Northwestern | McCORMICK SCHOOL OF ENGINEERING

FALL 2019

BIOMEDICAL ENGINEERING

SENSORS ARE FIRST TO MONITOR BABIES IN THE NICU WITHOUT WIRES

Soft, flexible sensors provide clinical-grade measurements, allow physical bonding between baby and parent

Professor John Rogers (left) developed the dual wireless sensors in collaboration with materials scientists, dermatologists, and pediatricians.

An interdisciplinary Northwestern University team led by Professor **John Rogers** has developed a pair of soft, flexible wireless sensors that replace the tangle of wire-based sensors that currently monitor babies in hospitals' neonatal intensive care units and pose a barrier to parent-baby cuddling and physical bonding.

The team completed a series of first human studies on 70 premature babies at Prentice Women's Hospital and Ann & Robert H. Lurie Children's Hospital of Chicago. The researchers concluded that the wireless sensors provided data as precise and accurate as that from traditional monitoring systems. The wireless patches also are gentler on a newborn's fragile skin and allow for more skin-to-skin contact with the parent. Existing sensors must be attached with adhesives that can scar and blister premature newborns' skin.

"We were able to reproduce all of the functionality that current wire-based sensors provide with clinical-grade precision," said Rogers, the Louis Simpson and Kimberly Querrey Professor of Materials Science and Engineering and Biomedical Engineering in the McCormick School of Engineering. "Our wireless, battery-free, skin-like devices give up nothing in terms of range of measurement, accuracy, and precision — and they even provide advanced measurements that are clinically important but not commonly collected."

The benefits of the new technology reach beyond its lack of wires — measuring more than what's possible with today's clinical standards.

The dual wireless sensors also monitor babies' vital signs — heart rate, respiration rate, and body temperature — from opposite ends of the body. One sensor lays across the baby's chest or back, while the other sensor wraps around a foot. (The chest sensor measures 5 centimeters by 2.5 centimeters; the foot sensor is 2.5 centimeters by 2 centimeters. Each sensor weighs about the same as a raindrop.) This strategy allows physicians to gather an infant's core temperature as well as body temperature from a peripheral region.

"Differences in temperature between the foot and the chest have great clinical importance in determining blood flow and cardiac function. That's something that's not commonly done today," said Rogers, who co-led the study published in the journal *Science* with materials scientists, engineers, dermatologists, and pediatricians.

Rogers estimates that his wireless sensors will appear in American hospitals within the next two to three years.

FROM THE CHAIR

Dear friends,

As 2019 comes to a close, I am glad to be able to send you updates from our department. First, I would like to note the loss of Professor **Richard Van Duyne**, who died this past summer. His discovery of surface-enhanced Raman spectroscopy, capable of detecting and identifying single molecules, was a transformative accomplishment. Professor Van Duyne was also an outstanding mentor to 70 doctoral students and 49 postdoctoral fellows during his career. His legacy continues in their many achievements.

Our faculty are broadly recognized for their cutting-edge research and 2019 was no exception. Last year, we received more than $43 million in new awards – exceeding FY18, which was also a record-setting year for the department. Some of the many notable awards include a $7.25 million grant to the Center for Innovation in Global Health Technologies (CIGHT) to advance point-of-care technologies for HIV treatment in Africa, and more than $7 million in grants to the Center for Advanced Regenerative Engineering (CARE), which will support its growing array of projects for improving the outcomes of medical interventions that require the repair and regeneration of tissues and organs. CIGHT and CARE are two of the five research centers connected to BME, each tackling significant interdisciplinary problems by leveraging the expertise of our faculty and connecting them to relevant collaborators across the Northwestern community and beyond. In this newsletter, you can learn about activities in the Center for Bio-Integrated Electronics, Center for Synthetic Biology, and our newest Center for Physical Genomics and Engineering.

We are grateful to Lou Simpson and Kimberly Querrey for their generous support of Northwestern University. The new Simpson-Querrey Biomedical Research Center on the Chicago campus is the largest biomedical academic research building in the United States. The top floor of this state-of-the-art building is dedicated to bioengineering research, representing a tremendous opportunity for our faculty and students of all levels.

