Improving Cancer Diagnosis and Treatment of Cancer Through Advanced Optical Imaging

UC San Diego bioengineering grad student Carolyn Schutt has helped developed a method that may enhance the diagnosis and treatment of cancer.

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Carolyn Schutt may be on to something big, something that will help revolutionize the way physicians diagnose and treat cancer.

The UC San Diego bioengineering grad student and her labmates Michael Benchimol and Mark Hsu are working on a method to use highly-sensitive light imaging and focused light therapies deep inside the body that will, for example, help detect and treat breast cancer more effectively. Schutt will present her findings during Research Expo April 14 in a poster titled "Ultrasound-Modulated Fluorescent Contrast Agent for Optical Imaging of Deep Tissue." She is one of 250 UC San Diego engineering grad students presenting their work during the annual event.

Millions of women over 40 undergo x-ray mammography each year in an effort to detect breast cancer in its infant stage, when it is the most treatable. However, traditional mammography involves exposure to harmful ionizing radiation and suffers from poor diagnostic accuracy, resulting in a high rate of false positive diagnoses. In contrast, optical fluorescence imaging is safe, inexpensive, and provides a more accurate visualization of whether a tumor is present. The major roadblock to optical mammography is the highly light-scattering nature of tissue, which limits optical imaging to very superficial depths.

"The contrast agent that we developed can enable fluorescence imaging of the breast at greater depths and with higher spatial precision, making sensitive optical mammography a reality," Schutt explained. "This technology has the potential to transform breast cancer imaging, improving its safety and diagnostic accuracy, and thus preventing thousands of unneeded biopsies. In addition, the more accurate early detection enabled by this technology can increase patient survival rates."

Schutt, whose advisor in the project is UC San Diego nanoengineering professor Sadik Esener, said the goal of the project is to create a smart particle contrast agent that can bridge optical and ultrasound imaging, combining the best features of both and rendering biological tissue effectively transparent to light. Such a particle would enable highly-sensitive light imaging and focused light therapies deep inside the body, improving the way we diagnose and treat cancer.

Optical biological imaging, highly desirable among the medical community, is highly sensitive, safe and inexpensive, and can provide critical information for tumor detection including chemical information.

"But for imaging inside the body, light is abysmal for locating anything with precision; the photons are scattered repeatedly, preventing you from seeing inside to any significant depth," Schutt said. "Just think of holding a flashlight up to your hand-instead of seeing through to your bones, you just see the diffuse pink glow of the scattered photons. In contrast, ultrasound scatters much less than light in biological tissue, and thus can let you see deep inside the body with a high level of spatial precision. But ultrasound has its own pitfalls-it lacks sensitivity and contrast, and does not provide valuable information on tumor activity that optical imaging can."

In this research, Schutt and her team have, for the first time, shown experimentally a "microbubble" contrast agent that changes its fluorescence intensity-it "blinks"-only in response to focused ultrasound. This is how it works: When gas microbubbles encounter an ultrasound pressure wave, they contract and expand in diameter, and consequently surface area, in response to the pressure peaks and troughs. By loading the microbubble surface with a fluorescent dye that quenches, or turns off, when it is very close to other dye molecules (that is, when the bubble surface area is reduced), the bioengineers have created a particle that blinks at the applied ultrasound frequency. This blinking was monitored in a custom setup which detected the fluorescence emitted from the contrast agent bubbles as they encountered focused ultrasound. Signals obtained from this setup show that the bubble fluorescence clearly changes intensity when ultrasound is applied and spectrum analysis verifies that the blinking frequency matches that of the applied ultrasound waves. The contrast agent developed by Schutt's team only blinks when it is located in the ultrasound focal zone. Special detectors can be used to identify and amplify only the blinking light, discarding all the light that did not originate from the ultrasound focus. This blinking light can then be used to create an image of whatever is located at the ultrasound focus (for example, a potential tumor) with the sensitivity and contrast offered by optical imaging.

"This is a new and powerful capability that we hope will significantly improve our present diagnostics as well as image guided therapeutic capabilities," Schutt said.

This project is an example, she said, of designing medical technology intelligently - combining the best features of two imaging modes into an innovative single platform. "Our contrast agent has the potential to drastically improve breast cancer imaging and enable therapies which focus laser light precisely to burn tissue," she said. "But this is only the tip of the iceberg - scientists have been searching for a way to create such a guide signal in the body for many years as it would open up a world of optical applications in the body never before possible."

Schutt is excited and hopeful that her research holds great promise to reduce the pain and suffering of the cancer diagnosis and treatment process and clear the roadblocks for new light-based therapies with minimal side effects.

"It is very fulfilling to be working toward improving cancer patients' quality of life," she said.

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