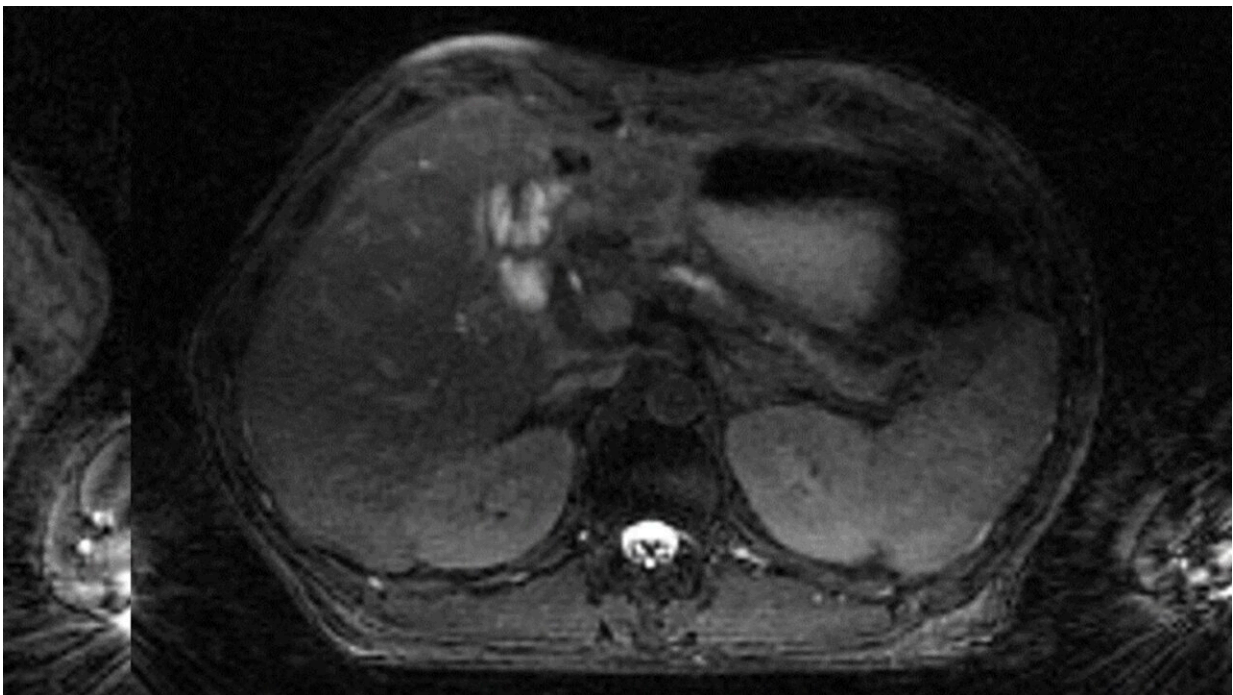


New radiotherapy with high-performance computing could improve therapy for hard-to-treat cancers

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Pancreatic adenocarcinoma 4D-MRI reconstructed using the new high-performance computing method. Credit: *Physics and Imaging in Radiation Oncology* (2023). DOI: [10.1016/j.phro.2023.100484](https://doi.org/10.1016/j.phro.2023.100484)

Researchers have used methods from high-performance computing to significantly reduce the time it takes to reconstruct images acquired

through four-dimensional magnetic resonance imaging (4D-MRI), a leading-edge, high-quality imaging technique.

The reduced reconstruction time may allow clinicians to use 4D-MRI to guide [radiotherapy](#) in real time for cancers in the thoracic and abdominal areas. These include liver, kidney and pancreatic cancers, which have proven difficult to treat with radiation because of the proximity of the tumors to vital organs.

The extra precision and accuracy afforded by 4D-MRI guidance makes radiotherapy more effective while minimizing side effects. It also provides the opportunity for real-time adaptive radiotherapy, which could revolutionize [cancer treatment](#).

Overcoming the primary obstacle

The barrier to real-time adaptive treatment—known as the online approach—has been the length of time it takes to reconstruct the images from the data acquired during the 4D-MRI scan. Before this research, the reconstruction process took about 17 minutes.

The researchers, who were led by scientists at The Institute of Cancer Research, London, and The Royal Marsden NHS Foundation Trust, set themselves the aim of reducing image reconstruction to below two minutes. This quick turnaround is necessary because the longer the time between scan and treatment, the more likely it is that anatomical changes will have occurred.

For example, when the patient lies on their back, their organs will typically sink towards the back of their body, and their muscles may relax. Any resulting changes in organ position and how the patient breathes will affect the safety and efficacy of the treatment. Also, the procedure is not comfortable for patients, particularly when abdominal

compression is used to minimize internal motion.

