Medical Imagers Lower the Dose

Radiation-lowering techniques were in the works even before studies showed a danger

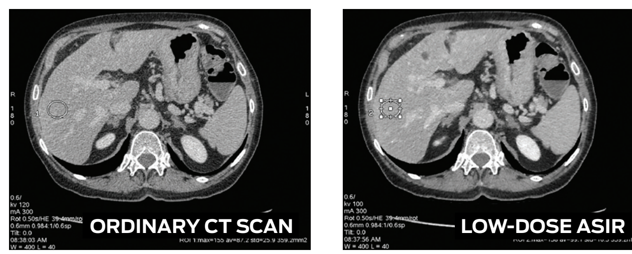
RECENT RESEARCH documenting that CT scans increase the risk of cancer has biomedical engineers looking for new ways to reduce patients' exposure to ionizing radiation.

CT scans, which use multiple X-ray images to build up cross-sectional and 3-D pictures of structures inside the human body, have soared in popularity in recent decades. A study published in December's *Archives of Internal Medicine* found that the number of CT scans grew from 3 million in 1980 to roughly 70 million in 2007. Those 70 million scans could eventually lead to 29 000 cancers, according to the same study. For each year's use of today's scanning technology, the resulting cancers could cause about 14 500 deaths.

But the makers of CT scanners are already taking steps to reduce the radiation dose from a scan, and consequently the risks of cancer. For instance, last year GE Healthcare introduced scanners that incorporate a technique it calls Adaptive Statistical Iterative Reconstruction. An ASIR scan uses a less intense X-ray beam, which means that the resulting raw image can contain more noise. ASIR compares voxels—volumetric pixels—side by side, and if one looks too different from its neighboring voxels, it's assumed to be noise and is removed from the data. ASIR then constructs a high-quality image from the cleaned-up data.

Amy Hara, an associate professor of radiology at the Mayo Clinic in Arizona, studied liver scans made using ASIR. She found that the images were better than low-dose images made without ASIR and required 32 to 65 percent less radiation, depending on such factors as the patient's size. Taking out the noise didn't eliminate any diagnostically important details, Hara says: "We're not losing any actual data. What we're seeing is that it's removing what it's supposed to remove."

Another radiologist, James Earls of Fairfax Radiological Consultants, in Virginia, looked at heart scans done with ASIR and found high-quality images with up to a 90 percent reduction in radiation. Hara says that ASIR studies will have to be done for all the important parts of the body typically scanned—such as lungs and heads—to make sure nothing of diagnostic importance is lost.



CATCH FEWER RAYS: Tricks of image reconstruction spare the patient by making every X-ray photon count.
PHOTO: IAN HOOTEN/GETTY IMAGES; IMAGES: GE HEALTHCARE (2)

Siemens has a similar approach that it calls Iterative Reconstruction in Image Space, which it plans to start selling in the second quarter of 2010. The general technique behind both the Siemens and GE technologies has been known for a while, but it's so computationally intensive that it wasn't practical until computers became more powerful and programmers came up with more streamlined algorithms.

Lower-dose CT scanning is a goal of researchers outside the major imaging firms, too. Ge Wang, director of the biomedical imaging division of the joint Virginia Tech–Wake Forest University School of Biomedical Engineering and Sciences, is developing a new low-dose CT technique called interior tomography. While typical scans cover a whole area—scanning the chest to image the heart, say, or the whole head to map out a cochlear implant—interior tomography focuses on a much smaller region of interest. "Data means radiation dose, so if you reduce data, you reduce radiation dose," Wang says. Scanning only the heart, for instance, immediately cuts the X-rays by about half.

When today's CT scanners image the chest, for example, part of the data they collect includes where the body ends and the open air begins. That defined edge provides the image-building algorithm with the reference values that allow it to calibrate the rest of the image and figure out such information as how dense a bit of tissue is. With the more targeted scan used in interior tomography, that reference is missing. Instead, the technique looks for reference points within the image. An air pocket or a region of blood, even a medical implant, scatters or absorbs X-rays in known ways. Finding those points gives the algorithm a place to start building up the image.

