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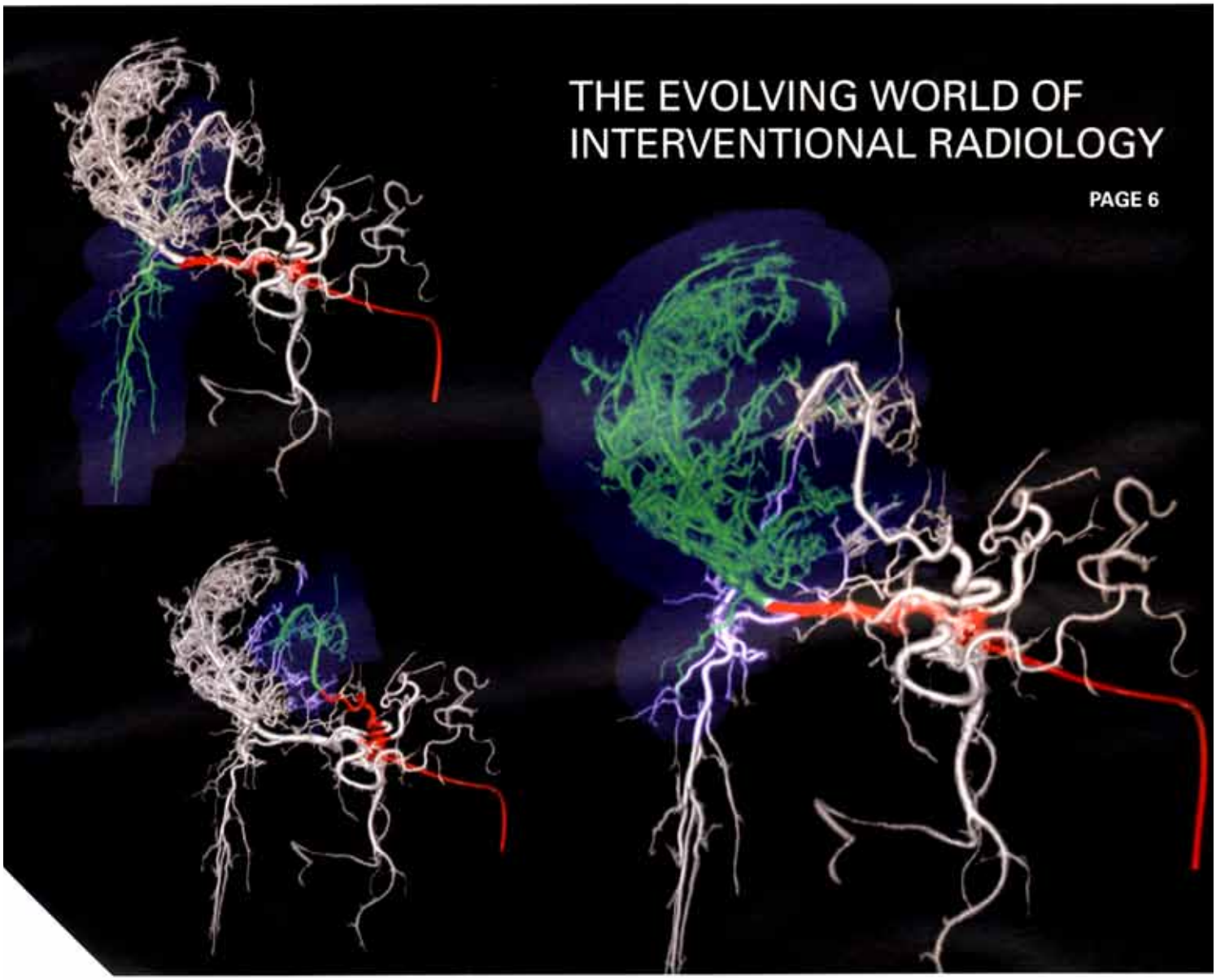

THE EVOLVING WORLD OF INTERVENTIONAL RADIOLOGY

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JEFFREY BERMAN | ARCHITECT

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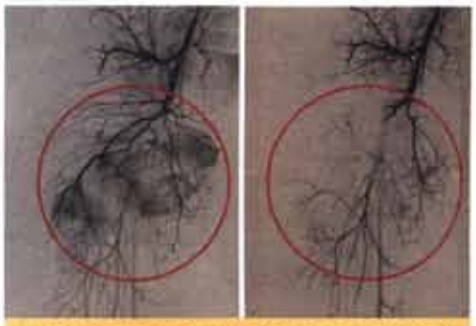
The Evolving World of Interventional Radiology

Sophisticated Imaging Technologies Allow Nonsurgical, Minimally Invasive Procedures to Treat Cancer

A small puncture in the right groin is all that MSKCC interventional radiologist Majid Maybody needs to access his patient's femoral artery. Then, guided by angiography and fluoroscopy, two of interventional radiology's imaging technologies, Dr. Maybody threads a very fine guidewire to his target — a tumor in the patient's left femur, or thigh bone. His goal: to embolize, or cut off, the blood supply to the tumor.

