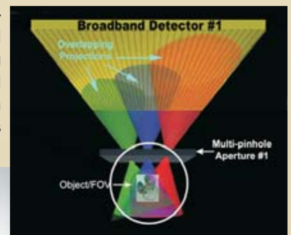
Research Center Juelich[1] Bioscan, Inc.[3] ErasmusMC Rotterdam[2]

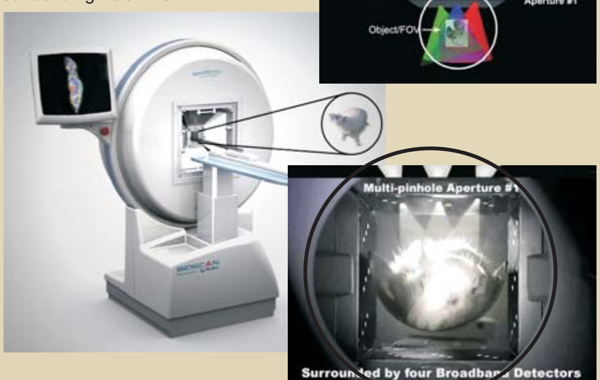
The NanoSPECT/CT™: a High-Sensitivity Small-Animal SPECT/CT with Sub-millimeter Spatial Resolution

N.U. Schramm[1], C. Lackas[1], F. Forrer[2], M. de Jong[2], J.W. Hoppin[3], S.C. Van Cauter[3], Y. Haemisch[3]
[1]Research Center Juelich, Juelich, Germany; [2]Erasmus Medical College, Rotterdam, Netherlands; [3]Bioscan Inc, Washington DC, USA
Sales@bioscan.com

INTRODUCTION: In this study, we demonstrate that by using broadband Anger camera detectors, a multiplexed multi-pinhole SPECT (MMP-SPECT) system can achieve sub-millimeter image resolution while, at the same time, improving sensitivity to enable dynamic imaging with high temporal resolution. By processing the signals of such broadband detectors with multichannel analyzers (MCA), spectral analysis can be performed to unfold the energy spectra of multiple isotopes for enhanced dual-isotope imaging. Mounted on a high-precision helical scanning mechanism, the broadband SPECT modality is integrated with a X-ray CT system so that a common mechanism ensures that the device can produce final three-dimensional images of anatomical and biological information fused together without user intervention.

MULTIPLEXED MULTI-PINHOLE SPECT: The diagram to the right shows the multi-pinhole imaging geometry. The colored volumes represent the overlapping projections of three pinholes selected from a nine-pinhole aperture mounted on one of the four broadband detectors surrounding the animal.





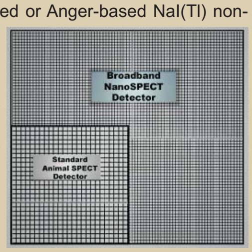
THE BROADBAND DETECTOR ADVANTAGE: The intrinsic performance of an imaging system in general, and a SPECT system in particular, depends on the information content that can be processed and transferred to the observer. Generally called the Space-Bandwidth Product (SBP) of a SPECT system, the SBP depends on (1) The effective area of its detectors - the larger the area, the more information can be processed; and (2) The intrinsic detector resolution - the finer the pixilation of the detector, the more information can be transferred. Therefore, the SBP of a multi-pinhole SPECT system can be expressed as:

$$SBP = \frac{(\text{Area of a Single Detector}) \times (\text{Number of Detectors}) \times (1 + \text{Multiplexing Factor})}{(\text{Intrinsic Resolution})^2}$$

(M. Kupinski & H. Barrett, Small-Animal SPECT Imaging, 2005 Springer Science Media)

The NanoSPECT system has been specifically designed to maximize the SBP by surrounding the animal with four large area detectors of 215mm x 230mm, each using a high resolution sampling matrix with <1mm pixel size (intrinsic resolution of 2mm). To further increase the effective detector area by 30%, multiplexing is used with overlapping multi-pinhole projections. This results in a SBP > 60,000; much higher than available on conventional pre-clinical SPECT imagers, whether equipped with CZT, pixilated or Anger-based NaI(Tl) non-broadband detectors.

The graphic on the right illustrates the size and pixelation density advantages offered by the broadband detector design of the NanoSPECT/CT system. The larger area and finer pixel resolution enable to transfer more image information with finer detail to the observer. Or, in other words, more information means higher sensitivity, and finer detail means higher resolution.



HIGHER RESOLUTION: The large size and high intrinsic resolution combination of broadband detectors makes it possible to obtain high resolution images without excessive pinhole magnification(4.9X). This is illustrated by the imaging results obtained from a micro Jaszczak 0.5-1 mm phantom.

