cool color. This motion is severe from apex to base with distortion of the left ventricle which might lead to an elevated TID ratio. The defects are so severe that ischemia cannot be excluded. It is recommended that a repeat study be performed.

Respiratory Motion Artifact

Respiratory motion artifact occurs more commonly with stress due to more labored breathing after administration of pharmacologic stress agents such as regadenoson. Dyspnea occurs in 40% of patients, and when it impacts imaging, it appears as an apical inferior defect (see **Figure 4**). It is generally confined to the first 3-4 slices at the apex but can extend to the mid-ventricular region. This defect mimics apical-inferior ischemia and is the cause of false positive results at cardiac catheterization. However, it is also associated with normal myocardial blood flow, which can help distinguish it from ischemia. Some PET/CT systems have software to correct this, but the software has not been completely validated.

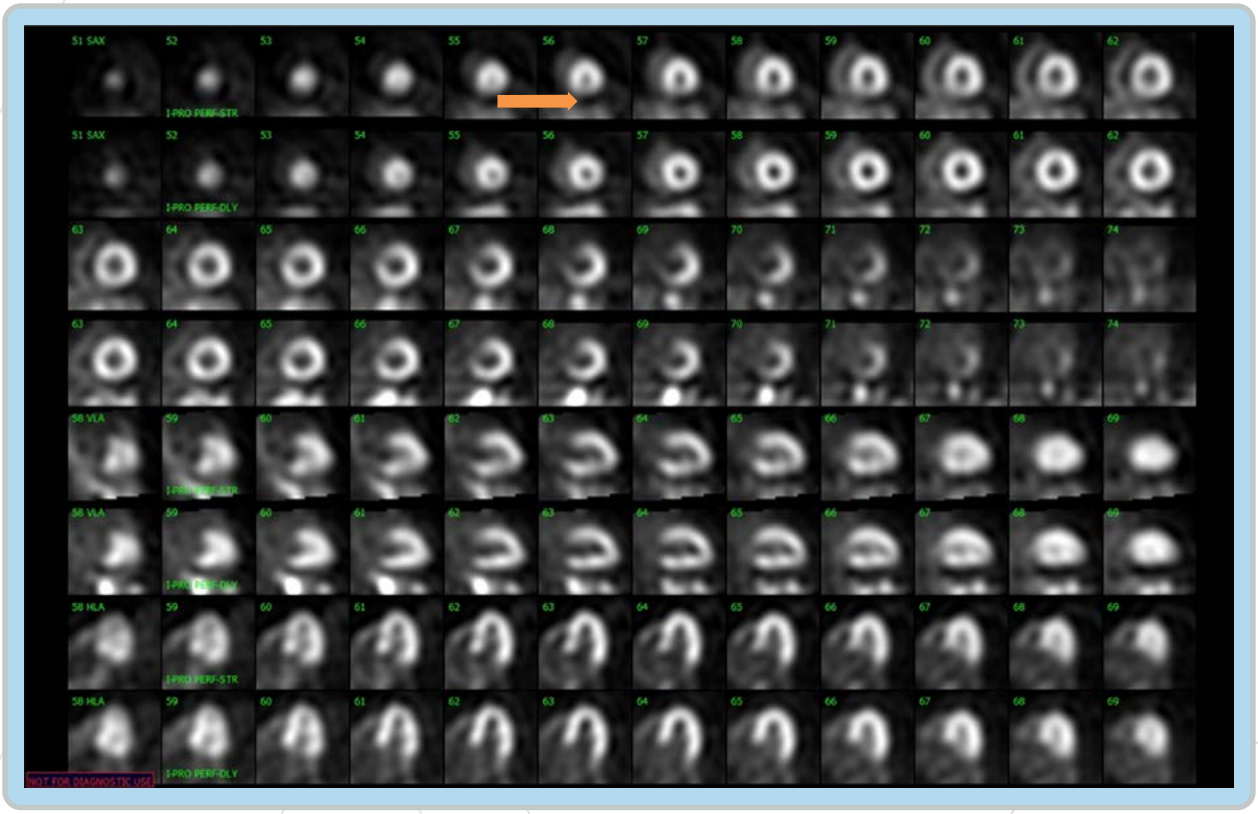

Figure 4: Rest/stress perfusion with respiratory motion artifact in the apical inferior region (see arrow).

