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Chapter 6

SINGLE PHOTON EMISSION COMPUTERIZED TOMOGRAPHY (SPECT)

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Introduction

Tomography in nuclear medicine did not originate after the introduction of X-ray computerized tomography (CT). Even in the days of rectilinear scanner, tomography was attempted with multiple detector heads rotating around the patient, but the counts at each plane were never very high to obtain a satisfactory image. A high resolution focusing collimator can look at different depths but taking several slices in one projection was a time consuming process. Rectilinear scanners lose lot of counts in the collimator to look at one point, at one time, in one plane. It is true that attempts to do tomography with gamma camera really got a boost after the success of CT. By that time, algorithms for doing reconstruction of images also were highly refined and far advanced.

Operational principles

The SPECT system comprises of a conventional gamma camera mounted on a special gantry and connected to an appropriate computer system. A series of planar images are collected, while the camera is rotated through either 180° or 360°, around the patient. These planar images are called projection images and are used to create transaxial slice images by filtered back projection of the data into a transaxial plane. The last sentence is sufficient to give rotational dizziness to a simple minded physician. There is no point in understanding the intricacies of data processing that the computer does for generating tomographic images. Suffice it to say that each projection image consists of counts in each pixel. Each pixel counts are corrected for attenuation, because the gamma photons arising from pixels at different depths undergo different degrees of attenuation. Image quality depends on the integrity of the counts in each pixel in each view.

Apart from the usual problems of uniformity, linearity and count rate capability that exist with the gamma camera, the rotation creates a few additional plights. When a powerful algorithm uses a series of images for the reconstruction of one image of a slice, any artefact of the planar image gets multiplied several fold. Moreover, an artefact may not be recognized as an artefact, because the final image is generated by manipulation of a large number of images, some good and some bad.

The following are the main components of a SPECT system.

(a) gamma camera with 37 or more photomultipliers; self-correcting mechanism for correction of uniformity,

(b) patient couch, which can be conveniently introduced into the scanning gantry. It is made from a special material to minimize attenuation. It should be possible to align the long axis of the bed with the axis of rotation of the camera.

(c) gantry. Controlled by microprocessor interfaced to main computer.

(d) rotation controller

(e) emergency stop and other patient safety devices

(f) position read-out devices.

Advantages of SPECT

What advantages SPECT offers, which are not there in gamma camera? Cost of SPECT is higher than the cost of an ordinary gamma camera. Is the extra cost justified? The stationary gamma camera sees a whole chunk of a solid mass of an organ in each projection. If there is a space occupying lesion in that organ, contributions to the overall count rate from the overlying and underlying tissues cannot be avoided in a planar gamma camera. A reconstructed single plane in SPECT has a sharp definition of a space occupying lesion, because of the better target to non-target ratio.

SPECT is not without problems. The count rates are low and is no where near to what one gets in CT. Having more than one detector head increases the cost considerably. A rotating detector head can not be too close to the patient, as the camera's resolution becomes inferior, further away it is from the object. Camera's uniformity, linearity, spatial resolution become worse in the rotating mode. A slight non-uniformity is amplified in the rotating mode leading to a high rate of false positives for the unwary. Dynamic studies where count rates change rapidly are not possible with the SPECT. Notwithstanding, the industry has done a remarkable job of improving the quality of the images obtained on the SPECT by improving the system uniformity and linearity, introducing on the fly corrections and refining the reconstruction software. In fact, the SPECT produces better images, where the lesion is of the positive type and not a cold area. As the tendency is to design more and more of lesion specific and function specific radiopharmaceuticals, the type of situations where it is possible to get positive images are increasing and the use of SPECT is increasing along with it.

Quality Control of SPECT

SPECT images can define a lesion better than planar image, but for that, it is necessary to calibrate (an old fashioned term but can be exchanged for quality control to appear erudite) the gamma camera perfectly, choose the right radiopharmaceutical, and get statistically reliable data, which can be processed for image reconstruction. The latter task needs a special kind of computer which, in turn, also requires attention to its quality control.

The following quality control evaluations need to be done for the SPECT regularly.

For the gamma camera part

field uniformity
energy resolution,
spatial resolution,
linearity,
count rate capability.

For the SPECT part

slice thickness,
tomographic contrast,
tomographic uniformity,
tomographic resolution,
tomographic linearity,
centre of rotation,
sensitivity - slice and volume.