This year we are rolling out a new laboratory curriculum for our undergraduates. The objective is to endow students with laboratory skills earlier in their careers, thereby increasing opportunities to conduct research on campus or in industry during the undergraduate years. Students will now be able to take a course in biomedical experimentation during their freshman year, providing them with knowledge about the principles of measurement and uncertainty, statistical design of experiments, and data analysis relevant to many research problems. In parallel, we are expanding our laboratory offerings to expose students to advanced measurement systems across the breadth of biomedical engineering. The first new course will focus on pharmaceutical engineering, funded in part by a generous gift from the Jaharis Family Foundation.

The remainder of this year's newsletter highlights a few accomplishments of the many achieved by our faculty, students, and alumni. These are accomplishments made by talented individuals supported through the incredible Northwestern community. I would like to end by thanking you for your contributions to that community. Our friends and alumni support our educational and research endeavors through philanthropy, mentorship, job placements, and networking. To keep abreast of future opportunities and activities within the department, please be sure to join the Northwestern Biomedical Engineering group on **LinkedIn: linkedin.com/groups/3299815**.

Eric J. Perreault
Department Chair

Northwestern Opens Largest Biomedical Academic Research Building in US

Building will promote collaboration between department and medical researchers

The Louis A. Simpson and Kimberly K. Querrey Biomedical Research Center — the largest new building solely dedicated to biomedical research at an American medical school, according to the Association of American Medical Colleges — officially opened June 17 at Northwestern University Feinberg School of Medicine.

The new center will promote collaboration between Northwestern Biomedical Engineering and medical researchers at the University and affiliate institutions. The center's 11th floor is dedicated to bioengineering and includes devoted space for the Center for Synthetic Biology, Center for Bio-Integrated Electronics, and the Simpson Querrey Institute for BioNanotechnology. It's the first space solely dedicated to the biomedical engineering department on Northwestern's Chicago campus.

Simpson Querrey Biomedical Research Building

CENTER FOR PHYSICAL GENOMICS AND ENGINEERING LAUNCHES

At symposium celebrating launch, researchers shared vision for burgeoning field

Northwestern's Center for Physical Genomics and Engineering officially launched in May with a symposium that brought together top faculty, students, researchers, and industry members in the field.

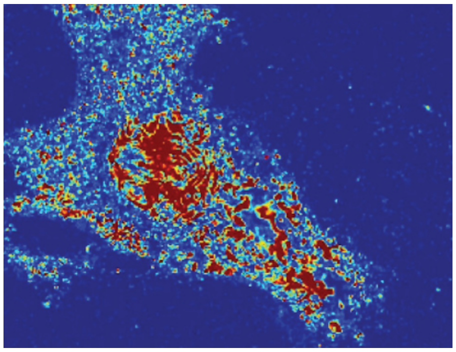
The center, led by Professor **Vadim Backman**, uses breakthrough optical imaging and computational genomics to reprogram the genome's chromatin, which regulates gene expression, in order to treat diseases like Alzheimer's disease and atherosclerosis. The technique has the ability to go beyond medicine and could also be used to improve crop yields and mitigate the impact of climate change on plants.

At the symposium on Northwestern's Chicago campus, Backman, the Walter Dill Scott Professor of Biomedical Engineering at the McCormick School of Engineering, and other researchers shared their latest insights, and offered their thoughts on where the field should focus going forward.

In addition to leading the field in physical genomics research, the center will also train next-generation leaders engaged in research that bridges molecular biology, bioengineering, physics, and chemistry.

New Imaging Technique Reveals 'Burst' of Activity Before Cell Death

For chromatin, the group of DNA, RNA, and protein macromolecules packed within our genome, motion is an integral part of its active role as a regulator of how our genes get expressed or repressed.



Above: Vadim Backman at the Symposium on Physical Genomics; Left: A eukaryotic cell undergoing cellular paroxysm

A research team led by Backman along with Professors **Guillermo Ameer** and **Igal Szleifer** has developed a new optical technique to study the movement of cells without using cumbersome labels or toxic dyes to track them.