Myocardial Blood Flow in the Setting of Motion Artifact

Myocardial blood flow is generally unaffected by mild/moderate or respiratory motion artifacts and is usually normal in the affected segments (**Figure 5**). In the setting of what appears to be a motion artifact, the presence of normal blood flow is reassuring that the defect is an artifact and not ischemia. In extreme motion and motion artifact cases, blood flow may be incorrectly abnormally low and should be considered with suspicion. In such circumstances, repeat testing is important.

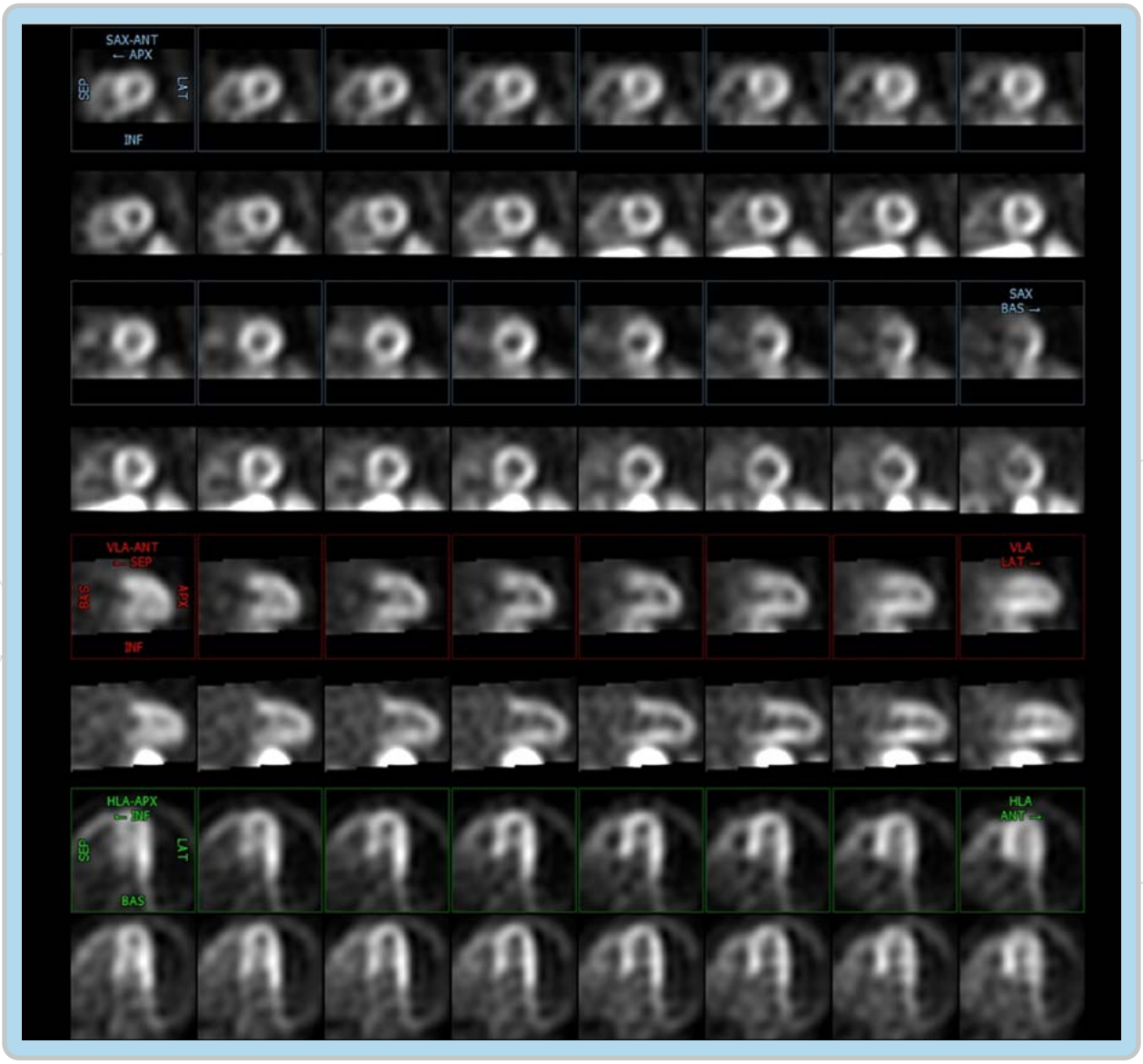

Figure 5a: Rest stress perfusion with moderate motion artifact anterior and inferior segments.

