Medical imaging breakthroughs aim to bring the invisible to light

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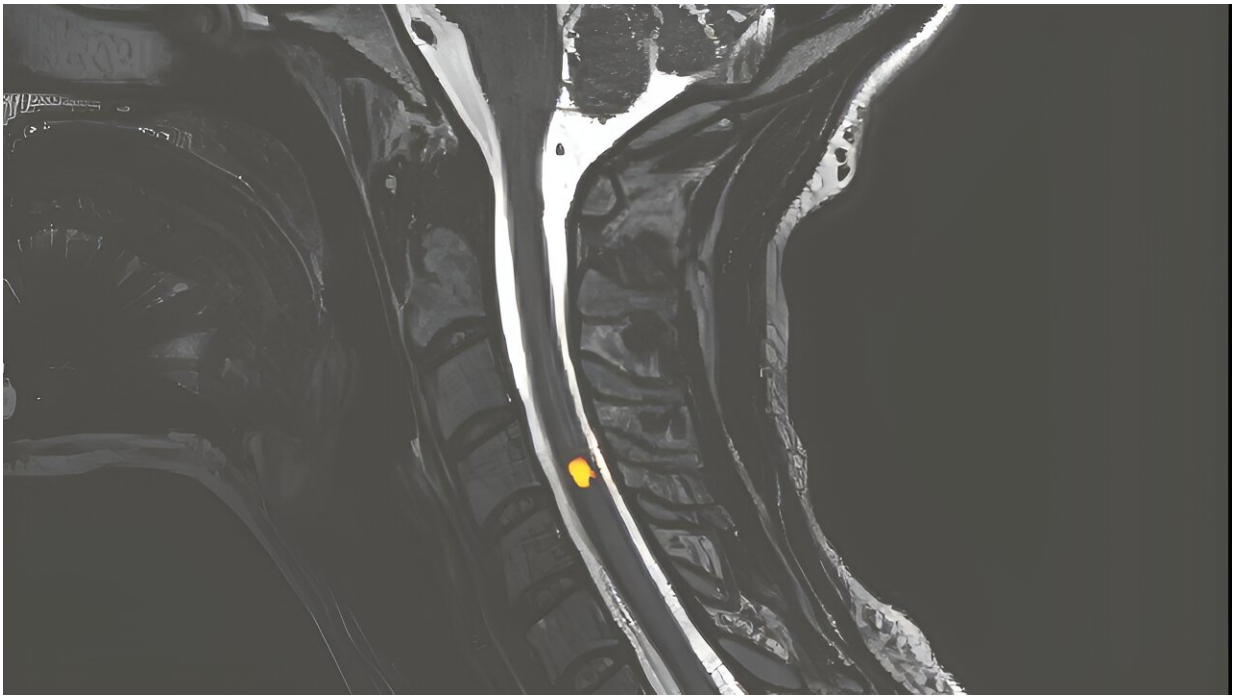

Spinal cord fMRI. Credit: EPFL—CC-BY-SA 4.0

Medical imaging technology—such as MRI, ultrasound and X-ray—is gaining in power and precision, especially in the wake of recent breakthroughs in artificial intelligence. Several EPFL research groups are contributing to this progress and actively shaping the future in this area.

Thanks to advances in medical imaging, doctors can localize a bone fracture, detect a tumor and observe a baby inside the uterus, all in a completely noninvasive manner. There's no telling just how far we'll be able to see inside the human body one day. The technology is developing at a rapid pace, generating images with ever-higher resolution that can be used to spot ever-smaller anomalies.

In the area of magnetic resonance imaging (MRI), Prof. Dimitri Van De Ville, the head of EPFL's Medical Image Processing Lab, has identified two opposing trends.

"The first trend is an increase in the strength of machines' magnetic fields, enabling them to reveal tiny irregularities such as microscopic injuries and very early stage cancer cells," says Van De Ville.

Most MRI machines in hospitals today have a magnetic field of 1.5 or 3 teslas. Engineers at the Alternative Energies & Atomic Energy Commission near Paris have invented a machine with a magnetic field of 11.7 teslas—the most powerful in the world.

According to Prof. Jean-Philippe Thiran, the head of EPFL's Signal Processing Laboratory, "The stronger the magnetic field, the better we can pick up weak signals that are otherwise hard to catch, giving us more granular information."

At EPFL, engineers have developed a 7-tesla machine—powerful enough to map human brains by neural layer in vivo. Prof. Friedhelm Hummel, the holder of the Defitech Chair of Clinical Neuroengineering, explains, "This will give us a better understanding of human brain structures, because for now the exact role of each structure isn't really clear."

The second trend that Van De Ville identified goes in the opposite

direction: the development of machines that have a magnetic field of well below 1.5 teslas, yet that can still generate images of good enough quality to make sound diagnoses. The goal is to create low-cost devices that are easy to transport and install, which can be especially useful in developing countries.

"This will be possible thanks to breakthroughs in imaging sensors, devices and data processing—some of which are being made right here at EPFL," says Van De Ville.

Ultrasound making a comeback

Another imaging technology—ultrasound—has changed very little since it was first invented. "Ultrasound is used to observe a patient's heartbeat or a baby moving inside the womb, for example," says Thiran, who specializes in this technology.

Scientists have been taking a fresh look at ultrasound's potential in recent years, as it can be coupled with systems for performing real-time calculations. "The latest machines are equipped with extremely powerful calculators that can process huge amounts of data in real time," says Thiran. "For instance, we can now measure a tissue's physical properties such as its elasticity. That will be useful for detecting cirrhosis and other liver diseases."

The powerful calculators will also enable ultrasound machines to run a lot faster. Today they can generate 30 to 40 images per second, but in the not-too-distant future their output will rise to 1,000 to 2,000 images per second. "That will let doctors observe dynamic processes such as blood flow, including in the brain," says Thiran.

The AI revolution

Artificial intelligence, including machine learning, data processing and algorithms, will be a key component of tomorrow's medical imaging systems. "AI is revolutionizing the field of medical imaging because it lets doctors compile information from different types of patient examinations," says Van De Ville.

"Soon they'll be able to combine the results of an MRI with those of an X-ray or even a patient's medical records in order to obtain a comprehensive view of a disease or the functioning of a specific organ."

Van De Ville, whose research involves human brain modeling, reckons that one day doctors will be able to establish forecasts by posing questions to an interactive program. "AI can already be used to classify images and spot anomalies, but the technology will go further and become more powerful," he says.

Thiran agrees, stating, "You'll soon hear people talking about computational or calculative medical imaging. The goal of all these advancements is to gain a better understanding of human organs and identify diseases more effectively."

However, Thiran notes that AI-enhanced imaging does have its limitations. "We need to use high-quality models to train AI programs so that the images and forecasts they produce are accurate. Otherwise, they'll give you hallucinations." The programs will therefore need to be fed vast amounts of data and be driven by robust algorithms.

Hummel, for his part, points to the ethical questions surrounding AI. "Suppose this kind of medical imaging predicts that someone has a fair probability of developing Alzheimer's, for example, years before the disease presents clinically. Should that person be told? And if so, how? And what if doctors aren't 100% sure of the prediction, and if there's still no treatment for the disease at that time?"

The latest advances in this area, like all forms of technological progress, should be accompanied by a consideration of the associated ethical issues—especially since medical imaging provides insight into the most intimate aspects of who we are.

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