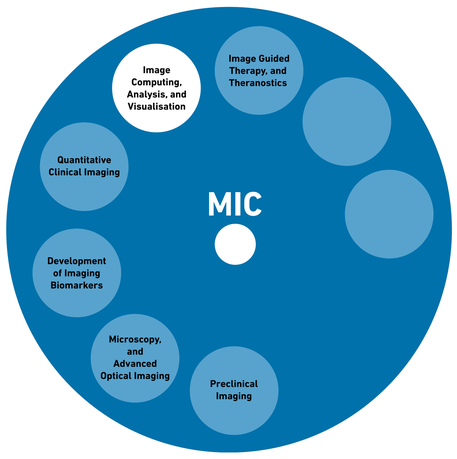


MIC-Node:
Image Computing, Analysis, and Visualisation

MEDICAL UNIVERSITY OF VIENNA


Georg Langs


Wolfgang Birkfellner


Christian Simader

Contact: mic_icav@meduniwien.ac.at

Expertise

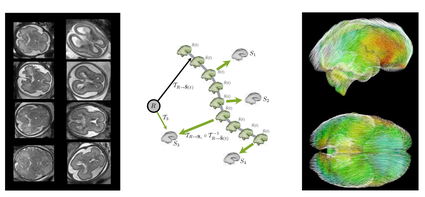
- Multi-disciplinary research teams: Radiology, Medicine, Computer Vision, Pattern Recognition, Machine Learning
- Fusing clinical know-how and expertise in computational method development

Objective

- To extract clinically relevant quantitative information from multi-modality image data
- To identify and explore significant imaging markers across large populations
- To provide tools for quantification of observations and processes from imaging data
- To develop methods/devices for innovative applications in clinical routine

Example

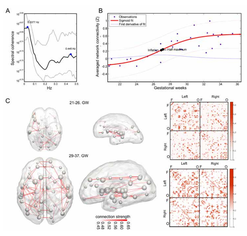
Fetal Development Modelling



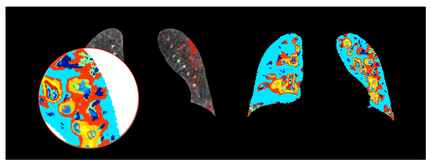
Cases of different gestational age | Spatio-temporal atlas building | 4D model of cortical development

Understanding the development of the human connectome

We now understand the very early development of the human brain connectivity architecture from functional imaging data.



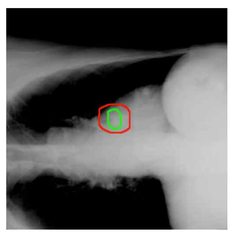
Large-scale imaging



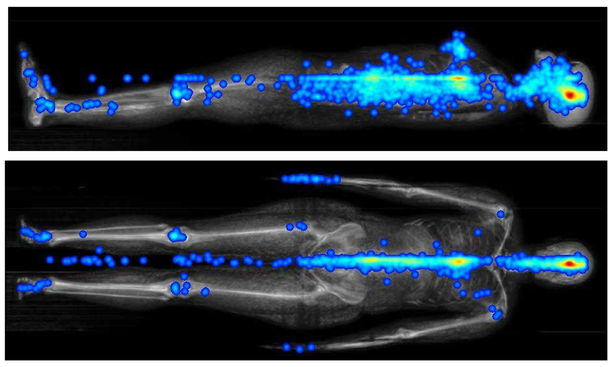
Discovering longitudinal disease paths that help us to understand disease progression, the effect of treatment, and develop novel imaging biomarkers.

Understanding the development of the human connectome

High-performance computing for real-time therapy guidance. Fusing image information across modalities and dimensions during image-guided therapy.

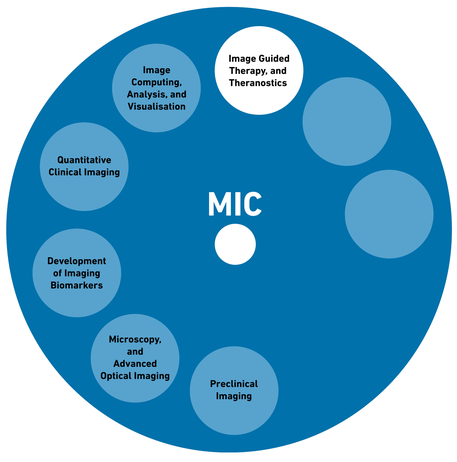


Large-scale imaging



We can mine large-scale imaging data to learn subtle imaging biomarkers. They will allow to identify diseases earlier and more accurately, and make corresponding treatment decisions.