The tumor — a kidney cancer metastasis — has so weakened the bone that it could break at any time; and the tumor is hypervascular, meaning that a large number of vessels supply it with blood. Before the development of embolization, the surgery that will be successfully performed later this same day by an MSKCC orthopedic surgeon — removing the tumor and placing a steel rod in the patient's leg to stabilize it — might have resulted in significant blood loss. However, the outlook has changed dramatically now that interventional radiologists are able to block the vessels prior to surgery, substantially lessening intraoperative bleeding.

Arriving at his target requires a meld of art and science on the part of Dr. Maybody. He employs an interventional radiology (IR) technique known as "roadmapping" — the use of a static, reference image of the patient's arteries and blood vessels overlaid on "live," or real-time, images of the same vessels and arteries. The reference image, or roadmap, is obtained through angiography, a type of x-ray in which a contrast material is injected into the bloodstream to visualize arteries or veins.



A soft tissue sarcoma in the hip and thigh of a five-year-old patient. An embolization procedure was performed to limit bleeding prior to surgery to remove the tumor. (Left) Before the procedure, the tumor is visible as the dark areas. (Right) After the procedure, the blood supply to the tumor is completely blocked and the tumor areas are no longer visible.

Then a fluoroscopy system, another variation of x-ray technology, superimposes subsequent live images over the roadmap as Dr. Maybody threads the guidewire to its destination. Taken together, the roadmap and real-time fluoroscopy help confirm that he is on the correct path — and the path is not without its unexpected twists and turns. Each individual's anatomy has its own variations and poses its own unique challenges. Along the way, Dr. Maybody must make several adjustments to adapt to this particular patient's anatomy.

Finally, satisfied that he has identified the artery supplying the tumor and that he has gotten as close to the tumor as he can, he slides a microcatheter over the guidewire and through it injects tiny nontoxic particles that clog the

The Center for Image-Guided Intervention

MSKCC's IR future includes the 2009 opening of the **Center for Image-Guided Intervention (CIGI)**. The facility will incorporate a multimodality and multidisciplinary approach to image-guided cancer therapy. Co-directed by IR physician Stephen Solomon and surgical oncologist Yuman Fong, Chief of MSKCC's Gastric and Mixed Tumor Service, "CIGI will give us an infrastructure for the image-guided treatments of tomorrow," says Dr. Hedvig Hricak, Chair of MSKCC's Department of Radiology. "Both Peter Scardino [Chair of the Department of Surgery] and I are very excited about the opportunities for innovation and discovery."

"Image-guided therapies cross many specialties," elaborates Dr. Solomon. "The CIGI concept, and one of the real innovations, is the multidisciplinary aspect — to open the tool chest so that all our groups can collaborate in ways that will allow us to care more effectively for patients." In addition, CIGI will have a laboratory in MSKCC's new Zuckerman Research Center devoted to developing the tools of tomorrow, including robotics, as well as designing new treatments and techniques in animal models that can eventually be put into clinical trials in patients.

artery. In turn, blood flow through the main artery supplying the tumor with blood is cut off. Dr. Maybody must be vigilant that the particles block only the artery supplying the tumor and do not escape into vessels supplying normal tissue.

