Medical physicists describe hybrid Linac-MRI system

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Canadian scientists at the University of Alberta's Cross Cancer Institute are developing a new technology that integrates two existing medical devices -- medical linear accelerators, or "linacs," which produce powerful X-rays for treating cancer, and magnetic resonance imagers (MRIs), which are widely used to image tumors in the human body.

The proposed hybrid Linac-MR system promises to help doctors treat certain types of cancer by allowing them to accurately monitor moving tumors in people's lungs and other soft tissues such as the liver or prostate in real time while the radiation treatment is ongoing. Though the new technology is not yet available in the clinic, the Canadian scientists have now demonstrated its feasibility for the near future.

In related research, a group from Stanford University is determining the specifications for how the new technology can be used. Both groups will discuss their latest findings at the 51st meeting of the American Association of Physicists in Medicine (AAPM), which takes place from July 26 - 30, 2009 in Anaheim, California.

The success of modern cancer radiotherapy often depends on how well radiation oncologists and medical physicists can determine the exact location and shape of a tumor. When doctors plan radiotherapy treatment for their patients, they will first define the outline of target tumors by collecting high-resolution 3-D images. The better they define the outline of a tumor, the more precisely they can irradiate it, and the more successfully they can kill the cancerous cells inside while sparing the surrounding healthy tissue.

Imaging techniques have improved to the point that doctors can now define the edges of many tumors to within a fraction of an inch. During treatment, however, many tumors will move. Tumors in the lungs, for instance, can move up to an inch or more as a person breathes, complicating treatment. Therefore, traditionally, radiation is delivered to a slightly larger area surrounding the tumor to ensure that the tumor is always in the beam's sight. This means, however, that adjacent normal tissue as well as critical organs such as the heart and spinal cord may receive harmful radiation dose.

In recent years, image-guided radiation treatment (IGRT) has emerged as a technique for following tumors as they move. In IGRT, doctors typically use implanted markers to localize the tumor or x-rays to generate computed tomography (CT) images of the patient just prior to treatment to determine the tumor position on that day and adjust the patient position to place the tumor to coincide with the high radiation dose.

According to B. Gino Fallone, the director of Medical Physics at the University of Alberta's Cross Cancer Institute, image-guided radiotherapy is simply the latest sophisticated way of doing what radiologists have always done. "Track it and treat it," he says. "That's been the goal of radiation oncology for 50 years."

While existing IGRT techniques are effective, they are limited because they do not give true image-based guidance of the entire volume of the tumor, says Amit Sawant, an instructor in the Department of Radiation Oncology at Stanford University. Instead of imaging the whole anatomic volume containing the tumor, markers and seeds simply provide a few points in space that doctors can follow -- something Sawant refers to as "faith-based radiation delivery."

While CT provides 3-D images, it is often difficult to distinguish tumors from normal tissues with CT scans. MRI provides superior distinction between normal and cancerous tissues, but the technology has not been available to place an MR scanner in the treatment room.

A more robust way to guide radiotherapy would be to image the entire tumor continuously and adjust the radiation beams accordingly. Fallone and his colleagues are testing a prototype Linac-MR system they built to do just that.

Linacs (short for linear particle accelerators) are basically devices that use radio waves to accelerate electrons to high speeds and crash them into a solid metal target -- typically tungsten -- producing high-energy X-rays in the collision. These high-energy X-rays destroy cancerous cells by causing irreparable damage to the cells' DNA, MRIs, familiar because of their ubiquity in modern hospitals, are very good at imaging soft tissue and would be an ideal technology for combining with Linacs because most cancers occur in soft tissue.

The problem is making MRIs and Linacs work together. Normally, each one would interfere with the other. Linac systems emit radio waves, which interfere with MRI hardware -- so much so that most hospital MRIs are placed in shielded rooms that specifically block radio waves. At the same time, MRIs employ strong magnets that can interfere with Linac systems.

Can two instruments that are not even supposed to be in the same room be combined into one body and be made to work together? This is something that is not possible now says Sawant, but an issue that at least three groups worldwide are examining

Fallone and his colleagues have managed to build a prototype linac-MR device that overcomes the obstacles to integrating the two technologies.

It is the first working system to do so.

They have a specialized design that shields the radio frequency waves and magnetic fields. Last December they performed experiments with the system to demonstrate that it works by taking MRI test images with the linac on and off to demonstrate that the interference is eliminated. A working, clinically-ready system is not here yet, but Fallone believes that it will be in five years or so.

In related research, Sawant and his Stanford colleagues Kim Butts Pauly and Paul Keall have been working out the technical details of just how a hybrid MRI+linac system could be used to achieve real-time image guidance. Anyone who has had an MRI scan knows that these procedures are long. Typical imaging times for MRI range from several seconds to a few minutes per image. Sawant says that their goal is to go at least ten times faster. They are developing imaging specifications for a system to accurately image the entire volume of a tumor in real time, about three times per second.

The key to implementing this technology may be to lower the magnetic field of the magnetic resonance used to image a tumor. Powerful hospital MR instruments employ large magnets with strong magnetic fields because these will give the best quality images. Better quality images help doctors spot tumors, and when someone with cancer is diagnosed, doctors prefer to have images that are as clear as possible, for accurate classification of the tumor. Integrating such strong magnets with linear accelerators is expensive and can be technically quite challenging.

During therapy, however, the images need not be the highest quality in order to track the tumors. Doctors simply need to be able to see the tumor boundaries so that they can make adjustments as the treatment proceeds. In Anaheim, Sawant and his colleagues will describe the results of their studies, which indicate the feasibility of such rapid imaging for hybrid MRI+linac systems in order to follow tumors in real time.

More information: AAPM home page: http://www.aapm.org.

Source: American Institute of Physics