Medical Imaging Cluster



MIC-Node:
Image Guided Therapy, and Theranostics

MEDICAL UNIVERSITY OF VIENNA


Dietmar Georg


Alexander Haug


Martin Funovics


Philipp Funovics

Contact: mic_igtt@meduniwien.ac.at

Expertise

- Image guidance with various imaging modalities
  - Fluoroscopy, Ultrasound, CT, MR, PET/CT, PET/MR, SPECT/CT
- Clinical expertise and Therapy modulation by following treatment options:
  - External/internal radiation, Targeted radionuclides, Thermic, Pharmaceutical, Mechanical/surgical, Implants, Multifunctional probes
- Technology developments
- Therapy monitoring
- Probe development and Model creation
- Methodological developments

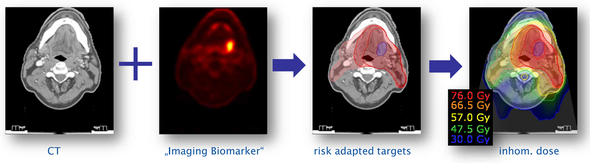
Objective

- Development and clinical exploration of new image guided therapeutic concepts in order to improve therapy effectiveness and minimal invasiveness.
- Development of theranostic probes
- Model development
- Liaise with other MedUni Vienna clusters

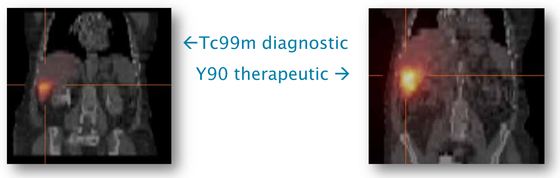
Example

Biologically Adaptive Radiotherapy

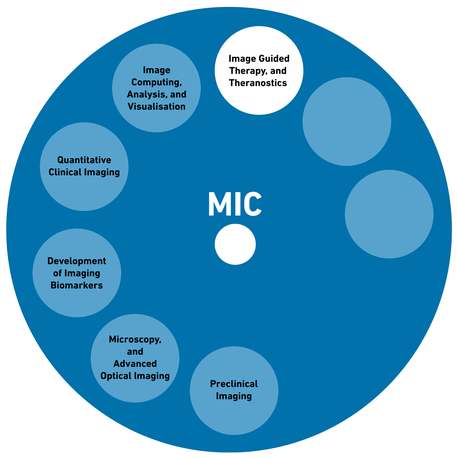
- Bio-ART is a novel concept in radiation oncology
- Integration of molecular and multiparametric imaging enables detection of resistant tumor subvolumes for local dose escalation



Targeted Radionuclide Therapy



Medical Imaging Cluster



MIC-Node:
Image Guided Therapy, and Theranostics

MEDICAL UNIVERSITY OF VIENNA


Dietmar Georg


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Image Guided Therapy, Theranostics
Visions and aims I

- Development and clinical exploration of new image guided therapeutic concepts in order to improve therapy effectiveness and minimal invasiveness.

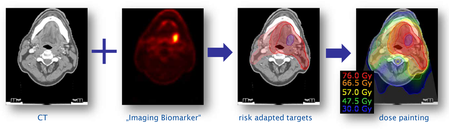


Image Guided Therapy, Theranostics
Visions and aims II

- **Development of theranostic probes**
- **Model development**

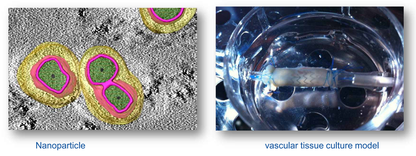


Image Guided Therapy, Theranostics
Visions and aims III

- Liaise with other MedUni Vienna clusters
  - Cancer Research, Immunology, Cardiovascular, Medical Neuroscience

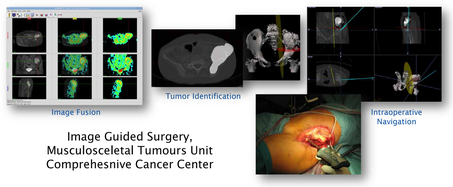


Image Guided Surgery, Musculoscelelal Tumours Unit Comprehesnive Cancer Center

Image Guided Therapy, Theranostics
IGT Assembly

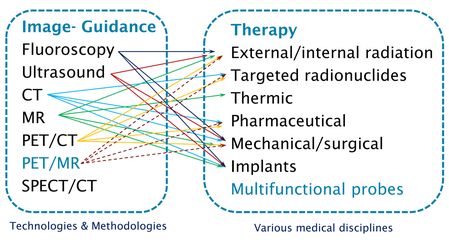


Image Guided Therapy, Theranostics
IG is multifaceted

- Treatment planning
- Navigation
- Therapy modulation
- Therapy monitoring
- Methodological developments
- Technology development
- Probe development
- Model creation

Morphologic imaging

Molecular imaging

Quantification

Image Guided Therapy, Theranostics
STATUS QUO

- Infrastructure and expertise for clinical evaluation & exploration of IGT
- Clinical and preclinical studies
  - Image Guided Adaptive Radiotherapy (CDL RadOnc)
  - Targeted radionuclide therapy
  - IG interventions
- Well established collaboration for R&D with NODE "Image Computing, Analysis and Visualization"

