The first integrated preclinical whole-body PET/MRI with 700 µm PET and 100 µm MRI spatial resolution

Preclinical Line
nanoScan® PET/MRI Introduction

Welcome to a fascinating new world of images that will change your research. Welcome to a stunning interplay of anatomy and function. Welcome to nanoScan® PET/MRI.

By combining the world’s highest-performing PET system and breakthrough compact MRI technology, nanoScan® PET/MRI gives you the power to plan discoveries with no precedent.

With the first member of the new nanoScan® imaging family, Mediso is pleased to provide again a revolutionary new platform for the life scientists.

Using the one-of-a-kind, easy but powerful MRI technology of nanoScan® PET/MRI, soft tissue images with detailed quantitative imaging data are achieved within just one study. As the nanoScan® PET/MRI uses the Aspect Imaging compact MRI system that is easy-to-operate and has zero magnetic fringe field, there is no need to worry about the complexity of MRI imaging, or the large investments in personnel and instrument siting that is usually associated with conventional MRI systems. The MRI is easy to operate by life scientists without MRI expertise and needs basically no maintenance. nanoScan® PET/MRI’s cutting edge PET and MRI technology is designed to become your routine research tool.

Both parts of the imaging chain represent high level on their own: PET offers quantitative spatial resolution at 700 µm combined with uniquely large field-of-view, unparalleled by any other system. The MRI provides you with 100 µm resolution with advanced sequences and ensures robust imaging across a broad range of biological applications.

Main advantages of the system

- Highest ever resolution in PET
- State-of-the-art Tera-Tomo™ 3D PET image reconstruction engine
- Extremely fast workflow of data handling and image processing
- Plug-and-publish: totally shielded, cryogen-free and maintenance-free MRI, no room modifications or shielding needed, just a standard voltage plug
- Silent operation, ideal for awake animal brain studies
- Easy installation, compact size: The whole system including PDU and spectrometer rack fits in any biological lab and needs less than 3 m² of lab floor space
- One-click MultiCell™ animal anesthesia / imaging bed support system

Pursuit of perfection

Always eager to find an even better solution, Mediso constantly strives to develop the highest level imaging technology possible.

We wish to serve the scientific community with our core value: supreme image quality.
The routine research tool of the future

Combining the best of both modalities to answer your biological questions

Flexible and affordable, the nanoScan® integrated PET/MRI offers the industry's best performance, quantitative high-resolution PET imaging combined to great anatomical details of the MRI – all in one in-line system. A single, integrated PET/MRI scanner has the ability to fulfill all the imaging needs of your laboratory.

If your work focuses on PET, the nanoScan® PET/MRI will improve resolution, sensitivity and quantitation for you with its unique high-end PET component. Besides the high-end PET, the scope of the PET scientist will be enlarged in a wide variety of biological questions using the nanoScan® PET/MRI’s integrated compact MRI.

The PET/MRI is the optimal modality for all types of longitudinal in-vivo functional imaging studies as there is no X-Ray therefore no dose concern.

If your imaging studies primarily applies magnetic resonance systems, the nanoScan® PET/MRI will offer an easy-to-use, simple and high quality MRI system that works right out of the box and needs no special cooling or room changes. All these are complemented by the quantitative metabolic or receptor status information from the PET modality. The application of a PET/MRI system will open entirely new frontiers for your research. High resolution and high sensitivity functional measurements will be available with user friendly environment by the nanoScan® PET/MRI system.

Applications where nanoScan® PET/MRI outperforms PET/CT:

- Oncology
- Tumor biology
- Stem cell investigations
- Regenerative medicine
- Neuroscience and receptor studies
- PET development of radiotracers
- Cardiovascular research
- Immunology, inflammation
- Multimodal contrast agent development
- Animal model development and phenotyping
- Nephrology
- Pharmacokinetics

Continuous upgrade path for existing NanoSPECT/CT® users:

For imaging facilities already using the world’s market leader NanoSPECT/CT™ system (also developed and manufactured by Mediso) the nanoScan® PET/MRI is a unique opportunity to upgrade onto the next level of multi-modality. With the integrated MultiCell™ animal bed and physiological monitoring system (designed and developed by Mediso), the studies will be seamless and referred across all major imaging modalities: SPECT, PET, MRI and CT from the same supplier. The simplest and most effective way to enhance scope and throughput for existing NanoSPECT/CT® users is to upgrade with nanoScan® PET/MRI.
MRI Magnet
- 1 Tesla permanent magnet
- Gradient strength: 450 mT/m
- < 5 ppm homogenity
- 100 µm spatial resolution
- Integrated gradient coil
- Integrated RF shielding

RF Coils
- Multiple solenoid coils available
- 35 mm Tx/Tr for mouse whole body imaging
- 60 mm Tx/Tr for rat whole body imaging
- Mouse head coil: ~ Ø 22-25 mm
- Custom coils available upon request

Fast, Easy Instrument Installation
- Cryogen-free design
- Compact size: 800 x 1200 x 1400 mm
- Weight: 1170 kg
- Zero magnetic fringe field
- No need for additional RF shielding in the lab
No compromise in image quality

PET/MRI Acquisition / Gantry Touchscreen User Interface
- Common interface for PET and MRI
- Touch-controlled bed movements
- Online animal monitoring
- On the fly persistence monitor function

PET Detector Ring
- LYSO crystal full ring geometry
- 1.12 x 1.12 x 13 mm pixel size
- 512 ch/module flat panel sensor
- 12 cm transaxial FOV
- 700µm spatial resolution by Tera-Tomo™ 3D PET engine

MultiCell™ Animal Anesthesia / Imaging Bed
- Automated positioning with µm accuracy
- 100% RF shielding for MRI imaging
- Closed circuit anesthesia system integrated into a pathogen-free imaging chamber
- One-click dockable PET / MRI / SPECT / CT compatible imaging chamber
- Integrated heating / temperature control and monitoring
- Respiratory and ECG gating and monitoring
- Compatible with NanoSPECT/CT® systems
PET Subsystem

Structure

Mediso’s traditions in nuclear detection technology and fine precision mechanics date back almost a century.

Leveraged by our expertise gathered across generations of patented, cutting-edge instrument innovations, the company has designed and built the most advanced crystal-based PET detector present in the market. The fine crystal pins and highest packing fraction combined with a series of innovations in optical design has led to a PET detector with unmatched combination of sensitivity and resolution.

Due to the multilayered magnetic shielding of the PET-ring supported by Aspect’s breakthrough technology – the compact high-performance permanent magnet with zero fringe field – the PET-detectors are able to operate as in a standalone device. This means excellent parameters and superior image quality without compromises.

The standalone PET use due to its large bore size allows high throughput imaging of animals including larger species. Marmoset heads or two rats can be imaged with the standalone PET mode.

![Multilayer detector logic board](image)

![RF and magnetic shielding disks](image)

![LYSO fine pixelated crystals](image)

![Interchangeable collimator for large PET bore (16 cm)](image)

![512 ch/module flat panel sensors](image)
Ultra-fast PET data flow and processing

The combination of Mediso high-end PET detector with advanced 3D Teraflop Computing for Tomography: Tera-Tomo™ 3D PET reconstruction engine leads to a PET resolution near the physical limits.

Data collected by the PET detector are sorted and processed using a proprietary, custom-designed circuit and application specific FPGA chip. The data stream is transmitted to the image reconstruction engines, based on a cluster of GPUs. This ultra-high performance system enable you to simultaneously acquire and reconstruct your PET study data.

For any tomographic detector, the acquired image is blurred and degraded due to the distortions of the imaging system. This blurring is characterized by the Point Spread Function (PSF) or impulse response of the system. The Tera-Tomo™ 3D PET reconstruction engine incorporates both projection-space (or data-space) and image-space PSF modeling in order to faithfully recover the original spatial resolution of the imaged objects.

Using corrections for physical factors such as detector geometry, Monte Carlo DOI estimation, object attenuation and scatter, randoms and dead time to even positron range, a quantitative three-dimensional PET reconstruction called Tera-Tomo™ 3D PET has been developed and applied by Mediso in collaboration with prestigious Hungarian universities.

Mediso always uses state-of-the art computers and acquisition electronics to optimize data processing with the nanoScan® PET/MRI.

