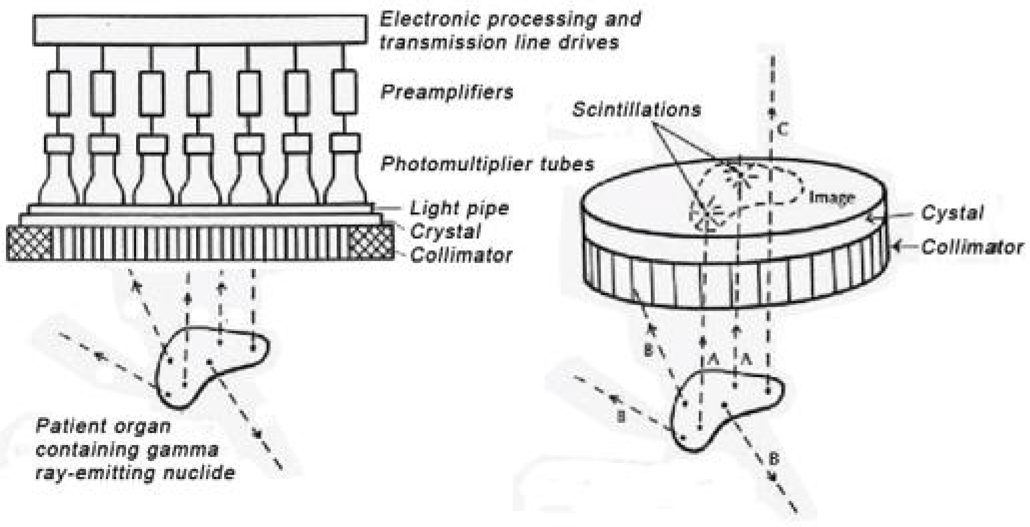
Single Photon Emission Computed Tomography (SPECT)

Single photon emission computed tomography (SPECT) is a medical imaging technique that is based on conventional nuclear medicine imaging (tracer) and tomographic reconstruction methods. The images reflect functional information about patients similar to that obtained with positron emission tomography (PET).A Single Photon Emission Computed Tomography (SPECT)scan is a type of nuclear imaging test that shows how blood flows to tissues and organs.The system detects single photons (energy emitted by the radioactive substance in the body) by rotating detectors around the body and recording events at each detector location. A computer is used to create a three-dimensional image (or tomogram) of the radioactivity detected.

The tracer will emit gamma rays that can be detected by the scanner. The computer collects the information emitted by the gamma rays and translates them into 2D cross-sections. These cross-sections can be added back together to form a 3D image. The radioisotopes typically used in SPECT to label tracers are iodine-123(^{123}I), technetium-99m (^{99m}Tc), xenon-133 (^{133}Xe), thallium-201(^{201}Tl), and fluorine-18 (^{18}F).

A radioactive-labeled pharmaceutical (radiopharmaceutical) is administered to a patient. Depending on the biodistribution properties of the radiopharmaceutical, it is taken up bydifferent organs and/or tissue types. Most radiopharmaceuticals used in nuclear medicine and SPECT are labeled with radionuclides that emit γ-rayphotons. Typically, a scintillation camera system is used as the imagingdevice. The scintillation camera consists of a lead collimator that allowsphotons traveling in given directions to pass through a large-area scintillator(commonly NaI(Tl) crystal) that converts the energy of γ-ray photons tolower-energy photons which are in turn converted to electric signals by photomultiplier tubes (PMTs). The signals from an array of PMTs are processedby electronic circuitry to provide information about the position at whicha photon interacts with the crystal. The scintillation camera provides atwo-dimensional projection image of the three-dimensional radioactivity distribution or radiopharmaceutical uptake within the patient. SPECT takesconventional two-dimensional nuclear medicine images acquired at different views around the patient and provides an estimate of the three-dimensionalradioactivity distribution using methods of image reconstruction from multiple projections.



SPECT data acquisition

In the case of SPECT, the isotope is natural and decays by generating a single photon so; the line is determined by using a collimator.

A SPECT scan is primarily used to view how blood flows through arteries and veins in the brain. Tests have shown that it might be more sensitive to brain injury than either MRI or CT scanning because it can detect reduced blood flow to injured sites.SPECT scanning is also useful for presurgical evaluation of medically uncontrolled seizures (Fig. 1). The test can be performed between seizures (interictal) or during a seizure (ictal) to determine blood flow to areas where the seizures originate.

Collimation Systems
The collimation system is the heart of the SPECT instrument – it's the front-endand has the biggest impact on SNR. Its function is to form an image by determining the direction along whichgamma-rays propagate. Ideally, a lens similar to that used for visible photon wavelengths would be usedfor high efficiency – not feasible at gamma-ray wavelengths. Absorbing collimation typically used.

Physical and Instrumentation Factors That Affect SPECT Images
Attenuation from photoelectric absorption and Compton scattering is themajor factor that affects the quantitative accuracy and quality of SPECTimages. The degree of attenuation is determined by (1) the path length between the source and the edge of the attenuating material, and (2) the linearattenuation coefficient, which is a function of photon energy and the amountand types of materials contained in the attenuating medium.

SPECT differs from x-ray computed tomography (CT) in that the radiation source is within instead of outside the patient. The goal of SPECT is to determine accurately the three-dimensional radioactivity distribution resulting from the radiopharmaceutical uptake inside the patient (instead of the attenuation coefficient distribution from different tissues as obtained from x-ray CT). SPECT utilizes radiopharmaceuticals that are common in nuclear medicine clinics, rather than those that emit positrons with subsequent generation of two 511-keV annihilation photons as is the case with PET. SPECT requires instrumentation and image reconstruction methods that differ from those used in other medical imaging modalities. The

amount of radiopharmaceutical that can be administered is limited by the allowable dose of radiation to the patient. This requirement results in a limited number of photons that can be used for imaging. Also, the acceptance angle or geometric response of the collimator further limits the fraction of photons that are acceptable for the projection data. The collimator can be designed to allow detection of more photons, but increased detection efficiency usually can be achieved only with a concurrent loss of spatial resolution. A major goal of SPECT instrumentation development is to increase the detection efficiency while at the same time improving the spatial resolution of the imaging system, goals that are pursued by adding more detectors around the patient. The SPECT imaging process imposes unique difficulties and challenges in image reconstruction. For example, before exiting the patient, many of the γ-ray photons experience photoelectric interactions that cause absorption of photons, and many thus experience Compton scattering, which changes the direction and energy of the original photons. When conventional reconstruction techniques (e.g., x-ray CT algorithms) are used in SPECT, the reconstructed images are severely affected by statistical noise fluctuations, poor spatial resolution, low contrast, and inaccurate quantitative information. Following is a brief discussion of the basic principles of SPECT imaging and the current status of SPECT instrumentation and image reconstruction methods. Emphasis is placed on the physics, mathematics, and engineering aspects of SPECT, and future trends and potential areas of further investigation are discussed. In combination with new radiopharmaceuticals and clinical applications, these developments
could ultimately improve patient care.

SPECT/CT

SPECT/CT offers the nearly simultaneous acquisition of**anatomic and functional information**, with image registrationcapabilities better than those possible with data acquisition onseparate scanners followed by image reorientation.Scanners that mount external sources (eg, gadolinium-153) for the measurement of attenuation along all LORsprovide precious additional information for attenuation correctionwhile adding_1% to the patient dose burden. In thisline of development, SPECT/CT is expected to lead to evenfurther advances but at a significant cost in dose unless CT isotherwise indicated. All 3 major manufacturers currently offerSPECT/CT systems. Increased cost and footprint are amongthe possible disadvantages.