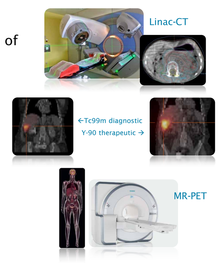
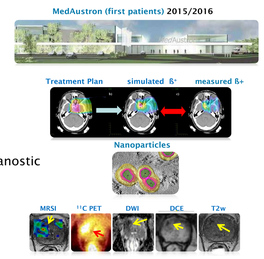


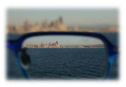
Image Guided Therapy, Theranostics
QUO VADIS

- Image Guided Ion Beam Therapy
- To enforce MR guidance
- Basic research
- IG micro-irradiator
- Clinical exploration of theranostic radiopharmaceuticals
- Clinical functional imaging studies



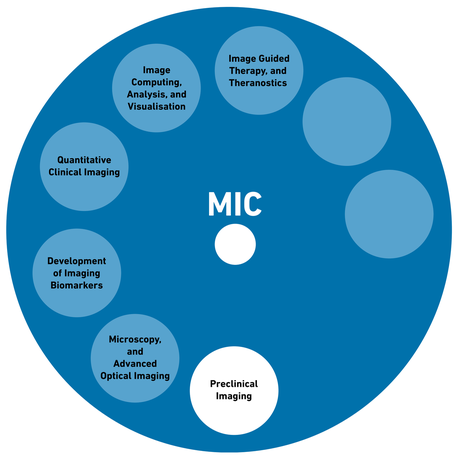
Relation with other nodes

- **Clinical research activities:** link w.r.t node Quantitative Clinical Imaging as well as the node Biomarker Development.


„Seeing helps"
© J. Lagendijk

- **Technological developments** will depend largely on software but also on hardware: technology development will be performed in close collaboration with the node on Image Informatics, Processing and Visualization.

Medical Imaging Cluster



MIC-Node: Preclinical Imaging

MEDICAL UNIVERSITY OF VIENNA


Markus Mitterhauser


Thomas Helbich


Wolfgang Doerr

Contact: mic_pi@meduniwien.ac.at

Expertise and Objective

Close cooperation between specialists
- Veterinary Medicine
- Medicine
- Physicists
- Engineers
- Chemists
- Pharmacists
- Biologists, ...

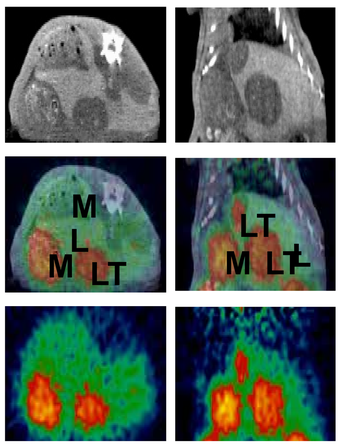
High end imaging techniques for the visualisation and interpretation of (patho)physiological processes
- functional MRI
- MRI-Spectroscopy
- µPET/µSPECT/CT
- Optical Imaging
- µCT
- µUltrasound

Multidisciplinary Expertise:
- hybrid Imaging
- molecular Imaging Biomarkers
- multimodal parametrical Imaging
- image fusion

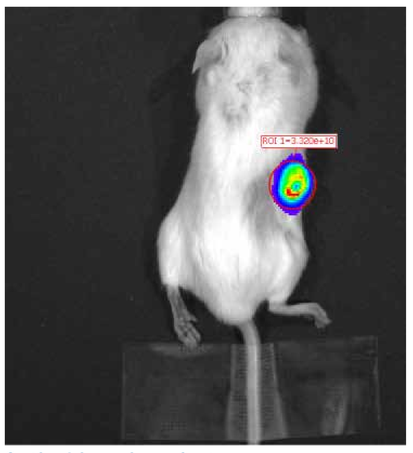
Translational Expertise:
- ...from the bench to the patient
- development of new Imaging Biomarkers