High-speed transfer and teraflops computing speed provides you with ultra-fast reconstructions for enhanced PET study throughput.
Quantitative reconstruction with high sensitivity

This is available to every nanoScan® PET/MRI user. Receptor binding potential or high precision SUV studies are robustly performed on the nanoScan® PET/MRI.

Activity concentration linearity for quantification
Quantitative accuracy: > 97%

Absolute sensitivity according to NEMA NU 4-2008: > 8.0%
Maximum sensitivity: > 9.0% (150-750 keV window)

Representation of quantitative accuracy of the nanoScan® PET/MRI’s PET component over 2 orders of magnitude. The radioactivity measured in the syringes is well repeated by the reconstructed values.

700 µm resolution by Tera-Tomo™ 3D PET engine

Below are the measured full width at half maximum resolution values of the PET subsystem in all 3 space dimensions in the FOV, (x=horizontal, y=vertical, z=axial, averaged with the RMS method) using Tera-Tomo™ 3D PET. Even your routine PET scans will bring you to yet unseen depth of 0.7 mm.

Point source 3D reconstructed spatial resolution with Tera-Tomo™ 3D PET reconstruction engine

Imaging performance with Tera-Tomo™ 3D PET Reconstruction Engine using 10 MBq ¹⁸F-FDG, 30 minutes PET and 6 minutes MRI acquisition in a micro Derenzo phantom.
Size of the rods: 0.7 mm – 1.2 mm
Exclusive PET Imaging Performance

Whole body PET imaging of glucose utilization in a mouse (10 MBq $^{18}$F-FDG, 50 min p.i., 30 min imaging time). Tissues with high glucose utilization rate (heart muscle, brown fat, spinal bone marrow, Harderian glands) are visible. Image courtesy of Karolinska Institute

Mouse brain $^{18}$F-FDG (20 MBq i.v., 30 min PET, 23 min MRI) PET/MRI study in an anesthetized animal. Besides obvious cortical uptake, subcortical and brain stem activity is visualized, too. Image courtesy of Karolinska Institute
The MRI subsystem is tuned to meet all the anatomical imaging needs of even the most discerning scientists. The compact, high-performance magnet system is developed by the pioneer in the field of compact permanent MRI systems – Aspect Imaging. The 1 Tesla is optimized to perform fast, routine studies and obtain high resolution (routinely up to 100 microns) soft tissue images with appropriate signal to noise ratio. In fact, a majority of MRI imaging applications can be performed with this compact MRI system but at a fraction of the cost and complexity of a high-field system. The integrated image acquisition software interface allows you to control both PET and MRI imaging parameters and create your own acquisition protocols.

The permanent magnet MRI system will satisfy your demands in combined PET imaging as well. The resolution is perfect to precisely delineate your Volumes of Interest for quantitative PET calculations.

The MRI component: designed to meet the needs of every scientist

T₂ weighted horizontal 2D FSE slice image of the mouse muzzle and whiskers, slice thickness 1.0 mm, in-plane resolution 250 microns, TR/TE 4734/80, acquisition time 1.6 minutes

T₂ weighted horizontal 2D FSE image of the abdomen of a 260g Wistar rat, slice thickness 1.5 mm, in-plane resolution 500 microns, TR/TE 4733/60, acquisition time 0.6 minutes

Rat Brain MR imaged using a Fast Spin Echo sequence TR/TE 2500/83, imaging time 17.5 min

Image courtesy of Karolinska Institute
An MRI system that is easy to use and efficient in soft tissue contrast

The MRI system’s simplicity of operation matched with its powerful imaging capabilities makes it easy to correlate functional PET data with anatomical morphology. The subsystem is unusually quiet as its whisper gradients generate less than 20 dB of noise. No brain study will be affected by excessive MRI-generated operating noise, notwithstanding the fact that nanoScan® PET/MRI is such a silent system that the whole staff of an imaging laboratory will like to use it. A variety of application-specific RF coils are available and are contained within the system, and are applied to the animals in a glove-like manner. Once an animal is anesthetized and placed in the animal holding system with the appropriate coil, you only have to define the imaging protocol. The system will take care about the rest.

