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Nobel Prize in Medicines 2003

Paul C. Lauterbur

Sir Peter Mansfield

The Nobel Prize in Physiology or Medicine 2003 was awarded jointly to Paul C. Lauterbur and Sir Peter Mansfield "for their discoveries concerning magnetic resonance imaging

Imaging of human internal organs with exact and non-invasive methods is very important for medical diagnosis, treatment and follow-up. This year's Nobel Laureates in Physiology or Medicine have made seminal discoveries concerning the use of magnetic resonance to visualize different structures. These discoveries have led to the development of modern magnetic resonance imaging, MRI, which represents a breakthrough in medical diagnostics and research.

Atomic nuclei in a strong magnetic field rotate with a frequency that is dependent on the strength of the magnetic field. Their energy can be increased if they absorb radio waves with the same frequency (resonance). When the atomic nuclei return to their previous energy level, radio waves are emitted. These discoveries were awarded the Nobel Prize in Physics in 1952. During the following decades, magnetic resonance was used mainly for studies of the chemical structure of substances. In the beginning of the 1970s,

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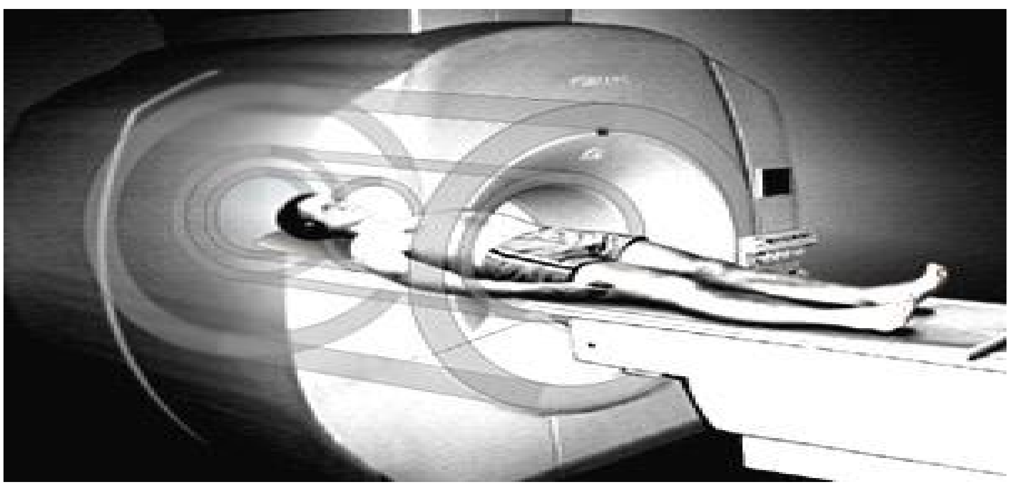
this year's Nobel Laureates made pioneering contributions, which later led to the applications of magnetic resonance in medical imaging.

Paul Lauterbur (born 1929), Urbana, Illinois, USA, discovered the possibility to create a two-dimensional picture by introducing gradients in the magnetic field. By analysis of the characteristics of the emitted radio waves, he could determine their origin. This made it possible to build up two-dimensional pictures of structures that could not be visualized with other methods.

Peter Mansfield (born 1933), Nottingham, England, further developed the utilization of gradients in the magnetic field. He showed how the signals could be mathematically analysed, which made it possible to develop a useful imaging technique. Mansfield also showed how extremely fast imaging could be achievable. This became technically possible within medicine a decade later.



MRI is used for imaging of all organs in the body.

Magnetic resonance imaging, MRI, is now a routine method within medical diagnostics. Worldwide, more than 60 million investigations with MRI are performed each year, and the method is still in rapid development. MRI is often superior to other imaging techniques and has significantly improved diagnostics in many diseases. MRI has replaced several invasive modes of examination and thereby reduced the risk and discomfort for many patients.

