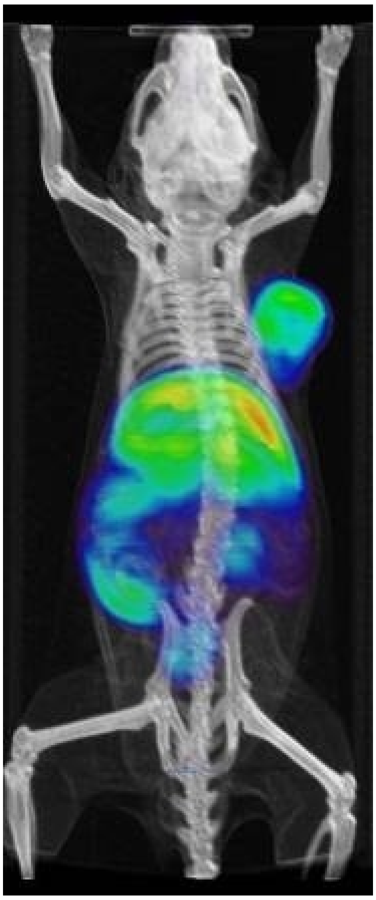
Molecular imaging - a close look inside the human body

"Molecular imaging" recognises the functional state of cells and molecules. It visualises biological processes on the cellular and molecular level and is thus able to detect pathological alterations a long time before disease symptoms become apparent. "Molecular imaging" offers new possibilities for improving diagnosis and enabling more targeted therapies than has previously been possible. Many experts regard "molecular imaging" as a paradigm shift in the healthcare system – moving away from a "service for the sick" to a "preventive health service".



Positron emission tomography (PET) enables the visualisation of what happens inside a tumour. Cancer cells are not only made visible, but can be simultaneously irradiated in the tissue. (Photo: Work group Prof. W. Weber)

Key technology, innovation driver and technology of the future are attributes “molecular imaging” can adorn itself with. And the expectations for molecular imaging are high: major benefits for patients and a huge contribution to medical progress and to the national economy.

“Molecular imaging” offers new possibilities for diagnosing diseases at an early stage, improving diagnosis and enabling more targeted therapies than has previously been possible. In many diseases, often before actual pathological signs are observed, the first molecular alterations manifest themselves on the cellular level. This usually happens way before a specific disease can be diagnosed using conventional imaging methods that mainly visualise anatomical and morphological changes. Molecular imaging recognises the functional state of cells and molecules. It visualises biological processes on the cellular and molecular level and is thus able to detect pathological alterations a long time before disease symptoms become apparent.

It is hoped that in future important pathological signs will be discovered prior to the appearance of a tumour, infarction or irreversible memory loss, meaning that the therapies will then have a more positive outcome as well as becoming cheaper. In addition, many people hope that molecular imaging will accelerate drug development because it allows physicians to visualise the drug at its target site and provide information on the effect of the substance relatively quickly.