High soft tissue contrast as illustrated here between a mouse MRI and CT images. The MRI imaging time was 17 minutes while the CT took 10 minutes (with the animal already placed on the bed). Images courtesy of Karolinska Institute

With the built-in 2D and 3D sequences, fast imaging, comparable in duration to an ordinary PET/CT, will be routine. Imaging of whole animals with 100 to 200 micron resolution can be achieved in cca. 40 minutes, while brain, abdominal or chest imaging of mice and rats will typically take no longer than 25 minutes.
MRI Subsystem with Integrated Coils

Robust MR imaging with ease

The homogeneity of the magnetic field, critical to provide controlled uniform contrast throughout the field of view, is remarkably high with a maximal of 5 ppm. This ensures that MR images contain virtually no artifacts. With such a homogenous field, the magnet is unique. The only external room requirement for nanoScan® PET/MRI is temperature stability between +/- 2 °C. The resulting soft tissue images are rich in detail.

### Coils

Tailor-made coils optimized for different animals (mouse, rat) and particularly the specialized head coil make possible the outstanding image quality of nanoScan® PET/MRI. What is more the production of exclusive custom coils may be also possible upon the request of a single costumer.

Optional coils:
- 35 mm Tx/Tr solenoid coil for mouse whole body imaging
- 60 mm Tx/Tr solenoid coil for rat whole body imaging
- Mouse head coil: ~ Ø 22-25 mm
- Custom coils available upon request

Coil changing is easy and fast, allowing the execution of various examinations continuously.

T₂ weighted transaxial 2D FSE image of the mouse brain containing the hippocampus, slice thickness 1.0 mm, in-plane resolution 250 microns, TR/TE 3199/80, acquisition time 1.2 minutes.

T₂ weighted horizontal 2D SE image (left) of a 40g Nude mouse with A431 epithelial cell carcinoma xenografts on both femurs, slice thickness 1.0 mm, in-plane resolution 342 microns, TR/TE 800/11. T₂ weighted horizontal 2D FSE image (right), in-plane resolution 342 microns, TR/TE 5762/81, acquisition time 0.5 minute each.
MultiCell™ Animal Anesthesia / Imaging Chamber

Continuous digital temperature control: by closed circuit airflow integrated into the wall of the chamber – avoiding the side effect of the open airflow (dehydration of the eyes, contamination by pathogens etc.)

Embedded anesthetic gas connection: for any isoflurane system through dockable connection to the mouse /rat nose cone via closed circuit tubes integrated into the wall of the chamber

Integrated head positioning: for precise and reproducible animal positioning

4D/5D imaging accessories: dockable connections for ECG and respiratory gating

Pathogen-free construction: for immuno-compromised animals

One-click connection imaging cells: for easy and fast connection of mouse /rat imaging cells to the PET/MRI – SPECT/CT scanners or dual bed docking station

PrepaCell™ Preparation Station: for complete preparation of the animal before the scan (“click and scan”)

- Multimodality imaging for PET+MRI+SPECT+CT modalities
- Multiple mouse scanning by one scan (optional)
- Multipurpose applications 4D-, 5D imaging by one-click connection
- Multifunctioning preparation station for the imaging cells
Shared Components

Acquisition and real-time reconstruction shall be a routine – quick and comfortable

- Faster and safer acquisition and data management via state-of-the-art, high-stability and high capacity solid state disks
- The ergonomic design of the common PET/MRI user interface and the touch-screen based bed movements make the acquisition control comfortable and fast.

Control / Equipment Room

Multimodality Acquisition / Processing Workstation

Nuclie™
Main Console WS

- Dual monitor WS with touchscreen
- PET/MRI acquisition and control
- Multimodal image visualization
- Post processing features after acquisition
- DICOM 3.0 and CFR21 part 11 compliant data handling
- Intel® Core™ i7 platform @ 3.4 GHz
- Non-stop operating WS thru liquid cooling
- Safe data handling by 0.5 TB SSD
- GPU based on the fly volume rendering
- Ease of use MRI scout for positioning
- 64 bit OS by MS Windows 7

Tera-Tomo™-Real 3D PET
Reconstruction WS

- Embedded Teraflop Computing
- PET real-time 3D reconstruction
- On the fly system matrix generation
- Real time image correction
- Post-reconstruction image manipulation after acquisition
- Intel® Core™ i7 platform up to 4.5 GHz
- Cutting edge computing with liquid cooling
- Safe raw data backup by 0.5 TB SSD
- GPU cluster with 6 GB memory
- Mainstream data transfer through dual 10 GbE
- Realtime 64 bit OS by Linux

Enhanced Routine and Research Workflow
Workflow management is designed to enhance throughput.