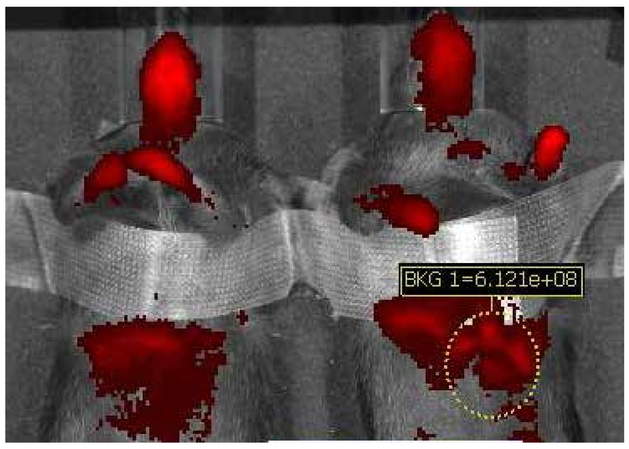
Example


Multiparametric MRI of a tumor



PET / CT of liver tumors

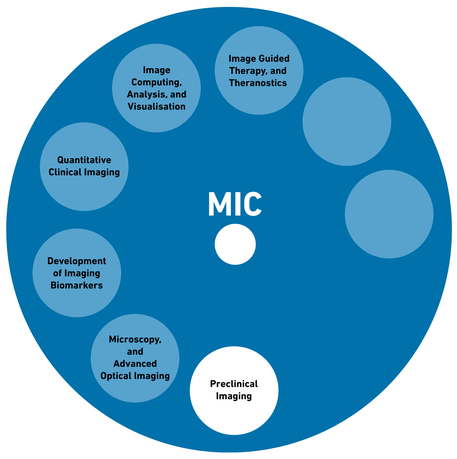

Optical imaging of a tumor



Optical imaging of arthritis


CT of a mouse

Medical Imaging Cluster



MIC-Node: Preclinical Imaging

MEDICAL UNIVERSITY OF VIENNA


Markus Mitterhauser


Thomas Helbich


Wolfgang Doerr

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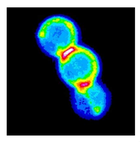
Development of a new boneseeker

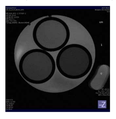
- [^{99m}Tc]ZOL was developed to detect bone-metastases and degenerative diseases more precisely than established boneseekers

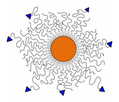
Nanoparticle Imaging

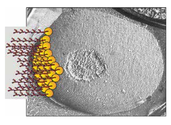
- Nanoparticle imaging
- From an idea to reality
- Cooperation with E. Reimhult



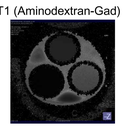
T2 (Fe-Nanoparticle)





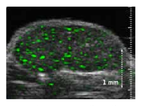


T1 (Aminodextran-Gad)



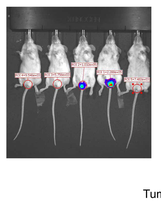
Miscellaneous

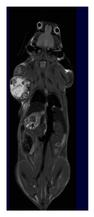
MRI of the beating mouse heart



Tumor imaging with ultrasound

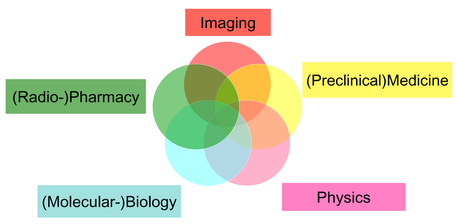
Optical imaging of a new vaccine



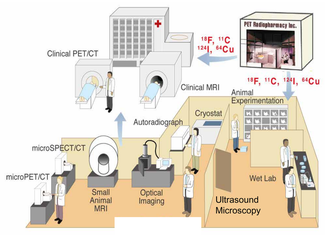


Tumor imaging with MRI

Close Interaction - Translation



Translational Lab: "from bench to beside"



Preclinical Imaging Lab:

AKH Part 24, Floor 1

PILab – What´s inside

- MRI-morphology/microscopy
- MRI-spectroscopy
- fMRI
- US-morphology
- US- functional
- µPET
- µSPECT
- CT
- µCT
- Autoradiography
- Microscopy
- Immunohistochemistry
- Optical Imaging (incl. OCT, photoacoustics)

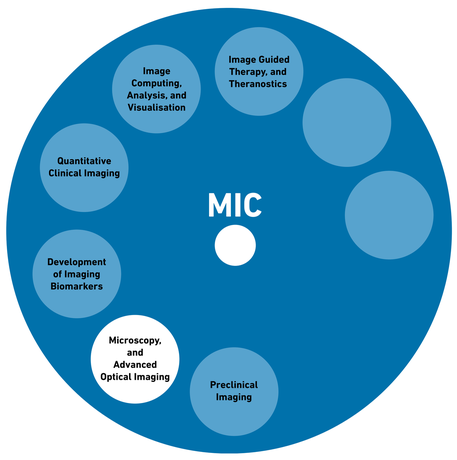
Quo vadis – node vision

- Multimodal one-stop shop for Preclinical Imaging
  - From the bench to the bed – translational research
  - Development of state of art biomarkers
  - Development of disease models
  - Development of humanized models

Status Quo and challenges

- Preclinical facilities available
  - Challenge to supply biomarkers
  -
- Laboratory equipment existing
  - Investments of recent years
- Projects already started
  - Tracer developments, Nanoparticle imaging,
  - Hybrid imaging of tumor angiogenesis
  - Metabolic & Biomarker imaging