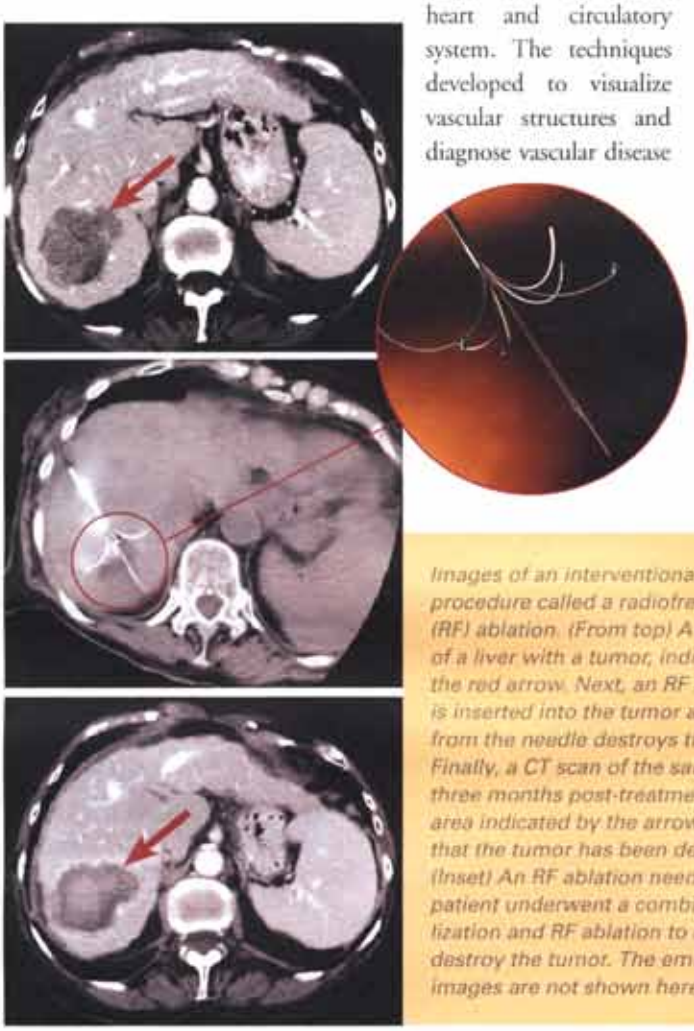
Throughout the procedure, he is assisted by IR technologists Angela Greco and Alvin Lopez and nurse Jo Ann Ruggiero, who delivers sedation to the patient as she also monitors his vital signs. If, in the moments after Dr. Maybody delivers the particles, oxygen saturation in the patient's blood starts dropping, this indicates that the particles may have traveled through abnormally large veins draining blood from the tumor into the bloodstream to the patient's lungs. The procedure must then be halted — sometimes temporarily, sometimes permanently. While this does not happen often, the role of nurses, technologists, and other IR healthcare professionals is critical in ensuring safe and successful outcomes. "It's simply not possible to do what we do without great teamwork," Dr. Maybody stressed. "We can do the most complex procedures here at MSKCC because everyone on the team is 100 percent dedicated."

At the conclusion of the embolization, Dr. Maybody and interventional radiologist William Alago close the puncture in the patient's groin with a special artery closure clip. The clip allows the patient to get off the table immediately following the procedure.

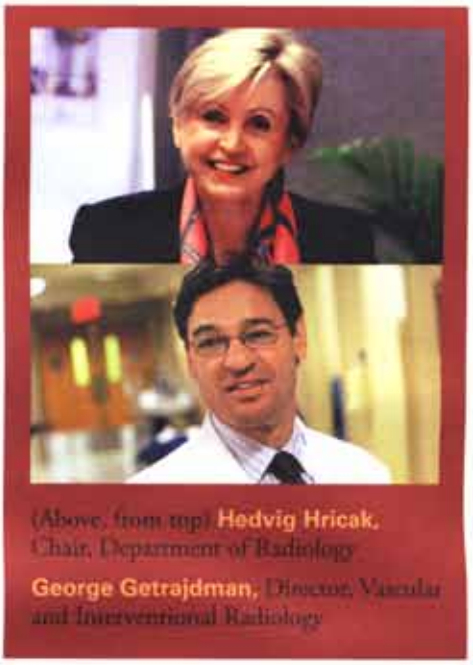
A Changing World, a Collaborative Enterprise

Speaking for the entire IR section, MSKCC interventional radiologist Raymond H. Thornton elaborated, "Everything we do in IR is made possible because we work in an enormously collaborative environment. From specially trained radiologic technologists, nurses and nurse practitioners, and our referring clinicians, to the people who prepare the rooms following each procedure — there's an extraordinary team behind every IR procedure."

A subspecialty of diagnostic radiology, interventional radiology had its beginnings in diagnostic angiography for the study of the heart and circulatory system. The techniques developed to visualize vascular structures and diagnose vascular disease



Images of an interventional radiology procedure called a radiofrequency (RF) ablation. (From top) A CT scan of a liver with a tumor, indicated by the red arrow. Next, an RF needle is inserted into the tumor and heat from the needle destroys the tumor. Finally, a CT scan of the same liver three months post-treatment. The area indicated by the arrow shows that the tumor has been destroyed. (Inset) An RF ablation needle. This patient underwent a combined embolization and RF ablation to completely destroy the tumor. The embolization images are not shown here.



