SPECT Gamma Camera

SPECT Centre-of-Rotation (COR)

1. Introduction and rationale
The transverse and axial alignment of the images with the centre of rotation of the camera (for multidetector systems) is of crucial importance for the image quality of SPECT images. Any deviation from the optimal geometry leads to artefacts in the reconstructed transverse slices, because the reconstruction algorithm is based on a precise (circular) rotation around a fixed central point. The effect of these deviations on the transversal image quality is a loss of spatial resolution and contrast. Point sources are displayed as ring-shaped.

2. Frequency
Because this check is essential for the SPECT image quality, it must be carried out often. The frequency can be adapted, but carrying out the COR check must first and foremost be solidly incorporated into the work routine, e.g. every week before starting work. In so doing, the different configurations (180°/90°/different collimators) can be checked alternately.

3. Method
As instructed by the manufacturer.
According to NEMA, recordings of three sources (one of which is positioned at the approximate centre of the axis of rotation) are made from at least four angles. From this, the absolute and relative (inter-source) deviations in the COR and the axial direction are determined. All modern cameras have a built-in protocol for the COR check, and the manufacturer's instructions may be followed. Ascertained that the calculation of the COR, as instructed by the manufacturer, is carried out in accordance with NEMA regulations (see NEMA NU 1-2001) and in particular that, in multi-detector systems, both the transverse and the axial deviations from the COR are determined. If a line source is specified or if the source is placed almost exactly on the axis of rotation, the NEMA requirements are not being met.

4. Required equipment, phantoms and sources
Follow the manufacturer's instructions.
According to NEMA:
Three point sources of ^{57}Co or ^{99m}Tc, source intensity approx 50 MBq. Lower source intensities may be used, but these require longer recording times.

5. Procedure
Follow the manufacturer's instructions.
According to NEMA (see NEMA NU 1-2001):

Place one source approximately on the axis of rotation in the middle of the field of view. The other sources are placed in line, both radially and axially at a distance of 25% of the axial FOV.

- Switch the correction table on
- Record at least one image at 0°, 90°, 180° and 270°
- The maximum pixel according to NEMA should be at least 20.000 cts per source per angle, corresponding to a recording time of several minutes at 50 MBq.
- The energy window is 15% for ^{99m}Tc and 20% for ^{57}Co
  Check all configurations in which SPECT images are made (180°/90°/different collimators)

6. Analysis and interpretation

Follow the manufacturer's instructions, use the software supplied.
According to NEMA (see NEMA NU 1-2001):

- For all angles, calculate the deviation from the transverse position of the source relative to the average transverse position.
- Calculate the average deviation of all angles
- Calculate the maximum for all detectors and sources
- Calculate the maximum difference in axial position at 0° and 180°for all detectors and sources
- For a multi-detector system also calculate:
  - the maximum difference in transverse deviation between the detectors.
  - the maximum of the average relative difference for all angles in axial position between the detectors. Do this for all sources.

The main causes of COR deviations are mechanical effects and/or poor alignment of the collimator-detector plane relative to the axis of rotation. Electronic faults can often be solved in a simple manner. Mechanical causes are much harder to correct. Mechanical effects do not commonly occur in multidetector systems where the detectors are mounted in a fixed ring; an electronic cause is most probable.

7. Action thresholds and actions

The COR must be within the manufacturer's specifications. SPECT images must not contain ring artefacts.

8. Pitfalls and comments

a. Inhomogeneity may also lead to ring artefacts in transverse slices (see 'Gamma Camera SPECT: uniformity'). The inhomogeneity will always be centred relative to the central axis, while deviations from the COR show up as a circle around the position of the corresponding point source.

b. To determine the COR corrections, follow the procedure as described by the manufacturer precisely; the algorithm and the determination of the COR offset may be based on a fixed source position relative to the axis of rotation.

c. The COR may be different for each collimator. In addition, changes in the mechanical load, e.g. through a different rotation radius, can affect the COR. The energy setting of the gamma camera can affect system parameters, such as offset and image size. If this affects the electronic axis of rotation, the latter will no longer coincide with the mechanical axis of rotation.

d. In some cameras, it is (too) easy to (accidentally) alter the calibration of the COR. This may be a reason to increase the frequency of the checks.

e. The manufacturer may require frequently re-recording of the COR correction. In which case, interim checks should be made to verify the camera is stable. Furthermore, the user will have to weigh up whether the time and radiation exposure expended on this is justified. If necessary, discuss possible adjustments to the procedure with the manufacturer.

f. Some cameras include software that detects the point sources by automatic peak detection. If the chosen source activity or recording time is too low, the peak detection does not work properly. This can result in a false negative COR test.

SPECT Spatial Resolution

1. Introduction and rationale

The spatial resolution of SPECT images depends not only on the acquisition geometry. In contrast to the planar situation, the following also jointly determine the final outcome: the reconstruction filter, the application of scatter corrections, the interpolation routine and/or the reconstruction algorithm.
The transverse spatial resolution may also further depend on the distance of the source to the axis of rotation. With SPECT, only the system resolution is important. The system resolution should therefore be understood as a system parameter determined under fixed geometrical conditions (collimator, circle of rotation, etc.) and as an unambiguous reconstruction protocol.