Medical Imaging Cluster



MIC-Node:
Microscopy, and Advanced Optical Imaging

MEDICAL UNIVERSITY OF VIENNA


Wolfgang Weninger


Wolfgang Drexler

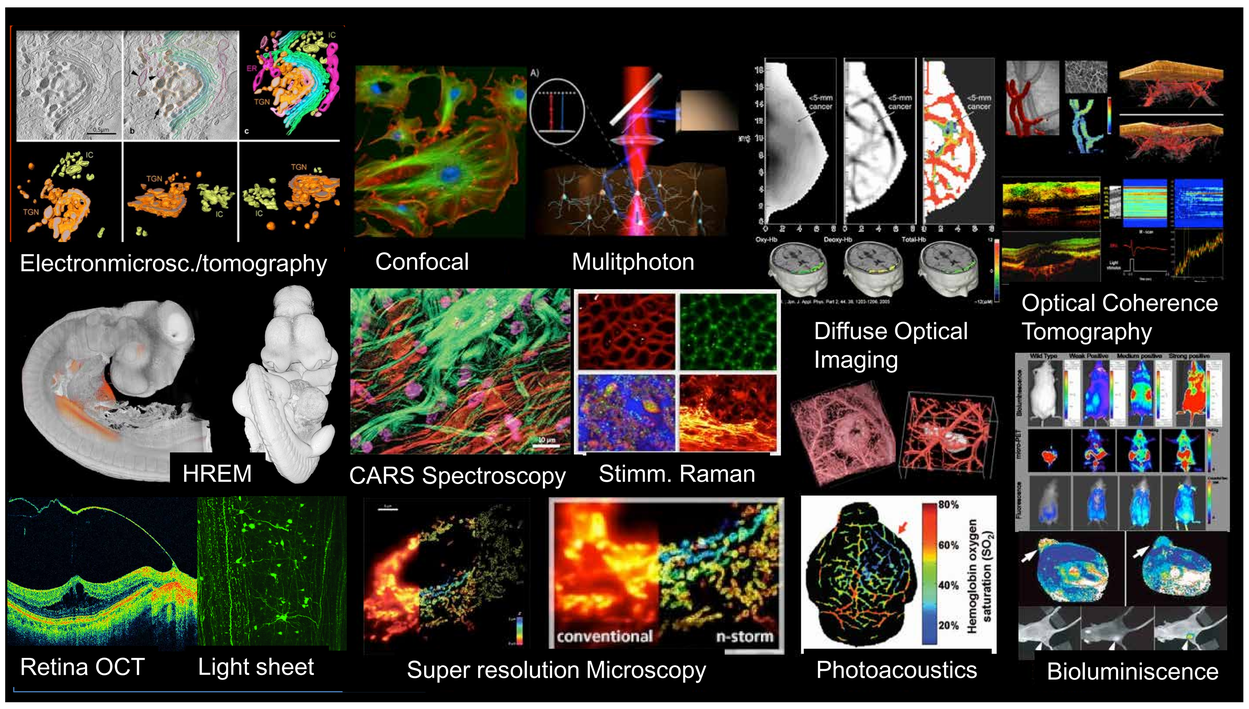

Ursula Schmidt-Erfurth

Contact: mic_mao@meduniwien.ac.at

Expertise

The node assembles a large number of associates, that are employed at different MedUni Vienna units. Together they cover and provide intellectual and apparative access to almost all modern in vivo and ex vivo microscopic & advanced optical imaging methods

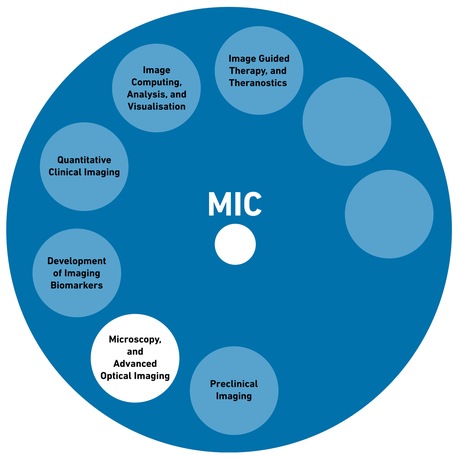
Example



Objective

- Providing an opportunity to get in contact with scientist applying & developing cutting edge imaging technologies
- Providing access to modern apparatuses for ex vivo & in vivo microscopy & advanced optical imaging
- Providing a platform for scientists to design scientific joint projects
- Triggering the establishment of multimodal, multi-scale imaging pipelines
- Supporting the translation of preclinical imaging approaches to clinical tools
- Representing a competent forum for discussion & training

Medical Imaging Cluster



MIC-Node:
Microscopy, and Advanced Optical Imaging

MEDICAL UNIVERSITY OF VIENNA


Wolfgang Weninger


Wolfgang Drexler


Ursula Schmidt-Erfurth

Contact: mic_mao@meduniwien.ac.at

Status Quo

Basic Research

Electron tomography
Confocal microscopy
Atomic force microscopy
Histological section – 3D (EMAC)
Episcopic 3D-microscopy
Plastination, incl. 3D-imaging
Light sheet microscopy
Super resolution microscopy
Optical coherence microscopy (OCM)
Stochastic optical reconstruction microscopy (STORM)
Photo activated localization microscopy (PALM)
Total interference reflectance microscopy
Structured illumination microscopy (SIM)
Förster resonance energy transfer (FRET)
Bioluminescence imaging/ tomo. (BLI/T)
…….