(Above, from top) **Hedvig Hricak,** Chair, Department of Radiology

George Getrajdman, Director, Vascular and Interventional Radiology

"are at the heart of the techniques we use in our procedures today — placing a needle precisely and then using a variety of wires and catheters to achieve our goal," explained Dr. Thornton.

Interventional radiologists are physicians who specialize in minimally invasive treatments carried out using image guidance that includes fluoroscopy, computed tomography (CT), ultrasound, positron emission tomography (PET), and magnetic resonance (MR) imaging. The procedures do not require large incisions, can often be done with "conscious sedation" (meaning that patients do not have to undergo general anesthesia), and offer less risk and shorter recovery times than surgery. Most patients having an IR procedure are able to return home the same day.

In the treatment of patients with cancer, interventional radiologists perform procedures that include destroying cancer by the application of heat or cold; treatments that block blood vessels that feed tumors or that deliver chemotherapy and radiation directly to tumors; and therapies that relieve the pain caused by cancer that has spread to the spine or other bones. In addition, interventional radiologists perform diagnostic needle biopsies; place tubes to remove infections and abnormal collections of fluid in

Interventional Radiology

continued

the chest and abdomen; and place venous access devices, including chest ports, so that patients who must receive regular infusions of chemotherapy drugs can have them delivered directly into the bloodstream without having to have their veins repeatedly punctured.

At Memorial Sloan-Kettering, under the leadership of Hedvig Hricak, Chair of the Department of Radiology, the practice of interventional radiology "has grown by leaps and bounds," said Dr. Thornton. "Dr. Hricak's vision has led to a tremendous invigoration of patient services, research, and faculty expansion."

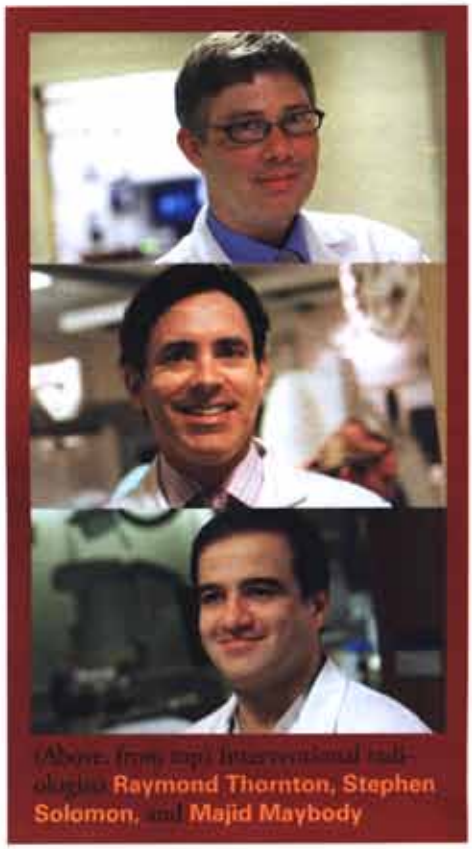
In 2006, MSKCC's Department of Radiology ranked eighth nationwide and first in New York City in National Institutes of Heath (NIH) funding for radiology research. The Center has one of the first "angio-CT" (combined angiography and CT) suites to be installed in the United States. This new technology allows MSKCC's IR physicians to produce three-dimensional images that reveal anatomy in exquisite detail and assists them in planning treatment with a precision heretofore unimaginable. "However, interventional radiology is more than just fancy technology; today, it involves patient contact across the entire continuum of care," said Dr. Hricak.

Earlier this year, MSKCC opened a new interventional radiology clinic at the Rockefeller Outpatient Pavilion on East 53rd Street. The clinic gives a patient the opportunity to meet with his or her IR physician in advance of treatment to discuss treatment options and the risks and benefits of any potential IR procedure. Additionally, it provides a venue in which to follow patients after procedures.

For many years, IR was dedicated almost exclusively to diagnosis. However, as the tools of imaging technology continue to mature and IR procedures become more therapeutic, it is increasingly important that interventional radiologists have close clinical relationships with their patients. "Our physicians need to see patients for an initial evaluation, for treatment, and then for follow-up," Dr. Hricak said. "Parallel to the establishment of the clinic, it's also important that they have admitting privileges. Historically, in radiology, admitting privileges were required for physicians in nuclear medicine who, in addition to diagnosis, also offered treatment, such as for thyroid cancer. Now MSKCC's interventional radiologists also have admitting privileges."