- High performance visualization and computational tools supported by ultra-large capacity (12 TB) on-line archiving system
- Parallel work of two scientists is supported: while reconstruction is running on the Reconstruction WS the additional post-processing workstation enables to analyze and quantify images from another study.

**Researcher’s Room**

**Multimodality Post-processing / Archiving Workstation**

*InterView FUSION™ Multimodality Processing WS*

- **12 TB raw/processed data archiving**
  - Post processing and comprehensive evaluations
  - Quantification and kinetic modeling
  - Advanced multimodality 3D/4D visualization
  - Auto-registration of PET & MRI images
  - Automatic MRI segmentations

- - Intel® Core™ i7 platform @ 3.4 GHz
- - Dual monitor WS with 30”/4M Pixel screen
- - 12 TB fault tolerant RAID5 archiving
- - GPU engine with CUDA™ based algorithms
- - Full functionality DICOM server services
- - Mainstream data transfer through dual 10 GbE
- - 64 bit OS by MS Windows 7

*Tera-Tomo™-Post 3D PET Reconstruction WS*

- **Best image quality for research**
  - Advanced PET post reconstruction
  - Detector and physical effect modeling
  - On the fly image correction by GPU engine
  - 3D/2D reconstructions (real-time /adaptive)
  - MRI-based PET correction

- - Intel® Core™ i7 platform up to 4.5 GHz
- - Cutting edge computing with liquid cooling
- - RAID 0.5 TB SSD for safe and fast data handling
- - GPU cluster with up to 9 GB memory
- - Mainstream data transfer through 10 GbE
- - Real-time 64 bit OS by Linux

**Management**

- Fast routine / ultra precision research tool

Workflow management is designed to enhance throughput.

- High performance visualization and computational tools supported by ultra-large capacity (12 TB) on-line archiving system
- Parallel work of two scientists is supported: while reconstruction is running on the Reconstruction WS the additional post-processing workstation enables to analyze and quantify images from another study.
Post-processing by **InterView™ FUSION**

InterView™ FUSION multi-modal application developed by Mediso is an essential part of nanoScan® PET/MRI system. The application provides a wide range of functionalities to evaluate PET-MRI preclinical data. 2D single, orthogonal and tiled, as well as 3D MIP and Volume Rendering viewers represent fast and flexible visualization techniques built on GPU acceleration. Viewers provide dual, triple and quadruple fusion to accurately compare and enhance multi-modal single and follow-up studies. Dynamic PET images together with MRI can be fused, and PET images can be studied over time.

Calculations and statistical evaluations for PET are available on voxel and ROI or VOI level. A wide range of ROI and VOI tools are available for evaluation (e.g. freehand, polygon, ellipse, rectangle, sphere, box and isocount).

MRI scout based body-air segmentation methods are provided that additionally reduce the effect of respiratory movement based artifacts.

An in-built state of the art automated rigid, affine and non-linear image registration framework provides a quick and accurate way to superimpose different studies for comparison.

Advanced segmentation methods for different modalities, tissues and organs are available for feature extraction (e.g. lung, vessel, bone, MRI body-air).

Arithmetic operations help differentiating follow-up studies on voxel level by several methods (e.g. sum, difference, absolute difference, average, minimum, maximum, multiply).

Mouse brain PET/MRI study of a new dopamine transporter PET ligand. In both transaxial and horizontal planes the uptake in the striatum and retina, Harderian gland is visualized. Image courtesy of Karolinska Institute.
Pharmacokinetic analysis is an essential task of PET imaging. Translational research and neuroscience rely more and more on non-invasive, in-vivo measurements of pharmacokinetic parameters. Measurements of pharmacokinetic parameters performed in small rodents using nanoScan® PET/MRI’s unique capabilities are suited for analysis with the industry’s leading pharmacokinetic analysis tool: the PMOD suite’s PKIN.