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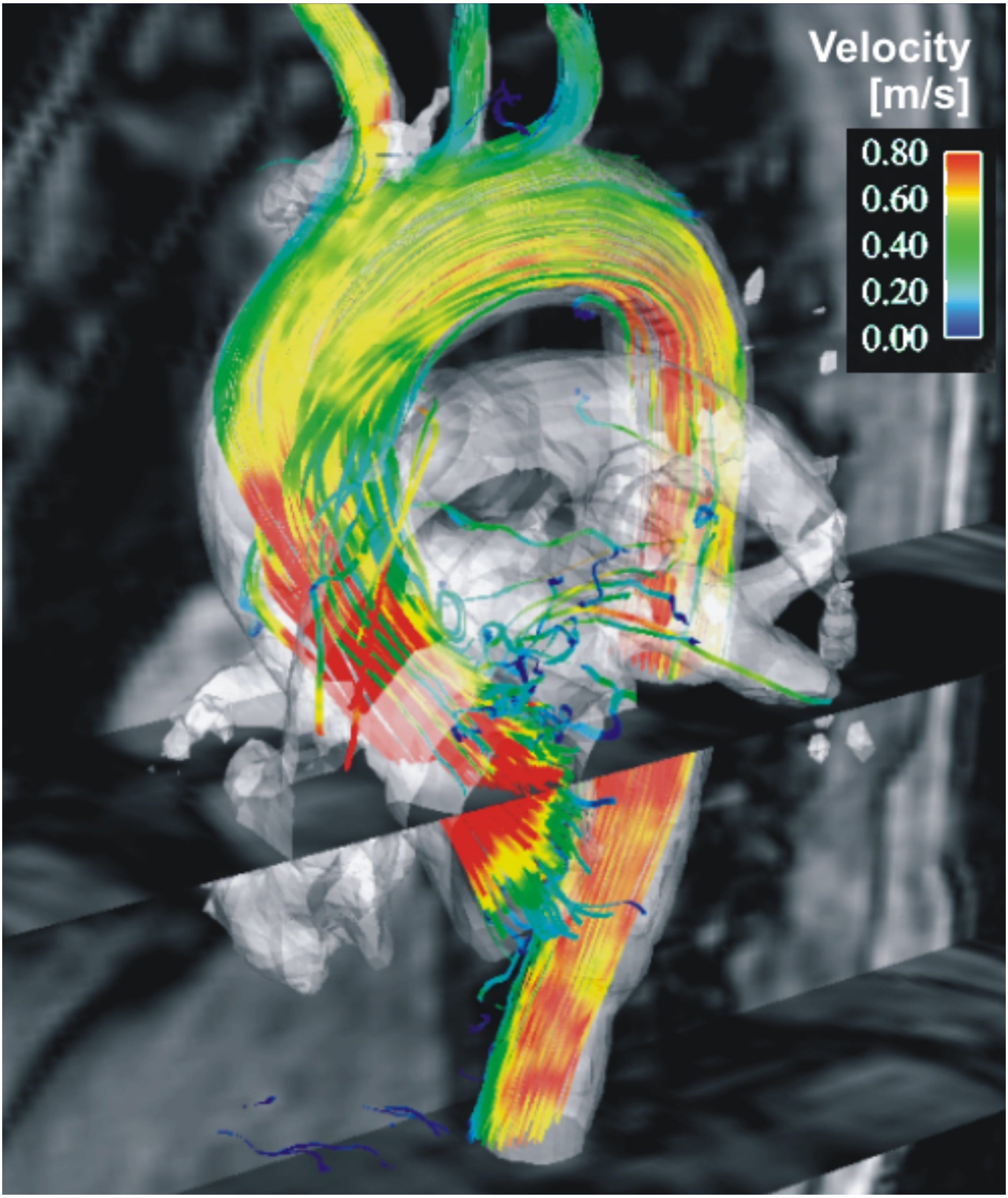
Nuclear medical methods

Molecular imaging methods involving radionuclides have made huge progress and are firmly established. Other proved and tested methods are scintigraphy, positron emission tomography (PET) and single photon emission computed tomography (SPECT). These methods are very sensitive, but unfortunately they are very expensive and expose patients to radiation. The amount of radioactivity to which patients are exposed during examination is not dangerous; one or two such examinations per year do not pose any risk, stresses the Freiburg nuclear medicine expert Prof. Dr. Wolfgang Weber. However, PET and the other aforementioned molecular imaging methods cannot be used for routine prevention or permanent therapy monitoring. Nevertheless, these methods have been very successful in many areas over the last years, in particular in the diagnosis of tumours (see BioRegio Freiburg article). This success confirms the validity of molecular imaging.

Positron emission tomography (PET) is a nuclear medicine imaging technique that visualises the distribution of a weak radioactive substance in the body. This enables the body’s biochemical and physiological processes to be reconstructed. PET uses radionuclides that emit positrons. If a positron hits an electron, then antimatter combines with matter and energy is released. Two photons are released in opposite directions at an angle of approximately 180 degrees. This particularity enables the experts to pinpoint the precise spot in the body where decay has taken place. Gamma rays are detected with 20 to 30 detector rings and the projections provide images of the area where the injected radioactive substances have accumulated. PET was not originally intended for the identification and assessment of cancer, but for the monitoring of the metabolic rate of brain and heart.