"IR runs hot and cold"

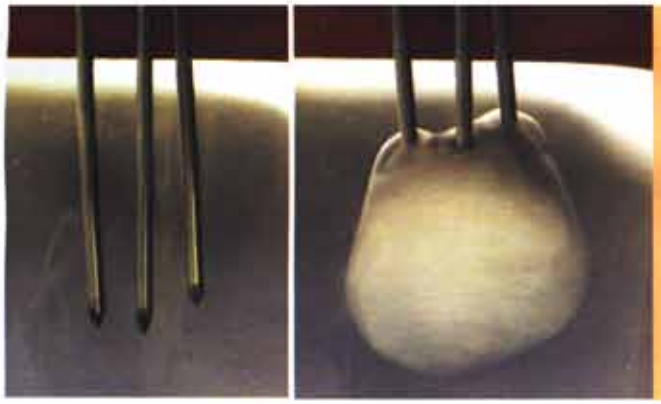
George I. Getrajdman, MSKCC's Director of Vascular and Interventional Radiology, is not being glib when he speaks of his specialty as "running hot and cold." He is referring to some of the multiple tools in the arsenal available to interventional radiologists to treat cancer.



(Above, from top) Interventional radiologists **Raymond Thornton, Stephen Solomon,** and **Majid Maybody**

In radiofrequency ablation, interventional radiologists use imaging to guide a customized needle to a target tumor. When turned on, the needle heats the tumor, destroying it. Similarly, cryoablation, the application of extreme cold, can destroy tumors. "Heat and cold don't play favorites," observed MSKCC interventional radiologist Stephen B. Solomon. "Ablation kills cancer cells regardless of what they may be like biologically — and since we're targeting exactly what we want to destroy, ablation spares virtually all normal tissue." The choice of whether heat or cold is used often depends on the type of tumor being treated; for instance, certain renal tumors and bone tumors may benefit more from cryoablation.

"Currently, we most commonly do ablation in the lung, the liver, and the bone," said Dr. Thornton. "In patients with lung tumors that cannot be treated surgically or by other means — for example, patients with emphy-

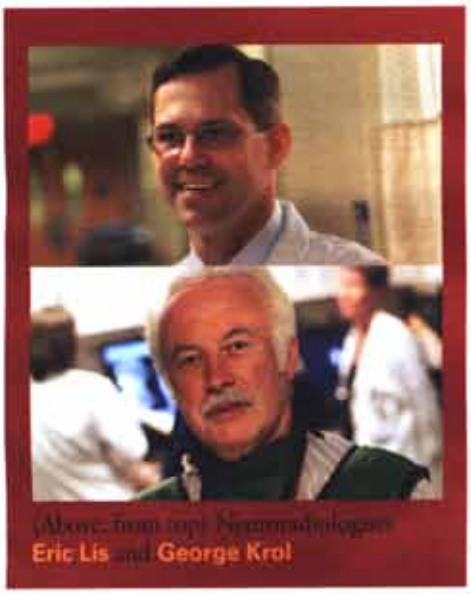


In cryoablation, extreme cold is used to destroy tumors. The physician employs imaging technology such as ultrasound or CT to guide a cryoablation probe into a tumor. The probe is activated and the resulting iceball kills the tumor. Here, three cryoprobes before and after an iceball forms.