Optical coherence tomography (OCT)
Advanced Doppler OCT
Fluorescence-lifetime imaging microscopy (FLIM)
Coherent anti-Stokes Raman scattering (CARS)
Second-, Third-Harmonic Generation (SHG, THG) microscopy
Stimulated Raman scattering microscopy (SRS)
Photoacoustic tomography microscopy (PAT/M)
(Immuno) Electron microscopy
Light-, fluorescence microscopy
In vivo confocal microscopy
In vivo microscopy
Confocal Laser Endomicroscopy (CLE)
Multiphoton microscopy
……..

Clinics

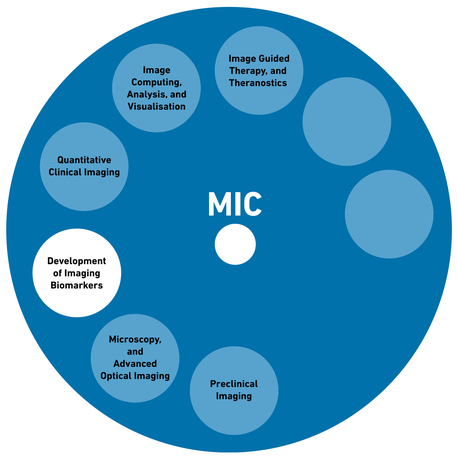
In vivo dermatoscopy
OCT (polarization sensitive, spectral domain OCT, swept source OCT)
Total body photography
Near-infrared spectroscopy
Diffuse optical tomography/spectroscopy (DOT/S)
……..

Microscopy | **Advanced Optical Imaging**

Quo Vadis

- Microscopy
  - 3D, 4D, 5D – visualisation, mathematical models & simulations
  - Expanding range of resolution (optimising field of view / resolution)
  - Imaging pipelines (in vivo - post mortem; radiology – microscopy)
  - In vivo approaches (examining patients & living model organisms)
  - Multifunctional instruments
- Advanced Optical Imaging
  - Improve ‚sensitivity and specificity' - improved diagnosis
  - 'Morphofunctional' and molecular multimodal optical imaging
  - User-friendliness, improved utility
  - Breadth of application – broader applicability discussion & training

Medical Imaging Cluster



MIC-Node:
Development of Imaging Biomarkers

MEDICAL UNIVERSITY OF VIENNA


Wolfgang Wadsak


Oliver Langer

Contact: mic_dib@meduniwien.ac.at

Expertise

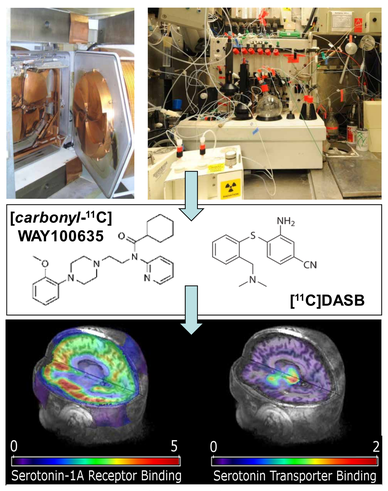
- Medicinal chemistry & radiochemistry for (pre-)clinical use
- Preclinical and (radio-)pharmacological testing
- Quantitative imaging aspects
- Mass spectrometry applications

Objective

- Molecular Imaging Biomarkers in Oncology (e.g. angiogenesis,hypoxia, proliferation) and Cardiovascular Disease (e.g.atherosclerosis)
- Neuroimaging (e.g. central receptors, transporters and enzymes in neurotransmission; blood-brain-barrier penetration and efflux transporters; neurodegenerative diseases)
- Combined Biomarkers for in-vivo hybrid techniques (e.g. PET/MR)
- Theranostic agents for the di rect translation from diagnostic imaging to therapeutic applications