Without the hard edges of empty space in the picture, the scanner cannot use the Fourier transform to reconstruct an image, the way standard image-processing systems do. Instead, Wang turns to a trick called the truncated Hilbert transform. Ironically, although the Hilbert transform has less data to work with, the computation is more demanding. It can take 10 minutes to an hour to create an image, depending on the size, but Wang believes that in two or three years he'll find a way to do it much faster.

Researchers hope these and other efforts will cut the cancer risk from CT scans while retaining their value in finding and treating disease. The Mayo Clinic's Hara says there's a growing awareness of the radiation risk. "For a long time it was about image quality, with less of an emphasis on dose," she says. "We all know that CT's very valuable and helpful, and that's been proven. You just want to make sure there's the least risk to the patient."

—NEIL SAVAGE

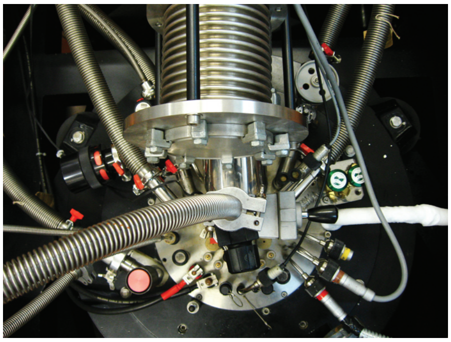
Scientists Solve Mystery of Superinsulators

The opposite of superconductivity might lead to strange new circuits

In 2008 a team of physicists from Argonne National Laboratory, in Illinois, and other institutions stumbled upon an odd phenomenon. They called it superinsulation, because in many ways it was the opposite of superconductivity. Now they've worked out the theory behind it, potentially opening the doors to better batteries, supersensitive sensors, and strange new circuits.

Superconductors lose all resistance once they fall below a certain temperature. In superinsulators, on the other hand, the resistance to the flow of electricity becomes infinite at very low temperatures, preventing any flow of electric current.

Valerii Vinokur of Argonne and Tatyana Baturina from the Institute of Semiconductor Physics, in Novosibirsk, Russia, discovered superinsulators when the pair chilled a thin film of titanium nitride to nearly absolute zero and tried to send a current through it. They found that the resistance shot up to 100 000 times its original level. The effect vanished at higher temperatures. The researchers also noticed that the effect was sensitive to the strength of a magnetic field; as they increased the strength of an external magnetic field, the resistance disappeared.



WELL CHILLED: Superinsulators like titanium nitride show their stuff only when cooled to nearly absolute zero.
PHOTO: ARGONNE NATIONAL LABORATORY

Vinokur and his colleagues say the effect could make new kinds of batteries possible. In most batteries, there is a certain amount of leakage when the battery is left exposed to air, because air is not a perfect insulator. Thus, an unused battery eventually drains. "If you pass a current through a superconductor, then it will carry the current forever; conversely, if you have a superinsulator, then it will hold a charge forever," says Vinokur. In fact, he points out, a device made from superconductors and superinsulators might lose no heat at all during operation.

Vinokur, Baturina, and Nikolai Chtchelkatchev, a theoretical physicist from the Moscow Institute of Physics and Technology, who also has an affiliation with Argonne, recently worked out a theory of how superinsulation works at microscopic scales, which they reported this past December in *Physical Review Letters*. They say that superinsulation, like superconductivity, is caused at low temperatures by electrons that form what are known as Cooper pairs. In a superconductor the pairs move together collectively, which means there is no resistance to impede the flow of current. In a superinsulator, on the other hand, the Cooper pairs repel one another, and thus prevent any current from flowing.

Vinokur says that while the qualitative picture of the phenomenon emerged in 2008, it was only recently that the team succeeded in working out the first set of detailed calculations.

Eugene Chudnovsky, an expert on superconductivity and a physics professor at Lehman College of the City University of New York, says that the nature of superinsulators has been hotly debated by physicists and that the theory by Vinokur and the Russian physicists is promising. Gergely Zimanyi, a physics professor at the University of California, Davis, says the theoretical physics community has "extremely high respect" for Vinokur's work.

So far the theory and experiments have been confined to thin films of titanium nitride, says Vinokur, who intends to investigate other compounds at higher temperatures next. "There are still plenty of unresolved questions," he says. "We can only remind [ourselves] that the microscopic theory of superconductivity appeared almost 50 years after the discovery. In this respect, we are proceeding incredibly fast."

—SASWATO R. DAS