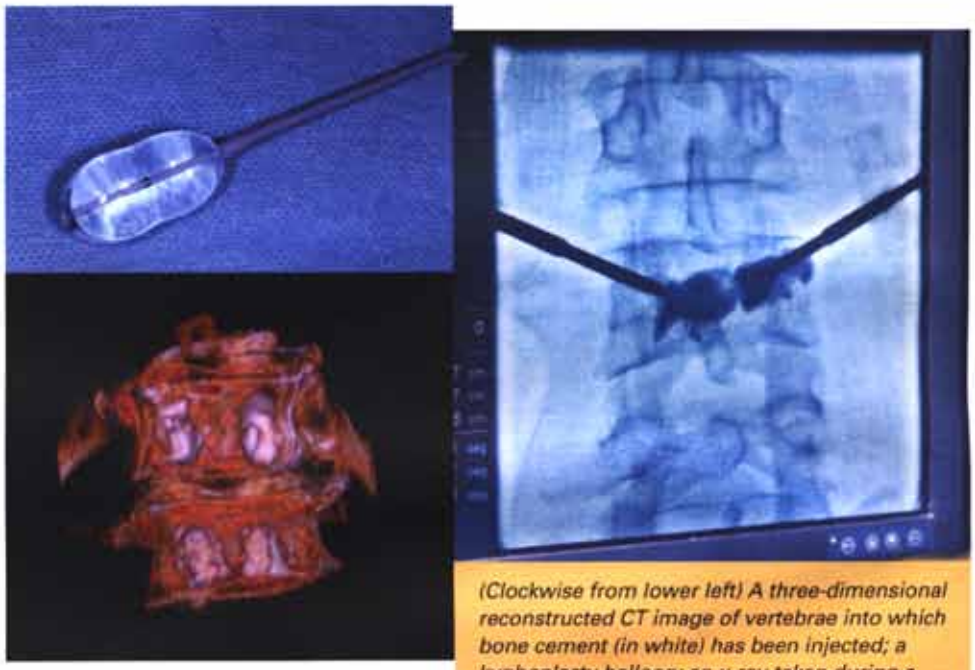
sema who cannot tolerate losing part of their lungs — we can often put a needle in and ablate their tumors."

Hypervascular tumors, such as primary liver cancer and certain other cancers that metastasize to the liver, benefit from embolization. In the liver, the procedure involves blocking branches of the hepatic artery, which feeds most liver cancer cells. With their blood supply cut off, starved of oxygen and nutrients, the tumors die. Because it receives its major blood supply from the portal vein rather than the hepatic artery, the healthy liver is not affected. "However, in these cases we're careful to tell patients that we're not necessarily curing the cancer — we're helping to manage the disease so they can continue to live," Dr. Thornton said. "And we have many patients who survive for years."

The determination of how to treat a tumor, whether with ablation or embolization, is also based in part on tumor size. Ablation works best when tumors are relatively small; larger tumors, or multiple tumors in the same organ, will generally be embolized; and sometimes ablation and embolization are combined.



(Above, from top) Neuroradiologist **Eric Lis** and **George Krol**



(Clockwise from lower left) A three-dimensional reconstructed CT image of vertebrae into which bone cement (in white) has been injected; a kyphoplasty balloon; an x-ray taken during a kyphoplasty procedure, as Drs. Krol and Lis work together with identical instrumentation to inject bone cement into a vertebral body. The cement is the dark material on the x-ray.

"Often, our procedures work together to produce a better result than one alone," said Dr. Solomon. And, added Dr. Thornton, "whatever we ultimately decide is the best treatment for a patient, we arrive at that decision by a multidisciplinary consensus that includes all our MSKCC colleagues, including surgeons, medical oncologists, and radiation oncologists."

A major advantage of ablation and embolization is that unlike surgery, chemotherapy, or radiation, if disease recurs or follow-up imaging studies reveal that not all the tumor was killed, then these procedures can usually be repeated numerous times.

An area of ongoing research is the delivery of chemotherapy directly to tumors, in particular liver tumors, using embolization. At MSKCC, the IR section performs what are termed "bland" embolizations; that is, embolizations without the addition of chemotherapy. In a paper published in 2006 in the journal *Cancer*, MSKCC investigators, including interventional radiologist Anne M. Covey, reviewed the records of 45 patients with recurrent liver cancer who had undergone bland embolization at MSKCC over a period of approximately ten years. The procedure was shown to be an effective strategy, with a median time to disease recurrence of 13 months and 47 percent of patients alive at five years.

"In the early 1990s, people began saying, 'Well, if embolization works, what if we also put in some chemotherapy?'" recalls Dr. Getrajdman. "'The chemo will hang around and kill more tumors.' It *sounded* good, but there was limited science behind it." Now, to further advance the science, an MSKCC clinical trial recently funded by the NIH and headed by interventional radiologist Karen T. Brown will study the use of chemoembolization using drug-eluting beads versus bland embolization. Like tiny sponges, the beads are soaked in a chemotherapy drug and then delivered to a liver tumor where "the drug slowly leeches out," explained Dr. Getrajdman. "The hope is that the drug-eluting beads will actually keep the chemotherapy in the tumor, and the study will show whether there is value to adding chemotherapy to embolizations for liver cancer."

In another area of investigation, interventional radiologist Constantinos Sofocleous is