The researchers managed to surpass their goal, achieving image reconstruction times of just one minute. The study has been [published](#) in the journal *Physics and Imaging in Radiation Oncology*.

Working with programming experts to find a solution

The research team included experts from the Department of Computing at Imperial, who helped with applying a known algorithm—a set of commands that a computer follows to make calculations—to data from four people with pancreatic cancer.

The data came from the MR Linac Unit based at the Sutton site of the ICR and The Royal Marsden NHS Foundation Trust. This groundbreaking machine can simultaneously perform MRI scans and deliver radiotherapy to patients.

The researchers demonstrated that while using a computer processing unit to run the algorithm reduced the image reconstruction process to less than two minutes, the quickest results were achieved by using a [graphics processing unit](#), which was able to produce images in just 60 seconds.

The researchers also trialed four different data preparation strategies to see how they affected the quality of the images. All of the reconstructed images were deemed identical to the reference ones, achieving a structural similarity index score of above 0.99, where 1 indicates an exact match.

MRI's increasing role in radiotherapy

In the past few years, adaptive radiotherapy has emerged as a way to enhance personalized care. This approach considers changes to both the tumor and its surroundings in the patient's body. If the tumor has shrunk slightly since the last treatment or the patient has lost weight, for example, the next radiation dose might be amended accordingly.

Clinicians have increasingly been using MRI in place of computed tomography (CT) in adaptive radiotherapy because it is better at distinguishing between healthy and cancerous tissues. 4D-MRI is more informative than the standard 3D-MRI as it accounts for internal bodily motions, which are dominated by movements related to breathing.

One way to prevent these movements from affecting treatment is to ask the patient to hold their breath, but not everyone can do this for long enough. Abdominal compression belts help reduce the respiratory motion, but in some patients, the organs still move slowly after the belt has been applied.

Respiratory-correlated 4D-MRI could be used to identify phases during the patient's breathing cycle during which radiation can more easily be delivered to the tumor. This increases accuracy, limiting the damage to the tissue around the tumor. Clinicians use this approach to target tumors that either move with a patient's breathing or are very close to radiosensitive tissue.

Until now, it has only been possible to take an offline approach. This means that data are captured from the scan and analyzed afterward so that the necessary calculations can be made ahead of the next treatment.

Achieving the best results would require an online approach whereby the 4D-MRI images are reconstructed directly on the scanner. This would allow clinicians to use this [real-time](#) information to automatically track the tumor with the treatment beam using a tool called a multi-leaf

collimator. As the study has demonstrated, by using a computerized method of reconstructing images, this may now become possible.

Sharing the findings to help more patients

The researchers plan to publish the source code for their fast image reconstruction technique so that others can use it. They are keen to help facilitate its adoption in the hope that it will lead to more patients being treated effectively and safely using respiration-correlated 4D-MRI for online adaptive MRI-guided radiotherapy.

First author Bastien Lecoer, a Ph.D. student in the Magnetic Resonance Imaging in Radiotherapy Group at the ICR, said, "We are pleased to have made 4D-MRI a viable option for monitoring internal motions in MRI-guided radiotherapy. The superior soft-tissue contrast that it provides could increase certainty around tumor positions and enable safer, more effective treatments. We hope that this will go on to benefit patients with a range of cancers."

Dr. Andreas Wetscherek, who leads the Magnetic Resonance Imaging in Radiotherapy Group at the ICR, said, "My team's mission is to create better MRI-guided radiotherapy workflows so that we can improve treatment for as many people as possible, including those with lung, liver and pancreatic cancer. We hope that this work will open new doors for those with access to an MR Linac system."

Scientists at the ICR, who have long been at the forefront of radiotherapy research, worked with The Royal Marsden to open the UK's first MR Linac unit in 2017. Since then, other units have opened, giving more researchers the opportunity to work on optimizing radiotherapy workflows in clinical practice.

Looking to the future, Dr. Wetscherek believes that we can develop 4D

radiotherapy even further. "Ideally, we will find a way to use time-resolved 4D-MRI, which will provide a volumetric visualization of the patient's anatomy for each second of the treatment in real time. If we can get there, we can work the treatment around any type of motion. This would remove the need for patient positioning devices or, in the case of pediatric patients, sedation."

More information: Bastien Lecoœur et al, Accelerating 4D image reconstruction for magnetic resonance-guided radiotherapy, *Physics and Imaging in Radiation Oncology* (2023). [DOI: 10.1016/j.phro.2023.100484](https://doi.org/10.1016/j.phro.2023.100484)

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