Pharmacokinetic models have successfully been employed for the analysis of tracer kinetics by specialized researchers since many years. The PMOD modeling tool gives an easy and intuitive access to the wealth of developed methods to any nanoScan® PET/MRI user. Blood and time-activity data of tissue regions can easily be imported into the modeling tool. More than 40 model configurations are available to be fitted to the data. All results can readily be exported for statistical analysis.

Visualization of extrastriatal dopamine D₂ receptors in the mouse brain using 15 MBq of °C-FLB-457 tracer. PET imaging time 90 min, MR imaging time 23.4 min. Image courtesy of Karolinska Institute

Image processing using VivoQuant™

VivoQuant™ is an image viewing, processing and analysis software suite from inviCRO, LLC. The VivoQuant™ supports data from both nuclear medicine and magnetic resonance imaging systems and is provided as dedicated processing software for the Aspect line of preclinical magnets. The software is available for use with the nanoScan® PET/MRI and supports advanced co-registration, viewing and processing of data from the system. Plug-in modules dedicated to neurology and oncology applications address the challenging bottlenecks imaging laboratories face in day-to-day operations.

Ideal suited to the nanoScan® PET/MRI is the Advanced Brain Analysis module, a set of tools that provides accurate brain region identification and quantitative processing in multi-modal neuro-studies. The tools quantify single acquisition and/or dynamic response across brain regions in brain scans made with the nanoScan® PET/MRI. Automated fusion routines register an application-specific brain atlas to preclinical image data and advanced statistical analysis methods are employed to provide rapid and thorough region-specific volume and uptake quantification.
Applications

High-definition in PET

Mediso’s nanoScan® PM PET/MRI performs quantitative PET studies with an unparalleled resolution of 700 microns. Due to the advanced physical corrections in 3D PET reconstruction, a remarkably uniform resolution is achieved throughout the field-of-view. Very small details and Volumes of Interest can be visualized and their Time-Activity Curves quantitated. The MRI system offers high-precision fitting of your VOIs and an effortless, radiation-dose free imaging of soft tissues in any longitudinal study. Neuroscientists Christer Halldin and Balázs Gulyás share their experience with nanoScan® PET/MRI at the Karolinska Institute.

The PET Centre at Karolinska Institute is one of the world’s pioneer institutions in its field. Research output both in publications and new tracer developments is one of the highest in the world. Mostly new carbon-11 and fluorine-18 labeled central nervous system tracers are developed by the in-house team, but general FDG and multi-modality studies are also in the forefront of research. The PET team is lead by Professor Christer Halldin, while the imaging laboratories are co-ordinated by Professor Balázs Gulyás. They are the first users of nanoScan® PET/MRI, as their work requires the highest level possible PET technology with a robust support of MRI images.

Christer Halldin, Professor
Director of Karolinska Institute PET Center

nanoScan® PET/MRI combines anatomical and molecular imaging modalities using a state-of-the-art PET module with exceptional resolution and sensitivity and a unique user friendly MRI module for preclinical studies.

Anesthetized mouse brain [18F]-FDG study visualized in three planes (12 MBq i.v., 60 min PET, 17.5 min MRI)
Image courtesy of Karolinska Institute

The installed nanoScan® PET/MRI system at Karolinska Institute
Balázs Gulyás, Professor
Karolinska Institute Small Animal Imaging Center

This cutting-edge PET/MRI technology provides us with a unique opportunity for using translational imaging approaches to study disease models in small animals with molecular imaging biomarkers.

The essential output of PET imaging, Time-Activity Curves of different brain regions are shown here, obtained using a novel dopamine transporter ligand. Small details in PET, identified both by MRI and MRI atlas coregistration, are quantified volume by volume.

Mouse brain study of dopamine D_2 receptors using ^11^C-Raclopride (12.1 MBq, dynamic imaging time 90 min PET, 23.5 min MRI)
Image courtesy of Karolinska Institute

Imaging heart metabolism with ^18^F-FDG (8 MBq, 30 min PET, 23.5 min MRI) in a mouse
Image courtesy of Karolinska Institute
Conformance Statement


Product design, development, production and services comply with EN ISO 13485 and EN ISO 14971.

Safety labels are attached to appropriate places on equipment and appear in all operation manuals.

The supplied software complies with DICOM standard.

For details and up to date information please contact your local distributor or Mediso Medical Imaging Systems.

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