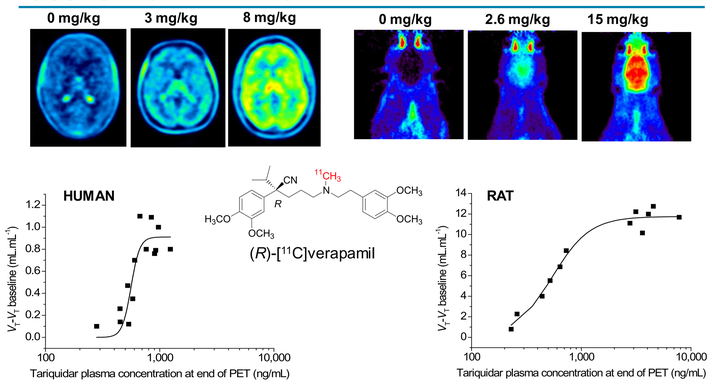
Example

Molecular in-vivo visualization of the serotonergic system – from radiotracer preparation to quantitative imaging



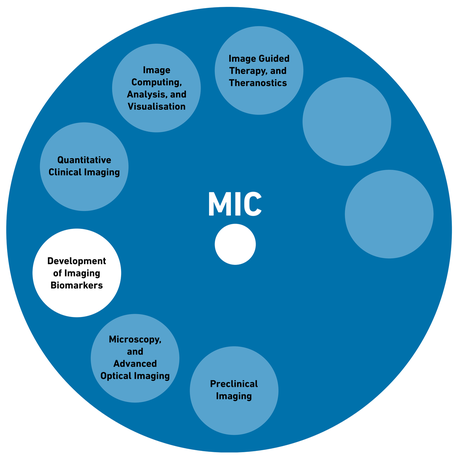
W Wadsak, M Mitterhauser, R Lanzenberger et al.
Radiochemistry @Nuclear Medicine & NeuroImaging @Psychiatry

Translational PET imaging of P-glycoprotein (ABCB1) function at the human and rat blood-brain barrier with (*R*)-[11C]verapamil and tariquidar



M Bauer, M Zeitlinger, R Karch, P Matzneller, J Stanek, W Jäger, M Böhmdorfer, W Wadsak, M Mitterhauser, JP Bankstahl, W Löscher, M Koepp, C Kuntner, M Müller, O Langer. Pgp-mediated interaction between (*R*)-[11C]verapamil and tariquidar at the human blood-brain barrier: a comparison with rat data. *Clin Pharmacol Ther* 91(2):227-233(2012)

Medical Imaging Cluster



MIC-Node:
Development of Imaging Biomarkers

MEDICAL UNIVERSITY OF VIENNA

Wolfgang Wadsak

Oliver Langer

Contact: mic_dib@meduniwien.ac.at

DEVELOPMENT OF IMAGING BIOMARKERS

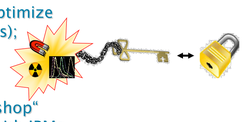
Mission statement

Our aim is…

- to define, develop and optimize Imaging Biomarkers (IBMs);

  and

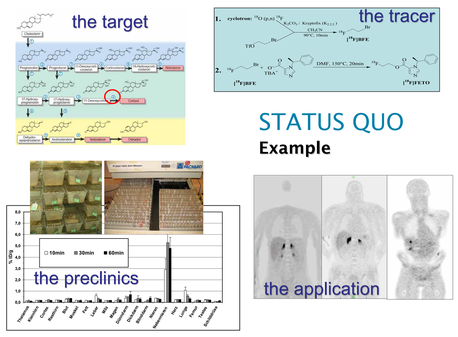
- to establish a "one-stop-shop" for researchers dealing with IBMs.



STATUS QUO

Areas of Expertise

- Medicinal chemistry & radiochemistry for (pre-)clinical use
- Preclinical and (radio-)pharmacological testing
- Quantitative imaging aspects



STATUS QUO

Partners & Projects

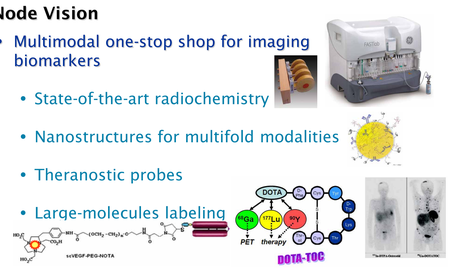
- AG Beisteiner (fMRT & electrophysiological Biomarkers)
- AG Haug (translational nuclear medicine)
- AG Hoffmann (theranostic probes)
- AG Lanzenberger (functional, molecular & translational Neuroimaging)
- AG Mitterhauser (Radiopharmacy - Preclinical Imaging)
- AG Stübiger (MALDI-Mass Spectrometry)
- AG Schmetterer (opt. coherence tomography)
- AG Willeit (psychiatric imaging)
- AG Yerlikaya (Gynecology)

- **Combined Biomarkers** for hybrid techniques (PET/MR)
- **Biomarkers for Biofilms** in infection imaging
- **Mass spectrometry** in the dev. of imaging probes

