Microscopy & Microtechniques Focus

THE X-RAY COMPONENT OF THE NANOSPECT/CT SMALL-ANIMAL IMAGING SYSTEM

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In this article we describe an X-ray CT upgrade to the multiplexing multi-pinhole SPECT imaging technique which has applications in 'small-animal' molecular imaging.

SPECT combined with X-ray CT introduces anatomical information and improves acquisition, (helps define axial regions of interest), reconstruction, (attenuation correction) and data analysis, (aids segmentation).

"THE X-RAY CT COMPONENT OF THE NANOSPECT/CT PROVIDES FAST LOW-DOSE HIGH-RESOLUTION IMAGES"

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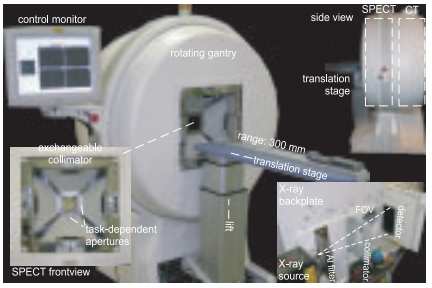


INSTRUMENTATION

The NanoSPECT Instrument (shown above) houses up to four gamma cameras outfitted with multi-pinhole apertures providing sub-millimetre resolution. The X-ray source and detector are mounted on the back of the high precision gantry and thus share the same axis of rotation as the SPECT component. Helical scanning is employed by both modalities and is performed by translating the animal through the SPECT and CT fields of view. The system is capable of acquiring partial- or full-body mouse and rat images ranging from 30 to 300mm enabling the reduction of dose in partial studies. This variable axial-length feature is also present in the SPECT modality, minimising measurement time.

MULTI-PINHOLE IMAGING

The left-hand side of *Figure 1*, displays the imaging geometry of the SPECT system. The coloured volumes represent the views and overlapping projections of three pinholes selected from a multi-pinhole aperture. This overlap results in an optimised covering of the detector surface and in turn an increase in sensitivity. In general the locations, tilts and acceptance angle of each pinhole are chosen according to the relevant imaging task. Helical scanning, as shown on the right-hand side, is made possible by stepping the object through the FOV along the axis of rotation of the gantry. The SPECT reconstruction is performed by a dedicated ray-tracing OSEM algorithm.

X-RAY CT

The x-ray source is a 90kVp microfocus (18µm) tube. The X-ray detector is made up of a 1024 x 2048 array of 48µm pixels (49.2 x 98.6mm^2). The geometric magnification of the system is 1.3 providing a reconstructed CT resolution below 100µm (SPECT resolution down to 0.5mm). Continuous motion of the gantry and the animal bed reduces time of acquisition.

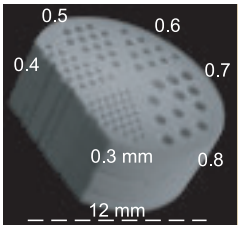


*Figure 2. Micro Jaszczak phantom study showing high spatial resolution capabilities. Maximum Resolution less than 100*µm.

In *Figure 2*, a volume rendered reconstruction of a 12mm Jaszczak phantom is displayed. The bore- holes range from 0.3mm to 0.8mm with at centre-to-centre distance of twice the diameter.

The collimator limits the X-ray cone to the volume actually visible by the detector. The dose administered to an animal was measured by a Victoreen 450P dose meter as 15 to 45 mGy for a three minute study, depending on the animal size and X-ray tube parameters. To further reduce the dose administered to the animal a 0.5mm aluminium filter and a lead collimator are used. The CT reconstruction algorithm, capable of working with low-statistical measurements, employes a ray-tracing based filtered back projection. The system in general is set up for image acquisitions ranging from fast low-dose up to high-resolution, depending on the needs of the researcher.

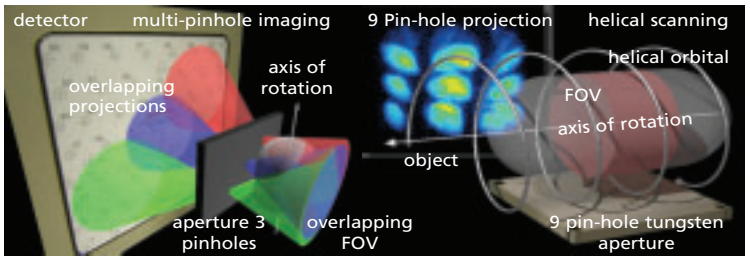


Figure 1. Schematic figures of multi-pinhole imaging and helical scanning.

CT STUDIES

The high resolution of the CT system provides ample detail of animal anatomy as exhibited in *Figure 3*, which shows volume rendering of a mouse skull.

SPECT/CT STUDIES

The full capabilities of the NanoSPECT/CT are shown in dual modality studies such as the Iodine-125 mouse study shown in *Figure 4*. The thyroids are displayed in a colour scheme and can be separated clearly. The SPECT detectors show high spatial resolution even for the low photon energies (28 KeV) of Iodine-125.