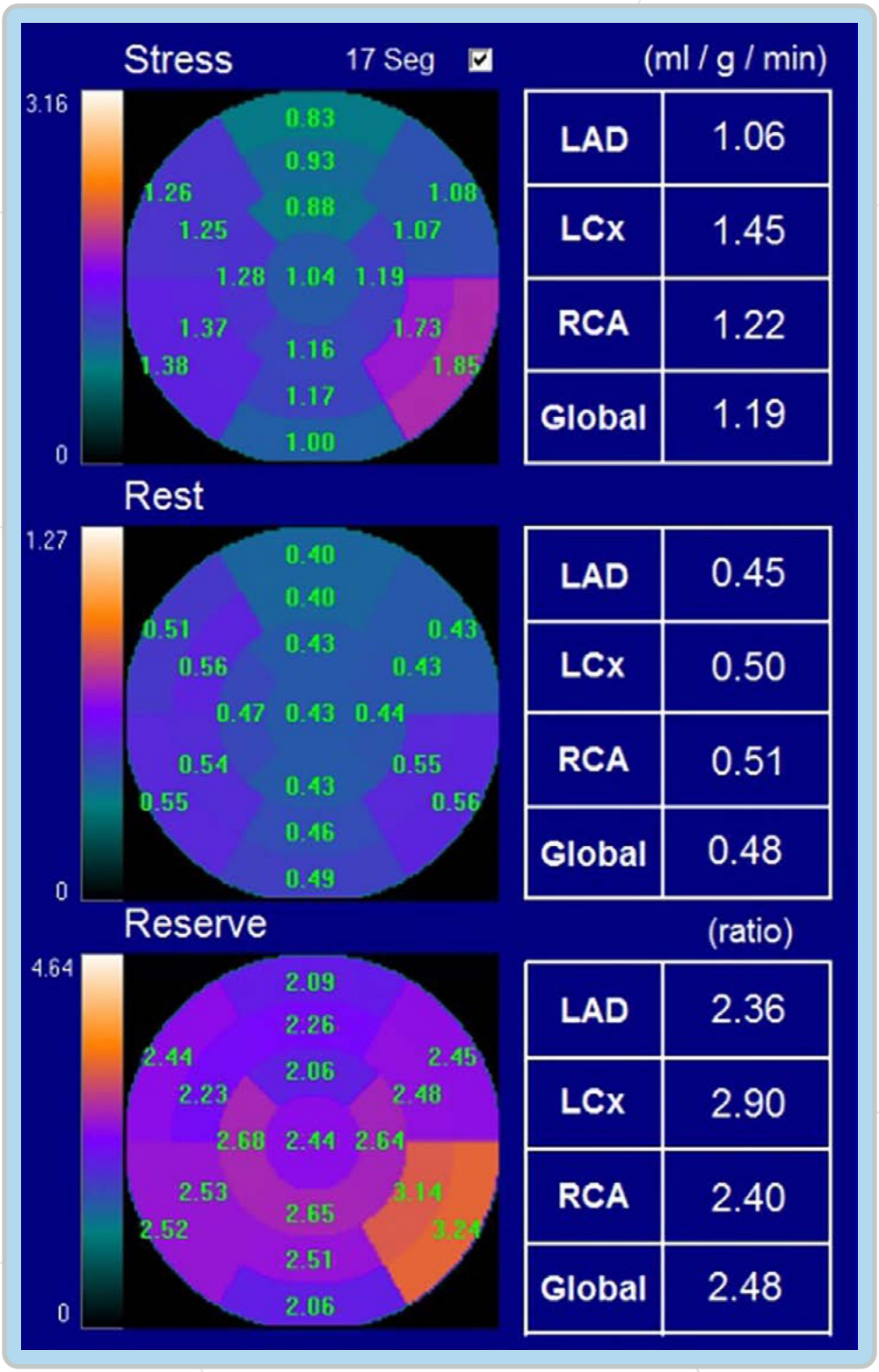

Figure 5b: Shows myocardial blood flow reserve which is entirely normal including individual segments the normal blood flow supports motion artifact and the study could be considered normal or probably normal with moderate motion artifact.

Interpretation of Motion Artifact

The interpretation/conclusion depends upon the physician interpreter's level of confidence that the defect is due to motion. The following is a guide/recommendation, but the reader must make the final decision.

1. **Mild motion artifact:** These abnormalities have characteristics that do not appear as ischemia, and the entire image can be considered normal with a statement on the report, such as "mild apical motion artifact but normal perfusion."

2. **Moderate motion artifact:** This finding is more generalized; however, the defect can still be considered a motion artifact, especially in the setting of normal regional and segmental blood flow. The interpreter may wish to identify the defect and state "probably" normal or normal overall.

3. **Severe motion artifact:** This situation is the most difficult, especially if the defect is worse in one portion (generally inferior). Even in the setting of normal blood flow, ischemia can not be completely excluded, and the recommendation is to report the study as "inconclusive to exclude ischemia" and advise repeating the study.

4. **Respiratory motion artifact:** The issue here is that it does look like ischemia, but a small apical/inferior defect is quite unlikely as the only area of ischemia, especially in the setting of normal myocardial blood flow in the same area. This scenario is somewhat common, so one could consider reporting "mild respiratory motion artifact but normal perfusion."

Prevention of Motion Artifact