2. Frequency

This check is recommended at (re)acceptance.

3. Method

SPECT reconstructions are made of at least three point sources (NEMA: 3 sources) using standardised recording and reconstruction parameters. In so doing, the reconstruction will make use of both a simple ramp filter and representative clinical parameters.

4. Required equipment, phantoms and sources.

At least 3 point sources ^{57}Co (or ^{99m}Tc) (1-10 MBq).

5. Procedure

- Mount the desired collimator (usually LEHR) on the camera.
- According to NEMA, the three sources should be mounted in a line, one source in the centre, the other two symmetrically around it with a shift of 50 mm along the axis of rotation and a radial shift of 75 mm. Mount the sources in such a way that no absorbent material will come between the sources and the detectors throughout full rotation. A few further sources can be mounted eccentrically. Any artefacts thereby become more visible.
- Use an energy window of 15%.
- Choose the matrix in such a way that one pixel is no greater than 2,5 mm.

- Rotate over 360° with at least 120 angles (step and shoot; circular) and a radius of 150 ±5 mm.
- Collect at least 20 kcts per angle (corresponding to approximately 2 min at 1 MBq).
- Ensure that the count rate per detector is not greater than 20.000 cps.

6. Analysis and interpretation

Reconstruct thick slices in transverse (130 mm), coronal (30 mm) and sagittal direction (180 mm) with FBP and the ramp filter, without attenuation or uniformity correction. Then integrate these thick slices in both directions and determine FWHM in each of the three slices in both directions. For the X, Y and Z directions, the FWHM is thus always determined twice. Finally, calculate the average value for each of the three directions.
Reconstruct the same acquisition data using the usual clinical reconstruction filters as well, to the extent that the matrix used is relevant. If the matrix in the clinical protocols differs significantly, consider using another matrix first. Determine the FWHM for these reconstructions as well.

7. Action thresholds and actions

Compare, if available, with the manufacturer's specifications (according to NEMA, using a reconstruction with ramp filter). For free measurements in air at the place of the axis of rotation, the transverse spatial resolution, obtained after reconstruction with the ramp filter, must be equal to the planar spatial resolution at a comparable distance from the collimator surface.
When using filters other than the ramp filter (such as are normally used in clinical protocols), the spatial resolution will be worse than the planar, in particular for the eccentrically located sources. Ensure that the user is informed about the expected resolution of the SPECT recording using different protocols.
Also look out for (moon-shaped) artefacts (see COR).

8. Pitfalls and comments

a. The interpretation of the measurements, expressed in mm, is determined by the pixel size; this must be unambiguously defined prior to the determination of the spatial resolution.
b. For large rectangular detectors, it may be necessary to zoom in during acquisition in order to meet the requirement of ≤2,5 mm/pixel. In which case, only a square portion of the detector can be tested.
c. A number of computer systems offer weighted addition of the matrix rows of the planar images as an integral part of the reconstruction process. These are also called Z- or Y-filtering. This option must not be used for this test.
d. The above is only valid for a parallel hole collimator. A divergent collimator geometry (e.g. convergent, fan beam) gives rise to intrinsic enlargement factors, possibly different for the X and Y directions of the planar images. In these cases, a different analysis is required.

9. Additional checks

The same checks can be performed in the presence of scattered radiation. The sources are then mounted into a Jaszczak phantom (NEMA 3.11).

Miscellaneous SPECT

1. Transverse homogeneity

The homogeneity of the reconstructed transverse slices is of direct importance for the usefulness of the SPECT images produced. However, according to NEMA requirements, this homogeneity cannot be evaluated using standard methods. Therefore, make an image of a Jaszczak phantom filled with a homogeneous solution of ^{99m}Tc on (re) acceptance only. Use approximately 50 MBq/l and ensure that the count rate is lower than 20.000 cps. In so doing, use the standard clinical recording settings and calculate the transverse reconstructions both with and without any attenuation and/or scatter corrections. Inspect the results visually for any clear deviations in homogeneity. These deviations must be submitted to the manufacturer. This check is very generic: there can be many causes for deviations. Ensure that the user is aware of what a “homogeneous” SPECT recording looks like.
Caveat: without, or with an incorrect, attenuation/scatter correction a radial trend in the number of counts is to be expected (i.e. a different number of counts in the centre of the phantom relative to the edge).

2. Contrast

Measurement of the contrast is not a NEMA test and specifications for the contrast are also not generally available. Nevertheless, upon acceptance, an image should be made of the Jaszczak phantom filled with “cold” and “hot” lesions respectively in order to give the user insight into the potential of the gamma camera. Cold lesions are simulated by Perspex spheres of different sizes (from approx. 3 mm); hot lesions with fillable spheres containing three times the background concentration (approx. 150 MBq/l). In both cases, the phantom is filled with water containing approximately 50 MBq/l (ensure the count rate is below 20.000 cps).
Record image(s) with clinically relevant SPECT parameters and determine the smallest visible sphere size. Ensure also that the user is aware of the possibilities and becomes familiar with the characteristic pattern of warmer and colder regions, even where there are no spheres. Again, without proper attenuation/scatter correction a radial trend in the number of counts will be apparent.