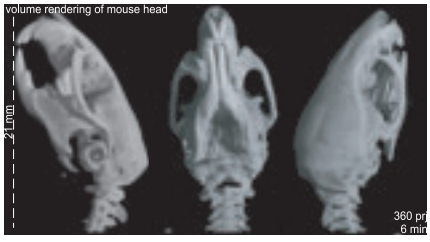


Figure 3. Volume rendering of reconstructed mouse skull

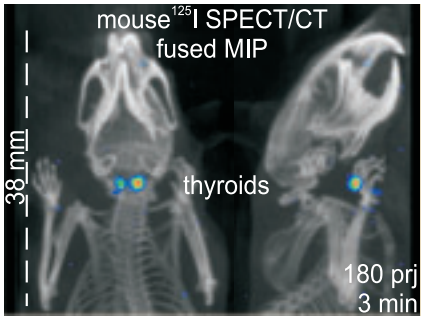
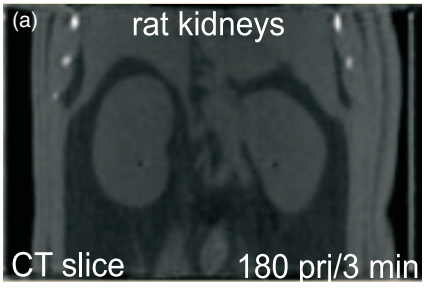


*Figure 4. The power of nanoSPECT in dual modality studies.**

SOFT TISSUE

With tube voltage ranging from 45 to 65 kVp the CT system is able to make soft tissue, like the rat kidneys in *Figure 5a*, clearly resolvable. The use of contrast agents can further increase the amount of information in CT images. Combined with SPECT, as shown in *Figure 5b*, functional and anatomical data come together. The images are automatically co-registered since both imaging modalities share a common gantry and thus axis of rotation.



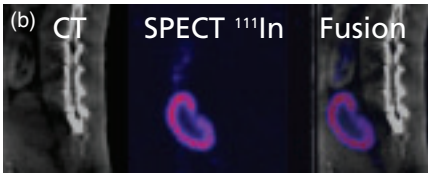


*Figure 5(a). A further example of CT imaging of soft tissue. 5(b). SPECT/CT and fused images***

SMALL-ANIMAL STUDIES

In the left-hand image of *Figure 6*, a full-body helical CT mouse scan is displayed. The maximum intensity projection (MIP) in the middle shows a fused SPECT using ^{99m}Tc-labeled MDP and a CT measurement. The overlap of the SPECT bone marker with the CT image is a good indicator of the level of image quality that can be obtained with this system. The image on the right-hand side of *Figure 6* shows a separate rat study. ^{111}In-labeled OctreoScan was used to image a tumour on the side of the rat. The kidneys are also clearly shown.

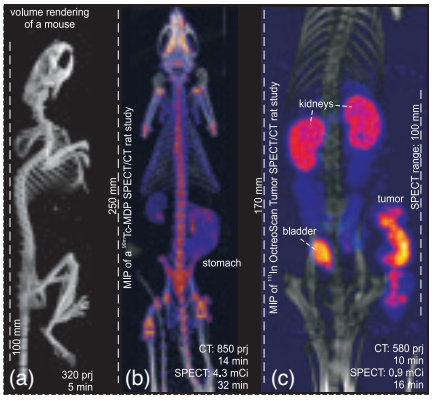


Figure 6(a). A volume rendered image of a mouse skeleton,
6(b). An overlap of a SPECT bone marker study.
6(c). An unrelated rat study showing tumours and kidneys.

CONCLUSION

The X-ray CT component of the NanoSPECT/CT provides fast and low-dose high-resolution images to aid in analysing the SPECT images and is consequently an optimal enhancement of the SPECT modality. Thanks to the common helical scanning mechanism used for both the SPECT and X-ray CT modalities, tomographic images are fused 'automatically'.

**Figure 4. Information supplied by: Professor Stephen J Mather, Cancer Research UK, Queen Mary College, University of London. Professor of Radiopharmacy, Dept. of Nuclear Medicine, St Bartholomew's Hospital, London.*

***Figures 5&6. Information supplied by: Dr. Marion de Jong, Department of Nuclear Medicine, Faculty of Medicine & Health Sciences, Erasmus University, Rotterdam.*

Fluorescence Light Source Line-up is Now Complete

Olympus Life and Material Science Europa GmbH has introduced the new EXFO X-Cite 120 PC automated fluorescent light source. This adjustment free metal-halide illuminator is fully controllable through Olympus cell* imaging software. The addition of this new automated illuminator means that Olympus offers a full range of illumination options for its extensive fluorescence microscopy range. This enhances Olympus' status as a complete system solution provider for all fluorescence experiments. Like the recently launched manually controlled EXFO X-Cite 120 illuminator, the PC version also offers low running costs with extended lifetime and ease of use. Although they have a light spectrum similar to that of conventional mercury lamps, the 120W metal-halide X-Cite 120 and X-Cite 120 PC both last far longer. The 1500 hour bulb life makes changes a rare occurrence. Through software control, using the X-Cite 120 PC is exceptionally easy. All functions are fully automated, including shutter and light intensity modulation, and readily integrated into the experimental workflow. Furthermore, the convenient user interface of the Olympus cell* software enables simple integration of these automated functions into fluorescence acquisition protocols. This system integration approach simplifies workflows for all types of fluorescence experiments enabling researchers to focus on generating and analysing data.

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