SPECT in a developing country

The developing countries usually have only one gamma camera in the nuclear medicine department and this single instrument can not do bone imaging, nuclear cardiology and SPECT, in addition to the already heavy load of liver and the thyroid. Even if the SPECT is available, it would be mainly used for planar imaging.

Of course, the SPECT will like to have more counts but apart from the quantity of counts, there is something like the quality of counts. Counts can be increased by widening the window, by slowing down the speed of rotation or using a low resolution collimator but this type of increase in the counts is going to degrade the image and not improve its quality.

One does not buy SPECT with the hope that it will provide images better than planar gamma camera NOW; one buys it with a hope that in a couple of years, there will be radiopharmaceuticals, which would need SPECT for satisfactory images. Just as the gamma camera got a boost after the introduction of $^{99}Tc^{m}$. The SPECT has still to find a match which will make the SPECT images almost obligatory for worthwhile diagnostic information. This is beginning to happen in the case of brain and heart.

Applications and potential

Clinical application of SPECT has become widespread now, because of the development of suitable radiopharmaceuticals and improvement in instrumentation. The SPECT provides a direct measure of regional organ function and is performed with nuclides such as ^{123}I and $^{99}Tc^{m}$ that emit a mono-image photon during their decay. SPECT is far less expensive than positron emission tomography.

Central nervous system

A number of radiopharmaceuticals have been developed recently that cross the blood-brain barrier, distribute in the brain proportional to the regional blood flow and remain in the brain long enough to permit cross sectional imaging with SPECT. These radiopharmaceuticals have revived the interest in brain imaging, which had dwindled after the advent of CT and MRI. Now, nuclear imaging is an investigation of choice for several clinical situations. The new cerebral perfusion agents are ^{123}I labelled amines and $^{99}Tc^{m}$ labelled HMPAO. The latter is likely to be available in the developing countries in near future.

In acute cerebral infarction, changes in blood flow are seen earlier than CT and MRI. The SPECT studies are better than other investigations to predict outcome and to plan treatment accordingly.

Perfusion SPECT is an accurate diagnostic test in patients with suspected Alzheimer's disease, allowing accurate separation of patients with Alzheimer's disease from those with multiple infarct dementia.

SPECT has proved a valuable and easily available tool for identifying the epileptic focus.

It can be used like PET to study neuro-receptors with receptor binding radiotracers in the diagnosis and understanding of a variety of neurological and psychiatric disorders.

Cardiovascular system

Many of the problems associated with planar myocardial scintigraphy, such as superimposition of one portion of the myocardium on another are reduced with emission tomography. Perfusion SPECT, after the injection of ^{201}Tl, during stress is more accurate than planar imaging for diagnosing the presence of coronary artery disease, for determining the location of the stenosed vessels, and for assessing the functional significance of coronary artery stenosis before and after angioplasty.

$^{99}Tc^{m}$ labelled perfusion tracers have resulted in improved image quality, since myocardial washout of the tracer is slower and photon flux is considerably greater for the same radiation dose to the patient.

Early assessment of the size of the infarct is also possible with SPECT. This parameter is useful in prognosis and planning of the treatment.

Skeletal system

Bone scintigraphy is an important part of the diagnostic strategy in patients with both malignant and benign disease. Regions of increased osseous metabolism appear as scintigraphic abnormalities before morphological changes can be detected by other imaging modalities. Planar scintigraphy often fails when there are overlapping osseous structures. Bone scintigraphy is very sensitive for the detection of subtle changes in bone metabolism. SPECT is more sensitive than planar imaging (85% vs 65%) for identifying increased metabolism at the site of the pathology.

Other applications

Hepatic SPECT using radiotracers, that are selectively extracted by the reticuloendothelial system, is more accurate than planar imaging for the identification of focal lesions but cannot compete with either CT or MRI for detection of small lesions
< 1 cm in diameter, for the identification of the total number of lesions. Single photon emission computed tomography is more accurate than planar imaging for detecting small (<3 cm) and deeply seated lesions. SPECT with labelled monoclonal antibodies may further improve tumour detection if current problems of specificity and poor image quality, can be overcome.

In its early years, SPECT was principally a research tool. Today its availability in many nuclear medicine facilities, its applications in dementia, stroke, and epilepsy; and its increased accuracy over standard planar techniques for heart, skeletal, and tumour imaging have made SPECT one of the major contributors to the current revolution in medical imaging.

SUGGESTED READING.

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