QUO VADIS

Node Vision

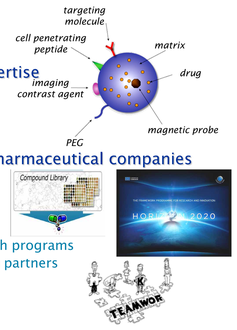
- Multimodal one-stop shop for imaging biomarkers
  - State-of-the-art radiochemistry
  - Nanostructures for multifold modalities
  - Theranostic probes
  - Large-molecules labeling



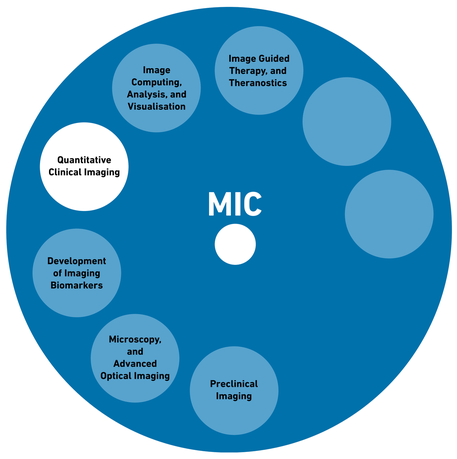
QUO VADIS

Future Challenges

- Increase and broaden expertise
  - large molecules
  - multi-modal probes
- Strengthen contact with pharmaceutical companies
  - access to chemical libraries
- Thematic focusing
  - initiation of selected research programs
  - identification of cooperation partners
  - attract substantial funding



Medical Imaging Cluster



MIC-Node: Quantitative Clinical Imaging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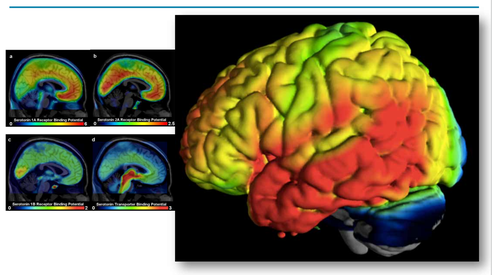
Think quantitative imaging!



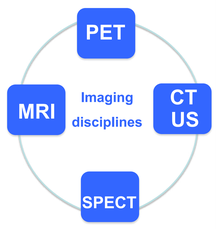
Quantitative Clinical Imaging (QCI)

To move from *anatomical* imaging to *quantitative anato-metabolic* imaging

To develop/implement dedicated imaging protocols

To liaise with MedUni Vienna clusters
- Allergology/Immunology/Infectiology (AIIC)
- Cancer Research/Oncology (CCC)
- Medical Neuroscience (MNC)
- Cardiovascular (CVC)

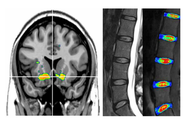
- to represent imaging expertise
- to support clinical studies



QCI - MRI

Strong technical & clinical background in MRI

Status quo
- Perfusion & DWI, Relaxometry (brain, breast)
- fMRI and MRS



Quo vadis
- Multi-parametric MR
- Whole-body multi-nuclear MRS
- Definition of imaging biomarkers (oncologic and non-oncologic)

QCI - CT

Advanced in-house technology in clinical routine

Status quo
- High-resolution/contrasted CT
- Iterative image reconstruction

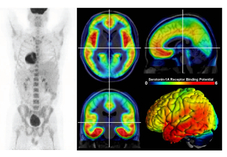
Quo vadis
- Personalized imaging protocols
- Photon-counting detectors

QCI - PET

PET/CT with unique clinical + physics expertise

Status quo
- Non-invasive, quantitative functional imaging
- Range of radiopharmaceuticals

Quo vadis
- Advanced quantitative corrections
- Multi-tracer imaging
- Simultaneous PET/MR
- In-vivo tissue characterization

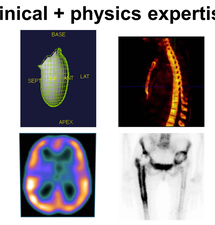


QCI - SPECT

SPECT/CT with unique clinical + physics expertise

Status quo
- SPECT and SPECT/CT with multi-slice CT
- High-sensitivity detector

Quo vadis
- Whole-body acquisitions
- Absolute quantification
- Low radiation levels



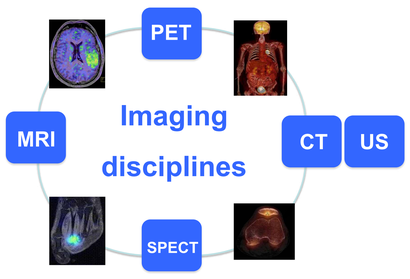
QCI - US

US technology with in-depth technical know-how

Status quo
- HR, contrast-enhanced US (2D & 3D)
- Sono-elastography (Research)

Quo vadis
- Image-guided local therapy & drug delivery
- Advanced data processing for tissue characterization

Quantitative Clinical Imaging (QCI)



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