Magnetic resonance imaging



Normal blood flow in the aorta. MRI also reveals pathological changes and enables the early prognosis of cardiovascular diseases. (Photo: Work group M. Markl)

Other projects are focusing on the development of magnetic resonance imaging, ultrasound and fluorescence methods (see BioLAGO article). High hopes are riding on high-field magnetic resonance therapy, in which the very strong magnetic field increases the spatial resolution considerably compared to the resolution obtained with devices that were previously used in clinical settings. High-field magnetic resonance therapy is expected to lead to better contrasts and thus enable additional statements on examined tissue function to be made. Special contrast agents that enhance these effects are currently being developed. At the German Cancer Research Centre (DKFZ) in Heidelberg, a high-field magnetic resonance scanner will be brought into operation shortly. This will be one out of four such systems in Germany. The 7 Tesla device, which is operated in cooperation with Siemens, will be exclusively used for the clarification of oncological issues. However, before the device can be used in clinical diagnostics, the researchers have to carry out comprehensive experimental measurements in order to optimise the device. The high field strength of the device does not only have advantages; it also has risks. Potential risks include the overheating of the tissue that is being investigated.

In clinical settings, MR scanners with field strengths of 1.5 to 3 Tesla are the most common systems. Medical experts can thus look closely into the human body to glean information. Over the last ten years, functional magnetic resonance imaging (fMRI) has delivered impressive images that record and visualise nerve cell activity in the brain. In terms of molecular imaging, MRI is also used in many other areas. The field of oncology (see BioRegion Rhein-Neckar-Dreieck article) and the diagnostics of cardiovascular diseases (BioRegio Freiburg article) as well as a project being carried out by Tübingen researchers are just a few examples of effective use of MRI. The Tübingen researchers are using MRI technologies to record changes in bone structure that might suggest the onset and progression of osteoporosis (BioRegio STERN article).

Magnetic resonance imaging (MRI) or nuclear magnetic resonance imaging, in contrast to nuclear medical methods, does not involve radiation. MRI employs a strong magnetic field and is generally regarded as minimally invasive. The positively charged nuclei of the hydrogen atoms in the human body – the protons – have a magnetic momentum and align according to the magnetic field. Upon exposure to radio frequencies, the protons are pushed out of alignment, but drift back into alignment when the radio waves are switched off, emitting a detectable radio frequency as they realign. These signals vary in relation to the chemical environmental of protons, for example fat tissue, muscles or blood. Aerials pick up the signals, which are then converted into an image using computer-based methods. There is a risk that this procedure could produce artefacts, which means that the image may reveal states or structures that are not present as such in the tissue (source: press office of the German Cancer Research Centre).

Government and industry want in

The Molecular Imaging Technology Initiative shows the importance that industry and government attach to imaging methods involving radionuclides, magnetic resonance scanners, fluorescence methods and ultrasound. The initiative was started in October 2007 by the German Federal Ministry of Education and Research (BMBF) and five German pharmaceutical and medical device companies. The companies, of which three are located in Baden-Württemberg (see articles by BioRegio STERN and BioRegion Ulm), will invest 750 million euros over the next ten years in the development of new molecular imaging methods. In addition, the BMBF will fund cooperative projects, involving scientific and industrial partners, with an additional 150 million euros. These funds will be used to develop and construct new devices and create effective data processing and image analysis systems. Another of the initiative’s goals is the development of new imaging diagnostic agents that bind specifically to molecules or surfaces, or nuclear tracers that are metabolised in the body and facilitate, or enable, an examination.

According to information from the BMBF, German corporations are world leaders in the field of medical imaging and imaging diagnostic agents. There are more than 100,000 people working in these two areas. This figure does not take into account people working for suppliers. In addition, medical technology companies and pharmaceutical companies achieve an export rate of 75 per cent in the field of imaging.

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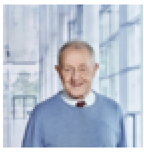

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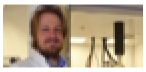

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