Nuclei of hydrogen atoms

Water constitutes about two thirds of the human body weight, and this high water content explains why magnetic resonance imaging has become widely applicable to medicine. There are differences in water content among tissues and organs. In many diseases the pathological process results in changes of the water content, and this is reflected in the MR image.

Water is a molecule composed of hydrogen and oxygen atoms. The nuclei of the hydrogen atoms are able to act as microscopic compass needles. When the body is exposed to a strong magnetic field, the nuclei of the hydrogen atoms are directed into order – stand "at attention". When submitted to pulses of radio waves, the energy content of the nuclei changes. After the pulse, a resonance wave is emitted when the nuclei return to their previous state.

The small differences in the oscillations of the nuclei are detected. By advanced computer processing, it is possible to build up a three-dimensional image that reflects the chemical structure of the tissue, including differences in the water content and in movements of the water molecules. This results in a very detailed image of tissues and organs in the investigated area of the body. In this manner, pathological changes can be documented.

Several Nobel Prizes

The resonance phenomenon is governed by a simple relation between the strength of the magnetic field and the frequency of the radio waves. For every type of atomic nucleus with unpaired protons and/or neutrons, there is a mathematical constant by which it is possible to determine the wavelength as a function of the strength of the magnetic field. This phenomenon was demonstrated in 1946 for protons (the smallest of all atomic nuclei) by Felix Bloch and Edward Mills Purcell, USA. They were awarded the Nobel Prize in Physics in 1952.

Other fundamental discoveries concerning magnetic resonance have in recent years resulted in two Nobel Prizes in Chemistry. In 1991, Richard Ernst, Switzerland, was awarded for his contributions to the development of the methodology of high resolution nuclear magnetic resonance spectroscopy. In 2002, Kurt Wüthrich, also Switzerland, was awarded for his development of nuclear magnetic resonance spectroscopy for determination of the three-dimensional structure of biological macromolecules in solution.

Discoveries of importance to medicine

This year's Nobel Laureates in Physiology or Medicine are awarded for crucial achievements in the development of applications of medical importance. In the beginning of the 1970s, they made seminal discoveries concerning the development of the technique to visualize different structures. These findings provided the basis for the development of magnetic resonance into a useful imaging method.

Paul Lauterbur discovered that introduction of gradients in the magnetic field made it possible to create two-dimensional images of structures that could not be visualized by other techniques. In 1973, he described how addition of gradient magnets to the main magnet made it possible to visualize a cross section of tubes with ordinary water surrounded by heavy water. No other imaging method can differentiate between ordinary and heavy water.

Peter Mansfield utilized gradients in the magnetic field in order to more precisely show differences in the resonance. He showed how the detected signals rapidly and effectively could be analysed and transformed to an image. This was an essential step in order to obtain a practical method. Mansfield also showed how extremely rapid imaging could be achieved by very fast gradient variations (so called echo-planar scanning). This technique became useful in clinical practice a decade later.

Rapid development within medicine

The medical use of magnetic resonance imaging has developed rapidly. The first MRI equipments in health were available at the beginning of the 1980s. In 2002, approximately 22 000 MRI cameras were in use worldwide, and more than 60 million MRI examinations were performed.