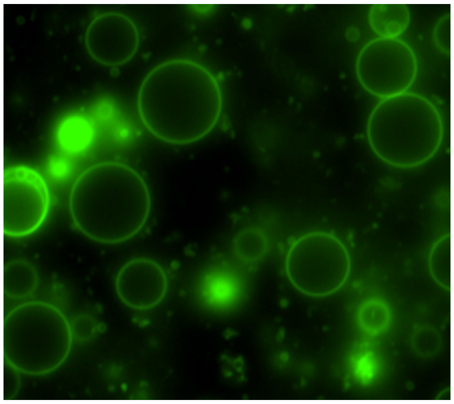
The new technique, called dual-PWS, is label-free and can image and measure macromolecular motion without using dyes. Using a technique previously created by Backman called Partial Wave Spectroscopy (PWS), the researchers applied dual-PWS by studying the nanoscale structural and dynamic changes of chromatin in eukaryotic cells in vitro. Using ultraviolet light to induce cellular death, the team measured how the movement of the cells' chromatin was changed.

What the researchers didn't expect was to witness just prior to a cell reaching its "point of no return" during decay, the cells' genomes burst with fast, instantaneous motion, with different parts of the cell moving seemingly at random.

The phenomenon, called cellular paroxysm, remains a mystery, but Backman believes the more insights researchers can gain about chromatin, the more likely they can one day be able to regulate gene expression, which could change how people are treated for diseases like cancer and Alzheimer's.

Technique Improves Folding of Membrane Proteins

Process could help design new therapeutics, biosensing materials



Hybrid vesicles made from phospholipids and deblock copolymers can help with studying membrane protein folding.

In setting out to synthesize membrane proteins outside of a cell, Professor **Neha Kamat** and her team have developed a new technique that improves the rate and yield of these proteins. The technique also gave rise to a new understanding of mechanical processes that could be occurring inside a cell.

At the heart of the technique is protein folding, where a new protein folds into a structure that ultimately determines its function. Researchers have found that when a protein begins to emerge from the ribosome, if a membrane is nearby, it will insert itself into that membrane and can often spontaneously fold into the correct structure.

The membranes Kamat used in the research were created with a diblock copolymer, which made the membrane material more elastic. That, in turn, had an effect on how quickly the proteins were made, and how much protein was made.

Neha Kamat

Researchers saw a four-fold increase in folding efficiency for one type of protein (MscL-GFP), and a 20-fold increase in folding efficiency for another membrane protein (chR2GFP) over previous techniques using membranes made from traditional phospholipids.

"This work could help us understand and use membrane proteins for a variety of applications," Kamat said. "Designing materials that incorporate membrane proteins could lead to a completely new class of materials that can sense, transport, or even target important biological signals and molecules within the body."

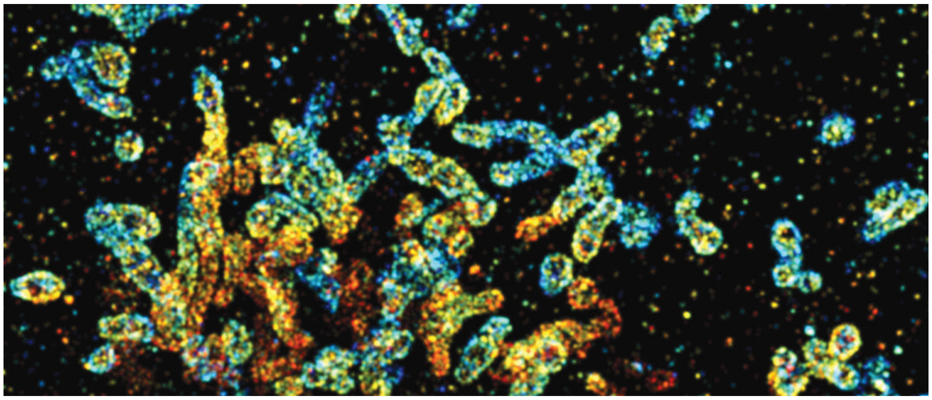
New Technology Images Molecules in 3D

New tool could help molecular biologists understand complex processes within cells

Northwestern Engineering researchers have developed a new platform that can image single molecules in 3D, allowing deeper probes into the inner workings of cells.

The platform uses spectroscopic single-molecule localization microscopy (sSMLM), a tool that can simultaneously capture the spatial information of single molecules and their spectroscopic signatures.

Researchers improved the tool by combining existing sSMLM with a two-mirror system, allowing it to image molecules in 3D at much larger depths. This new tool could help molecular biologists understand complex processes inside cells.



