The Kanzius Machine: A New Cancer Treatment Idea From an Unexpected Source

By Charles Schmidt

G reat advances rarely come from massive, federally funded directives. So said the late Francis Moore, M.D., surgeon in chief at Brigham and Women’s Hospital in Boston and Harvard Medical School professor, reflecting on whether the government’s war on cancer might ever yield a cure. Rather, he opined, they tend to come from creative people whom no one has heard of before, working in obscurity.

Enter John Kanzius, a retired TV engineer and ham radio operator without a college education, whose use of radio waves for treating cancer has brought him to the attention of the cancer world. Featured on the program 60 Minutes last April, Kanzius is now coordinating the research of scientists at the University of Texas M. D. Anderson Cancer Center in Houston and the University of Pittsburgh Medical Center—from his home in Erie, Pa.

Kanzius’ contribution is a radio frequency (RF) transmitter of his own design that excites metal nanoparticles inserted into cancer cells. When exposed to radio waves, these nanoparticles generate tiny, localized bursts of heat that kill cancer cells without harming adjacent tissues. The technique has so far been tested only in laboratory experiments with cultured cancer cells and animal models. Moreover, several toxicity and safety issues must still be resolved before the technique can be considered viable for testing in humans. Kanzius and his collaborators acknowledge that human clinical trials are years away.

Hyped-up cancer cures routinely pop up and fade in the media. But Kanzius’ method has intrigued some researchers. Richard Smalley, Ph.D., a Nobel Prize–winning pioneer in nanotechnology, was so taken with the method that even as he lay dying of cancer, he reportedly urged Kanzius and his collaborator Steven Curley, M.D., a professor of surgical oncology at M. D. Anderson, to “keep going, no matter what.” In an interview for this article, Shuming Nie, Ph.D., the director for nanotechnology and bioengineering at Emory University’s Winship Cancer Institute, described the method as “very exciting … with major implications.” Nie tempered expectations, though, pointing out that Kanzius and his collaborators must still find a way to direct nanoparticles injected into the body toward cancer cells exclusively. “And even if they achieve that, this won’t produce a cure for all cancers,” Nie added. “But if they can solve this in vivo targeting problem, then we could be looking at an entirely new mechanism for killing cancer cells.”

Diagnosed with leukemia in 2002, Kanzius came up with his approach while pondering the notion that radio waves can heat metals without necessarily harming living tissue. He later built an RF field–generating machine in his garage and used it to heat solutions of copper sulfate injected into hot dogs, finding that upon radio wave exposure, only the metal-infused parts of the hot dog got warm, whereas the rest stayed cold. That finding reinforced his belief that RF signals might actually heat and destroy cancer cells into which metallic particles had been injected, leaving normal cells unscathed.

Kanzius patented his RF machine, generating some local publicity for its cancer-treating potential and was soon contacted by David Geller, M.D., a surgeon and co-director of the University of Pittsburgh Medical Center’s liver cancer center. Geller was treating patients with RF ablation (RFA), a method that kills cancer cells by exposing them to heat-inducing radio waves emitted by a needle electrode that clinicians insert into a tumor. Geller was enticed by notions of needle-free RFA that Kanzius’ machine promised, and he suggested a modification. As designed, the machine used a power generator, a transmitter head that gives off radio waves, a receiver head that absorbs them, and a copper-plated “dispersive pad” placed against the body that sends RF signals to ground. Worried that the pad might burn patients should it get too hot during treatment, Geller asked Kanzius if he could create a transmitter powerful enough to excite metal particles in free space. “That was a tall order,” Kanzius said. But to Geller’s surprise, a few weeks later Kanzius presented him with a modified pad-free RF instrument that could generate extremely high-energy electromagnetic fields with remarkably low currents, as measured by voltage. That development was crucial because high currents harm and kill humans. Metallic particles excited by those fields reach microtemperatures of 300–400°C, enough to explode the cells that contain them. But macrotemperatures beyond the metal-infused cells barely rise, so adjacent tissues survive unscathed. Geller ran some experiments with the machine and showed that it could heat and kill liver cells infused with ionic solutions of copper sulfate and other metals. In accompanying experiments with rats, he also showed that RF exposure could generate localized tissue death where the metal ions had been introduced by injection. Those results were published in February 2007 as an abstract in the Journal of Surgical Research.

While Geller was running his experiments in early 2005, Kanzius was also in contact with M. D. Anderson’s Curley, a leading figure in RFA treatment. Kanzius knew that the metal ions he was working with could be toxic when administered intravenously. So he asked Curley if metallic nanoparticles—which might not disturb blood chemistry—could be more appropriate. As it turned out, Curley had a source for nanoparticles, or more specifically, single-walled carbon
nanotubes (SWNTs), because he was treating Richard Smalley, the nanotechnology scientist, for an infection related to his leukemia. Smalley dismissed the notion that SWNTs, which measure just 25 nm long, could be excited to release heat by RF signals with wavelengths more than 70 feet long. Until then, nanoparticles had been shown to release heat only when exposed to energy with far shorter wavelengths, such as those generated by infrared light. But Smalley supplied the nanotubes anyway and was shocked when the experimental results proved his initial assumptions wrong. “The machine heated SWNTs to temperatures far in excess of what we had predicted,” Curley said. “So for the remaining 3 months, Smalley and I worked furiously to test the method.”