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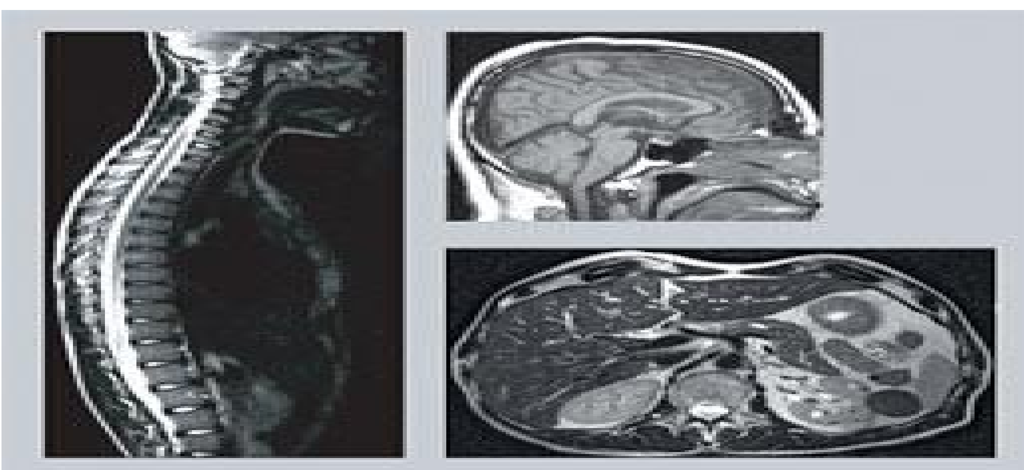
A great advantage with MRI is that it is harmless according to all present knowledge. The method does not use ionizing radiation, in contrast to ordinary X-ray (Nobel Prize in Physics in 1901) or computer tomography (Nobel Prize in Physiology or Medicine in 1979) examinations. However, patients with magnetic metal in the body or a pacemaker cannot be examined with MRI due to the strong magnetic field, and patients with claustrophobia may have difficulties undergoing MRI.

Especially valuable for examination of the brain and the spinal cord

Today, MRI is used to examine almost all organs of the body. The technique is especially valuable for detailed imaging of the brain and the spinal cord. Nearly all brain disorders lead to alterations in water content, which is reflected in the MRI picture. A difference in water content of less than a percent is enough to detect a pathological change.

In multiple sclerosis, examination with MRI is superior for diagnosis and follow-up of the disease. The symptoms associated with multiple sclerosis are caused by local inflammation in the brain and the spinal cord. With MRI, it is possible to see where in the nervous system the inflammation is localized, how intense it is, and also how it is influenced by treatment.



Examination with MRI is especially valuable for detailed imaging of the brain and the spinal cord.

Another example is prolonged lower back pain, leading to great suffering for the patient and to high costs for the society. It is important to be able to differentiate between

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muscle pain and pain caused by pressure on a nerve or the spinal cord. MRI examinations have been able to replace previous methods which were unpleasant for the patient. With MRI, it is possible to see if a disc herniation is pressing on a nerve and to determine if an operation is necessary.

Important preoperative tool

Since MRI yields detailed three-dimensional images, it is possible to get distinct information on where a lesion is localized. Such information is valuable before surgery. For instance, in certain microsurgical brain operations, the surgeon can operate with guidance from the MRI results. The images are detailed enough to allow placement of electrodes in central brain nuclei in order to treat severe pain or to treat movement disorders in Parkinson's disease.

Improved diagnostics in cancer

MRI examinations are very important in diagnosis, treatment and follow-up of cancer. The images can exactly reveal the limits of a tumour, which contributes to more precise surgery and radiation therapy. Before surgery, it is important to know whether the tumour has infiltrated the surrounding tissue. MRI can more exactly than other methods differentiate between tissues and thereby contribute to improved surgery.

MRI has also improved the possibilities to ascertain the stage of a tumour, and this is important for the choice of treatment. For example, MRI can determine how deep in the tissue a colon cancer has infiltrated and whether regional lymph nodes have been affected.

Reduced suffering for patients

MRI can replace previously used invasive examinations and thereby reduce the suffering for many patients. One example is investigation of the pancreatic and bile ducts with contrast media injection via an endoscope. This can in some cases lead to serious complications. Today, corresponding information can be obtained by MRI.

Diagnostic arthroscopy (examination with an optic instrument inserted into the joint) can be replaced by MRI. In the knee, it is possible to perform detailed MRI studies of

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the joint cartilage and the cruciate ligaments. Since no invasive instrument is needed in MRI, the risk of infection is eliminated.

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