A new platform uses spectroscopic single-molecule localization microscopy to simultaneously capture the spatial information of single molecules and their spectroscopic signatures.

"Our design is relatively easy to implement and will allow us to study molecular interactions much better than before," said **Hao Zhang**, professor of biomedical engineering and coauthor of the research. "Now we can not only see where molecules are, but also what they are."

Zhang developed the technology with Northwestern Engineering's Cheng Sun, associate professor of mechanical engineering.

'Trojan Horse' Anticancer Drug Disguises Itself as Fat

Promising system delivers chemo drug straight into tumors with fewer side effects

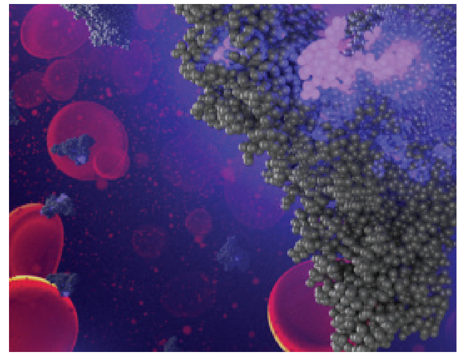
A stealthy new drug-delivery system developed by Professor **Nathan Gianneschi** disguises chemotherapeutics as fat in order to outsmart, penetrate, and destroy tumors.

Thinking the drugs are tasty fats, tumors invite the drug inside. Once there, the targeted drug activates, immediately suppressing tumor growth. The drug also is lower in toxicity than current chemotherapy drugs, leading to fewer side effects.

"It's like a Trojan horse. It looks like a nice little fatty acid, so the tumor's receptors see it and invite it in. Then the drug starts getting metabolized and kills the tumor cells," said Gianneschi, Jacob and Rosaline Cohn Professor of Chemistry, Materials Science and Engineering, and Biomedical Engineering.

To develop the targeting system, Gianneschi and his team engineered a long-chain fatty acid with two binding sites — able to attach to drugs — on each end. The fatty acid and its hitchhiking drugs are then hidden inside human serum albumin, which carries molecules, including fats, throughout the body.

Researchers found they could deliver 20 times the dose of the chemotherapy drug paclitaxel with their system, compared to two other paclitaxel-based drugs. But even at such a high quantity, the drug in Gianneschi's system was still 17 times safer.



A modified chemotherapy drug hitches a ride through the bloodstream on human serum albumin.

"IT'S LIKE A TROJAN HORSE. IT LOOKS LIKE A NICE LITTLE FATTY ACID, SO THE TUMOR'S RECEPTORS SEE IT AND INVITE IT IN."

NATHAN GIANNESCHI

New Method for Engineering Metabolic Pathways

Two approaches provide faster way to create complex molecules

As synthetic biologists look to re-engineer cells to make molecules for specific needs, including pharmaceuticals and energy applications, the trial-and-error process is difficult and time-consuming, and often competes with the cell's other goals and processes, like growth and survival.

A new method developed at Northwestern Engineering combines two state-of-the-art research approaches to create a fast, efficient way to engineer and analyze metabolic pathways.

The approaches — cell-free protein synthesis and self-assembled monolayer desorption ionization (SAMDI) mass spectrometry — combine to make a new tool to help engineers better understand the pathways to create molecules.

Michael Jewett and Milan Mrksich

"With these two methods, we can build thousands of potential mixtures and test them all in a single day, a much faster process that will give new insights and design rules for synthetic biologists," said **Milan Mrksich**, the Henry Wade Rogers Professor of Biomedical Engineering, Chemistry, and Cell and Molecular Biology.

Mrksich co-led the research with Northwestern Engineering's **Michael Jewett**, professor of chemical and biological engineering. The paper was published in *Science Advances*.

The SAMDI mass spectrometry technology measures biochemical reactions extremely quickly and cheaply. "We can easily test 10,000 reaction mixtures in a single day to determine which molecules were synthesized and how much of each is present in the reaction mixtures," Mrksich said.

Pathbreaking Chemist Richard P. Van Duyne Passes Away

The discoverer of surface-enhanced Raman spectroscopy made a fundamental impact on his field

Professor **Richard P. Van Duyne**, a Northwestern University analytical chemist renowned for his discovery of surface-enhanced Raman spectroscopy (SERS), passed away on July 28. He was 73.