Most motion artifacts, especially severe, are preventable by communication with the patient. There are many ways of doing this, but it certainly involves emphasizing to the patient that movement, especially during the 7-minute rest and stress portion of the study, will result in poor information for the interpretation of the study. Some technologists warn that movement may result in an inclusive study, necessitating study repeat. A good approach is communicating before and during the rest and stress acquisition.

Making the patient as comfortable as possible is important because discomfort leads to more significant movement and subsequent artifacts. Placing the patient's arms at their side may be necessary, and if so, they should be positioned the same on both the rest and stress acquisitions. While not ideal, it may mitigate motion and result in a better image.

Respiratory motion is more difficult to prevent, but the technologist should remind the patient to take regular rather than deep and prolonged inspirations.

Motion Artifact during Blood Flow Acquisition

Some programs for blood flow assessment, called "single compartment" software, are very susceptible to minor patient movement during blood flow acquisition. Motion during the blood flow phase is not the same type of motion discussed previously. The solution to motion during the blood flow phase involves correcting the position of the blood flow so that it is in the left ventricle, either automatically by computer or manually by the technologist. By doing so, blood flow data is optimized. Again, this maneuver should not be confused with overall patient motion during the 7-minute acquisition, for which correction is currently not possible.

Summary

Cardiac PET imaging has considerable benefit over SPECT by eliminating attenuation artifact. However, patient motion during either rest or stress data acquisition interferes with successfully determining the presence or absence of ischemia. This whitepaper presents the patterns associated with motion artifacts, their interpretation, and prevention.

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