Unfortunately, Smalley never lived to see the results of that research, which generated media publicity when they were published in Cancer in November 2007. The findings showed that human cancer cells injected with SWNTs could be destroyed by RF exposure in vitro. RF exposure drove nanoparticles to self-assemble into linear “nanoantennae,” which could be excited to higher-than-predicted temperatures, creating thermal effects that, to the scientists’ knowledge, had not been reported previously. Likewise, the research team used RF energy to eliminate SWNT-treated tumors in rabbits. Here SWNTs were introduced by intratumoral injection, a delivery method for research that wouldn’t be appropriate for clinical use in humans. Two minutes of RF exposure produced no observable toxic effects in the animals up until they were killed 48 hours later. When viewed under a microscope, SWNT-treated tumor sections revealed complete thermal necrosis, whereas control tumor sections that were free of the nanoparticles remained viable.

Leonard Lichtenfeld, M.D., deputy chief medical director at the American Cancer Society, applauds Kanzius and his collaborators for emphasizing that the technique will be clinically useful only if the nanoparticles can be made exclusively to target cancer cells after being injected into the bloodstream. “They’ve made it clear that more time and effort will be needed to show this could be effective as cancer treatment,” he said. “But in a nutshell, I do see opportunities here.”

The means to achieving targeted delivery, Nie said, lie with antibodies or peptides attached to the nanoparticles that seek out cancer cells like homing pigeons.

Two schools of thought now influence that research, he said. One holds that scientists should identify nonspecific compounds that target as many tumors as possible. The other suggests that the compounds should narrow their targets to highly specific cancers. “Both have their benefits,” he said. “But the broad-spectrum approach is more likely to produce a blockbuster.”

Geller’s view is that eight to 10 targeting molecules will be required to make treatment viable, in part because cancer cells don’t always express the characteristic surface proteins that targeting antibodies would otherwise be attracted to. For instance, he explained, among patients with liver cancer, just 50%–60% have cancer cells that express abnormal levels of alpha-fetoprotein, a diagnostic marker for the disease. Geller said that in upcoming experiments he plans to use antibodies that target cell receptors including HER2/neu for breast cancer, alpha-fetoprotein for hepatocellular carcinoma, and carcinoembryonic antigen for colon cancer. Curley, meanwhile, said that he has been able to direct nanoparticles to cancer cells by using antibodies targeted to what he described as “transmembrane proteins, tyrosine kinase receptors, that are either abnormal in cancer cells only or that are overexpressed in cancer cells compared with normal cells.” Those results are currently being considered for peer-reviewed publication, Curley said.

Beyond cancer cell targeting, the next major challenge falls to Kanzius himself. To excite injected nanoparticles in systemic distribution, including those in metastatic cells, RF treatment will have to cover the entire body. So far, Kanzius’ latest-generation machine covers only an area of 36 square inches. Kanzius claims that he’s already designing a machine that will look like a computed tomography scanner when completed, possibly by late fall of this year.

Finally, toxicity issues from the nanoparticles themselves will also have to be addressed. SWNTs have a questionable toxicity record; few studies have investigated the topic, Nie said, and evidence suggests that cells will try to degrade carbon nanotubes with oxidative compounds that might cause inflammatory reactions. The better option, scientists generally agree, could be gold, which has passed regulatory review for treating conditions that include rheumatoid arthritis. Both Geller and Curley have recent published reports showing that RF treatment destroyed cancer cell lines infused with gold nanoparticles. Curley’s results showed that more than 99% of Hep3B cells treated with a 67 µM/L dose of gold nanoparticles were killed by RF exposures ranging from 1–5 minutes. Similar results were noted in human pancreatic cells from the Panc-1 cell line. The findings were published in the Journal of Nanobiotechnology in January. Geller’s results, to be published in the August 2008 issue of Surgery, showed that HepG2 liver cancer cells cultured with gold nanoparticles were killed by RF exposure from Kanzius’ most current machine, which transmits radiowaves at 13.56 MHz. (Curley has access to an identical machine).

Nonetheless, neither researcher can yet say how they will overcome what Lichtenfeld has raised as a key worry, namely, that nanoparticles released into the blood after cancer cell death might wind up in lymphatic tissue, which could be harmed during repeated RF exposures. “We’re studying that [effect] now,” Curley said. Kanzius acknowledges that repeat RF treatment could be necessary for eliminating large tumors, to avoid clogging the kidneys to the point of failure with cancer cell fragments. “We might have to treat larger tumors with two or three treatments,” he said.

Whether the research will accelerate progress in cancer or will fade like other radical approaches that never panned out is hard to say, Lichtenfeld concedes. “I’ve learned enough not to be judgmental,” he said. “Those of us who have been in the cancer research business for a long time have all been seduced by promising new treatments that never made it out of the lab. But I’d be the last person to say that something will never work.”