Van Duyne's discovery of SERS — which is capable of both detecting and identifying single molecules — has had a huge effect on chemistry, physics, materials science, and medicine around the world. He discovered the technique in 1977, six years after joining the faculty at Northwestern, where he spent the entirety of his career as a professor and researcher.

Richard P. Van Duyne

Van Duyne was the Charles E. and Emma H. Morrison Professor of Chemistry in Weinberg College and a professor of biomedical engineering in the McCormick School of Engineering.

Van Duyne was a trailblazer in the field of plasmonics — the study of how light interacts with metal surfaces that support surface plasmons. In addition to his discovery of SERS, Van Duyne was also known for his advancement of nanosphere lithography, which helped transform the field of nanoparticle optics, and of localized surface plasmon resonance spectroscopy.

These breakthroughs enabled Van Duyne to develop a broad spectrum of new analytical tools to apply to problems in chemical and biological sensing, electrochemistry, materials science, ultrahigh vacuum surface science, and even art conservation science.

Among his many honors, Van Duyne was listed among the world's top 100 chemists by Thomson Reuters between 2000 and 2010, as measured by the impact of his published research. He was elected to the US National Academy of Sciences in 2010 and won the American Chemical Society's Analytical Chemistry Award that same year. In 2004, he was elected to the American Academy of Arts and Sciences.

Faculty Honors

Guillermo Ameer was elected fellow of the American Association for the Advancement of Science. He also received the Martin E. and Gertrude G. Walder Award for Research Excellence from Northwestern University.

Mitra Hartmann received a Charles Deering McCormick Professor of Teaching Excellence Award from Northwestern University.

Neha Kamat received a 2019 Young Investigator Research Program award from the Air Force Office of Scientific Research.

Chad Mirkin and **John Rogers** each received a 2019 Nakamura Award from the American Association for Advances in Functional Materials. Rogers also received the 2019 Benjamin Franklin Medal in Materials Engineering.

Milan Mrksich received the 2020 Pittsburgh Analytical Chemistry Award.

Jonathan Rivnay was awarded a 2019 Sloan Research Fellowship from the Alfred P. Sloan Foundation and a Collaborative Research Catalyst Award from Northwestern University.

Jason Wertheim received a Presidential Early Career Award for Scientists and Engineers.

CENTER PROPELS TECHNOLOGIES FOR HIV DIAGNOSTICS IN AFRICA

Northwestern Biomedical Engineering is leading the newly formed Center for Innovation in Point-of-Care Technologies for HIV/AIDS at Northwestern University (C-THAN). Focused on developing and commercializing technologies critical for improved management of HIV-infected individuals in Africa, the multi-institutional center has received a five-year, $7.5 million grant from the National Institutes of Health.

Led by Professors **Robert Murphy**, **Matthew Glucksberg**, and **Sally McFall**, C-THAN will work with partners in Africa to foster an ecosystem of point-of-care technology development to better detect and monitor HIV and common comorbidities and complications, as well as support training opportunities for technology developers and evaluators so they can lead testing at validation sites in the field.

BME PROFILES

Dorothea Koh

Alumna entrepreneur uses AI to help doctors treat patients around the world

Dorothea Koh doesn't make small goals. As the founder and CEO of Bot MD, an AI assistant for doctors, she hopes to impact 100 million patients in emerging markets by the time she turns 40.

Koh, who graduated from Northwestern with degrees in biomedical engineering and economics, founded the company in 2018 after spending nearly a decade working for large Fortune 500 healthcare companies, including Baxter Healthcare and Medtronic. It was during that time she witnessed firsthand — in countries like China, Indonesia, and the Philippines — the need for fast, reliable medical information to help doctors provide effective medical care for the growing number of patients in the region.

Bot MD uses natural language processing to provide instant responses to clinical queries using only trusted medical sources of information. Used by more than 10,000 doctors around the world, the free app offers instant answers to a variety of medical questions — from appropriate doses of common drugs to clinical guidelines — as well as voice-to-text transcription of clinical notes and medical procedural videos to help doctors with point-of-care clinical decisions.

Koh, who participated in Y Combinator's summer 2018 accelerator program, says her biomedical engineering degree has been instrumental in sparking her passion to innovate new products to impact healthcare around the world. She recalled working with biomedical engineering professors on a capstone design project in the area of biomaterials, where she developed a non-stick diagnostic probe using hydrophobic biomaterials that could enable the ultrasensitive detection of Alzheimer's disease.