By courtesy of D. Mathe, OSSKI, Budapest, Hungary

HIGHER SENSITIVITY: Another inherent advantage of the large area and high intrinsic resolution of broadband detectors is the high space-bandwidth-efficiency product, also called the figure of merit (FOM), defined as:

$$FOM = \frac{\text{Area of Detector}}{\text{Area of Resolution Cell}} \times \text{Detector Efficiency}$$

(M. Kupinski & H. Barrett, Small-Animal SPECT Imaging, 2005 Springer Science Media)

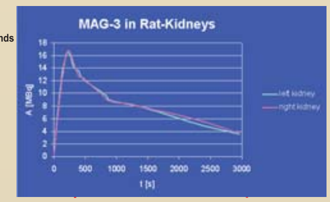
With an effective area of > 64,000 mm^2 for each of the four detectors and resolution cells of 4 mm^2, the FOM for the NanoSPECT broadband detector design is > 40,000. This high FOM enables one to exploit the full advantages of multi-pinhole SPECT by maximizing both the number of pinholes and the size of the field-of-view (FOV). For a 36-pinhole configuration and a 36mm x 20mm FOV, the NanoSPECT achieves sensitivities of up to 2,000 cps/MBq at sub-millimeter resolution. As illustrated below, this enables one to perform high-resolution kinetic studies with excellent temporal resolution.

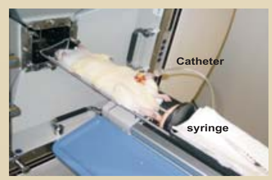
Dynamic kidney study

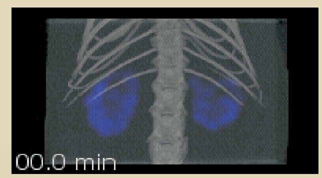
By courtesy of M. de Jong, ErasmusMC Rotterdam, Netherlands

- 420g rat
- X-ray topogram to find kidneys
- Fast CT for anatomical information
- 0.5mCi Tc99m-MAG3
- Injection trough catheter
- 45 scans, 1 min. each, start 0:00 p.i.

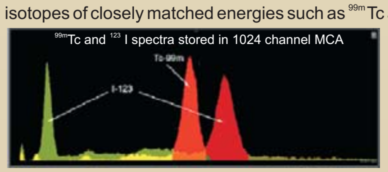
⇒ Time resolution: 1 min



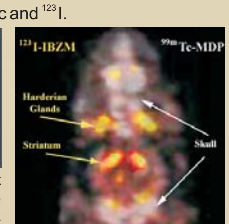




BETTER ISOTOPE SEPARATION: The broadband detectors of NanoSPECT/CT use multi-channel spectral analysis (MCA) for image data processing. As shown below, this makes it possible with single scans to accurately separate and image dual tracer experiments, including tracers with isotopes of closely matched energies such as ^{99m}Tc and ^{123}I.



The coronal slice image to the right illustrates that simultaneous SPECT image acquisition of bone metabolism (^{99m}Tc-MDP) and D2 receptor binding (^{123}I-IBZM) is possible with a single scan.



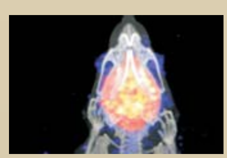
A.Wirrwar et al, Duesseldorf, Germany

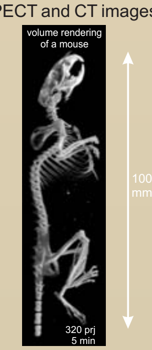
AUTO-FUSION OF DUAL-MODALITY IMAGES: The SPECT and X-ray CT modalities are mounted on a common helical scanning mechanism. Image acquisition is accomplished by continuously stepping the object through the FOV along the axis of rotation of the gantry. SPECT reconstruction is performed by a dedicated ray-tracing based MLEM algorithm, while the CT reconstruction algorithm, capable of working with low-statistic measurements, is employing a ray-tracing based filtered backprojection The use of a common gantry, the same axis of rotation and a common scan range ensures that SPECT and CT images can be fused "automatically" as illustrated below.

Mouse brain study

By courtesy of H. Esumi, National Cancer Center, Tokyo, Japan

- 25g wild-type mouse
- 0.3mCi I125-Iomazenil
- Benzodiazepine receptor marker
- 3 minute CT scan
- 30 min. SPECT scan (30 min. P.i.)





CONCLUSION: With proven performance in over twenty installations, MMP-SPECT using broadband detector technology enables functional imaging with high sensitivity and excellent spatial and temporal resolution. With a common helical scanning platform for both functional and anatomic imaging, NanoSPECT/CT is able to provide dual-modality SPECT and CT images of unmatched quality for a wide range of applications.