"As it turned out, my capstone design project spurred one of my first startup ideas that I worked on," Koh said. "In some ways, you could say that the experience kickstarted the rest of my entrepreneurial career."

Israel Oluwasakin

Senior brings design interests to internship

Israel Oluwasakin is a biomedical engineer with an eye for human-centered design. As a design assurance engineering intern at medical device company Medtronic, he conducted verification studies for a continuous glucose monitoring device for diabetes patients to ensure the device met user needs and design requirements. The work involved testing methods to reduce variation during destructive tests, as well as applying statistical methods to improve the selection of raw materials used for the device.

Oluwasakin's interest in design stems from his experience taking Northwestern Engineering's Design Thinking and Communication course as a first-year student. It was there that he helped design a cup that dispenses a fixed amount of viscous liquid upon every sip for patients with dysphagia at Shirley Ryan AbilityLab.

OLUWASAKIN'S INTEREST IN DESIGN STEMS FROM TAKING NORTHWESTERN ENGINEERING'S DESIGN THINKING AND COMMUNICATION COURSE.

When he's not gaining experience in industry, Oluwasakin is a prominent member of Northwestern student groups. As vice president of Northwestern's chapter of the National Society of Black Engineers, he helps produce successful programming aimed at promoting minority involvement in STEM fields. He also serves on the Medical Makers Executive Board of Northwestern's Biomedical Engineering Society chapter and is co-captain on Northwestern's intramural soccer team.

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Biomedical Engineering

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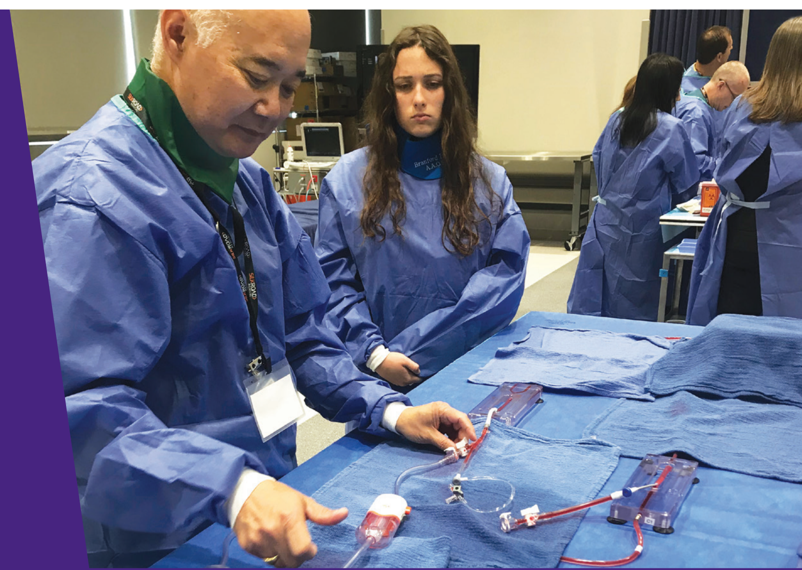
Engage with Biomedical Engineering

Gifts to the Department of Biomedical Engineering are used to aid innovative educational experiences and help the department reach new levels of excellence and impact. Donations made to the department can be directed specifically to student endeavors, including:

Summer Research Awards, which provide biomedical engineering students with immersive, full-time, nine-week summer research experiences within faculty labs, including: **Center for Advanced Regenerative Engineering**, **Center for Bio-integrated Electronics**, **Center for Physical Genomics and Engineering**, and **Center for Synthetic Biology**.

Student Travel, which provides funding for students to present their work at research conferences or to take part in immersive experiences during company visits.

To contribute to our department, please direct your gift to **mccormick.northwestern.edu/biomedical/donate**. To support any of our undergraduate initiatives, please write "BME Undergraduate Program Chair" in the additional comments box.



Alumnus Stewart Kume ('92), senior director of research and development at medical device company Silk Road Medical, invited a group of biomedical engineering students to take part in didactic training and explore the lab where vascular surgeons practice Silk Road Medical's new TransCarotid Artery Revascularization (TCAR) procedure.